IRWIN CREEK

STREAM RESTORATION PLAN

60% CONCEPTUAL DESIGN

MECKLENBURG COUNTY, NORTH CAROLINA

October 2003

PREPARED BY:

HDR

HDR Engineering, Inc.
of the Carolinas

Habitat
Assessment and
Restoration
Program

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1.0 INTRODUCTION

HDR Engineering, Inc. of the Carolinas (HDR) and Habitat Assessment and Restoration Program (HARP) have prepared this stream restoration plan (Plan) of Irwin Creek in Charlotte, NC, for the intended use of the North Carolina Wetland Restoration Program (WRP).

The development of a restoration design for the approximately 5,000 to 6,000 feet of Irwin Creek entailed a multifaceted study of the historical and current stream conditions within the Irwin Creek watershed (Project Area). Historical human activities, including development within the watershed and physical alteration of the stream channel, have led to the current desire to restore the stream to a more natural state. However, the urban environment of the Irwin Creek watershed prohibits any restoration to absolute natural conditions. Constraints including development, historical dredging, and large volumes of storm water runoff from impervious surfaces restrict the number of applicable restoration options.

In most urban streams and creeks, restoration to pristine condition is an unrealistic goal due to the extent of prior watershed alteration. It has been documented that degradation of stream quality occurs at relatively low levels (10 to 20 percent) of imperviousness; and at watershed imperviousness levels above 30 percent, predevelopment channel stability and biodiversity cannot be fully maintained, even when Best Management Practices (BMPs) or retrofits are fully applied. The restoration objectives in urban streams should then be set to target realistically attainable conditions. For the reach of interest along Irwin Creek, this translates to reduction of bank erosion and partial restoration of aquatic and riparian habitat.

This report documents the attainable goals and objectives of restoring Irwin Creek within the Project Area and presents an implementation strategy. Plans are based on Rosgen stream restoration principles and reference reach analysis. In addition, a monitoring plan and schedule ensure the long-term stability and success of this restoration effort.

2.0 GOALS AND OBJECTIVES

The approach to design in this project is not, strictly speaking, a full restoration; rather, it is oriented to the identification of strategic improvements, such as enhancements which are restoration-oriented, that will maximize a matrix of environmental benefits. These potential benefits, when combined with site constraints, technical guidelines, and the availability of funds, form the primary set of inputs to the design. Given the need to prepare a design that is selective in nature, it is important at the outset to identify the specific benefits that can be realized by the various alternatives posed by the design process. These benefits include the areas of water quality, habitat, stream stability, land values, and education. The potential benefits are briefly discussed below, prior to the discussion of the specific design goals and recommendations for each of the four zones described in Section 5.0.

Water Quality could be enhanced by bank stabilization, channel bed adjustments, off-line wetlands (located on a flood plain bench to be built in the buy-out area), and enhanced lower bank and berm vegetation. Bank stabilization would reduce the amount of sediment entering the stream during high flow events due to the vegetative cover locking up soil particles. Bed adjustments would help stabilize existing sediment reservoirs in the stream and provide continuity for sediment transport. The enhanced vegetation would provide additional shade in the reach, thereby lowering thermal pollution. The vegetation planted on the banks also would help filter overland runoff, removing soil particles and other nutrients present in storm water. The flood plain bench would act as a repository for soils suspended in the water column during high flow events and would also act as a water storage structure to allow sediment to further settle out of captured water. This design would allow for slower recharge of the storm water back into the groundwater subsurface network.

Aquatic habitat would increase due to the presence of diverse habitat and a shift from a homogeneous creek substrate to a more varied creekscape. Food sources for fish should react positively to the heterogeneous habitat provided by the design and other requirements for aquatic life, such as dissolved oxygen levels, are likely to improve given the proposed rock structures. Riffle augmentation in the dominantly sand run system, which currently exists in 90 percent of the reach will improve oxygen levels and provide velocity microstructure necessary for a diverse aquatic habitat. Enhanced lower bank vegetation will lower stream water temperatures, thus improving habitat. Stabilizing bed forms, such as the lateral bars, will assist with the establishment of a community of aquatic organisms requiring attachment and flow continuity.

In addition to affecting water quality and aquatic habitat, stream stability also impacts adjacent lands and infrastructure. Unstable streams represent one of the largest maintenance costs for urban storm systems. To the extent that enhancement can promote channel stability, stabilizing the stream can minimize future costs and impacts on riparian lands.

In general, stream and habitat improvements represent intangible community benefits, which can increase the quality of a given community and its land values. While this project is not part of an established park or trail system, the habitat improvements, particularly for the buyout area, should represent open space of community value. In addition, the improved aquatic, wetland, and riparian habitat will provide a convenient location for citizens in the vicinity to observe a diversity of natural phenomena.

3.0 GENERAL WATERSHED DESCRIPTION

Irwin Creek drains to the Catawba River, and at the study location drains approximately 31 square miles of the central and central northern portions of the City of Charlotte (City). The extent of the contributing watershed is shown in Figure 1. The watershed is part of the Piedmont physiographic province of the SE-U.S. and is characterized by rolling hills of low to moderate relief. The study reach has a streambed with an average elevation of approximately 590 feet above sea level, and hilltops in the drainage basin rise to approximately 700 to 800 feet above sea level. The reach under study for restoration/enhancement is a 5,000- to 6,000-foot long reach of Irwin Creek shown in Figures 2 and 3.

The lands within the contributing watershed lie within the urban and suburban (northernmost extents) of the City, and have been cleared and developed, with exception to 10 to 15 percent of the northernmost portions of the drainage basin. Of the developed portions, approximately 30 to 40 percent are commercial and industrial lands, and the remainder residential. This land-use pattern would suggest that the watershed is impacted by approximately 25 to 35 percent impervious cover. The lower portions of the watershed, relative to the study reach, are the more commercial and industrial sectors, and thus, impacted more severely by storm runoff.

The Irwin and Stewart Creek watersheds lie within the geologic zone of the North and South Carolina Charlotte Pluton Belt, a region dominated by plutonic and metavolcanic rocks of Paleozoic age. Based on the Geologic Map of the Charlotte 1 x 2 Quadrangle (USGS, 1988), the upper portion of the watershed is located within a quartzite (Stewart Creek) and metadiabase (Irwin Creek) complexes. The metadiabase is a favored unit for crushed aggregate and riprap, and a large quarry operation exists within the upper zone. The co-occurrence of riprap of diabase used in banks within the reach, as well as naturally within the watershed makes it more difficult to differentiate natural from unnatural bed materials. The immediate portions of Irwin Creek under consideration for restoration have predominantly exposures of a metamorphosed quartz diorite, tonalite, and granodiorite with subordinate northwest oriented mafic dikes.

4.0 LOCATION INFORMATION

The Study Area is located on Irwin Creek in the Catawba River Basin (USGS HUC No. 03050103). The North Carolina Division of Water Quality (NCDWQ) lists this tributary in Subbasin No. 03-08-34 and classifies the best usage of the waters as Class C. Class C waters are waters protected for secondary recreation, fishing, wildlife, fish and aquatic life propagation and survival, agriculture and other uses suitable for Class C. Secondary recreation includes wading, boating, and other uses involving human body contact with water where such activities take place in an infrequent, unorganized, or incidental manner. There are no restrictions on watershed development activities. Wastewater discharge and storm water management requirements are applicable (NCDWQ, 1999).

Irwin Creek is listed on North Carolina's 303(d) list of Impaired Waters from its source to Sugar Creek. This impairment is a result of fecal coliform contamination from industrial and municipal sources as well as urban runoff. In addition, Mecklenburg County (County) Water and Land Resources assigns a Water Quality Index to its watersheds. Irwin Creek in the vicinity of the Project Area is rated as Poor-Fair (MCWLR, 2002). Fish and macroinvertebrate sampling data are provided in Appendix A.

Irwin Creek is channelized through the upstream portion of the Project Area and has been impacted by urbanization in its watershed. Other dredging activities may have occurred downstream of the Irwin Creek Wastewater Treatment Plant (WWTP). The channel is entrenched and has steep banks. Channel substrate material is primarily composed of sand with bedrock outcroppings throughout the Study Area. Photographs 1 through 7 were taken at low flow in late December and indicate typical conditions of the bed and banks within the reach.

5.0 EXISTING STREAM CONDITIONS

5.1 Historic Dredging in Irwin Creek

The earliest documentation identified for waterway works on Irwin Creek comes from a paper by Hariot Clarkston (1917?), entitled "Drainage Work in Mecklenburg County". This document reference is made to the establishment of a Mecklenburg County Drainage Commission in the period 1910-1912 under whose direction a program of dredging was implemented for many of the streams of Mecklenburg County. The paper by Hariot

Clarkston does not outline in any comprehensive manner those creeks that had been dredged or that were scheduled for future dredging within the drainage program. Landowners appear to have contributed significantly to the capital and operational costs and were influential in the selection and timing of areas being dredged.

The paper does provide sufficient descriptive comments on the completed and ongoing operations circa 1911-12 to conclude that Irwin, Stewart, Sugar, Little Sugar, and Briar Creeks were all dredged in their upper reaches. The typical dredging characteristics are also described as providing a channel some 20 to 30 feet in width and 8 to 11 feet in depth. The dredge boats used were 18 x 70 x 5.5 feet in dimension, and had steam-powered 1.5-yard "dip buckets", as well as a "dynamo" for lighting to continue the work at night. Crews were brought in to break up the rock ledges by hand to pass the dredge, and in some instances, either bridges were partially dismantled or the dredge was partially dismantled to pass bridge obstructions. It was noted in one instance that over 1,200 feet of granite were broken up along Little Sugar Creek to pass the dredge. The comment was made that one of the two dredges commenced on Big Sugar Creek "going up Stewarts Creek; thence down Big Sugar Creek." At the time the paper was written, some 11 miles of Little Sugar Creek and 8 miles within Stewart and "Big Sugar" Creeks had been completed; however, the implication is that dredging was still in progress within the "Big Sugar" Creek (Sugar-Irwin-Stewart Creek) watershed. While the paper provides a semi-quantitative estimate of average finished channel dimensions, there is insufficient information to conclude that a set standard was to be achieved. A comment was made that Irwin Creek, near the uptown West Trade Street area, had been lowered 2 to 3 feet in grade.

The information and inferences that can be drawn from this early dredging program are incorporated in this report to postulate the pre-urban (pre-dredged) dimensions of Irwin Creek in the Study Area.

5.2 Hydrologic Analysis

5.2.1 USGS Gaging Data and Recurrence-Discharge Analysis

The gaging station at the northern end of the WWTP (just south of the bridge) has been in operation continuously since 1963 and provides sufficient data on annual peak flows to determine a storm discharge return interval. The annual peak data is shown in Table 1. A convention for analyzing the frequency or return interval for floods of a given magnitude for streams of mid-latitudes has been adopted, which uses annual peak flow data for a minimum period of 20 years. This method has been referred to as the Weibull method (Dalrymple, 1967; Chow, 1964). The method requires that peak discharges for the period of record be ranked from highest to lowest discharge, and assigned a probability of "exceedance", P which is calculated by:

$$P = [m^*/(n^*+1)]\ 100\%, \text{ where}$$

n^* = number of years of record, and
m^* = rank or magnitude (1 for the largest, etc.)

The recurrence interval, T, can then be expressed as:

$$T = (n^*+1)/m^*$$

Once the probabilities, or recurrence intervals, have been calculated, the data can be plotted on log-probability paper, or on semi-log paper in the case of the recurrence intervals, to estimate values beyond the period of record (e.g., 100-year flood). The probability and recurrence interval plots are shown in Figure 4 for Irwin Creek at the WWTP. From these plots, the discharge for the 1- and 1.5-year storms can be estimated. These return intervals are thought to be close to the dominant or "channel-forming" storm within the North Carolina Piedmont (Harmon et. al, 1999, Doll, et. al, 2000). These estimates are 2,440 cubic feet per second (cfs) for the 1-year return storm, and 2,930 cfs for the 1.5-year return storm.

5.2.2 North Carolina Regime Analysis

A second method of determining the likely dominant (channel forming) discharges in a given setting of the North Carolina Piedmont is to use "regime" relationships worked out by analysis of streams that have good bankfull morphologic indicators as well as USGS gaging. This analysis has been done for both rural and urban streams in the North Carolina Piedmont (Harmon et. al, 1999, Doll, et. al, 2000) and generated the following sets of relationships:

Urban Streams (this set is in meters and km^2)

Abkf = 3.11 Aw 0.64
Qbkf = 5.44 Aw 0.57
Wbkf = 5.79 Aw 0.32
Dbkf = 0.54 Aw 0.32

Rural Streams (this set is in feet and mi^2)

Abkf = 66.57 Aw 0.89
Qbkf = 18.31 Aw 0.75
Wbkf = 11.89 Aw 0.43
Dbkf = 1.50 Aw 0.32

In these equations,

Aw = the drainage basin contributing area
Abkf = cross-section area of flow at the bankfull stage
Qbkf = discharge at the bankfull stage
Wbkf = width of the water surface at the bankfull stage
Dbkf = mean depth of flow at the bankfull stage

The drainage area for Irwin Creek at the WWTP is approximately 31 square miles. In Figure 5, the regime curves have been generated in the same units for both urban and rural watershed. On each of the graphs, a vertical line is drawn for the Irwin Creek watershed at the WWTP. Intercepts are shown for both the rural and urban curves. It should be noted that a preponderance of the data used to generate the urban curves were obtained from urban streams in the County. Those with drainage areas larger than a few square miles have bankfull widths in excess of 20 feet and could have been dredged in the dredging program operated in the County in the early part of the 20^{th} century. Thus, it is uncertain whether or not the urban data represent equilibrium conditions obtained by natural channel processes. The values for bankfull discharge at Irwin WWTP are estimated for the rural curves at 1,402 cfs and urban curves at 2,326 cfs. The values for bankfull width are 52 feet and 77 feet, for rural and urban conditions, respectively. The values for bankfull cross-section area are 238 and 550 square feet, for rural and urban conditions, respectively. Bankfull mean depths are 5.2 and 7.2 feet, for rural and urban settings, respectively. The differences between these two estimates allow a comparison of current and probable pre-development conditions, which are shown in Figure 6.

5.2.3 Bankfull – Manning Equation-Based Estimation of Bankfull Discharge

The observance of bankfull indicators along the upper and lowest most zones of the Irwin restoration reach (Zones 1 and 4) at approximately 8 to 9.5 feet above the average channel bed surface provides an additional means for calculating the bankfull or dominant discharge. This approach uses the Manning Equation. Bankfull stage, cross-section area for flow, water surface slope, and a Manning roughness factor are needed to solve the Manning Equation. The dimensional data are shown in Figures 7-7d, and Table 2 shows all the parameters and results. The greatest ambiguity in these calculations is the Manning roughness factor. Here, since the depth of flow at the bankfull stage is greater than three times the mean grain diameter that makes up the bed, an estimate of the Manning roughness (n) can be derived by the Strickler (1923) function:

$$n = .04 \times d50\ 1/6$$

This value would then be modified for other resistance factors such as bank vegetation, channel irregularities, or obstructions. As the reach in question is straight and close to 100 feet in width at the top of bank, the Strickler function should provide a reasonable base estimate. However, an additional resistance factor of 0.005 has been added for bank vegetation in one scenario, and an additional 0.005 for larger scale bed forms has been added in a second scenario. A D_{50} of approximately 3 cm (.03m) is used for these calculations. In Scenario 1, this yields a roughness factor of approximately 0.0025; in Scenario 2, this yields a roughness factor of approximately 0.003. These resulting discharges for the four cross-sections, shown in Figure 7, are tabulated in Table 2. For all except the constricted profile at the WWTP bridge, the results lie between 2,000 and 3,000 cfs, which is in reasonable comparison to the values determined from the frequency analysis of the annual peak flow data, and the estimates made from the NC urban regime curves. The mean value, excepting the WWTP bridge/gage station section, is 2,776 cfs, which lays between the 1- and 1.5-year return storms for the United States Geological Survey (USGS) gage data previously discussed. This value, 2,776 cfs, is believed to represent dominant discharge in the reach under current watershed and hydraulic conditions.

A fourth and final indicator of bankfull discharge comes from the Hydrologic Engineering Center HEC-1 and HEC-RAS modeling completed for the Project Area. These data are provided in Appendix B. One theory on bankfull discharge is that the dominant discharge reflects a set interval within any one climactic and physiographic set of watershed conditions. In the North Caroline Piedmont, it has been suggested that this return interval is close to the 1.5-year storm (Harmon et al., 1999; Doll, et al., 2000). From the HEC-1 model, the peak flow for the 1.5-year return interval and future land-use conditions has been estimated at 4,000 cfs for Irwin Creek at the WWTP, with a drainage area of approximately 30.3 square miles. This estimate is considerable larger than the estimates made by the other three techniques, partly due to its reliance on future land use conditions. The other three techniques are reasonably consistent with each other (given the uncertainties). On May 21 and 22, 2003, the Irwin Creek watershed experienced heavy rainstorm. Between 2:40 p.m. on May 21, and 4:45 p.m. on May 22, 3.13 inches of rainfall were recorded at USGS Gage 0214620760 on Irwin Creek at Starita Road. According to Technical Paper 40, a 1-year, 24-hour rainfall is 2.9 inches and a 2-year, 24-hour rainfall is 3.5 inches (USDA, 1961). HDR staff noted water levels near Whitehurst Road between 0.5 and 1.0 feet below the top of bank. At the same time, USGS gage station 02146300 recorded a peak flow of 4,040 cfs and a gage depth of 13.01 feet. This flow value corresponds with the future land use condition 1.5-year peak flow. At HEC-RAS cross-sections 5,492 (from the FIS) and 5,240 and 5,049 (approximate), located in the Whitehurst Road area, a peak flow of 4,000 cfs produces a cross-section depth of 13.9 to 14.3 feet, with a water surface elevation approximately at the top of the left channel when looking downstream. This observation is clear indication that the future land use condition 1.5-year Federal Emergency Management Agency (FEMA) design storm used for modeling purposes correlates with the top of bank storm but not with the bankfull morphologic indicators in this reach. Additionally, the USGS historical data, obtained at the gaging station at the WWTP, reflects a constricted cross-section and will over estimate channel depths for low flows. The historical USGS data also reflects less developed watershed conditions and is biased to a higher historic return interval for the current 1.5- or 2-year storm. It would be instructive to use the HEC models to run the antecedent watershed conditions, e.g., 1965 land cover conditions, and see if the model reflects the historical peak annual flow data.

5.2.4 FEMA Flooding Analysis

The City and County had previously contracted with Watershed Concepts for the development of a storm runoff model for the main watersheds in the area. For this project, a series of preliminary hydrologic analyses have been performed in support of the design. These analyses included determination of the 1.5-, 2-, 10-, 25-, 100-, and 500-year discharge and flood stages for a series sections along Irwin Creek within the restoration reach. All hydrologic analytical results are presented in Appendix B. These studies indicate that the design approach is not likely to negatively affect flooding; however, more detailed analyses will be performed prior to completion of the designs. Discharge and velocity estimates from the flow modeling have been carried over into Table 3 on morphologic parameters and are used to estimate bed shear or traction forces for varying stream and runoff conditions shown in Table 4.

5.3 Soils

Soil information for the watershed comes from the County Soil Survey (USDA, 1980). Based on the General Soil Map of the County, Irwin and Stewarts Creeks are located with Cecil-Urban type soils. These soils can be nearly level to strongly sloping. These well-drained soils have predominantly clayey subsoil, which is formed in place from acid igneous and metamorphic rocks. Fluvial sediment, classified as Monacan Soils, is found in the flood plains of these two creeks. Monacan soils are nearly level and somewhat poorly drained. These soils contain predominantly loamy subsoil. The detailed soil maps from the same source indicate that the upland soils are typically comprised of soils classified as Enon, Helena, and Vance. These soils all have low organic content in the surface soils, low permeabilities and medium surface runoffs. Side slopes are typically comprised of soils classified as Cecil and Pacolet. Pacolet soils also have low organic content in the surface soils and low permeability but are expected to have rapid runoff.

5.4 Plant Communities

The composition and distribution of plant communities are reflective of topography, soils, hydrology, and past and present land use. In this case, the vegetation of the Study Area is primarily determined by land use. The vegetation on the southeast side of the stream within the buyout area is residential with no natural community cover and is currently maintained by the County. The WWTP is also on this side of the stream. On the northeast side of Irwin Creek, between the stream and the utility rights-of-way (ROWs), a sparse canopy of Pine, Ash, Sweetgum, Red maple and mixed Oaks (white and red) exist.

5.5 Protected Species

A review of the North Carolina Natural Heritage Program database of rare species and unique habitats (as of December 2002) shows one occurrence of Federally protected species within one mile (1.6 km) of the Project Area. The Carolina heelsplitter (*Lasmigona decorata*) was present in Irwin Creek and is documented as a historic record only. The current range of this species in Mecklenburg County is restricted to Goose Creek in the extreme eastern edge of the County. The Project will not impact this species.

Other Federally protected species occurring within Mecklenburg County include the Bald eagle (*Haliaeetus leucocephalus*), Smooth coneflower (*Echinacea laevigata*), Schweinitz's sunflower (*Helianthus schweinitzii*), and a historic record of Michaux's sumac (*Rhus michauxii*). HDR staff has surveyed for these species along the Project length and none were observed. Additionally, habitat for these species is not present within the Project Area due to its disturbed, urban conditions and steep bank slopes. The Project will not impact these species.

5.6 Stream Geometry

Irwin Creek can be classified as a Rosgen Class C3 to C5 stream. Class C streams are typically slightly entrenched with a moderate to high width to depth ratio (Rosgen, 1996). Irwin Creek, at the WWTP, exhibits an entrenchment ratio of between 1.4 and 2.4 and a high width to depth ratio of 13.5 to 16.1 (Table 3). More specifically, Class C3 to C5 streams exhibit a slope ranging from 0.001 to 0.02 (Rosgen, 1996). Irwin Creek exhibits a slope of 0.0013, which is within this range. Bedrock outcroppings also influence the channel slope and sinuosity by creating nick points.

However, this stream segment does not exhibit all the parameters for a Class C channel. Irwin Creek has been channelized and dredged; therefore, it does not have the high sinuosity typical of Class C streams (Table 3). Additionally, the relationship between the stream channel and flood plain has been altered by these activities. Flash flooding occurs in this urban area. Dredging has also altered typical riffle and pool sequences.

5.7 Stream Substrate

The stream travels over several zones of bedrock and, downstream of the WWTP, large outcrops of the native bedrock material can be seen in the stream channel and along the banks. The channel bottom is comprised primarily of sand and pebbles, with several areas of cobble riffles, a few large boulders, and native rock outcrop zones.

Riffle, pool, and point bar pebble counts present a quantitative characterization of streambed material, sediment transport, and hydraulic stress. Surface particles, or pavement material, are usually coarser than subpavement particles. These later particles are likely to be mobilized by stream flows and velocities associated with near bankfull storm events. The riffle substrate D_{50} particle size is 73 mm, while the streambed D_{50} is 30.5 mm. The point bar D_{50}, which is much smaller than the riffle and a streambed measurement, is 6.1 mm. The larger D_{84} sizes are 110 mm in riffles, 45.3 mm in the streambed, and 9.6 mm in the point bars (Table 3). Further substrate analysis is presented in Section 7.2.

5.8 Constraints

5.8.1 Site Constraints

Utilities

A 36-inch sewer line parallels the right stream bank, looking downstream, for the northern end of the Project to the WWTP. A natural gas line Right-of-way (ROW) also parallels this bank at a further distance. Another sewer line travels down Whitehurst Road and continues along a ROW on the right stream bank before crossing to Irwin Creek WWTP. One storm sewer outfall discharges from Whitehurst Road on the left stream bank, looking downstream.

Irwin Creek Wastewater Treatment Plant

The Irwin Creek WWTP began operation in 1927 and serves the northwest portion of the County including the Paw and Long Creek basins. The facility has been expanded over time and is currently a 10- to 12-million gallon per day (mgd) facility. The facility operates under National Pollutant Discharge Elimination System (NPDES) Permit NC 0024945, which permits discharge up to 15 mgd to Irwin Creek (NCDENR, 2001a).

FEMA Actions

Levee Protecting Irwin Creek WWTP

In an effort to both protect Irwin Creek WWTP from floodwaters and the Irwin Creek from WWTP pollution, a floodwall was constructed in 2001 around the Irwin Creek WWTP. This wall is built to an elevation sufficient to protect the facility from a 500-year flood event.

Buyout Area

The County owns the parcels along the north side of Whitehurst Road. Houses on these parcels have been razed. In addition, one house at the end of Abeline Road has also been razed. As a result, the dead-end section of Abeline Road has been abandoned. Utility lines running behind these houses were abandoned after demolition. These addresses are as follows:

- 1218 Abeline Road
- 4000 Whitehurst Road
- 4012 Whitehurst Road
- 4018 Whitehurst Road
- 4024 Whitehurst Road
- 4030 Whitehurst Road
- 4036 Whitehurst Road
- 4100 Whitehurst Road
- 4108 Whitehurst Road
- 4114 Whitehurst Road

5.8.2 Technical Constraints

In the sections that follow, fluvial geomorphic and hydrologic data are presented and discussed in light of the proposed design. The design follows the basic procedures laid out in the Technical Guide for Stream Work in North Carolina (NCDENR, 2001b) in that a reference reach approach is initially used to define the basic fluvial geomorphic elements of pattern, dimension and profile. These data are summarized in Table 3. There are three factors that make a strict reference reach approach to the restoration problematic. First, storm flow from piped storm drains in the older and more urbanized parts of the City has produced a flashy, storm surge in Irwin Creek that limits the direct applicability of reference reach data. Second, the greater majority of Irwin Creek (and its upstream tributary of Stewart Creek) was enlarged and entrenched by dredging prior to 1917, which lowered the creek with respect to the surrounding landscape. Unfortunately, these activities were followed by 80 plus years of fill and construction within the Irwin Creek floodway. Restoration to original conditions is currently not tenable as it would require elevating the streambed by approximately 3 to 5 feet with substantial losses in conveyance and an increase in flood damages within the FEMA designated floodway. Third, the reach contains one of the primary WWTPs for the County and City. The treatment plant, along with the various utility easements along the Creek, limits restoration efforts to the enhancements that can be developed primarily within the existing creek corridor.

5.9 Site Specific Data

Nine lines of site-specific preliminary data have been investigated to formulate a strategy and conceptual design for the restoration and enhancement of Irwin Creek near the Irwin Creek WWTP. These are as follows:

- Recent color aerial photography,
- Current County engineering topographic data (2-foot contours),
- Field survey of cross-sections where bankfull indicators are present,
- Field survey of bedforms at a 20-foot resolution,
- Field survey of longitudinal profile,
- Field survey of bank conditions,
- Field survey of tributary cross-sections and longitudinal profiles at all confluences,
- Field survey of storm water out falls, and
- Field and laboratory assessments of sediment characteristics.

For the purposes of this discussion, the site-specific data are broken down into four restoration or enhancement zones from north to south, which are shown in Figure 8. These zones carry forward in the development of the design for restoration and enhancement.

5.9.1 Recent Color Aerial Photography

The aerial photography is used as a base for Figure 2, and illustrates the land cover and land use in and along the reach. Notable from these data is the limited opportunity for the development of a conservation buffer along the northwest bank of Irwin Creek in Zones 1 through 3 due to the existing utility ROWs. Also notable is the limited access into the stream corridor in the lowermost Zone 4 for heavy equipment that may be needed to install restoration/enhancement instream structures. Elements in the design plan for this lower area are contingent upon finding an access with an acceptable level of impacts on surrounding hardwood bottomland forest stands.

5.9.2 Engineering Topographic Data

Two-foot topographic contours obtained from the County are used as a base for Figures 2 and 9-15. From these data, a series of four initial cross-sections was prepared to determine the approximate cross-section areas for storms with varying stage and discharge. The topographic data provide important bank and flood plain information to extend observations and interpretations drawn from field cross-section and longitudinal data. They are used to calculate the drainage areas for the tributaries entering Irwin Creek above and below the buyout areas. In addition, the data are used to estimate the areas and storm water loads associated with each of the mapped tributaries and storm water outfalls. However, the more detailed cross-sections determined by detailed field surveys show that the localized bank slopes cannot be reliably estimated from the 2-foot contour data. Both the detailed cross-section and bank erosion hazards assessments show that the topography maps underestimate local slope conditions. Morphologic data that was initially determined from the topographic data (and included in the 30 percent design) have been replaced by data determined from detailed field surveys.

5.9.3 Field Surveyed Cross-Sections

Six detailed cross-sections have been obtained in representative areas of the restoration reach. The locations of the cross-sections are shown on Figures 14 and 15. These include inflection, meander, and straight run sections of the reach. From these data, it is clear that the reach was dredged at some point in the past. For example, on cross-sections 2 and 3, berms of dredge spoils are preserved in the cross-section data. Notably, these features are two small to have been seen in the County data. These dredge spoils are not universally present, and suggest that secondary grading along Whitehurst Road probably removed this material to promote the drainage of flood plain areas where infrastructure (e.g. residences) was at-risk. The width of the stream narrows considerably in north end of the WWTP, and bank assessments indicate that a more recent bank armoring of rip rap has closed in the stream cross-section from that seen north or south of this area. The design discussed below accommodates the varying cross-section conditions encountered in the reach. The cross-sections allow the calculation of bankfull areas, flood prone areas, entrenchment ratios, low flow channel widths, and top-of-bank stage heights. Standard geomorphologic parameters are included in Table 3 along with reference reach parametric data. A number of the primary geomorphic parameters are also shown on regime graphs in Figures 5 and 16 along with reference reach data, and North Carolina rural and urban Piedmont data.

5.9.4 Field Surveyed Bedform Structure

The mapping of bedforms was completed at approximately a 20-foot resolution and carefully interfaced with the survey of the longitudinal profile, so water and bed surface elevations and slopes could be correlated with bedform characteristics, such as bedrock ledges and riffle crests. The bedform characteristics are represented in Figures 14 and 15, and illustrate the run, riffle, and pool areas along the reach. In addition, the figures show the location of all significant bedrock exposed along the reach, as well as the main sand bars.

5.9.5 Field Survey of Longitudinal Profile

The longitudinal profile for the Irwin Creek reach is shown in Figure 7d. The pool, run, and riffle areas have been overlain on this profile. This overlay allows for the calculation of the characteristic slopes for run, riffle, and pool areas. The individual values are shown in Table 5, and then summarized in Table 3.

5.9.6 Field Survey of Bank Conditions

Bank conditions along this reach were semi-quantitatively assessed using slope, vegetation, and substrate parameters needed to obtain a bank erosion hazard ranking (BEHI protocol). The assessment was completed at a resolution of 50 feet horizontally and 5 feet vertically. It was clear from initial qualitative reviews of the creek that the banks had very different bank stability states along its toe, middle, and upper areas. With bank heights in excess of 14 feet throughout most of the reach, the top 1/3 of the banks had conditions largely controlled by flood plain vegetation. The middle 1/3 of the banks had conditions controlled by the irregular development of an 8- to 10-foot bankfull bench, and the lower 1/3 of the banks had conditions determined by bank substrate and hydraulic erosion forces at persistent low stage creek flows. Thus, six independent BEHI values were determined for each 50-foot segment of creek, three values for the right bank and three values for the left bank. These values are tabulated in Table 6 and diagrammatically shown in Figure 17. In addition to the BEHI values, Figure 17 also shows where the bank survey encountered bedrock or c-horizon weathered rock along the toe of the bank. These zones provide high resistance to bank erosion and substantially diminish the need for artificial bank protection structures at the toe. The presence of bedrock also limits the use of either coir fiber logs or root wads as these cannot be practically emplaced in bedrock areas. A comparison of the bedrock areas noted in the bank survey with the bedrock areas noted in the bedform map (Figures 14 and 15) shows that Zones 2, 3 and 4 all have substantial amounts of bedrock in the banks and channel bed, which act to prevent all but localized areas of bed and bank erosion. The detailed assessment performed of substrate conditions along the reach substantially lowers the amount of hard and artificial structures that need to be used in the restoration to stabilize both bed and banks in Zones 2, 3, and 4.

5.9.7 Field Survey of Tributary Confluences

The reach has five tributaries which discharge significant flows into the reach. The confluence areas of each of these tributaries may need to be considered for stabilization during the restoration. The location and the profile and cross-section data collected for each tributary are shown in Figures 14 and 15 and in Appendix C. Specific construction details for each of the confluence areas will need to be completed in the final phase of the design work, but it is anticipated that where these confluences are not bedrock-based, a rock-faced, stepped outfall zone may be needed to control and dissipate energy at the confluence, while still allowing migration of aquatic organisms. Inspection of the cross-sections and profiles for these tributary confluences indicates that each of these represent substantially different conditions, dictating that each be separately evaluated prior to the preparation of the final construction plans.

5.9.8 Field Survey of Storm Water Outfalls

An instream survey for storm water outfalls was performed to locate and characterize each outfall. In Appendix D, these are shown on Figures 1 and 2 and tabulated in Table 1. There are two outfalls that drain lands east of Whitehurst Road, which may be intercepted by the construction of the flood plain bench discussed below in the design. Depending on the depth of the pipe approximately 80 feet northwest of Whitehurst Road, the storm drain may be terminated onto the flood plain bench, where water quality improvements can be realized by the bio-retention of storm water in this zone. If it is possible to intercept these storm outfalls, the additional water will promote potential wetland habitat on the southeast flank of the flood plain bench. The invert elevation of the larger storm water outfall is at the elevation of the channel so no step-down protection is necessary if the outfall cannot be relocated.

5.9.9 Field and Laboratory Survey of Sediment and Grain Size Distributions

Finally, in order to understand the impact of sediment transport and storage in the channel along this reach of Irwin Creek, a series of field and laboratory measurements of sediment sizes were obtained. These were obtained from lateral and point bars and riffle areas. The individual site and sample results for the sediment analysis are included in Appendix E. The data for Irwin Creek are tabulated in Table 7, and average riffle, bar, and bulk stream grain sizes are presented in Table 3.

5.9.10 Conclusions

The combined sources of data for existing conditions along Irwin Creek in the restoration area permit some generalizations for the existing conditions for each of the four zones of the restoration reach.

The northernmost zone (Zone 1) is the 1,100- to 1,200-foot long reach adjacent to the FEMA buyout area along Whitehurst Road. This reach has a bedrock ledge at the northern end near the confluence with the unnamed tributary; however, this zone is a sand dominated run without significant pools or riffles. The channel has numerous lateral and medial bars, which were largely submerged at the time of the preliminary field assessments. The reach is essentially straight, with a sinuosity of one. The aerial photographs indicate that woody vegetation is limited to stream banks and a narrow 10- to 40-foot fringe of land along the banks. The topographic data show a fairly typical fourth to fifth order Piedmont tributary grade of 0.0011 to 0.0013. The banks are evenly laid bank along this reach and have slopes of approximately 2:1 to heights on average of 10 to 15 feet. A bench is discontinuously developed along the banks with a top inner berm height of approximately 8 to 9.5 feet. This bench is used as the bankfull indicator for the preliminary conceptual design. Two cross-sections are shown in Figure 7 for Zone 1 along with dimensional data on cross-section area, bankfull widths, flood prone widths, width/depth and entrenchment ratios. A comparison of dimensional data with reference reach and other information follows in this section. The west bank has a few areas where the bank is barren and eroding along its upper edge. Two additional first order channels enter the reach, one from the west at the upper end of the buyout area, and one from the east at the southern end of the buyout area. The one on the west is heavily armored by riprap as it crosses the main sewer line; this area is the cleared easement seen on Figure 2. The other is deeply incised in the confluence area. The tributary at the south end drains less than 0.1 square miles, and its relationship to the proposed flood plain bench is discussed below. Both tributaries are very incised or entrenched in the confluence area within the flood plain for Irwin Creek. This is a condition, which has been exacerbated by past dredging operations along Irwin Creek. Bedrock ledges were noted in the tributary at the south end of the buyout area, and rock is present in Irwin Creek just north of the restoration area at the confluence with an additional tributary that enters from the southeast. This zone of Irwin Creek has the least exposed rock, highest lower slope bank erosion hazard index values, lowest riffle and pool structure, and largest amount of lateral bars.

Zone 2 is the 960-foot long reach that extends from the FEMA buyout area down stream to the northern edge of the WWTP. This reach is also has a sinuosity of one, and the bank characteristics and channel cross-section dimensions are similar to Zone 1. There are a few areas of bank erosion, also located on the west side. In this zone, the channel has a few rock ledges forming short riffle areas, but past dredging has caused the channel to be dominated by a sand bed run. Bedrock is also more prevalent along the toe of the bank slopes.

Zone 3 consists of the 1,500 feet of stream that traverses the WWTP. This area essentially has a sinuosity of one and has vegetated riprap from toe to top of bank. The cross-section 3 (Figure 7) was constructed from this zone just south of the bridge crossing, near the gaging station. The upper 1/3 to 1/2 of this WWTP reach has a constricted cross-section area in comparison to the areas north and south. The banks are also steeper in this area, suggesting that armor was aggradationally emplaced on top of a preexisting cross-section similar to that seen north or south of the constricted area. Photographs 3 and 4 illustrate this zone. The WWTP has facilities that encroach to edge of bank on both sides, and the east side has the constructed flood protection wall to heights sufficient for the 500-year flood. As noted in the photographs, lateral bars have formed in the lower portions of this reach. The channel is dominantly a sand bed run. The reach has a grade that increases slightly at the southern end. Due to the constricted profile in the upper zone and the lack of appreciable change in grade or roughness characteristics, it is highly probably that a hydraulic jump develops immediately north of the WWTP bridge during major storms.

Zone 4 extends approximately 1,500 feet downstream from the southern end of the WWTP and has a slope that is transitional from that seen in the lower end of the WWTP to values similar to that seen north of the WWTP. There are four meanders in Zone 4, all of which show considerable bank stress. Two of the meanders have radii of curvature much lower than that expected to be stable for the dimensions of the channel; however, they are controlled by bedrock. There are several areas where bedrock is exposed in the channel and lower banks in this zone. Despite the appearance of some bedrock in the banks and bed, most of the riffle areas are short, with a dominance of sand deposition within the riffle area. This is likely the product of an over widened channel from prior dredge activity. The sinuosity in Zone 4 is approximately 1.3, due to the preservation of the original creek planform in this zone. There are several areas of extensive flood plain development in this lower zone underlain by Monacan, or fluvial soils. However, bank and bed surveys also reveal areas of substantial bedrock. The presence of substantial bedrock in this zone, along with preserved original meander bends and sinuosity, allows a restoration and enhancement plan that focuses on the augmentation and stabilization of existing features.

6.0 REFERENCE REACH DATA

The reference reach information for this design is provided in Table 3. These data come from reference reach assessments conducted in the last 12 months for this project, and the adjoining WRP project on Little Sugar Creek. Together, over 14 possible reaches with comparable watershed sizes and physical settings have been inspected for the feasibility of providing adequate regime or equilibrium relationships. From these inspections, three reference reaches, two identified from the Little Sugar Creek WRP project (Briar and Long Creeks), and one identified from this study (Leepers Creek, Lincoln County) were surveyed to obtain reference reach regime data for the design. Following are a few general comments made regarding the Briar and Long Creek reference reaches. However, a complete reference reach data set for the

Leepers Creek site is provided in Appendix F. The three datasets are combined along with the NC regime datasets to provide an integrated reference framework for selecting design parameters for the restoration work along Irwin Creek.

The Briar Creek reference reach was previously studied by Dames and Moore (2001) on behalf of the U.S. Army Corps of Engineers (USACE) in order to provide a foundation for an initial design framework for FEMA-based restoration work along Little Sugar Creek from East Boulevard to Tyvola Road. The reference reach on Briar Creek was chosen based on recommendations from City/County Storm Water staff regarding the stability of the reach in the vicinity of the Myers Park High School. The reach in question has substantial portions of both bed and banks composed of bedrock. The rock has essentially stabilized the channel regardless of watershed land cover changes. However, the channel is wide enough to pass the dredges used in early 1900s; therefore, one cannot preclude the channel within this reach having been altered. The Clarkson drainage report specifically mentions that Briar Creek was dredged but did not discuss in any detail the limits of dredging along the creek. Also the reach has a sewer line, which had to be blasted into the bedrock along the east side of Briar Creek. This created a bench composed of rock aggregate along the east bank and modified the cross-section of the stream. Despite these detractors, Briar Creek has the most similar land cover and land use to Irwin Creek. As a part of design research, additional data in the WRP Little Sugar Creek project was used to augment and confirm the data collected in the Dames and Moore USACE study.

The Long Creek watershed drains to the Catawba River in the northern most part of Lake Wylie just below the dam to Mountain Island Lake. The reference reach on Long Creek is just 1/4 mile southeast of the Gar Creek Cove on Mountain Island Lake. It can be accessed from Prim Road, along a County or NCDOT access into the future Interstate-485 corridor. The reach will eventually be partially impacted by the new outer belt. The watershed that drains to the reference reach has approximately 10.5 square miles of drainage from predominately residential lands but with subordinate forested and commercial/industrial tracts. Conventional stream assessment survey techniques were used (e.g., Rosgen 1994) to acquire this information. The Long Creek reference reach has dimensions smaller than 18 feet and would not have passed the dredges used in the early 1900s dredging program. The Long Creek reach also has a bedrock based riffle section with v-shaped valley profile inconsistent with the rock removal and down cutting practices used in conjunction with the earlier dredging program. While Long Creek has a substantially smaller drainage area than the impacted Irwin reach, the site is located within the same geologic, soils, and physiographic settings as Irwin Creek and has the benefit of being just under the dimensions that could have permitted the passing of the early 20th century dredge barges. This, in addition to the clearly un-altered bedrock valley cut within the Long reference reach, makes it a bench mark site for having preserved natural morphologic relationships within the NC Piedmont's Charlotte granite belt.

The Leepers Creek watershed is located approximately 20 miles northwest of Charlotte in Lincoln County within the Kings Mountain Belt geologic terrane. This area has similar gneiss and granitic rocks to the Charlotte granite belt within the Leepers Creek watershed. In addition, it has a similar topography and climate. The primary difference is that the watershed is dominated by rural, open and wooded lands. The reference reach encompasses approximately 3,000 linear feet of the creek just north of the Highway 73 Leepers Bridge crossing and just west of the intersection of Highway 73 and Trinity Church Road. It is located approximately 5 to 6 miles east of Lincolnton, NC. The reach has a drainage area of 28.2 square miles and, therefore, is almost identical in size to the Irwin Creek watershed at the WWTP site. A second attribute that makes the reach attractive for reference reach data is that the stream slope is only 0.002, comparable to the 0.002 slope at the Irwin Creek WWTP site. The other two reference reaches had significantly higher stream slopes. In general, stream slope decays with watershed size, and streams move from sediment generating valley channel beds to sediment transporting channels. The similar watershed size and water slope suggests that these two systems have comparable geomorphologic settings with respect to sediment erosion and transport channel dynamics in the North Carolina Piedmont. A complete reference reach assessment of this reach was made during March, April, and early May at this site. Due to abnormally high rainfall during this period (more than 20 inches since early March), the assessments could not be performed at low flow, which limited some of the observations of bed structure and bed materials. Conventional stream assessment survey techniques were used (e.g., Rosgen, 1994) to acquire this information. In addition to standard field pebble counts, meander, point bar and riffle substrate samples were collected for laboratory grain size analysis to more accurately assess grade and cross-section influences on bed transport characteristics within this reach. Watershed area (Figure L1), planform and bed structure (Figure L2), cross-sections (Figures L3 and L4), longitudinal profile (Figure L5), and photographs of characteristic features have been provided in Appendix F. Sediment size information (Figures S16 to S23) has been provided in Appendix E.

6.1 Regime Data Analysis

The data included in Table 3 from Irwin, Long, Briar, and Leepers Creeks can be compared to other data collected in rural and urban areas of the Piedmont of North Carolina to determine whether or not they are internally consistent and appropriate for providing a reference for the restoration design. As mentioned previously, a strict reference reach approach for Irwin would be problematic due to project constraints and the urban setting of the watershed. Therefore, restoration goals for the pattern, dimension, and profile of the restoration design are developed using these data taken in combination with empirical (USGS gaging data) and hydrologic modeling data.

Figure 5 shows the Irwin, Briar, Long, and Leepers Creek bankfull parameters on North Carolina Piedmont Regime Data curves. Data collected by various engineers and scientists over the last decade have been incorporated into these curves. The rural curves come from a diversity of areas in the North Carolina Piedmont (Harmon et al., 1997). The urban curves are largely derived from data collected in Charlotte by Wilkenson, et al., 1997; or Keaton, 1999; and these data have been integrated into a report by Doll, et al., 2000. Both of the City projects were done by the first authors as part of Master Thesis requirements in the Department of Civil Engineering at UNC-Charlotte. The larger urban streams in the Wilkenson et al. study have channel dimensions consistent with the operation of the dredging program in the early 1900s. The use of these urban regime curves should be taken with great caution, not only because we cannot be confident they were not dredged, but also because bedrock-founded sections can not easily adjust to urban conditions within short time cycles. While bankfull indicators may be developing along the banks of the City's urban creeks, which would provide some indication of the storm that is most likely to be dominant in shaping the fluvial channel, the channel, once dredged and widened, would have an artificially altered width to depth ratio inconsistent with natural equilibrium width/depth ratios. Assuming that the dredged channels have attained a new "urban" equilibrium relationship within their existing altered profiles, the bankfull indicators within these systems, e.g., inner benches or upper berm features, provide important information on both the dominant discharge and its corresponding bankfull cross-section area, but would yield misleading information on channel dimensionless ratios based on bankfull average depth or width. Designing to width/depth ratios derived from the these urban regime curves is likely to yield designs with lowered sediment transport dynamics than that derived from equivalent discharge, bankfull area rural curves.

The selection of the design parameters for restoration and enhancement at the Irwin Creek WWTP is shown in Figure 16, and Table 3. It is important to note that this is not a Priority 1 restoration and has channel (e.g., utility ROWs) and watershed (e.g., FEMA) constraints that do not permit recovery of original width/depth ratio, entrenchment ratio, or sinuosity at the bankfull stage. However, much of the degraded aquatic and water quality characteristics of this channel are dependent on the impacted or altered low flow channel conditions within this dredged and over-widened channel. The regime and reference reach data provide an important perspective on the stabilization of the low flow channel system. Using these data, a design based on natural equilibrium principles has been developed, which restores some of the original pattern, dimension, profile, and habitat characteristics that would have existed prior to the 20th century in this watershed.

7.0 STREAM RESTORATION PLAN

7.1 Restoration and Enhancement Measures

The attached design plans for Zones 1 through 4 (Figures 9-13) incorporate a diversity of enhancement. These elements aim to improve stability, water quality and habitat. Some are single purpose structures; however, most are multifunctional.

The restoration/enhancement measures proposed include modifications of profile, dimension, and low flow pattern, combined with extensive bed restructuring to promote sediment transport and aquatic habitat improvements. The physical elements within the proposed restoration plan are multifunctional, in that they help to promote stream equilibrium and channel stabilization, as well as water quality and habitat improvements in the reach. The structural aspects of this plan are laid out in Figures 9 through 13, 18, and 19. Standard details are provided in Appendix G. The design of these elements follows from the analysis of the reference and regime data shown in Table 3 and in Figures 5 and 16, as well as stability and sediment transport analysis discussed in Section 7.2 and addressed in Table 4 and Figures 20 and 21. The overall restoration elements can be categorically discussed as seven measures affecting the physical, chemical and biological aspects of the stream corridor. They include:

1. Construction of approximately 1,100 linear feet of a flood plain bench:

    a. 90-foot extension of flood prone width, to lower entrenchment ratio.
    b. Construction of top of bank levee for enhancement of flood plain bio-retention.
    c. Construction of step-down structure through levee to stream.
    d. Establishment of approximately 2.6 acres of flood plain bottomland hardwoods with up to 1 acre of potential wetlands.
    e. Establishment of 2 acres of upland forest riparian buffer.

2. Establishment of five new riffle zones to add 450 additional linear feet of riffle area; Augmentation of 13 existing riffle zones extending each by 20 to 60 linear feet; enhancement of water quality, and habitat.

3. Creation of 11 inner channel meander bends with associated pools by emplacement of artificial inner berms; improved sediment transport, water quality, pool habitat, and potential transitional wetland habitat (55,000 square feet of vegetated areas within 1 to 3 feet of low flow water surface). Inner berms store and remove nutrient and sediment loads.

4. Installation of bank vegetation, including trees and shrubs, where plant coverage and root density is very poor.

5. Installation of flow control structures (e.g., rock vanes) in the lower area with good sinuosity to promote sediment transport, bank stability, and pool habitat.

6. Installation of stepped rock confluence and outfall structures to promote stability and aquatic habitat.

7. Re-vegetation of the riparian buffer from the edge of top of bank back to 50 feet or easement ROW. The areas where significant revegetation is anticipated are shown in Figures 20 and 21.

The rationales for most of these changes are discussed on a zone-by-zone basis, with the exception of the bank and buffer stabilization work, which is discussed separately.

The design schematics for Zone 1 and 2 are shown in Figures 9 through 11. Figures 9 and 10 are plan views, and Figure 11 is a hypothetical cross-section for the flood plain bench to be cut into the FEMA buy-out area. Zone 1 design elements include: inner meander berms, hybrid cross vane riffles, augmented riffles, rock vanes, grade and energy controls on storm outfalls or the 1st order tributaries, and the flood plain bench in the FEMA buy-out area. The inner meander bends are based on reference reach studies in Long, Little Sugar, Briar and Leepers Creeks. The determination of the wavelength and radii of curvature for these inner meanders is shown in Figure 16. Riffles with built-in cross vanes are used in all inflection areas without bedrock, and augmented riffles are used in areas where bank and bed surveys revealed bedrock at the base of the channel. Each of the inner berm features helps to restore approximately 60 to 80 feet of pool habitat, and each riffle provides approximately 80 to 90 feet of riffle habitat. Berms, on average, provide approximately 5,000 square feet of riparian or potential transitional wetland habitat within 0 to 4 feet of the low flow water surface.

The diagrams of Figures 10 and 11 illustrate the design details for the flood plain bench. This bench runs for approximately 1,000 to 1,100 feet along the southeast banks of Irwin Creek adjacent to Whitehurst Road and encompasses approximately 81,500 square feet (≈ 2 acres) and is approximately 90 feet in width. The bench includes a restored flood plain levee to be crested along the top bank edge of the creek at bankfull plus 1 foot. The main level of flood plain bench is cut back from bankfull minus 1 to bankfull minus 1.5 feet. The slight back slope may promote wetlands hydrology along the back edge of the bench. The average depth of the cut is approximately 6.5 feet, yielding approximately

500,000 cubic feet (ft^3) of fill dirt. The bulk of this fill dirt is placed into a screening mound along the southeast edge of the bench to be stabilized as upland hardwood habitat. The screening mound is not to exceed the 100-year flood level minus 1 foot. Side slopes are not to exceed 2 to 1. The screening mound shown on Figures 10 and 11 provide for the placement of approximately 442,000 ft^3 of dirt excavated from the flood plain bench cut. This leaves approximately 58,000 ft^3 of dirt from the cut to be used as loam top fill for the 55,000 to 60,000 square feet of inner berms to be created within the channel. Thus, the design should not create the need for off site disposal, which can be very costly.

A geotechnical report on soils at the site of this bench is provided in Appendix H. From the report, it is clear that soils at this site are fluvial sand, silt, and clays with sandy units dominating the upper few feet, and more silt and clay rich horizons at depth. The presence of clay rich units at depth may provide sufficiently low permeabilities, which when combined with low slope drainage and shading from the upland forest to be placed on the southeast berm, will promote the potential development of a northwest facing hill slope wetlands. These frequently occur within the Piedmont of North Carolina but depend on a balance of environmental conditions that promote the seasonal development of a perched water table wetland in late winter to early summer. This potential perched water table wetland is illustrated in Figures 10 and 11. Water budget studies must be performed using site-specific soil and hydrologic data to determine whether or not jurisdictional wetlands are likely to be achieved at this site. To augment this potential wetland cell, the plan intercepts two storm drains that drain from the upslope residential areas to the southeast of Whitehurst Road. This will depend on the two drains being elevated to the bankfull minus 1.5 depth of the flood plain bench cut level along the southeast flank of the potential wetland cell. An alternative to providing additional water to this wetland was to try and connect the bankfull stage level for the tributary that runs adjacent to the southern edge of the proposed flood plain bench. To investigate this alternative, cross-sections and a longitudinal profile were obtained along the tributary. These data, and its relation to the proposed flood plain bench, are shown in Figures 23 and 24. Unfortunately, the drainage area for this tributary is too small for it to have a bankfull stage sufficiently elevated in reasonable proximity to the flood plain bench to connect this water to the bench or potential wetland cell.

In Zone 3, there are two different channel areas. In the northern end, near the gaging station and bridge, the section is constricted, and there is insufficient room for the construction of inner meanders. Thus, in this area, one or two habitat structures is all that is likely feasible. In the lower half, however, the channel widens, and lateral bars re-emerge. For this lower zone, a recommendation is made to construct similar inner meander bends to those in the northern half. This segment has a steeper grade, and may have significant rock, which may eliminate the necessity of constructing cross vanes in the inflection areas. No bank stabilization is recommended in this zone.

Four significant meanders occur in Zone 4, all with some indications of bank erosion. The bank and bed structure survey reveals that these areas have significant cohesive soil and bedrock. The presence of rock in the banks on the meander bends limits the ability to install root wads or to significantly reshape the meander or bank profile. These limitations make the use of instream flow control structures (e.g., rock vanes) the preferred method of stabilization. Only in one area, where there is no bedrock, and the bank is composed of layered sand and silty Monacan soils, does the plan involve the emplacement of root wads in addition to rock vanes to further lower bed shear stresses at the water/bank interface. In addition to the use of rock vanes to protect banks in this zone, bedrock ledges within the channel should be augmented to extend and enhance the habitat and water quality in each inflection area. These bedrock areas were likely knocked down in the early dredging operations, and thus, lost a significant amount of their relief and extent within the channel.

Table 6 provides a detailed listing of bank conditions along the reach, and Figure 17 diagrammatically illustrates bank conditions for each area with unique findings. In addition to the BEHI values, Figure 17 also shows where the bank survey encountered bedrock or c-horizon weathered rock along the toe of the bank. These zones provide high resistance to bank erosion and substantially diminish the need for artificial bank protection structures at the toe. The presence of bedrock also limits the use of either coir fiber logs or root wads, as these cannot be practically emplaced in bedrock areas. A comparison of the bedrock areas noted in the bank survey with the bedrock areas noted in the bedform map (Figures 14 and 15) shows that Zones 2, 3, and 4 all have substantial amounts of bedrock in banks and channel bed that act to prevent all but localized areas of bed and bank erosion. The detailed assessment performed of substrate conditions along the reach substantially lowers the amount of hard and artificial structures that need to be used in the restoration to stabilize both bed and banks in Zones 2, 3, and 4. The primary design elements of this project are restricted to areas within the existing banks and should be able to be implemented with minimal bank disturbance. For areas without any regrading of banks, the only recommended bank stabilization is to augment bank vegetation by live staking in areas with very poor root density and depth. The two exceptions to this recommendation are 1) the areas of rock vane and root wad installation, and 2) the area to have the flood plain bench installed. In these areas, complete bio-engineering of the newly graded bank areas using coir fiber log and/or rock footers below root wads for toe protection and appropriate matting and replanting of the banks with appropriate riparian species is recommended. Details for planting will be provided with the final design.

7.2 Stability and Sediment Transport Analysis

There are four approaches to the analysis of stability for this restoration. First is the reference reach foundation for the design's pattern, dimension, and profile. This paradigm assumes that nature finds a stable design for any given watershed setting, provided there is sufficient time for adaptation and evolution. This design model assumes that nature will find comparable fluvial morphologies for comparable sets of watershed characteristics (topography, climate, soils, bedrock, land use, etc.). Thus, one check on the stability of a design is that it has similar characteristics to those observed in the selected reference reach areas.

A corollary to this reference reach model is the regime approach. The regime approach states that at a regional level, there are some central tendencies in streams of similar morphologic class (e.g. Rosgen E- or C-type streams) to have comparable morphologic parameters for similar drainage areas. The regime approach has the benefit of averaging out a lot of "noise" that occurs in individual watersheds, such as disruption of normal tendency by odd events or features (e.g. hurricane, downed tree, small pond, etc.). Neither the reference reach nor the regime approach is necessarily sufficient to achieve a stable design. Both sets of data are susceptible to yielding guidelines that may be erroneous for a given circumstance. Thus, independent of the reference reach or regime data, a separate effort must be made to check or verify the stability of the restoration design.

The second and third methods used here for stability analysis are the determinations of transport thresholds for bank and in-stream materials. These checks on transport, or erosion potential, for bed and bank materials are either a minimum velocity analysis or critical traction force analysis. There are two approaches for checking velocity thresholds for the design at Irwin Creek and two approaches for the critical traction force analysis.

Finally, stability can be examined from a structural viewpoint. Structures can be emplaced or found (e.g. the stream can be located over or within bedrock) to provide added stability. These structural approaches are usually folded into a given project as a design unfolds and areas of greater risk, or opportunity, are discovered.

7.2.1 Reference Reach and Regime Analysis

Table T5 shows the reference reach information gathered from various sources. None of the reference reaches are sufficiently comparable in stream or watershed attributes to use a direct design template and assurance for stability. Also, constraints in the restoration reach of Irwin Creek limit the extent that reference data sets of morphologic parameters could be directly matched by the restoration. These morphologic interpolation graphs are shown in Figures 5 and 16 and provide fields of conditions that are consistent with both sets of reference reach information. These graphs allow one to extrapolate or interpolate to conditions that vary from those in the reference reaches.

The regime curves developed for the rural and urban Piedmont are also shown in Figure 5. These curves are log-log plots and have a high degree of variance with the reference data used for their definition. As previously discussed, the reference reach data are reasonably consistent with the regime curves, and therefore, provide a reasonable basis for the extrapolation of restoration parameters.

The restoration design attached in planform, section, and longitudinal view can be characterized by the morphologic parameters indicated in Table T5. In the design, it is not possible to elevate Irwin Creek 3 to 5 feet to bring the bankfull stage to the current top of bank. This entrenchment cannot be recovered due to encroachment within the floodway. However, the entrenchment can be accommodated by the construction of an inner flood plain bench at the 8- to 9.5-foot stage, coupled with the use of lower inner berms to constrict the lower portions of the channel and to add low flow sinuosity. This tiered channel system allows the design to yield Rosgen or fluvial geomorphology parameters comparable to the reference reach and regime data sets. While the design does not restore the original conditions, it restores a natural balance of stream morphologic characteristics.

7.2.2 USDA and USACE Velocity Analysis

The USACE (1994) published a graph of allowable velocity-depth data for granular materials ranging in size from 0.1 to 500 millimeters (mm). The range of expected velocities extend from 4 to 11 feet per second (fps), with water depths ranging from 8 to 18 feet. The expected range in velocities are plotted in Figure 18 on a stability chart from the USACE that can be used determine the range of sizes of granular materials that would be unstable as exposed noncohesive materials along the channel. This is the shaded area shown in the figure. From this analysis, it is clear those materials with D_{50}s less than 7 to 10 centimeters (cm) will be unstable..

7.2.3 Newbury and Gabory's (1993) Traction Force-Criteria and Shield Curve Analysis

For streams with non-cohesive bed materials greater than 1 cm in diameter (fine gravel), a general rule of thumb for stability may be approximated as:

Tractive Force (kg/m^2) = incipient diameter (cm)

This is an empirical relationship arising from a compilation of in transport streambed materials and tractive force observations for a wide range of channels worldwide. The Newbury and Gaboury criteria are derived from compilations presented by Lane (1955) and Magalhaes and Chau, (1983). These critical traction force versus grain size analyses and curves are sometimes referred to as Shield Curves. Table 2 includes calculations of the bed traction force derived using the following equation:

Tau (kg/m^2) = 1,000 x (depth (m)) x (slope (ft/ft))

This relationship is roughly equivalent to the Tau = RS formulation used by Rosgen (1994) but can yield more accurate estimations of the maximum traction forces needed for stability analysis, as a maximum depth can be used in lieu of the hydraulic radius. For a successful restoration, one is more concerned with the maximum conditions that may exceed thresholds and trigger failure in the channel system. Thus, the DS rather than RS method is used here to calculate critical traction forces.

Figure 19 shows a variation of a "Shield Curve" with data from Leopold (1964), upon which the minimum and maximum traction forces for conditions within Irwin Creek are shown. These were calculated from the maximum depth and velocity estimates made by the hydraulic modeling for the 1.5-, 2-, 10-, and 100-year storms.

These critical traction force calculations indicate that the bed will need to have in riffle areas with cross vane armor crests with D_{50}'s ranging from 37 to 70 cm to insure stability.

7.2.4 Bed and Bank Stability Structures

The attached plans, cross-sections, and longitudinal profiles show the location of structures present in the design to assist in the stabilization of the restored channel.

First, with respect to bed stability, this reach of Irwin Creek contains numerous bedrock nick points that have been carefully considered in the preparation of the channel's low flow channel design. Where bedrock does not exist, cross vane/riffle structures are emplaced to assure that bed degradation will not occur within the zone.

Riffles and pools will also need to be sized using the aforementioned critical traction force estimates. The estimates for D_{50} and D_{84} for riffle and pool armor are noted in Table 4.

Tributary confluences and storm water outfalls will need to be reviewed for consistency with restoration efforts at each location. Where necessary, these will need to have additional structural modifications to interface with the various restoration elements. Final design details, to be developed in the next phase of the work, will further identify solutions appropriate for each outfall and tributary confluence.

8.0 STREAM PERFORMANCE CRITERIA AND MONITORING PLAN

Restoration of Irwin Creek will be determined a success after the monitoring period is complete. The stream channels should maintain their dimension, pattern, and profile over time. Additionally, instream structures should remain secure and stable during the monitoring period.

It is expected that there will be some minimal changes in the cross-sections, profile, and/or substrate composition. Changes that may occur during the monitoring period will be evaluated to determine if they represent a movement toward a more unstable condition (e.g., down cutting, deposition, and/or erosion) or if they are minor changes that represent an increase in stability (e.g., settling, vegetative changes, and/or decrease in width-to-depth ratio). Unstable conditions that require remediation will indicate failure of restoration activities.

8.1 Substrate Monitoring

A Modified Wolman Pebble Count (Rosgen, 1996) provides a quantitative characterization of streambed material. This composition information is used as an indicator of changes in stream character, channel form, hydraulics, erosion rates, and sediment supply. Pebble count data can be used to interpret the movement of materials in the stream channels. Established D_{50} and D_{84} sizes should increase in coarseness in riffles and increase in fineness in pools. Data collected over the monitoring period should be plotted over that of the previous year(s) for comparison. Over time, established D_{50} and D_{84} should be compared.

8.2 Vegetation

Native vegetation, as determined by reference reach vegetation inventories, will be planted. During the construction period, the invasive plant species in the project area will be removed and their growth will be controlled. Survival of vegetation within the riparian buffer will be evaluated using survival plots. Survival of live stakes will be evaluated along the stream corridor of the restoration site. Vegetation survival of target dominant species will be confirmed. Woody vegetation will be monitored for five years, or for two bankfull events. Plants should be replaced per the contract documents.

8.3 Monitoring Schedule

Annual monitoring is required for a 5-year period beginning in 2004 and ending in 2008. Reports will be submitted in 2004, 2006, and 2008 to the WRP.

8.4 Monitoring Methods

Monitoring at established locations will ensure consistency and allow comparison of data over time. Permanent cross-sections will be established in Irwin Creek. Cross-section changes can indicate changes in the width-to-depth ratio of the stream. Bank slopes should remain stable. Comparison of longitudinal profiles during the monitoring period will indicate excessive changes over time. Monitoring at these locations, as well as established vegetation plots and pebble count locations, will ensure consistency and allow comparison of data over time.

9.0 Stream Restoration Benefits

One goal of restoration is to promote long-term channel stability. Channel stability implies sediment transport continuity, aquatic habitat stability, and improved water quality, for all of the reasons stated in Section 2.0. Most elements affecting flow in the channel can influence stability. Thus, all aspects of the proposed work must be evaluated using a number of analytic means (mostly by comparison to known stable reference streams or published hydraulic relationships). Currently, the channel in the lower area below the WWTP has a number of meander bends with steep and poorly vegetated banks. Some of these steep banks expose Monacan soils, while others are cored by weathered granite. The channel bed throughout most of the reach is characterized by a shifting sheet of sand and fine gravel, forming unstable bar formations and is entrenched and over-widened due to past dredging operations (Figure 9). A bank erosion hazards assessment (Figure 17) indicates that moderate to high erosion potential predominates the upper and middle thirds of the bank profiles, and high bank erosion indices predominate at the lower 1/3 of the bank profiles. Thus channel and bank stability is one of the primary challenges in the design. The seven point design plan described in Section 7.0 brings a multifaceted solution the creation of a more stable channel founded on nature stream equilibrium principles.

A secondary goal of restoration is to enhance and stabilize aquatic habitat within the low flow channel. Currently the channel has a scarcity of both pools and riffles. Due to the very low stream grade, limited additional habitat can be added by riffles alone because of the need to use large stones for stability as well as keep individual riffles to very low drops (less than 3 to 6 inches). This is further complicated by the shifting of the sand bed load within the channel. After major storms, large quantities of sand and fine gravel are repositioned sporadically within this channel and would likely bury low drop structures. A straightened channel with steeper grade could be managed primarily by the construction of the artificial riffles following designs adapted after Newbury and Garoury (1993). As part of this design, new and augmented riffles (cobble and boulder additions) would be emplaced. However, due to the low grade and shifting sand bars, this is not a sufficient strategy. The channel dredging combined with increased urban storm runoff has produced an entrenched, over-widened channel that inhibits re-establishment of an appropriately sized low flow channel, which is self-maintaining. In order to compensate for this disturbance, appropriate width/depth ratios need to be maintained during the low flow interstorm period to provide continuous transport of the bulk of sand size sediment. This can likely be accomplished by the construction and stabilization of inner berms that form low belt width meanders within the existing over-widened channel, as is shown in the included plan sheets for Zones 1, 2, and 3.

A third goal of restoration is to improve on the overall water quality and stability of the stream by the construction of a flood plain bench. This essentially re-connects Irwin Creek to its flood plain by lowering the flood plain in lieu of restoring the lost grade due to prior dredging. Because of FEMA constraints, this is the only option to reduce stream power at storms above the bankfull stage. However, for practical reasons, the bench can only be cut in the FEMA buyout area along Whitehurst Road. This buyout area is clear of mature trees and the utilities have been removed. If the flood plain bench were to be expanded, a mature forest of hardwoods would need to be removed. That effort would not be practical. This bench should be cut close to the bankfull stage for Irwin Creek and provide for both flow attenuation of the peak storm and improved water quality. Details regarding this flood plain bench are further discussed under the plans for Zones 1 and 2.

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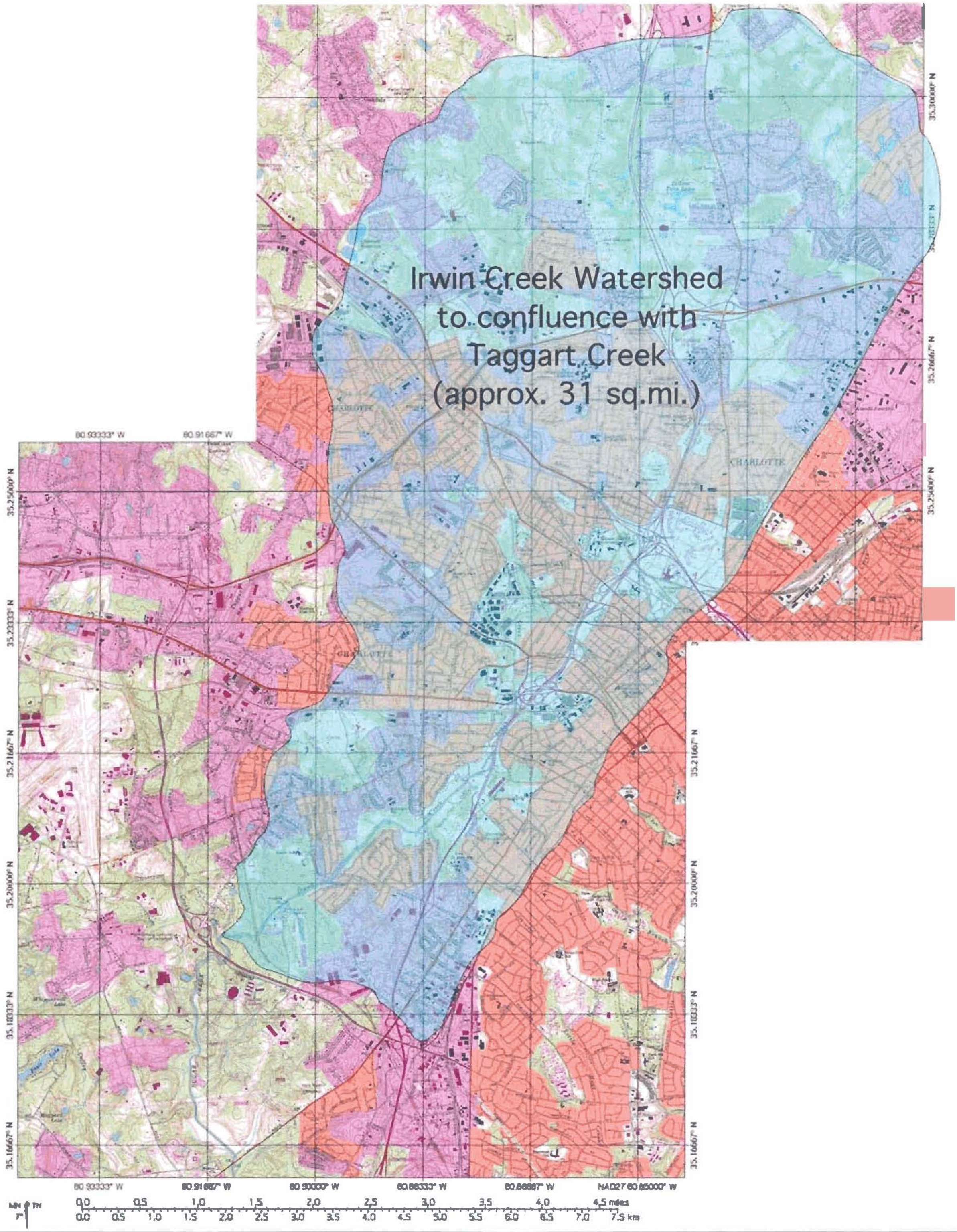

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Figure 1: Watershed Area
Stream Restoration Plan
Irwin Creek

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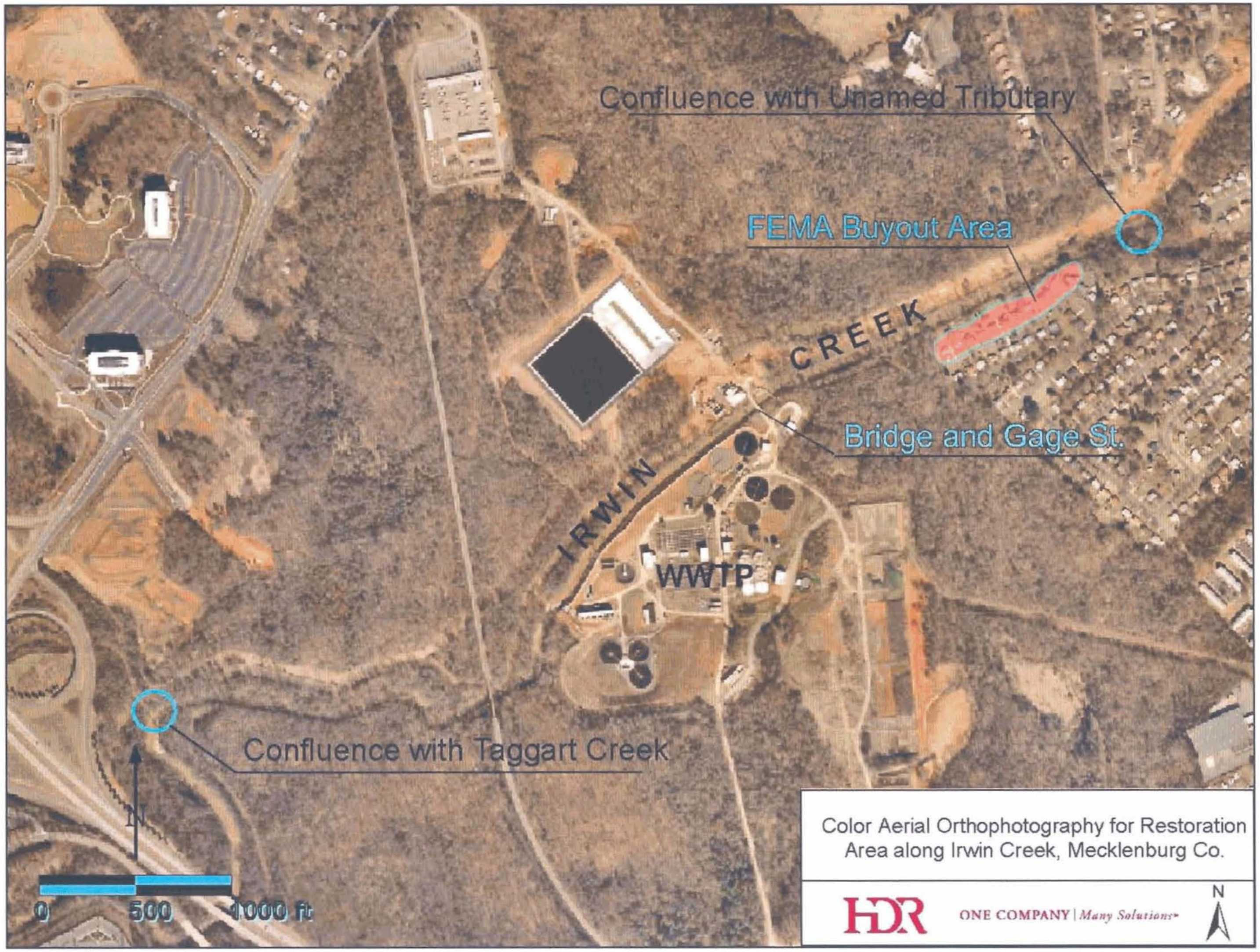

HDR Engineering, Inc. of the Carolinas	Habitat Assessment and Restoration Program Inc.	**Figure 2: Aerial Photography** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018

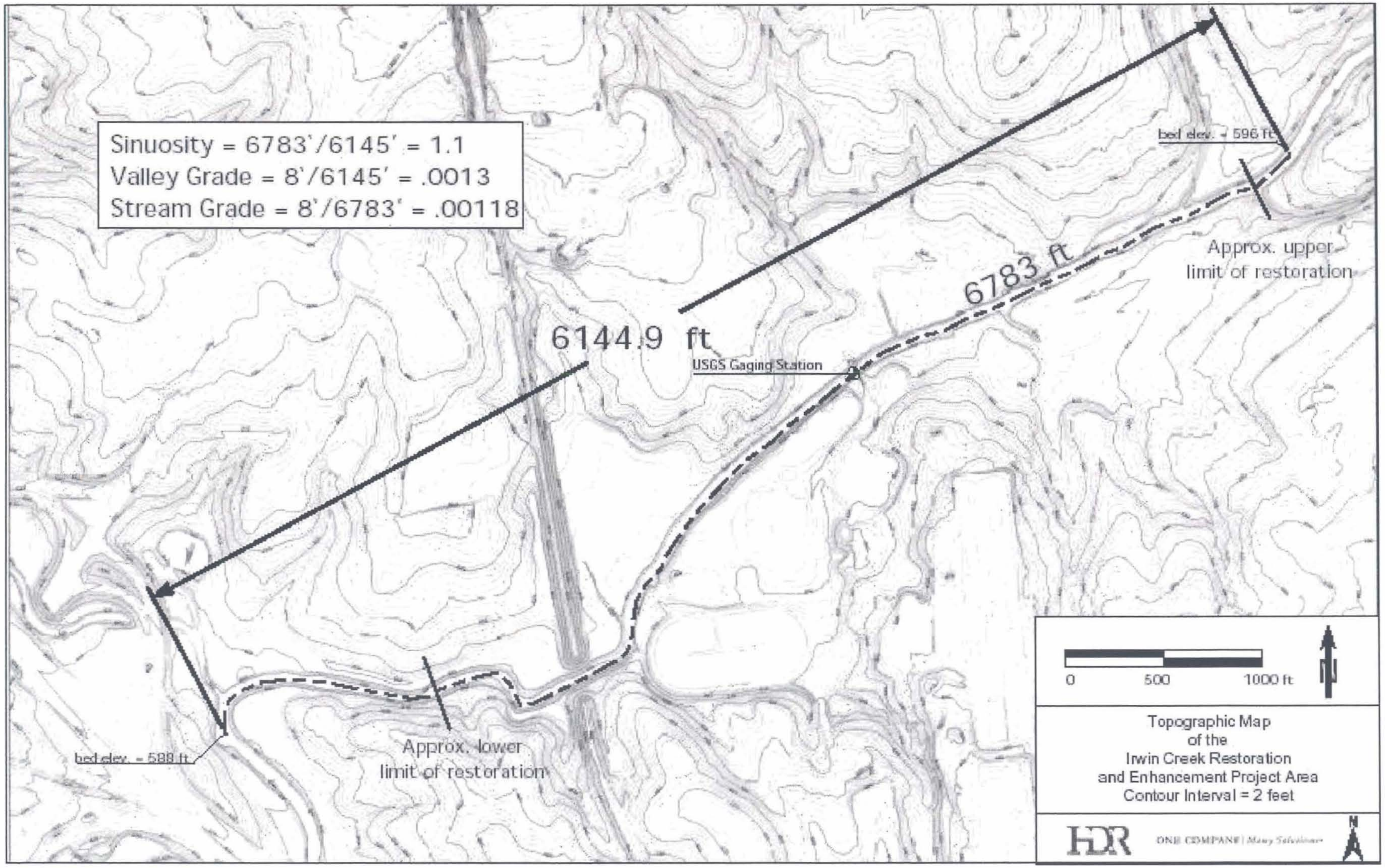

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Figure 3: Topography
Stream Restoration Plan
Irwin Creek

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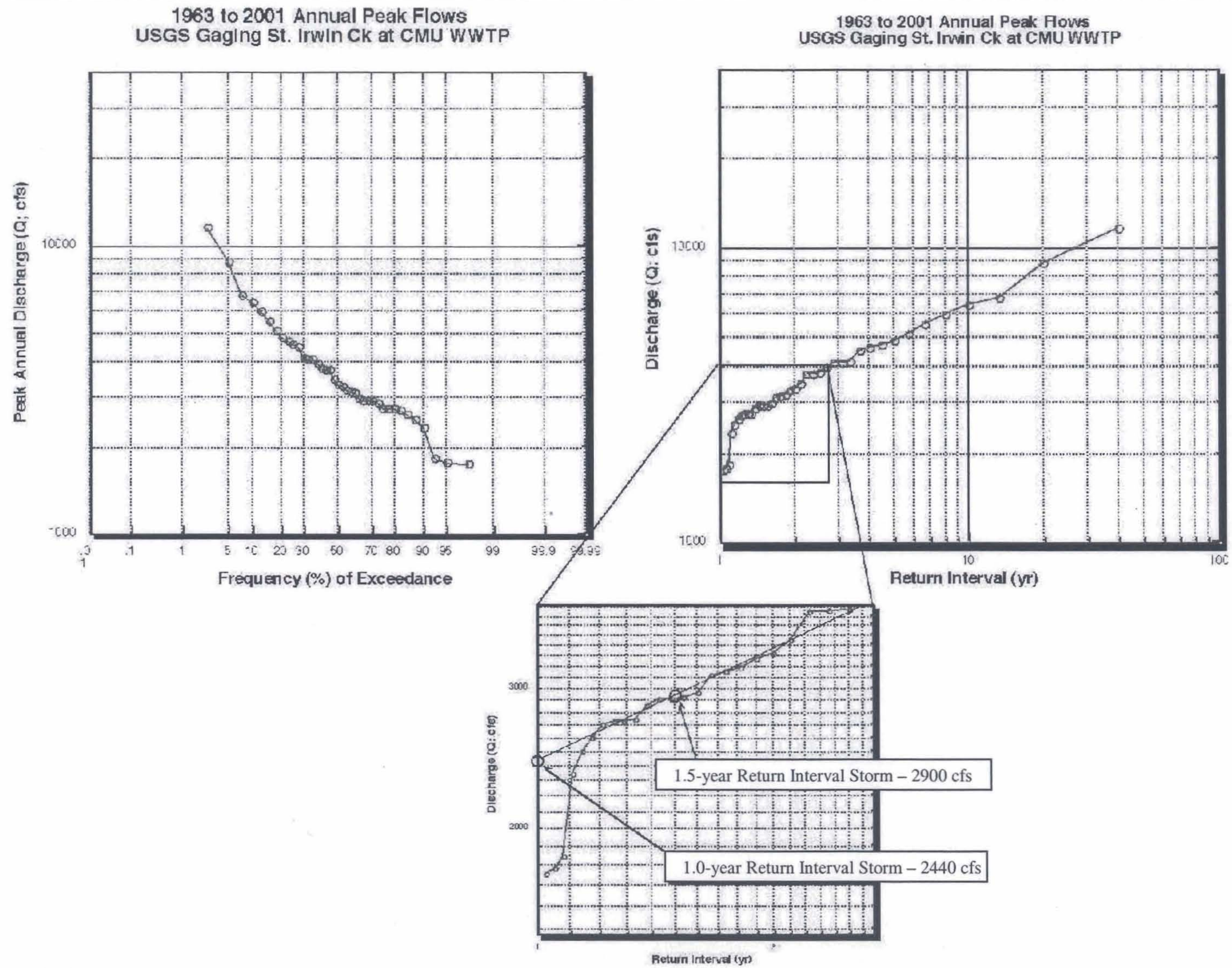

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Figure 4: USGS Gaging Station Annual Peak Flows

Stream Restoration Plan

Irwin Creek

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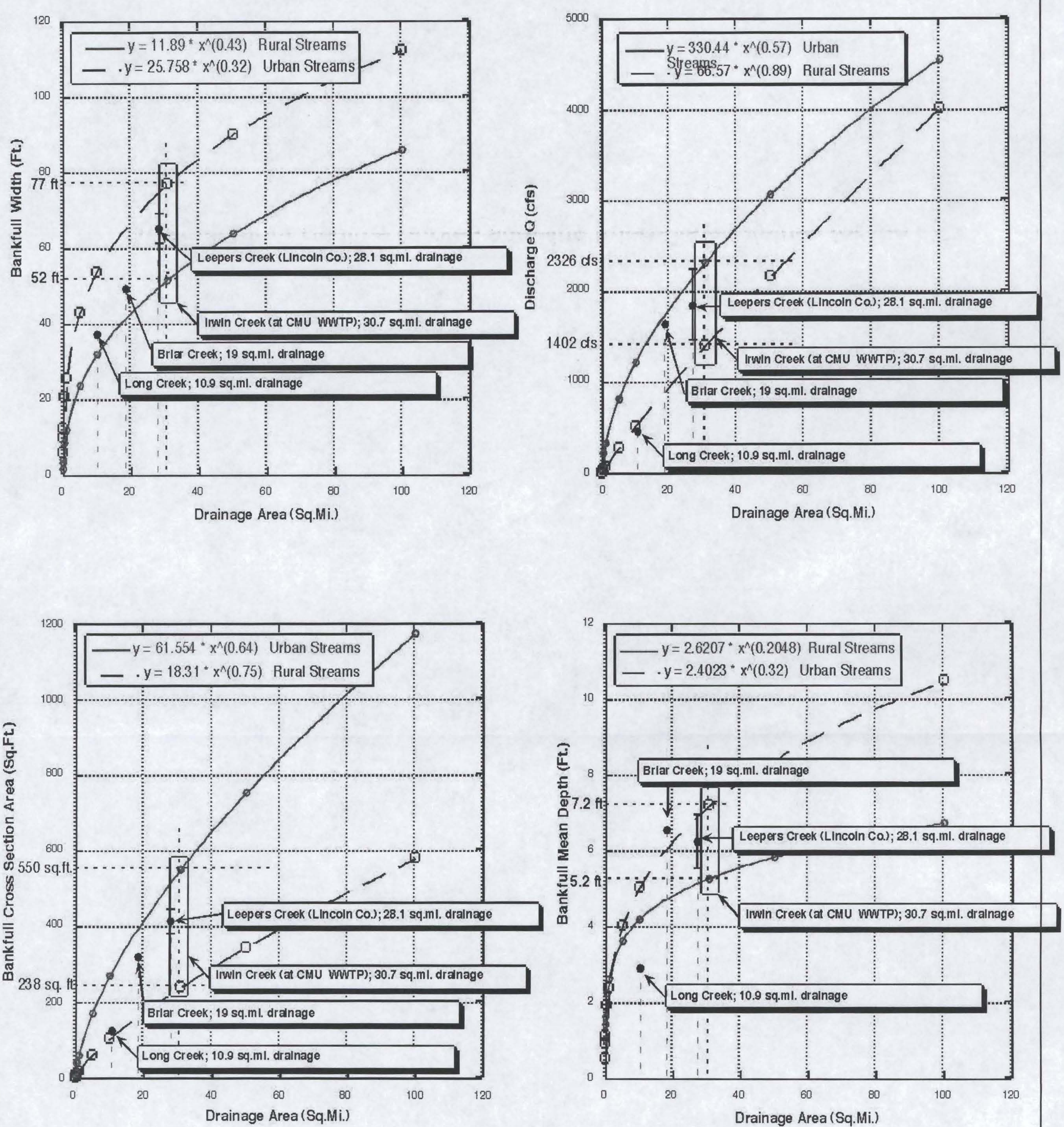

NC Piedmont Regime Curves showing Interpolated Values for the Irwin Creek Restoration Reach Watershed

HDR HDR Engineering, Inc. of the Carolinas	Habitat Assessment and Restoration Program Inc.	**Figure 5: Piedmont Regime Curves** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018

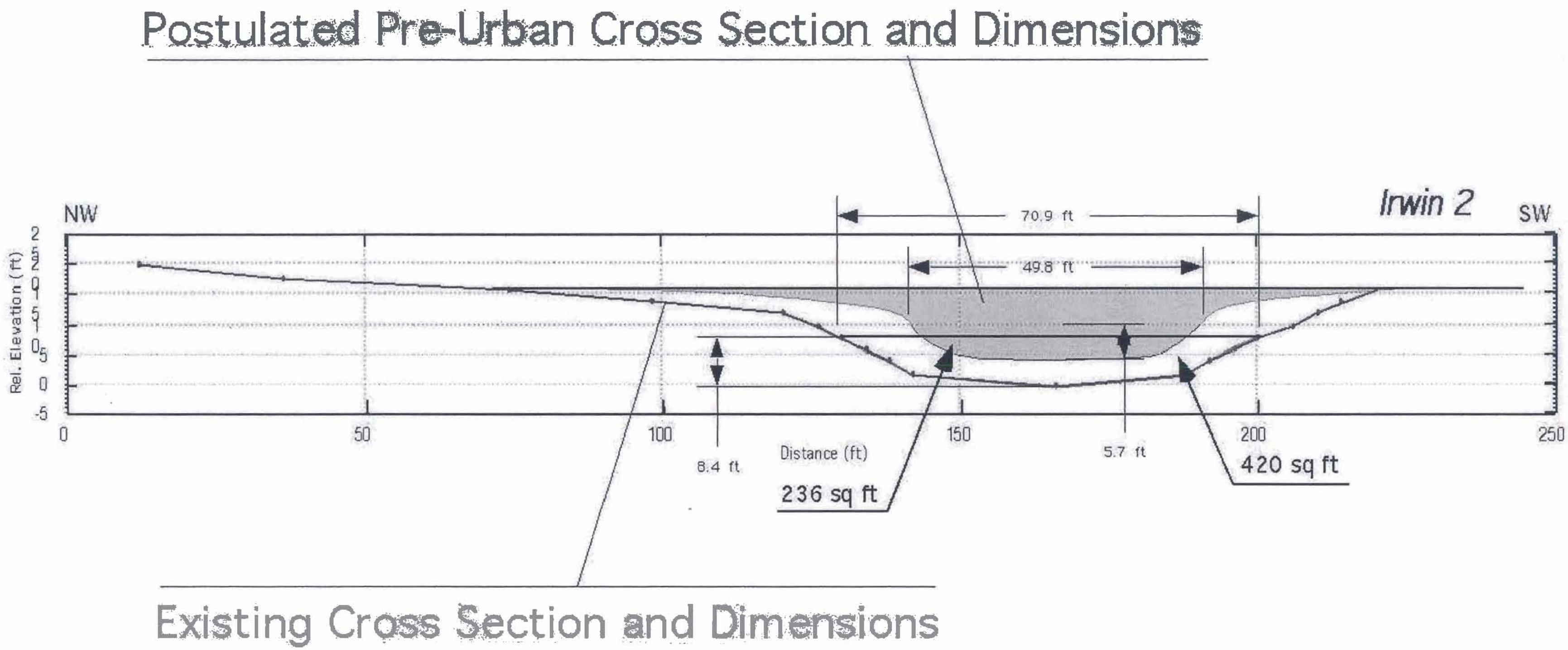

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Figure 6: Comparison of Pre-urban and Current Dimensions for Irwin Creek
Stream Restoration Plan
Irwin Creek

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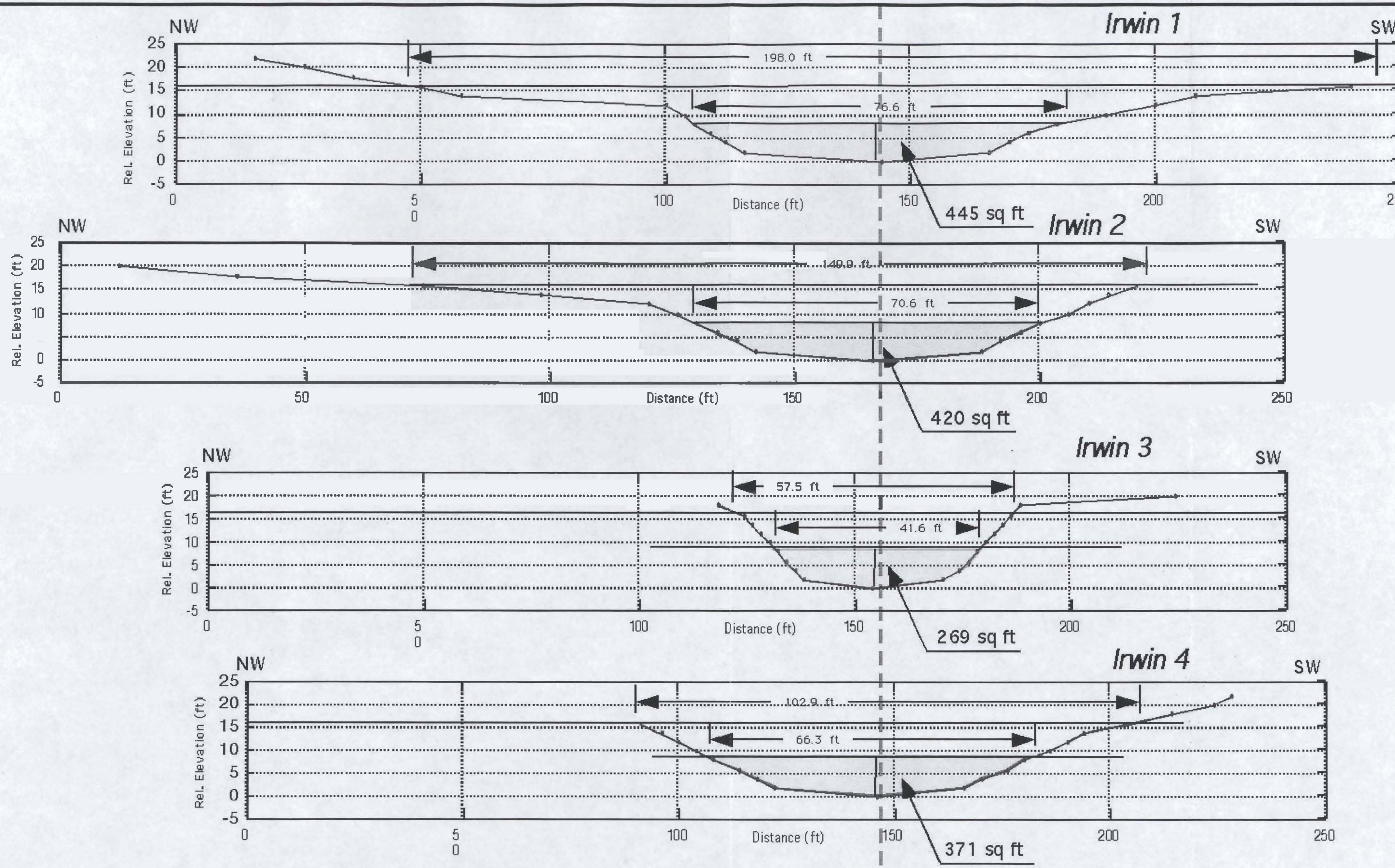

	Bankfull Area	Bankfull Width	Bankfull Mean Depth	Floodprone Width	W/D Ratio	Entrenchment Ratio	Wetted Perimeter
Irwin 1.	445 sq.ft.	76.6 ft.	5.8 ft	198 ft	13.2	2.58	78 ft
Irwin 2.	420 sq.ft.	70.6 ft.	5.9 ft	150 ft	12.0	2.12	73 ft
Irwin 3.	269 sq.ft.	41.6 ft.	6.5 ft	58 ft	6.4	1.37	48 ft
Irwin 4.	371 sq.ft.	66.3 ft.	5.6 ft	103 ft	11.9	1.55	69 ft

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Figure 7: Irwin Creek Cross Sections
Stream Restoration Plan
Irwin Creek

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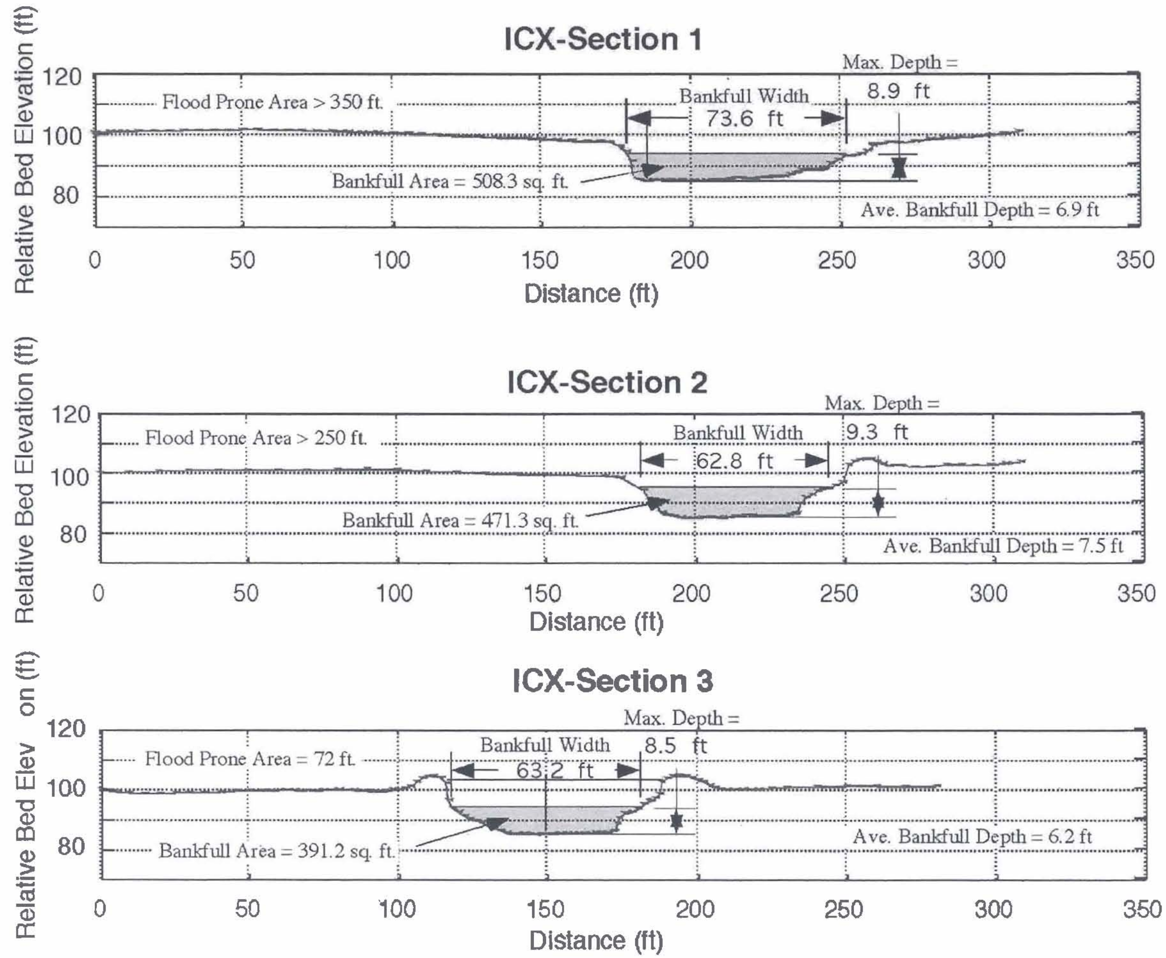

Scale

0 *50* *100 ft.*

Irwin Creek Cross Sections

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Figure 7a: Cross Sections 1, 2, & 3
Stream Restoration Plan
Irwin Creek

October 2003

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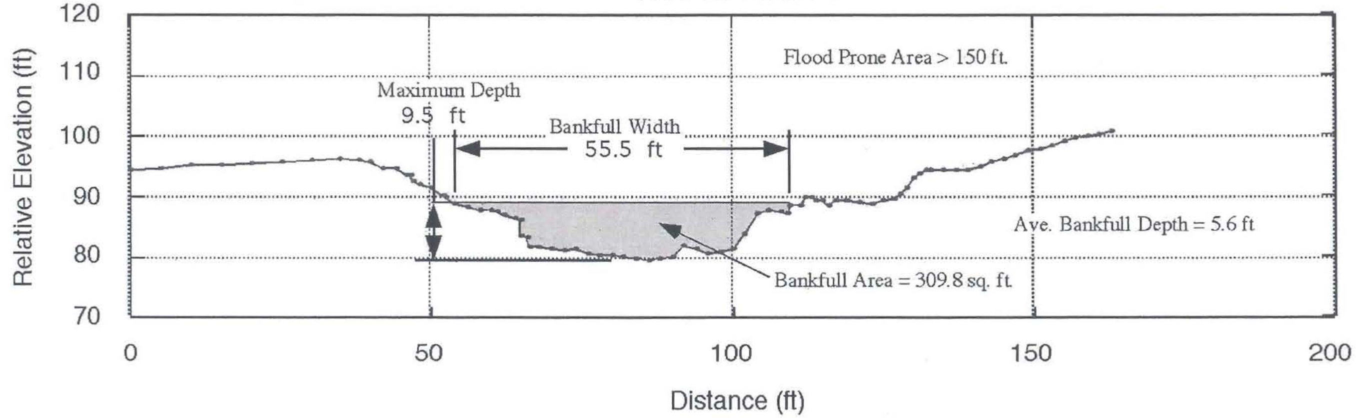
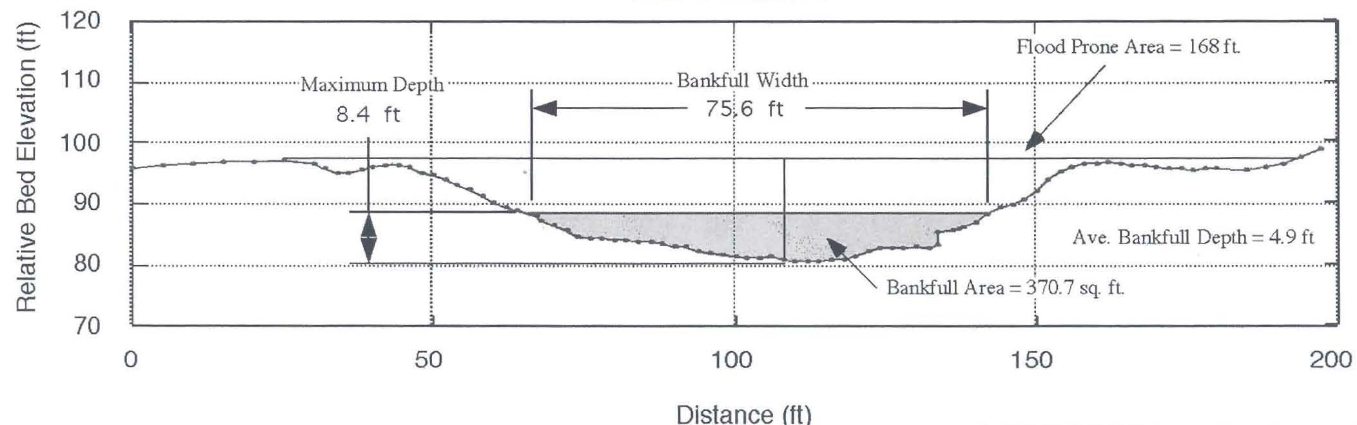
ICX-Section 4



ICX-Section 5



Scale

0 25 50 75 100 ft.

Irwin Creek Cross Sections

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Figure 7b: Cross Sections 4 & 5
Stream Restoration Plan
Irwin Creek

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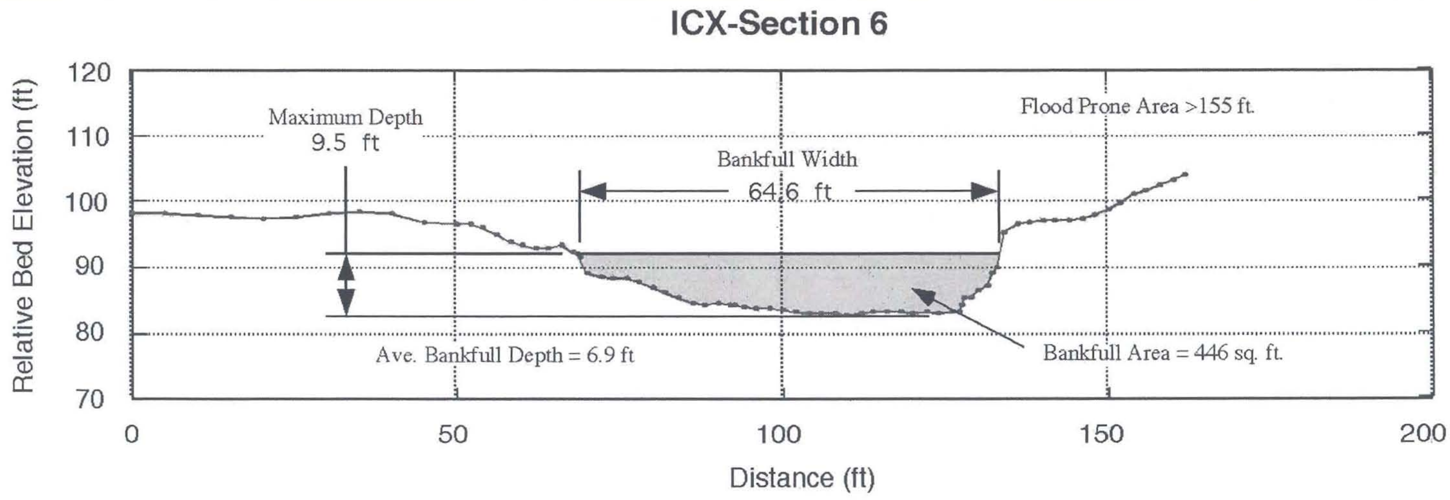

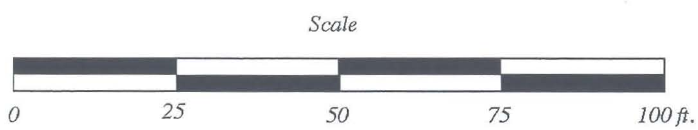

Irwin Creek Cross Sections

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Figure 7c: Cross Section 6
Stream Restoration Plan
Irwin Creek

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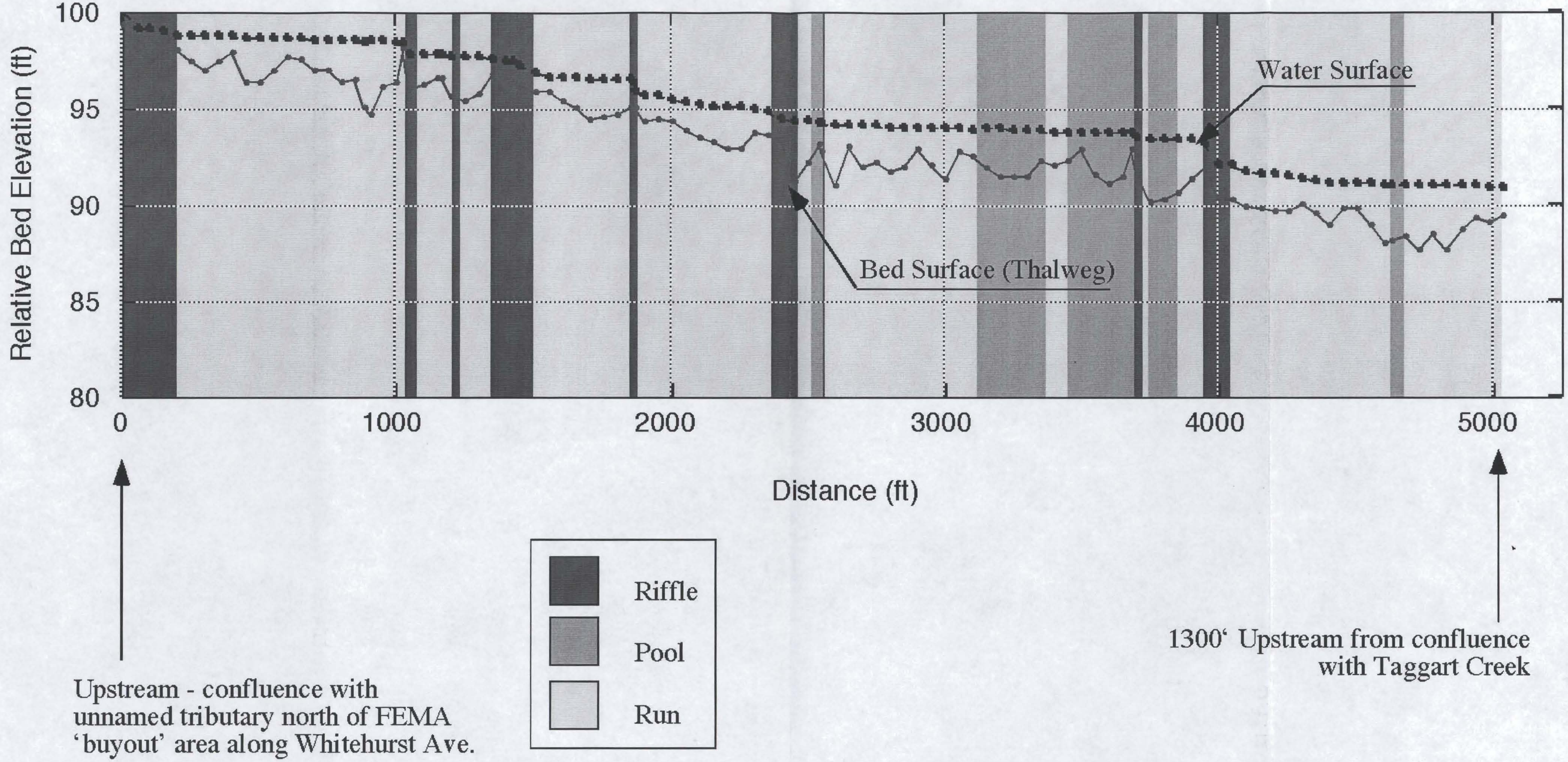

Longitudinal Profile of Irwin Creek

Data collected using WAAS-enable (2-3 meter) GPS and laser range finder (+/- 1 m) for horizontal positioning and Lasermark laser level (1/8" at 100') for vertical positions.

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Figure 7d: Longitudinal Profile
Stream Restoration Plan
Irwin Creek

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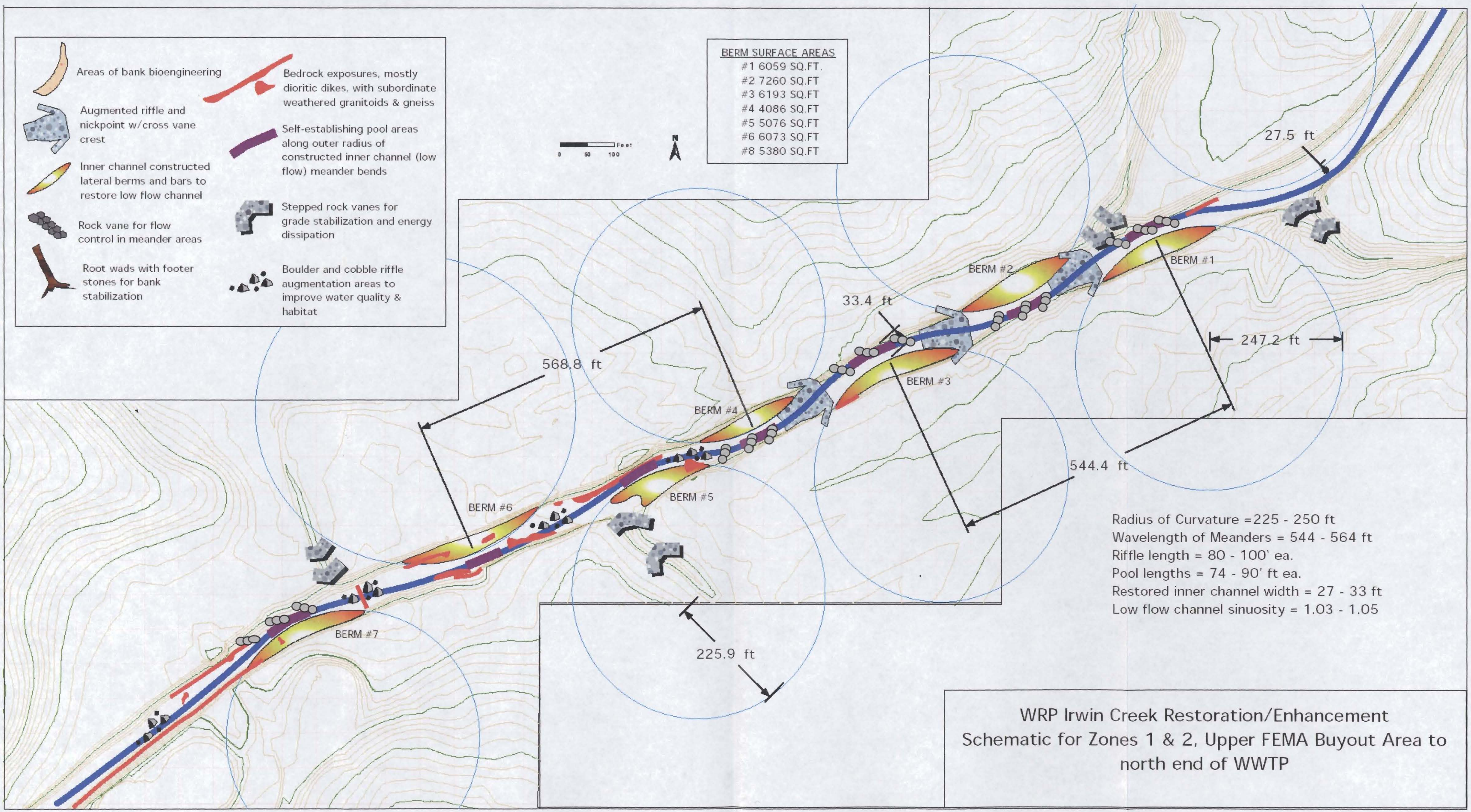
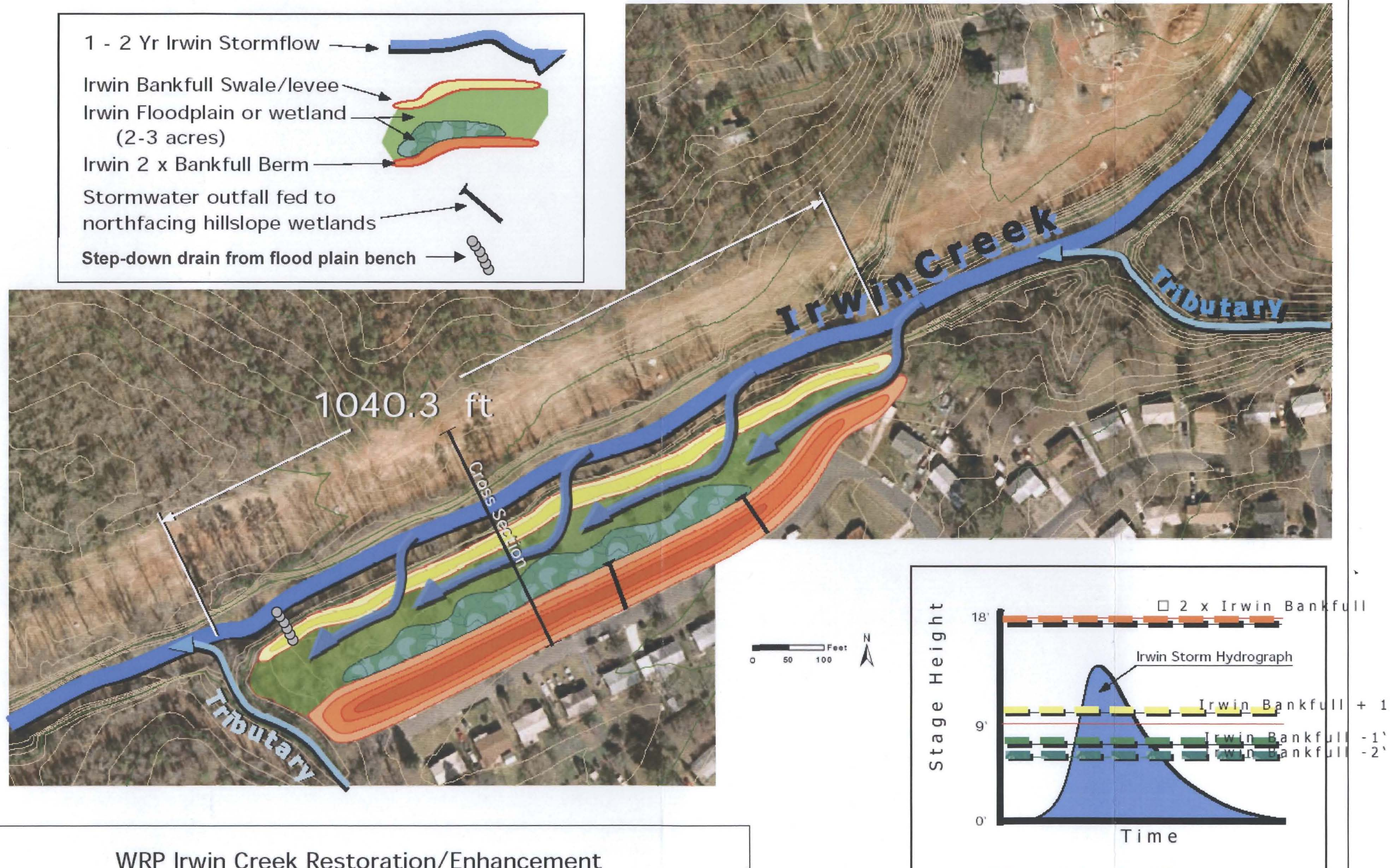


HDR HDR Engineering, Inc. of the Carolinas	Habitat Assessment and Restoration Program Inc.	**Figure 9: Planform for Zones 1 & 2** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018



WRP Irwin Creek Restoration/Enhancement
Schematic for Zone 1, Upper FEMA Buyout Area

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Figure 10: Planform for Floodplain Bench
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

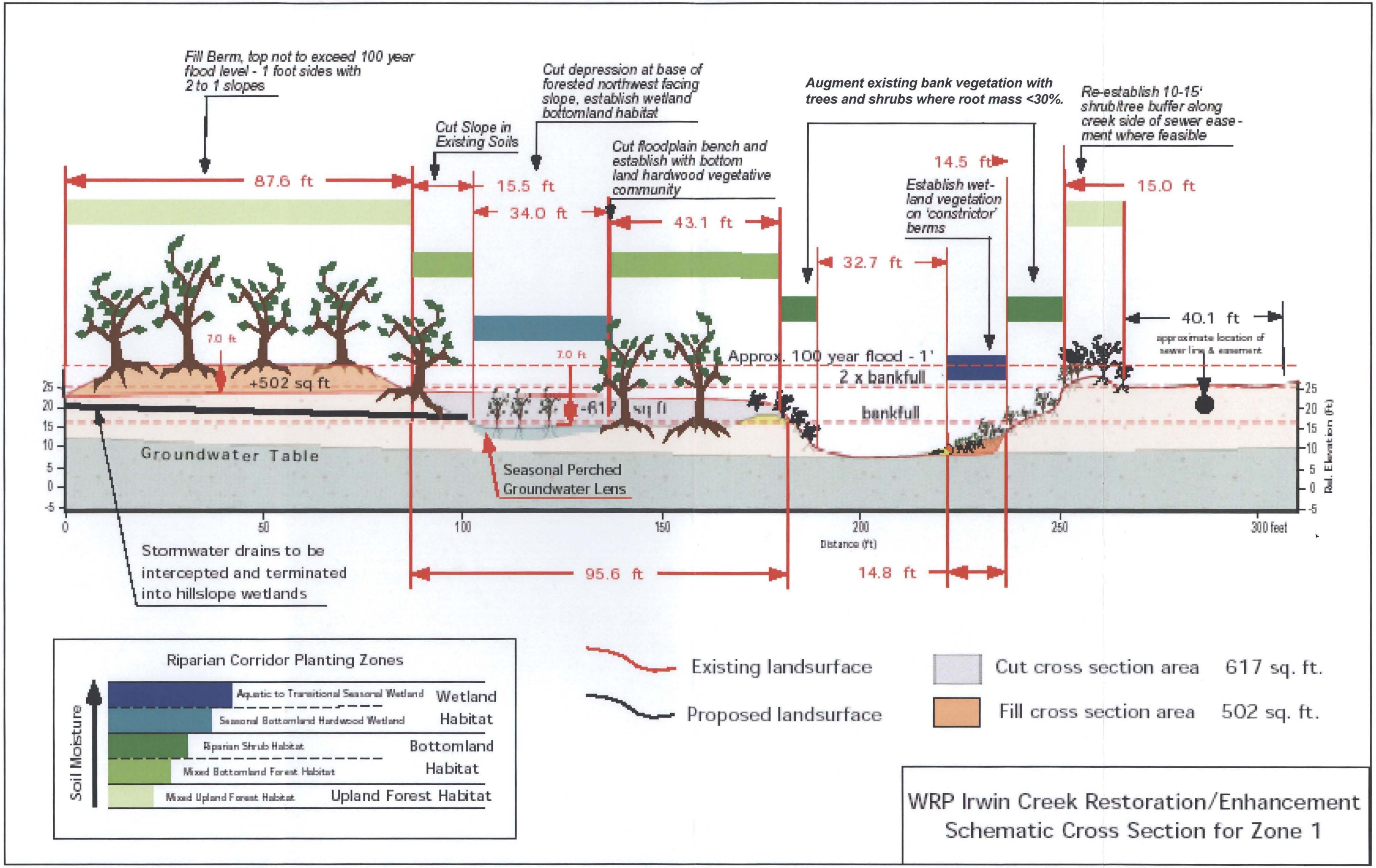

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Figure 11: Cross Section for Flood Plain Bench
Stream Restoration Plan
Irwin Creek

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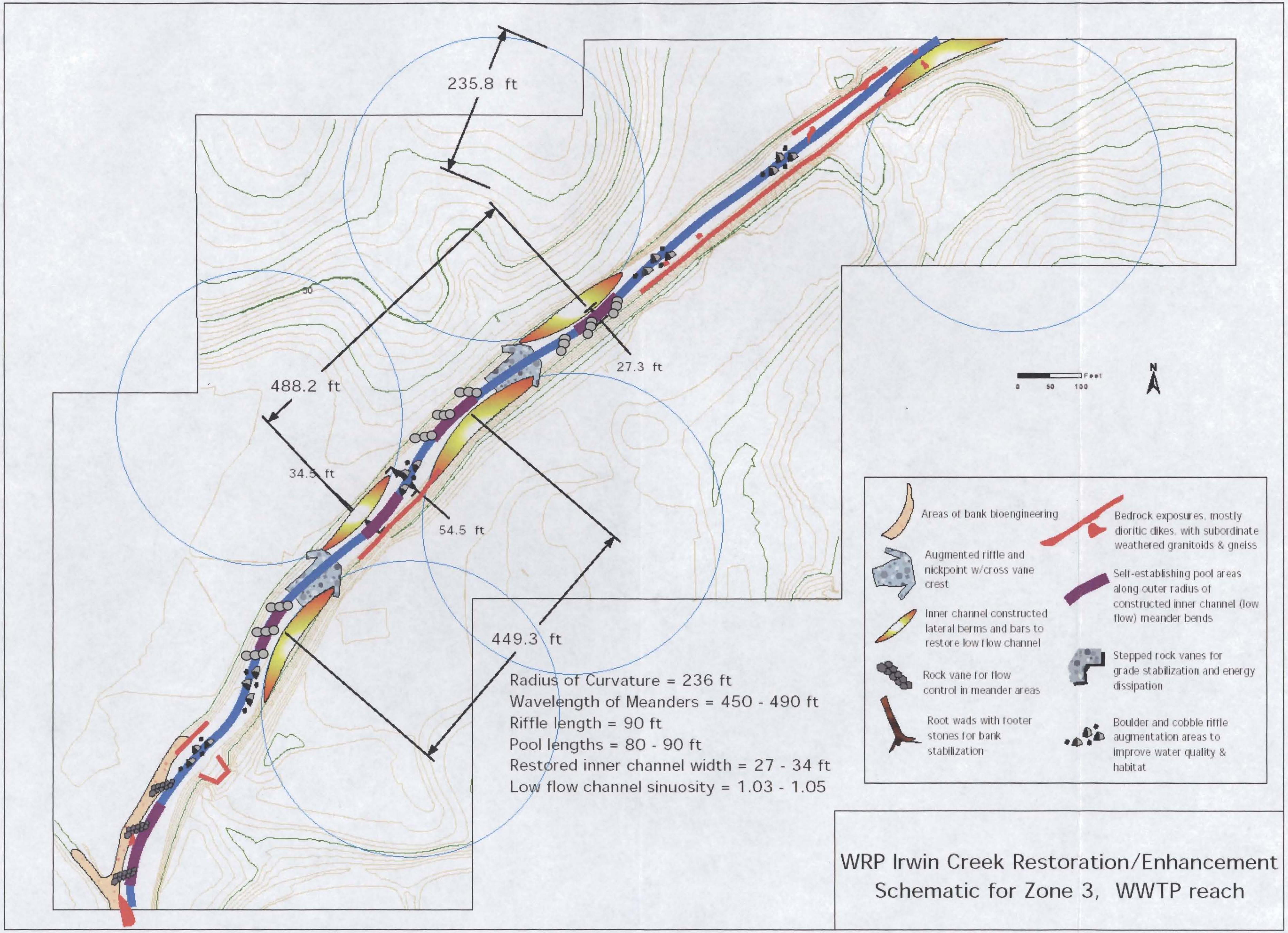

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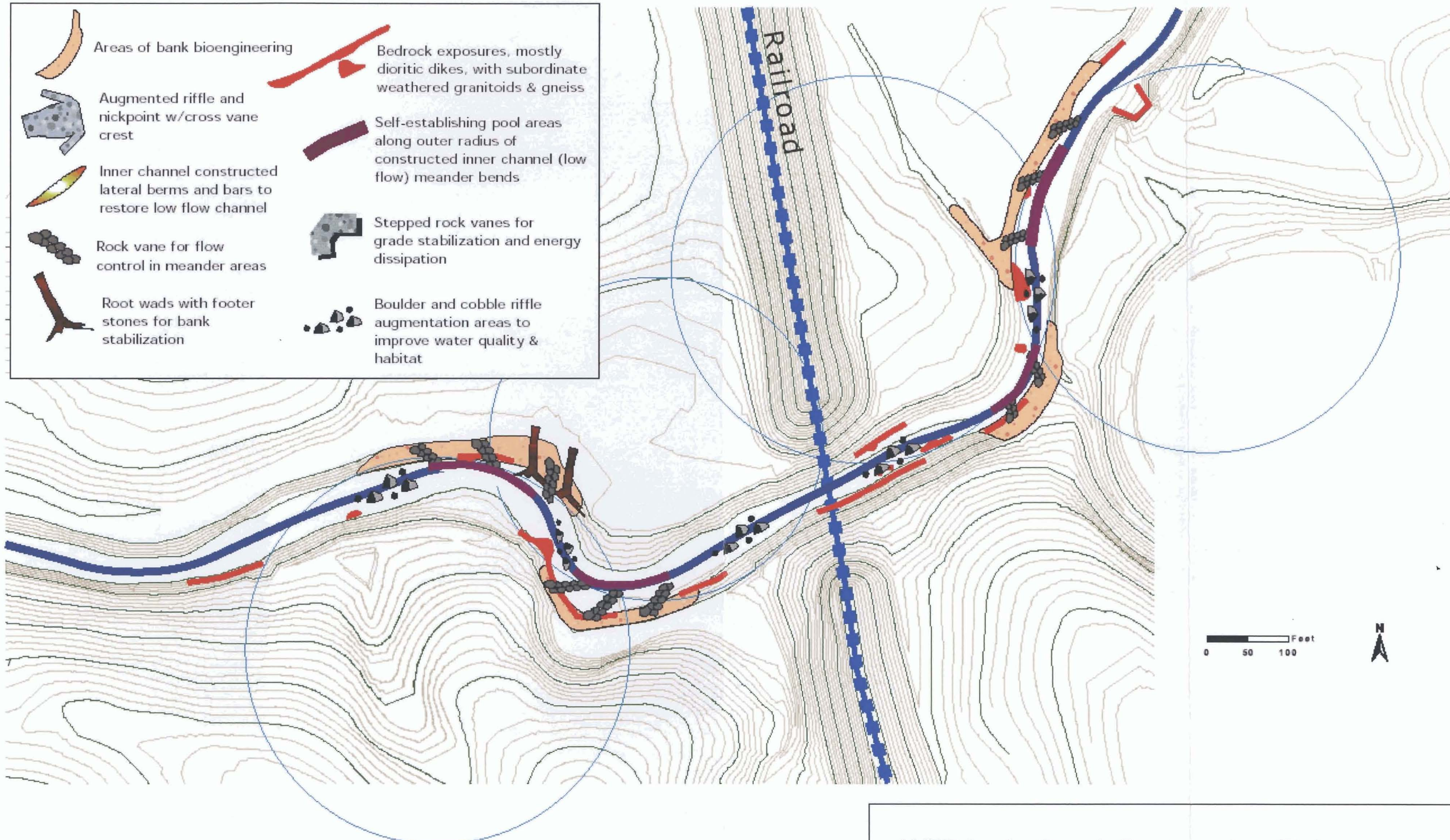
Figure 12: Planform for Zone 3
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



WRP Irwin Creek Restoration/Enhancement
Schematic for Zone 4, Below WWTP

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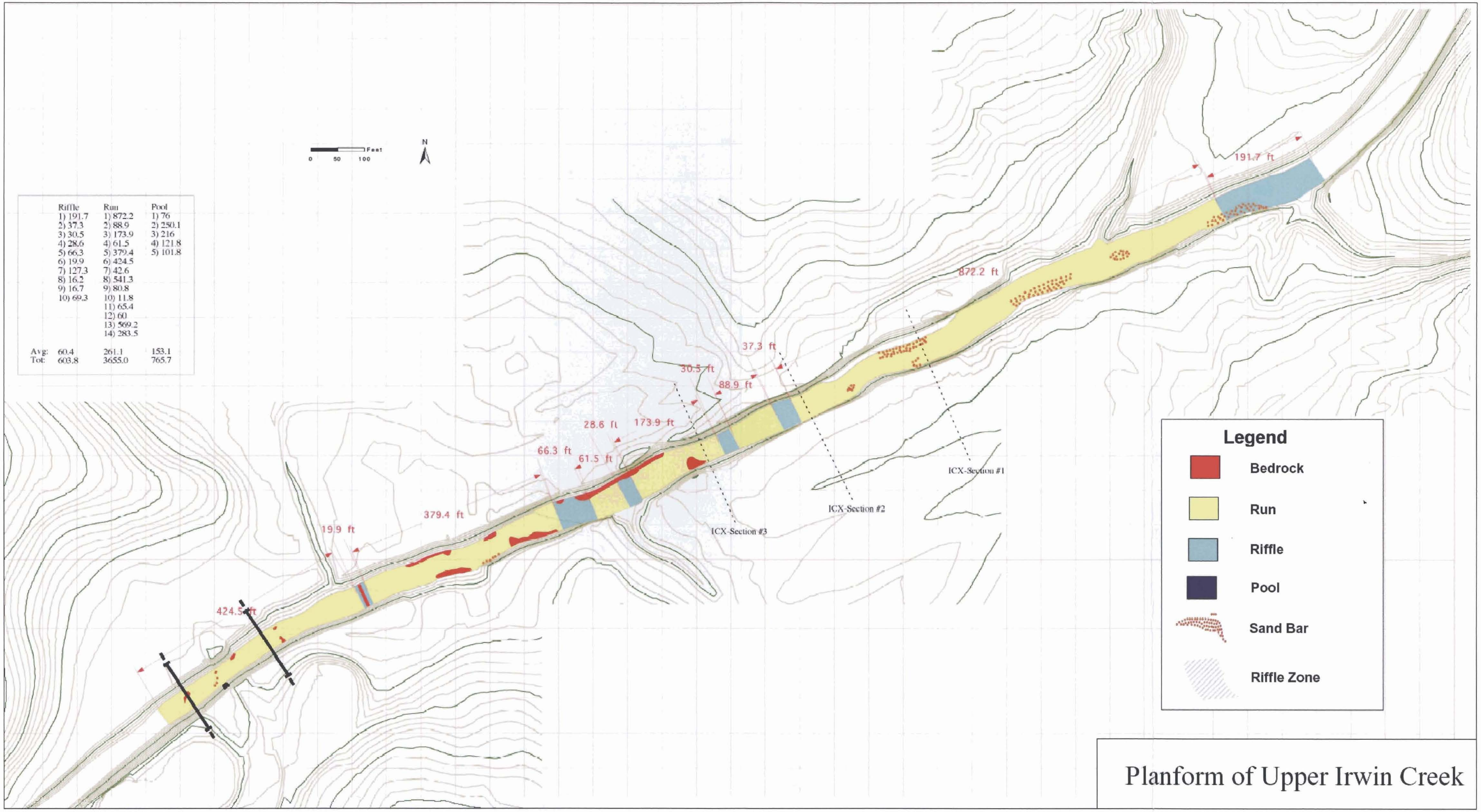
Figure 13: Planform for Zone 4
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



	Riffle	Run	Pool
	1) 191.7	1) 872.2	1) 76
	2) 37.3	2) 88.9	2) 250.1
	3) 30.5	3) 173.9	3) 216
	4) 28.6	4) 61.5	4) 121.8
	5) 66.3	5) 379.4	5) 101.8
	6) 19.9	6) 424.5	
	7) 127.3	7) 42.6	
	8) 16.2	8) 541.3	
	9) 16.7	9) 80.8	
	10) 69.3	10) 11.8	
		11) 65.4	
		12) 60	
		13) 569.2	
		14) 283.5	
Avg:	60.4	261.1	153.1
Tot:	603.8	3655.0	765.7

Planform of Upper Irwin Creek

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Figure 14: Planform of Upper Irwin Creek
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

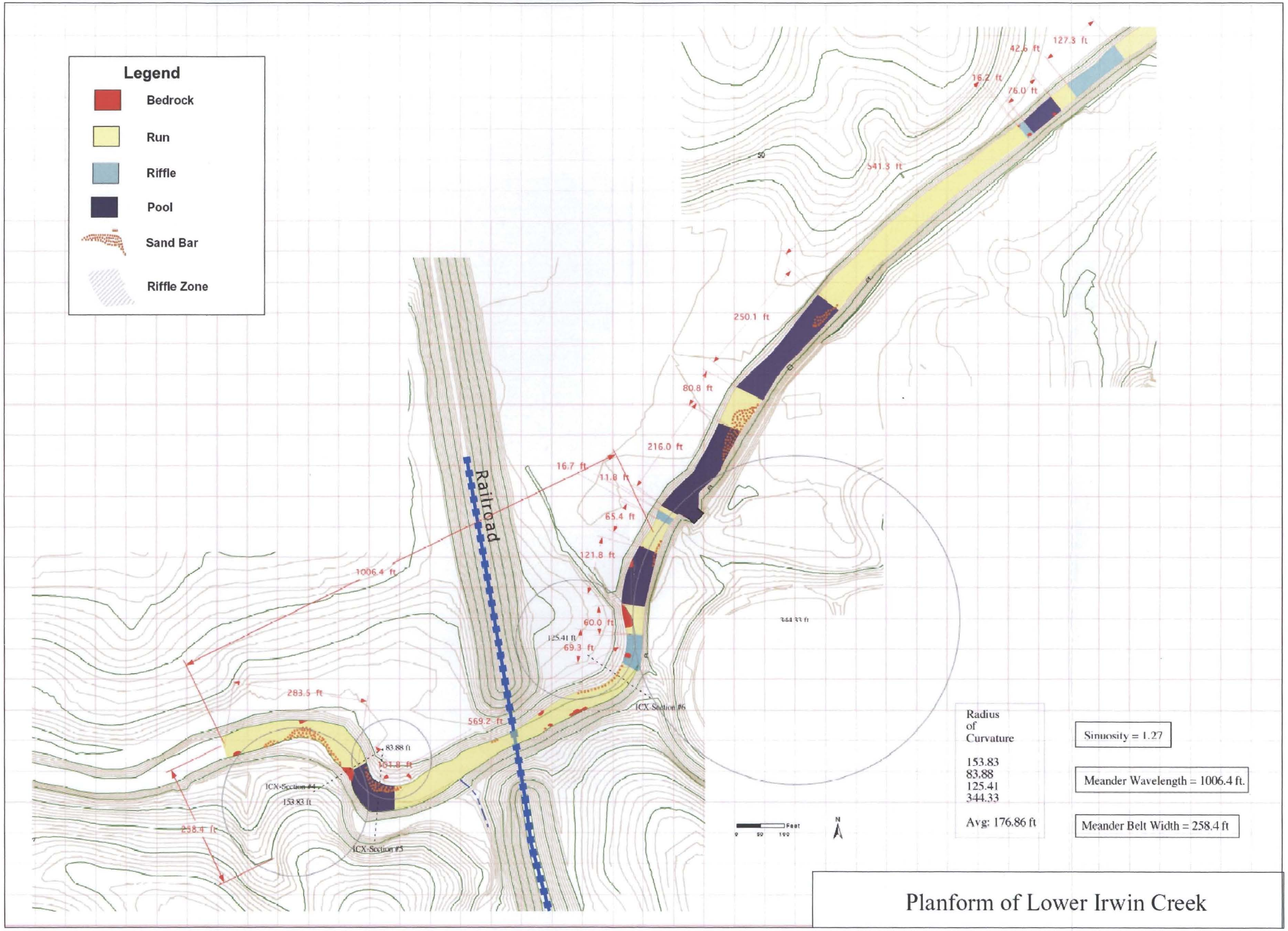

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Figure 15: Planform of Lower Irwin Creek
Stream Restoration Plan
Irwin Creek

October 2003

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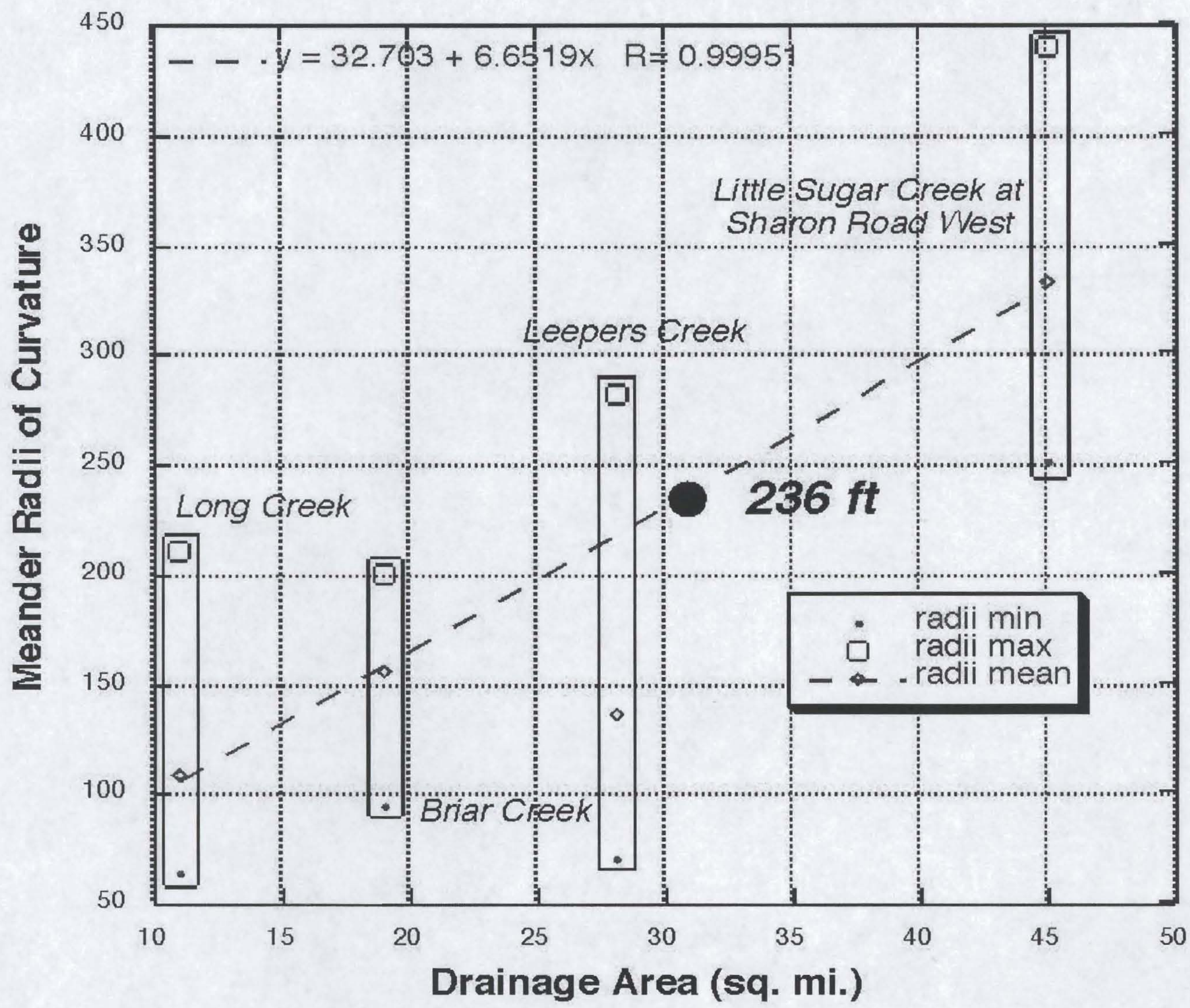

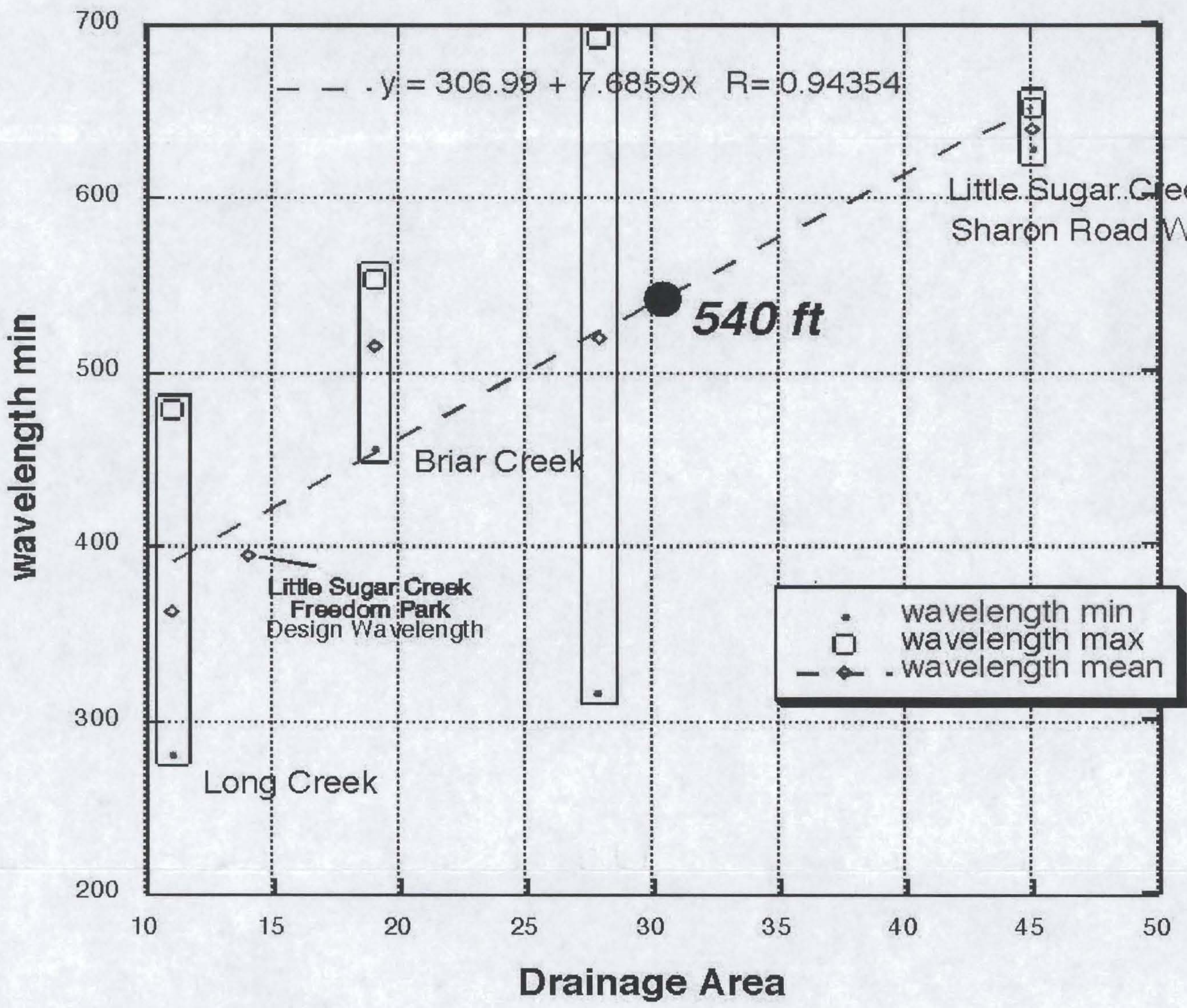

Interpolation Graphs for Preliminary Wavelength and Radius of Curvature Values for Irwin Creek Restoration

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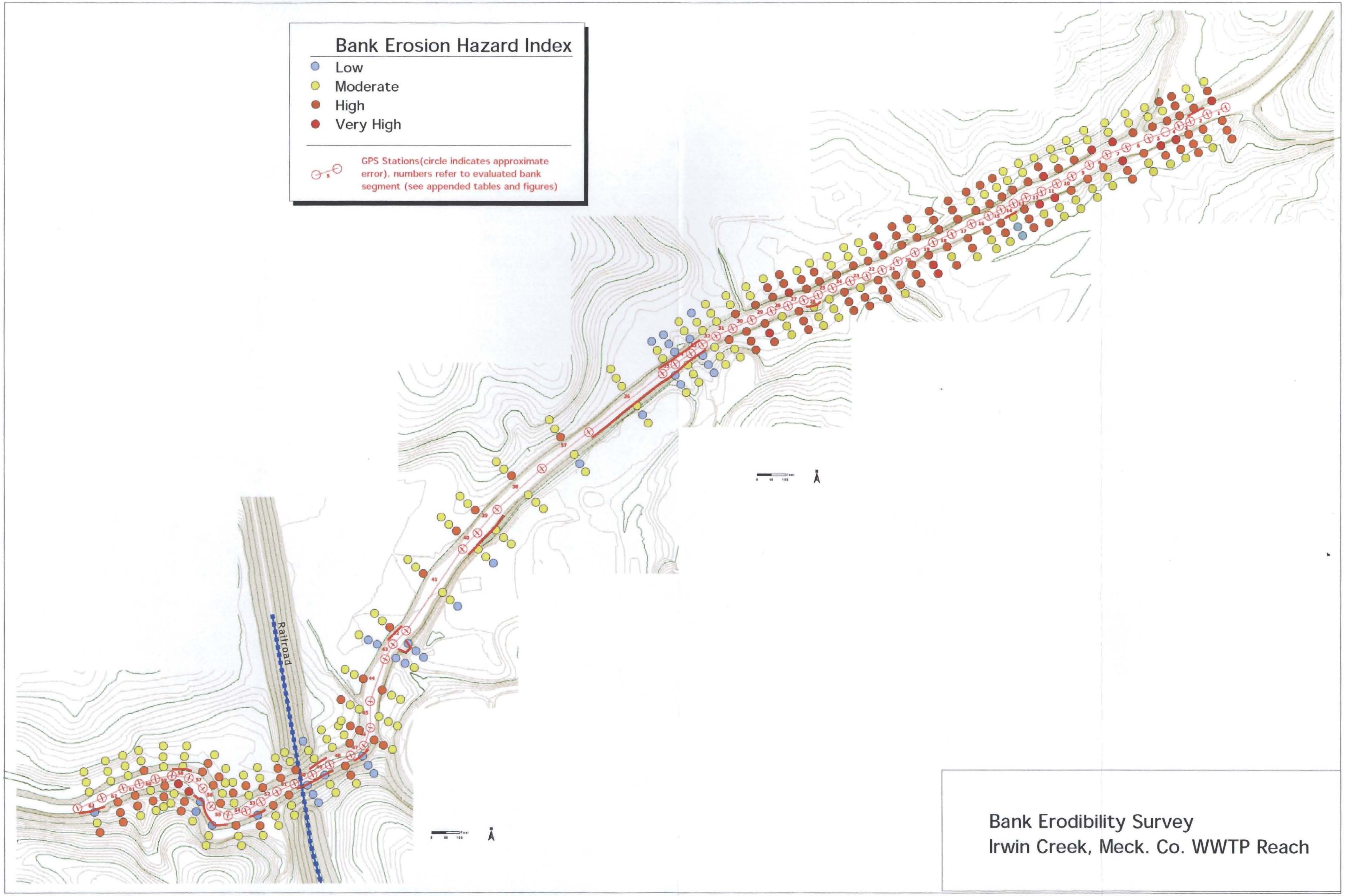

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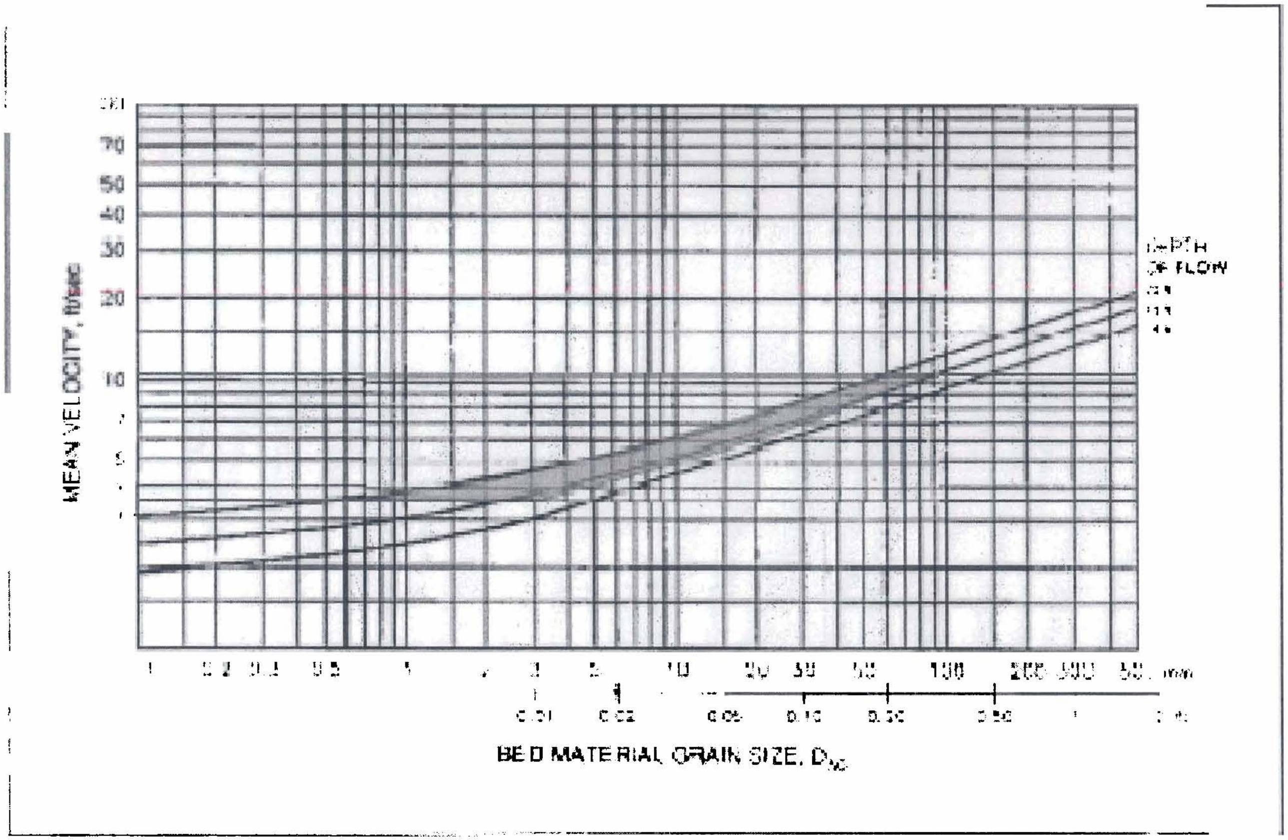
Figure 17: Bank Erosion Hazard Index
Stream Restoration Plan
Irwin Creek

October 2003

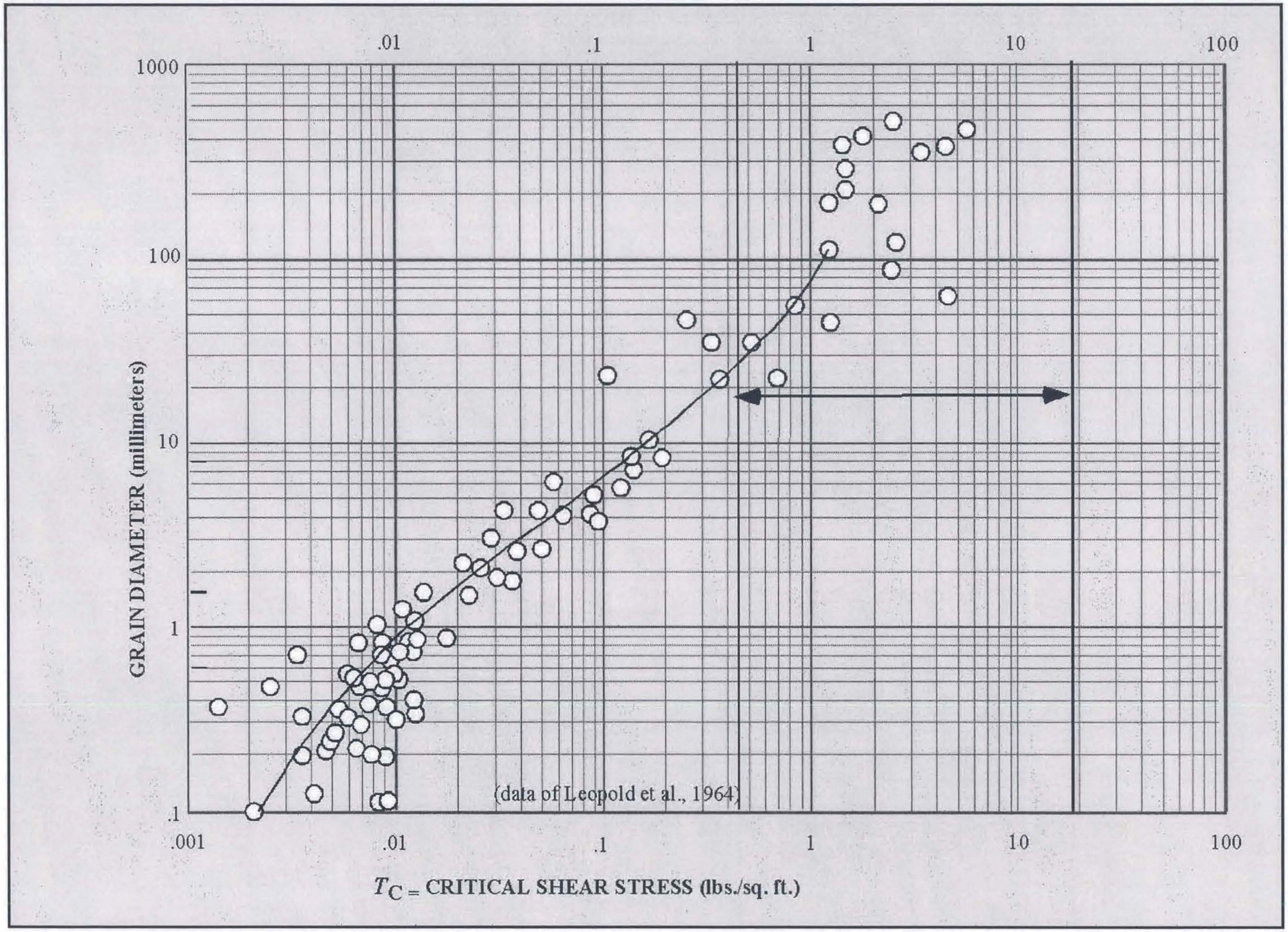
Project: 09177-021-018



Example of allowable velocity-depth data for granular materials.
From USACOE 1994 Appendix A and B.

Range of estimated velocities for Irwin Creek bankfull to 10 year storm plotted on the Mean Velocity vs Bed Material Size (D 50) chart from the USACOE 1994 guide to stream stabilization.

HDR Engineering, Inc. of the Carolinas	Habitat Assessment and Restoration Program	**Figure 18: USACE Velocity Analysis** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018



Shield Curve with Range of Conditions for Irwin Creek, WWTP Reach.

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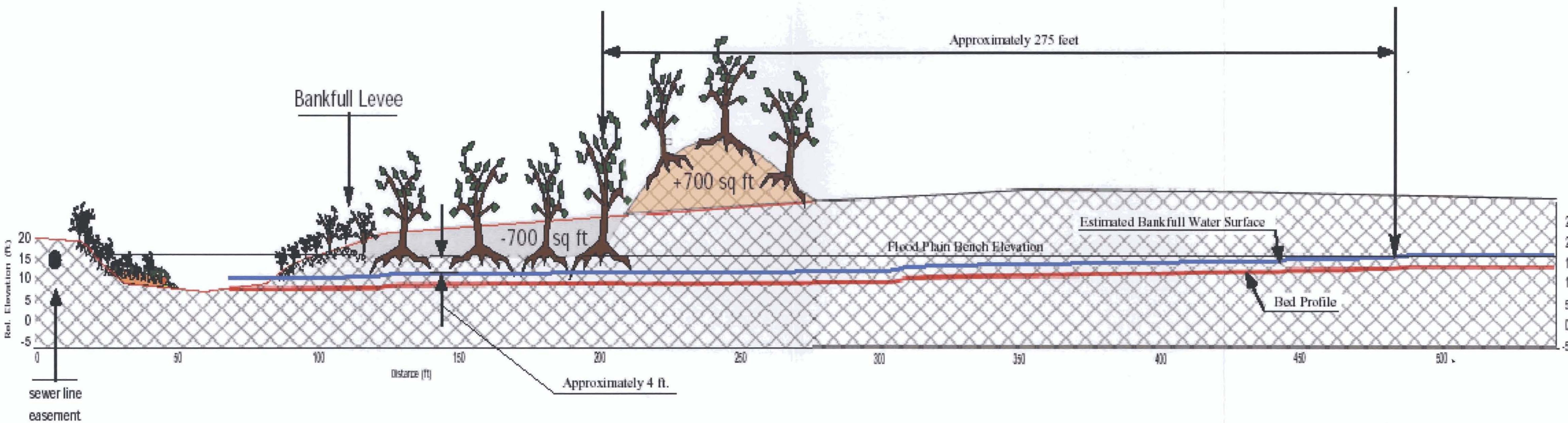

450 ft Longitudinal Profile of Tributary to Irwin Creek (WWTP) superimposed on the cross section for the proposed flood plain bench to be constructed in the FEMA buyout area, with an estimated bankfull water surface shown above the bed profile.

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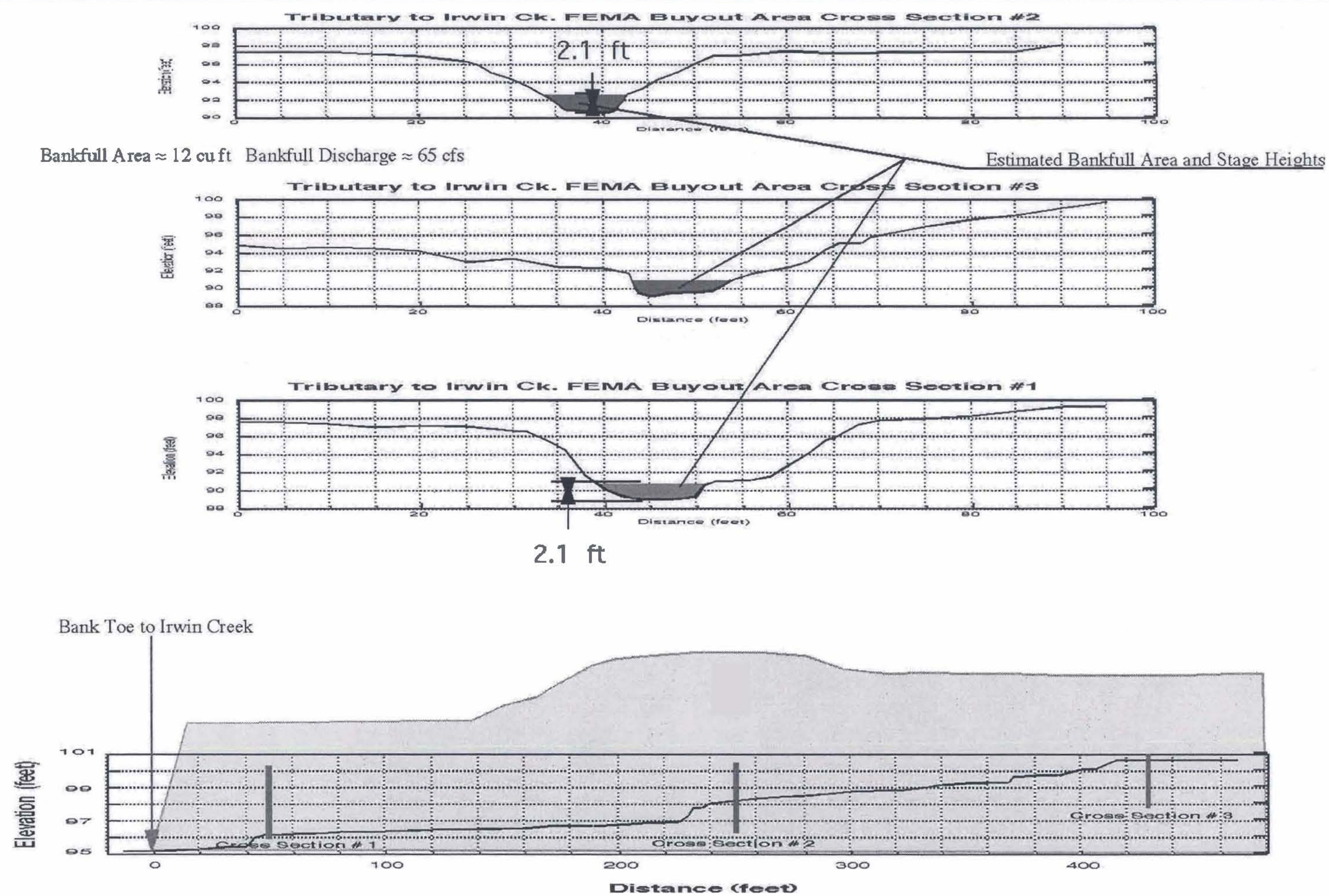
Figure 20: Intersection of Tributary 1 with the Floodplain Bench
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



Unnamed Tributary to Irwin Creek, Lower FEMA buyout area, Cross Sections and Longitudinal Profile

HDR Engineering, Inc.
of the Carolinas

HABITAT ASSESSMENT AND RESTORATION

Figure 21: Cross Sections & Longitudinal Profile for Tributary 2

Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

Table 1
Annual Peak Flow data for the Irwin WWTP Gaging Station (1963-2001)

Year	Date	Stage (ft)	Discharge (cfs)
1963	Mar. 6, 1963	11.64	2,720
1964	Apr. 7, 1964	9.46	1,780
1965	Jul. 28, 1965	11.49	2,500
1966	Mar. 4, 1966	12.20	2,850
1967	Aug. 23, 1967	13.12	3,320
1968	Jun. 9, 1968	11.93	2,720
1969	Aug. 2, 1969	9.65	1,840
1970	Dec. 10, 1969	9.41	1,750
1971	Jun. 21, 1971	13.33	3,450
1972	Oct. 16, 1971	12.29	2,900
1973	Feb. 2, 1973	13.78	3,750
1974	Sep. 6, 1974	13.80	3,760
1975	May 30, 1975	18.04	8,880
1976	Oct. 8, 1975	12.07	2,960
1977	Oct. 9, 1976	16.38	6,740
1978	Jan. 25, 1978	12.39	3,180
1979	Sep. 30, 1979	13.77	4,090
1980	May 20, 1980	9.77	2,920
1981	Sep. 7, 1981	9.45	2,740
1982	Jun. 10, 1982	14.98	6,400
1983	Feb. 2, 1983	10.35	3,110
1984	Dec. 6, 1983	12.75	4,660
1985	Jun. 7, 1985	12.65	4,590
1986	Nov. 21, 1985	12.96	4,810
1987	Sep. 7, 1987	10.61	3,260
1988	Aug. 29, 1988	8.91	2,340
1989	Sep. 22, 1989	14.40	5,910
1990	May 28, 1990	12.16	4,070
1991	Oct. 22, 1990	13.39	3,740
1992	Jun. 11, 1992	10.40	2,900
1993	Mar. 23, 1993	12.54	4,050
1994	Aug. 17, 1994	12.33	3,930
1995	Aug. 27, 1995	15.02	5,510
1996	Jan. 26, 1996	13.29	4,470
1997	Jul. 23, 1997	20.38	11,600
1998	Apr. 9, 1998	14.50	5,110
1999	Jan. 23, 1999	10.50	2,600
2000	Jul. 12, 2000	11.55	3,150
2001	Mar. 29, 2001	10.70	2,700

Table 2 Manning Equation - Based Discharge and Velocity at the Morphologic Bankfull Channel Dimension														
Section	Bankfull Cross Section Area	Bankfull Width	Bankfull Mean	Floodprone Width	W/D	Entrenchment Ratio	R	Wetted Perimeter	n1	n2	Slope	^Q1 (cfs)	^^Q2 (cfs)	Velocity (ft/sec)
IRWIN														
CX-1	445.0	83.0	5.15	198	16.10	2.38	5.705	78.0	0.03	0.025	0.00113	**2366**	**2839**	6.4
CX-2	420.0	76.2	5.38	150	14.10	1.96	5.753	73.0	0.03	0.025	0.00113	**2245**	**2695**	6.4
CX-3	269.0	42.9	6.27	58	6.80	1.37	5.604	48.0	0.03	0.025	0.00170	**1733** *	**2080** *	7.7
CX-4	371.0	72.7	5.39	103	13.50	1.41	5.377	69.0	0.03	0.025	0.00130	**2034**	**2440**	6.6
ICX-1	508.3	73.6	6.9	350	10.67	4.76	5.816	87.4	0.03	0.025	0.00119	**2809**	**3371**	6.6
ICX-2	471.3	62.8	7.5	250	8.37	3.98	6.058	77.8	0.03	0.025	0.00160	**3103**	**3724**	7.9
ICX-3	391.2	63.2	6.2	72	10.19	1.14	5.175	75.6	0.03	0.025	0.00215	**2688**	**3226**	8.2
ICX-4i	309.8	55.5	5.6	150	9.91	2.70	4.645	66.7	0.03	0.025	0.00047	**926**	**1111**	3.6
ICX-5m	370.7	75.6	4.9	168	15.43	2.22	4.341	85.4	0.03	0.025	0.00063	**1226**	**1472**	4.0
ICX-6m	446.0	64.6	6.9	155	9.36	2.40	5.689	78.4	0.03	0.025	0.00323	**4001**	**4801**	10.8
											AVG.	**2313**	**2776**	**7**
LEEPERS														
CX-1m	372.7	58.4	6.4	120	9.13	2.05	5.235	71.2	0.03	0.025	0.00030	**964**	**1157**	3.1
CX-2i	422.0	61.0	6.9	200	8.84	3.28	5.642	74.8	0.03	0.025	0.00150	**2566**	**3079**	7.3
CX-3i	394.9	69.3	5.7	250	12.16	3.61	4.893	80.7	0.03	0.025	0.00350	**3336**	**4003**	10.1
CX-4m	279.5	54.9	5.1	170	10.76	3.10	4.293	65.1	0.03	0.025	0.00350	**2164**	**2596**	9.3
											AVG.	**2257**	**2709**	**7**

^ Discharge based on a Manning roughness of .03
^^Discharge based on a Manning roughness of .025

Table 3
Preliminary Estimates of Fluvial Morphologic Parameters
Irwin Creek Restoration Project

Parameters	Briar Creek Reference Reach (**)	Long Creek Prim Road Reach	Irwin Creek at WWTP Existing Conditions	Leepers Creek Reference Reach	Irwin Creek at WWTP Proposed
Watershed Area (sq. miles)	19	10.9	30.7	28.2	30.7
Bankfull Width (ft)	49	37	72.7 - 83	61 - 69.3	72.7 - 83
Bankfull Area (sq. feet)	314	119	392 - 428	394 - 422	392 - 428
Ave. Bankfull Depth (feet)	6.41	2.8	5.15 - 5.39	5.7 - 6.9	5.15 - 5.39
Max. Depth (feet)	11.09	5.2	9	10.3	9.5
Flood Prone Width (feet)	>150	71.6	100 - 198	>225	150-200'
Entrenchment Ratio	>>2.2	1.9	1.41 2.38	>3.45	>3
Width/Depth Ratio	7.64	13.2	13.5 16.1	8.8 - 12.2	13.5 16.1
Valley Slope (feet/feet)	0.0086	0.0045	0.0013	0.00354	0.0013
Average Water Slope (feet/feet)	0.0078	0.0033	0.002	0.002	0.002
Sinuosity	1.1	1.39	1.1	2.367	1.2
Riffle/Pool Ratio	0.86	0.58	0.79	2.33	1.5
Ave. Pool Spacing (feet)			385		270
Riffle Slope	.006-.074 (avg, .033)	0.012	.0039-.014 (avg. .0077)	.0011-.019 (avg. .0064)	.0039-.014 (avg. .0077)
Pool Slope	0 -.0027 (.0009)	0 - .002	-.0002 - .0009 (avg. .0002)	-.0015-.0023 (avg. .0002)	-.0002 - .0009 (avg. .0002)
Ave. Riffle Spacing (feet)	98	104	385	280	270
Riffle D50 (mm)	45.0	84.0	73.0	51.0	370****
Riffle D84 (high) (mm)		150.0	110.0	104.0	550****
Point/Medial Bar D50 (mm)		0.7	6.1	1.6	6.1
Point/Medial Bar D84 (high) (mm)		1.1	9.6	4.7	9.6
Bulk Stream Bed D50 (mm)		31.6	30.5	35.6	30.5
Bulk Stream Bed D84 (high) (mm)		55.7	45.3	70.5	45.3
Meander Radius of Curvature (ft)	94 - 200 (avg.155)	64 - 210 (avg. 109)	176.9	141.1	236
Meander Wave Length (ft)	456 -552 (avg. 515)	281 - 478 (362)	1006	512	540
Meander Belt Width (ft)	92 - 150 (115)	200	258	958.1	258
Bankfull Discharge (cfs) via * or **	2100 (**)		4000		4000
Bankfull Discharge (cfs) via ^ or ^^		495 (^^^)	Avg. = 2776	1157 - 4000 ^^^ (2707 Avg)	Avg. = 2776
Bankfull Est. Mean Velocity (ft/sec)	6.68	4.16	Avg. = 7	4.1 - 5.7 ^^^ (7 Avg)	Avg. = 7
Rosgen Class (***)	C/E (3-5)	C3-C5	C3-C5	C5/E5	C3-C5 & E5

(*) HDR estimate at watershed buildout
(**) Army Corp. Eng. 2001 Study Estimate
(***)Rosgen & Silvey, 1998, however none of the above fit all parameters for C or E channels
(^) estimates from recorded annual peak flows at USGS gage stations near reference reach
(^^) estimated using Manning Eq. Assuming Manning Coef. .03
(^^^) See Table X (Manning Equation Leepers Creek Table)
**** from bed shear stress tables

Table 4 Estimated Maximum Bed Traction Force And D84 for Stability WWTP Reach of Irwin Creek for top-of-bank event												
Section No.	**Reach Type**	**Max. Depth (ft)**	**Max. Depth (m)**	**Slope min.**	**Slope max.**	**Velocity (fps)*** **	**Velocity (mps)**	**Tractive Force min.** (kg/m^2)**	**Tractive Force max.** (kg/m^2)**	**Tractive Force min. (lb/ft^2)**	**Tractive Force max. (lb/ft^2)**	**Grain siz (cm)* incipient movemen min.**
ICX#1	Run	13.8	4.21	0.0005	0.013	6.6	2.01	2.10	54.68	0.43	11.20	2.10
ICX #2	Run	14.9	4.54	0.0005	0.013	7.9	2.41	2.27	59.04	0.47	12.09	2.27
ICX #3	Riffle	15.4	4.69	0.0005	0.02	8.2	2.50	2.35	93.88	0.48	19.23	2.35
ICX #4	Run	14.7	4.48	0.0005	0.013	3.6	1.10	2.24	58.25	0.46	11.93	2.24
ICX #5	Pool	16.1	4.91	0.0005	0.002	4	1.22	2.45	9.81	0.50	2.01	2.45
ICX#6	Riffle	14.5	4.42	0.0005	0.02	10.8	3.29	2.21	88.39	0.45	18.10	2.21
					D84 for cross vane stability ≈ 1.5 x Avg.Max. = 61 * 1.5 = 91.5 cm							Avg. Max.:

Table 4a Estimated Maximum Bed Traction Force And D84 for Stability WWTP Reach of Irwin Creek for "bankfull" event												
Section No.	**Reach Type**	**Max. Depth (ft)**	**Max. Depth (m)**	**Slope min.**	**Slope max.**	**Velocity (fps)*** **	**Velocity (mps)**	**Tractive Force min.** (kg/m^2)**	**Tractive Force max.** (kg/m^2)**	**Tractive Force min. (lb/ft^2)**	**Tractive Force max. (lb/ft^2)**	**Grain siz (cm)* incipient movemen min.**
ICX#1	Run	8.9	2.71	0.0005	0.013	6.6	2.01	1.36	35.27	0.28	7.22	1.36
ICX #2	Run	9.3	2.83	0.0005	0.013	7.9	2.41	1.42	36.85	0.29	7.55	1.42
ICX #3	Riffle	8.5	2.59	0.0005	0.02	8.2	2.50	1.30	51.82	0.27	10.61	1.30
ICX #4	Run	9.5	2.90	0.0005	0.013	3.6	1.10	1.45	37.64	0.30	7.71	1.45
ICX #5	Pool	8.4	2.56	0.0005	0.002	4	1.22	1.28	5.12	0.26	1.05	1.28
ICX#6	Riffle	9.5	2.90	0.0005	0.02	10.8	3.29	1.45	57.91	0.30	11.86	1.45
					D84for riffle armour stability ≈ 1.5 x Avg.Max. = 37 * 1.5 = 55.5 cm							Avg. Max:

* For non-cohesive bed materials greater than 1 cm in diameter the relationship of tractive force to stable grain diameter is approximated as:
**Tractive Force (kg/m^2) = incipient movement diameter (cm); e.g. 52 kg/m^2 = 53 cm diameter cobbles at incipient movement
*** From Manning Eq.-based estimates of flow (Irwin Creek Manning Eq. Table)

Table 4b Bed Shear Stress Estimates **Tau** (lb/sq.ft) **= Water density** (lb/cu.ft) **x Depth** (ft) **x slope** (ft/ft) **from hydrologic modelling**								
	Slope	**Density of Water (lb/cu.ft)**	**Max. Depth 1.5 yr**	**Bed Shear Stress 1.5 yr**	**Max. Depth 2 yr**	**Bed Shear Stress 2 yr**	**Max. Depth 10 yr**	**Bed Shear Stress 10 yr**
Max. Pool Slope	0.0020	62.4600	14	1.74888	15.5	1.93626	18.3	2.286036
Max. Riffle Slope	0.0200	62.4600	14	17.4888	15.5	19.3626	18.3	22.86036

Table 5
Irwin Creek Longitudinal Calculations

STA	Water Depth		Water Elevation	Notes/Comments	Character	Distance	Riffle Slope	Run Slope	Pool Slope
	ft	in							
TBM									
0.0	0	8	100.13	Opposite tributary #1	Riffle				
60.0	1	1	99.21		Riffle				
100.0	1	9	99.21		Riffle				
150.0	1	0	99.00		Riffle				
191.7			98.83		Riffle	191.7	0.0068		
200.0	0	9	98.83		Run				
250.0	1	3.5	98.83		Run				
300.0	1	9	98.79		Run				
350.0	1	4	98.83	~12' above tributary #2	Run				
400.0	0	10.5	98.88		Run				
450.0	2	4	98.75		Run				
500.0	2	3	98.71		Run				
550.0	1	8.5	98.75		Run				
600.0	0	10.5	98.67		Run				
650.0	1	0.5	98.67		Run				
700.0	1	7.5	98.63		Run				
750.0	1	6.5	98.63		Run				
768.0			98.63		Run, X-SECTION #1				
800.0	2	2.5	98.63	below rock vein	Run				
850.0	2	0.5	98.63		Run				
879.0	3	4	98.50		Run				
903.0	3	9.5	98.54	saprolite	Run				
950.0	2	4	98.58		Run				
993.0			98.50		Run, X-SECTION #2				
1000.0	2	1	98.50		Run	828.3		0.0004	
1020.0	0	3	98.50	Bedrock	Riffle				
1050.0	1	9	97.88		Riffle	43.9	0.0141		
1063.9			97.88		Run				
1100.0	1	6.5	97.88						
1101.2			97.83						
1150.0	1	2.5	97.83		Run				
1161.0	1	2.5	97.83		Run	126.2		0.0004	
1190.1			97.83		Riffle				
1200.0	2	0.5	97.71		Riffle				
1203.0			97.71		Riffle, X-SECTION #3				
			97.71	bedrock	Riffle	30.5	0.0039		
1220.6			97.71		Run				
1250.0	2	2.5	97.75		Run				
1300.0	1	11	97.71		Run				
1350.0	0	9.5	97.67		Run	173.9		0.0014	
1394.5			97.46		Riffle				
1400.0	1	7	97.46		Riffle				
1423.1	1	0	97.46		Riffle				
1450.0	1	0.5	97.46		Riffle				
1484.6			97.46		Riffle				
1500.0	0	10.5	96.88		Riffle	155.5	0.0051		
1550.0	0	8	96.67	Saprolite	Run				
1550.9			96.63		Run				
1600.0	1	1	96.63	Saprolite	Run				
1650.0	1	5.5	96.63		Run				
1700.0	1	11.5	96.54	Saprolite	Run				
1750.0	1	10.5	96.54	Saprolite	Run				
1800.0	1	10	96.58		Run				
			96.58		Run				
1850.0	1	5.5	96.58		Run				
1863.0	0	4	96.46	Top of concrete incasement, mid-channel	Run	350		0.0026	
1866.0	0	10	95.96		Riffle				
1900.0	1	4.5	95.75		Riffle	30.3	0.0069		
1930.3			95.73		Run				
1950.0	1	1	95.67		Run				
1950.2			95.67		Run				
2000.0	1	1.5	95.50		Run				
2050.0	1	4.5	95.33		Run				
2100.0	1	7.5	95.25		Run				
2150.0	1	10.5	95.17	below road	Run				
2200.0	2	1.5	95.17		Run				
2250.0	2	1.5	95.08		Run				
2300.0	1	3	95.04		Run	419.7		0.0019	
2350.0	1	2.5	94.92		Riffle				
2374.7			94.69		Riffle				
2400.0	1	2	94.58		Riffle				
2450.0	3	0.5	94.38		Riffle	100	0.0054		
2500.0	2	1	94.38		Run	50		0.0000	
2502.0			94.38		Pool				
2525.0			94.38		Pool	44.6			0.0009
2544.6	1	2	94.33		Riffle				
2550.0	1	5	94.29		Riffle	5.4	0.0077		
2600.0	3	1.5	94.17		Run				
2620.6			94.17		Run				
2625.0			94.17		Run				
2636.8			94.17		Run				

Table 5
Irwin Creek Longitudinal Calculations

STA	Water Depth ft	Water Depth in	Water Elevation	Notes/Comments	Character	Distance	Riffle Slope	Run Slope	Pool Slope
2650.0	1	1	94.17		Run				
2700.0	2	1	94.17		Run				
			94.17	below road	Run				
2750.0	1	10.5	94.13		Run				
2800.0	2	4	94.08		Run				
2850.0	2	1	94.08		Run				
2900.0	1	1.5	94.08		Run				
2950.0	1	11.5	94.08		Run				
3000.0	2	7	94.04		Run				
3050.0	1	2.5	94.04		Run	550		0.0007	
3100.0	1	4	93.92		Pool				
3150.0	2	0	94.00		Pool				
3178.1			94.00		Pool				
3200.0	2	5.5	94.00		Pool				
3250.0	2	4.5	93.96		Pool				
3300.0	2	5.5	93.96		Pool				
			93.96	below dike wall	Pool	250			-0.0002
3350.0	1	6.5	93.96		Run				
3400.0	1	8	93.88		Run				
3428.2			93.88		Run	78.2		0.0010	
3450.0	1	6	93.88		Pool				
3500.0	0	10.5	93.88		Pool				
3509.0			93.88		Pool				
3550.0	2	3	93.88		Pool				
3600.0	2	7	93.83	~10' above wing wall	Pool				
3650.0	2	4	93.88	@ lower wing wall	Pool	249.8			0.0002
3678.0	0	10.5	93.83		Riffle				
3700.0	1	10	93.63		Riffle	30	0.0069		
3725.0			93.63						
3730.0			93.63		Run				
3736.8			93.50		Run	20		0.0065	
3750.0	3	2.5	93.50		Pool				
3753.5			93.50		Pool				
3800.0	3	2	93.50		Pool				
3818.9			93.50		Pool	100.0			0.0000
3850.0	2	9	93.50		Run				
			93.50		Run				
3900.0	2	0	93.42		Run				
3940.7			93.42		Run	90.7		0.0009	
3950.0	1	2.5	93.25		Riffle				
4000.0	1	8	92.13		Riffle				
4000.7			92.13		Riffle	100.3	0.0129		
4041.0			92.13		Run, X-SECTION #6				
4050.0	1	8.5	92.13		Run				
4070.0			91.87		Run				
4100.0	1	9	91.79		Run				
4150.0	1	9.5	91.67		Run				
4200.0	1	10.5	91.63		Run				
4250.0	1	9	91.54		Run				
4300.0	1	4	91.46		Run				
4350.0	1	8	91.29		Run				
4400.0	2	3	91.25	@ drainage	Run				
4450.0	1	5	91.25		Run				
4500.0	1	5	91.25		Run				
4550.0	2	1.5	91.21		run				
4600.0	3	0	91.13		Run				
			91.08		Run	584		0.0018	
4625.0	2	10	91.08		Pool				
4639.2			91.08		Pool				
4674.0			91.08		Pool, X-SECTION #5				
4675.0	2	7	91.08		Pool	50			0.0000
4725.0	3	4	91.08		Run				
4741.0			91.08		Run				
4775.0	2	6	91.08		Run, X-SECTION #4				
4825.0	3	4	91.08		Run				
4883.0	2	3	91.08		Run				
4933.0	1	8.5	91.13		Run				
4983.0	1	10.5	91.00		Run				
5033.0	1	5	91.00		Run	358		0.0002	
5033.0			91.00		Run				
0+00			91.00	Station 0+00 of x-sections 5 & 6					

	Riffle Slope	Run Slope	Pool Slope
Minimum	0.0039	0.0000	-0.0002
Maximum	0.0141	0.0065	0.0009
Points	9.0000	12.0000	5.0000
Mean	0.0077	0.0015	0.0002

Notes: Longitudinal profile tied horizontally to x-sections 1,2,3,5,6 and vertically to 4 and 5.
Treatment Plant outfall wingwalls at 1204 yards (3612 feet) and 1216 yards (3648 feet).

Table 6
Bank Conditions
Irwin Creek Restoration Reach

Segment	Attribute *Distance (meters)*	1 *0-20*	2 *20-40*	3 *40-60*	4 *60-80*	5 *80-100*	6 *100-120*	7 *120-140*	8 *140-160*	9 *160-180*	10 *180-200*	11 *200-220*	12 *220-240*	13 *240-260*	14 *260-280*
	SLOPE BEHI Index	8.5	3.5	8.5	8.5	8.5	6	3.5	2.5	1.5	3.5	2.5	8.5	8.5	3.5
	% TREES	20	5	30	10	25	10	20	10	30	30	50	5	10	10
	% SHRUB	50	75	15	50	60	40	15	80	50	20	30	10	40	20
	% GRASS		15	5	25	10	20	5	10	20	50	20	45	20	40
	% No Plant Cover	30	5	50	15	5	30	60					40	30	
	% Rock														30
	Saprolite														
Top 1/3 Left Bank	Bedrock														
	Riprap														1
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.36	8.36	8.58	8.54	7.92	8.77	8.97	8.13	7.83	8.12	7.45	9.36	8.77	8.99
	BEHI root density ind	3.42	2.90	3.81	2.85	3.26	2.89	3.61	3.03	3.21	2.89	3.52	2.37	2.89	2.61
	BEHI surface% index	2.65	1.39	4.19	1.80	1.39	2.65	5.14	1.22	1.22	1.22	1.22	3.36	2.65	1.22
	BEHI +/- factor	2.25	0.38	3.75	1.13	0.38	2.25	4.50	0.00	0.00	0.00	0.00	3.00	2.25	2.25
	BEHI Index	32.18	23.52	35.82	29.82	28.45	29.56	32.72	21.88	20.76	22.73	21.69	33.59	32.06	18.57
	SLOPE BEHI Index	3.5	0	3.5	6	8.5	3.5	3.5	3.5	3.5	2.5	2.5	0.375	8.5	3.5
	% TREES	5	20	10	5			30			5		30		
	% SHRUB	15	20	10	25	40	50	10	70	60	25	20	10	20	10
	% GRASS	5	10				5	5		10	60	60	5	30	30
	% No Plant Cover	75	50	80	70	60	45	55	30	30	10	20	55	50	20
	% Rock														40
	Saprolite														
Middle 1/3 Left Bank	Bedrock														
	Riprap														1
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.57	8.83	9.51	9.41	9.32	9.09	8.67	8.76	8.86	8.93	9.24	8.67	9.48	9.69
	BEHI root density ind	3.07	3.36	3.76	3.24	2.99	2.90	3.90	2.99	2.84	2.41	2.27	3.90	2.40	2.27
	BEHI surface% index	6.78	4.19	7.38	6.20	5.14	3.76	4.65	2.65	2.65	1.58	2.06	4.65	4.19	2.06
	BEHI +/- factor	5.63	3.75	6.00	5.25	4.50	3.38	4.13	2.25	2.25	0.75	1.50	4.13	3.75	4.50
	BEHI Index	35.54	27.14	37.16	37.10	37.45	29.62	31.85	27.15	27.11	23.17	24.56	28.72	35.32	19.21
	SLOPE BEHI Index	3.5	2.5	3.5	6	8.5	8.5	8.5	3.5	2.5	3.5	3.5	8.5	3.5	3.5
	% TREES	5	5					5			5	10			
	% SHRUB	10	10	20	10		30	15	25	5	10		15	20	5
	% GRASS	5	30	10	5	20	10			5	5		5	20	15
	% No Plant Cover	80	55	70	85	80	60	80	75	90	80	90	80	60	40
	% Rock														40
	Saprolite	1	1	1	1	1	1	1	1			1	1	1	1
Lower 1/3 Left Bank	Bedrock					1								1	
	Riprap														1
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.68	9.48	9.64	9.89	9.98	9.44	9.61	9.62	9.99	9.68	9.71	9.78	9.56	9.91
	BEHI root density ind	3.08	2.48	2.65	2.65	2.06	2.73	3.36	2.99	2.49	3.08	4.65	2.73	2.49	2.27
	BEHI surface% index	7.38	4.65	6.20	8.02	7.38	5.14	7.38	6.78	8.68	7.38	8.68	7.38	5.14	3.36
	BEHI +/- factor	6.00	4.13	5.25	6.38	6.00	4.50	6.00	5.63	6.75	6.00	6.75	6.00	4.50	6.00
	BEHI Index	36.64	30.23	34.24	39.93	40.92	37.31	41.86	35.51	37.41	36.64	40.30	41.40	32.19	21.62
	SLOPE BEHI Index	6	8.5	3.5	3.5	3.5	3.5	8.5	8.5	3.5	8.5	8.5	8.5	2.5	8.5
	% TREES		5	10	5										30
	% SHRUB			10	5	15	10	5	10	20	30	5	10		10
	% GRASS	10	20	5	5	25	10	5		5		20	20	20	
	% No Plant Cover	90	55	75	85	60	80	90	90	75	70	75	70	80	60
	% Rock		20												
	Saprolite	1	1	1	1	1	1	1	1	1	1	1	1		1
Bottom 1/3 Right Bank	Bedrock														
	Riprap						1								
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	10.06	9.76	9.47	9.78	9.62	9.85	9.99	9.93	9.68	9.52	9.87	9.77	9.98	8.71
	BEHI root density ind	2.06	2.46	3.36	3.11	2.38	2.49	2.49	2.99	2.79	2.99	2.22	2.34	2.06	4.19
	BEHI surface% index	8.68	4.65	6.78	8.02	5.14	7.38	8.68	8.68	6.78	6.20	6.78	6.20	7.38	5.14
	BEHI +/- factor	6.75	5.63	5.63	6.38	4.50	6.00	6.75	6.75	5.63	5.25	5.63	5.25	6.00	4.50
	BEHI Index	40.54	31.53	35.74	37.79	32.14	36.22	43.41	43.85	35.37	39.46	40.00	39.06	34.92	38.04
	SLOPE BEHI Index	3.5	3.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	3.5	2.5	2.5	2.5
	% TREES	10		5	20	10		5	25	5		15	10	5	20
	% SHRUB	30	20		5	10	50	30	60	50	60	5	65	75	20
	% GRASS		30	40	40	40	10	15		10	10	20	5		25
	% No Plant Cover	60	10	55	35	40	40	50	10	35	30	60	30	20	35
	% Rock		40												
	Saprolite														
Middle 1/3 Right Bank	Bedrock														
	Riprap														
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.12	9.48	9.60	8.88	9.19	9.05	9.20	8.00	8.85	8.86	9.25	8.43	8.48	8.71
	BEHI root density ind	3.36	2.40	2.28	2.78	2.55	2.82	2.82	3.43	2.94	2.84	2.99	3.11	3.08	3.02
	BEHI surface% index	5.14	1.58	4.65	2.99	3.36	3.36	4.19	1.58	2.99	2.65	5.14	2.65	2.06	2.99
	BEHI +/- factor	4.50	3.75	4.13	2.63	3.00	3.00	3.75	0.75	2.63	2.25	4.50	2.25	1.50	2.63
	BEHI Index	32.62	18.13	30.16	26.78	27.60	27.73	29.46	23.27	26.91	26.11	32.38	25.94	24.62	26.85
	SLOPE BEHI Index	8.5	8.5	8.5	8.5	3.5	2.5	3.5	3.5	3.5	2.5	8.5	2.5	2.5	8.5
	% TREES	25	25	35	35	30	30	5	10	20	30	60	5	30	35
	% SHRUB	50	60	5	15	35	30	80	80	50	40	20	65	50	10
	% GRASS	10	5	10	5	30	20	15	5	10	30		25	15	15
	% No Plant Cover	15	10	50	50	5	20		5	20		20	5	5	40
	Rock														
	Saprolite														
Top 1/3 Right Bank	Bedrock														
	Riprap														
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.09	7.96	8.53	8.38	8.01	8.18	8.27	8.17	8.28	7.92	7.41	8.46	7.87	8.40
	BEHI root density ind	3.30	3.34	3.85	3.88	3.11	3.27	2.91	3.09	3.22	3.10	4.19	2.79	3.28	3.59
	BEHI surface% index	1.80	1.58	4.19	4.19	1.39	2.06	1.22	1.39	2.06	1.22	2.06	1.39	1.39	3.36
	BEHI +/- factor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	BEHI Index	28.70	28.39	32.07	31.95	23.01	23.01	22.90	23.14	24.06	21.75	29.17	22.13	22.04	30.85
Avg. BEHI left bank		**34.79**	**26.96**	**35.74**	**35.62**	**35.61**	**32.16**	**35.48**	**28.18**	**28.43**	**27.52**	**28.85**	**34.57**	**33.19**	**19.80**
Avg. BEHI right bank		**33.95**	**26.01**	**32.65**	**32.17**	**27.58**	**28.99**	**31.92**	**30.09**	**28.78**	**29.10**	**33.85**	**29.04**	**27.19**	**31.92**

Table 6
Bank Conditions
Irwin Creek Restoration Reach

Segment	Attribute *Distance (meters)*	15 *280-300*	16 *300-320*	17 *320-340*	18 *340-360*	19 *360-380*	20 *380-400*	21 *400-420*	22 *420-440*	23 *440-460*	24 *460-480*	25 *480-500*	26 *500-520*	27 *520-540*	28 *540-560*
	SLOPE BEHI Index	3.5	3.5	3.5	8.5	8.5	8.5	2.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
	% TREES	20	10	15	15	20	10	25	10	5	10	10	10	15	10
	% SHRUB	60	10	10	50	10	20	20	40	20	10	55	75	40	55
	% GRASS	15	80	30	5		10	15	20	15	30	20		5	5
	% No Plant Cover	5		40	30	70	60	40	30	60	50	15	15	40	30
	% Rock			5											
	Saprolite														
Top 1/3 Left Bank	Bedrock														
	Riprap														
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.07	8.87	9.07	8.51	9.11	9.23	8.60	8.77	9.39	9.27	8.49	8.29	8.69	8.61
	BEHI root density ind	3.13	2.34	2.80	3.23	4.05	3.08	3.33	2.89	2.78	2.65	2.91	3.16	3.27	3.12
	BEHI surface% index	1.39	1.22	3.36	2.65	6.20	5.14	3.36	2.65	5.14	4.19	1.80	1.80	3.36	2.65
	BEHI +/- factor	0.38	0.00	3.38	2.25	5.25	4.50	3.00	2.25	4.50	3.75	1.13	1.13	3.00	2.25
	BEHI Index	23.45	22.93	27.82	32.14	40.10	37.45	27.79	32.06	37.31	35.37	29.83	29.89	33.82	32.13
	SLOPE BEHI Index	3.5	3.5	3.5	2.5	8.5	3.5	3.5	3.5	8.5	2.5	3.5	3.5	3.5	3.5
	% TREES	5	15	10	30			5			10	5	20	25	15
	% SHRUB	30	35	20	25	10	25	20	35	25	10	60	30	5	25
	% GRASS	5	10	5			5	5	10	5	5	5	10	10	5
	% No Plant Cover	60	40	60	45	90	70	70	55	70	75	30	40	60	50
	% Rock														5
	Saprolite														
Middle 1/3 Left Bank	Bedrock														
	Riprap														
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.28	8.74	9.27	8.43	9.93	9.58	9.47	9.34	9.58	9.47	8.71	8.64	8.92	8.97
	BEHI root density ind	3.04	3.18	3.26	3.84	2.99	2.82	3.05	2.76	2.82	3.36	3.02	3.30	3.66	3.36
	BEHI surface% index	5.14	3.36	5.14	3.76	8.68	6.20	6.20	4.65	6.20	6.78	2.65	3.36	5.14	4.19
	BEHI +/- factor	4.50	3.00	4.50	3.38	6.75	5.25	5.25	4.13	5.25	5.63	2.25	3.00	4.50	4.13
	BEHI Index	32.45	28.78	32.66	28.91	43.85	34.35	34.48	31.38	39.35	34.74	27.13	28.81	32.72	29.80
	SLOPE BEHI Index	3.5	3.5	2.5	3.5	2.5	2.5	3.5	8.5	3.5	2.5	3.5	3.5	3.5	3.5
	% TREES	15				5		5	5				5	5	20
	% SHRUB		5	20	30	15	5	20	20	10	10	50		15	5
	% GRASS	5	10	15	5		5	5	20	15	5	10	10		5
	% No Plant Cover	80	80	60	65	80	90	70	55	60	85	40	55	75	45
	% Rock		5	5						15			30	5	25
	Saprolite	1	1	1	1	1		1	1			1		1	1
Lower 1/3 Left Bank	Bedrock				1	1						1	1	1	1
	Riprap														
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.47	9.95	9.60	9.48	9.61	9.99	9.47	9.35	9.81	9.89	9.05	9.84	9.61	9.16
	BEHI root density ind	3.87	2.34	2.56	2.84	3.36	2.49	3.05	2.69	2.40	2.65	2.82	2.76	3.36	3.83
	BEHI surface% index	7.38	7.38	5.14	5.66	7.38	8.68	6.20	4.65	5.14	8.02	3.36	4.65	6.78	3.76
	BEHI +/- factor	6.00	6.38	4.88	4.88	6.00	6.75	5.25	4.13	5.63	6.38	3.00	6.38	6.00	5.25
	BEHI Index	37.22	35.04	30.33	33.35	35.86	37.41	34.48	36.32	29.29	36.43	28.73	25.81	34.74	25.70
	SLOPE BEHI Index	8.5	8.5	8.5	8.5	8.5	3.5	3.5	3.5	8.5	3.5	2.5	8.5	8.5	8.5
	% TREES	5	10	20	15	15	5		10	5	10	10	5	10	15
	% SHRUB	35	25	10	25	50	20	15	30	40	15		5		
	% GRASS	5	10	20	20	5	5	15	10	5	10	20	30	10	15
	% No Plant Cover	55	50	50	40	30	70	70	50	50	65	70	60	80	70
	% Rock		5												
	Saprolite	1	1	1	1	1	1	1	1	1	1		1	1	1
Bottom 1/3 Right Bank	Bedrock											1	1	1	1
	Riprap														
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.18	9.13	8.95	8.85	8.51	9.47	9.70	9.04	9.08	9.33	9.55	9.58	9.63	9.39
	BEHI root density ind	3.03	3.07	3.14	2.99	3.23	3.05	2.49	3.07	3.03	3.10	2.76	2.42	3.18	3.18
	BEHI surface% index	4.65	4.19	4.19	3.36	2.65	6.20	6.20	4.19	4.19	5.66	6.20	5.14	7.38	6.20
	BEHI +/- factor	4.13	4.13	3.75	3.00	2.25	5.25	5.25	3.75	3.75	4.88	5.25	4.50	6.00	5.25
	BEHI Index	36.49	34.43	35.53	33.71	32.14	34.48	34.15	30.54	35.55	33.46	33.27	37.13	41.69	39.51
	SLOPE BEHI Index	3.5	3.5	3.5	3.5	2.5	3.5	8.5	3.5	3.5	2.5	3.5	3.5	3.5	3.5
	% TREES	5	20	5	10	20	10	20	25			5	10	10	10
	% SHRUB	55	50	25	40	50	20		35	50	25	35	35		
	% GRASS	10		5			10	5	5	10	25	10	5	15	10
	% No Plant Cover	30	30	65	50	30	60	75	35	40	50	50	50	75	80
	% Rock														
	Saprolite														
Middle 1/3 Right Bank	Bedrock														
	Riprap														
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.76	8.36	9.37	8.92	8.36	9.23	9.26	8.40	9.05	9.42	9.14	8.98	9.59	9.63
	BEHI root density ind	2.94	3.42	3.04	3.29	3.42	3.08	4.02	3.48	2.82	2.49	2.92	3.18	2.92	3.18
	BEHI surface% index	2.65	2.65	5.66	4.19	2.65	5.14	6.78	2.99	3.36	4.19	4.19	4.19	6.78	7.38
	BEHI +/- factor	2.25	2.25	4.88	3.75	2.25	4.50	5.63	2.63	3.00	3.75	3.75	3.75	5.63	6.00
	BEHI Index	27.10	27.18	33.45	30.66	26.18	32.45	41.18	28.00	28.73	29.35	30.50	30.60	35.42	36.69
	SLOPE BEHI Index	8.5	8.5	8.5	8.5	8.5	8.5	8.5	3.5	8.5	8.5	8.5	3.5	8.5	8.5
	% TREES	25	30	20	20	25	30	10	20	10		15	20	25	25
	% SHRUB	10	20	10	10	15	10	40	50	60	50	35	35	10	30
	% GRASS	25	5			10	20	15	10	20	20	20	15	15	15
	% No Plant Cover	40	55	70	70	50	40	35	20	10	30	30	30	50	30
	Rock														
	Saprolite														
Top 1/3 Right Bank	Bedrock														
	Riprap														
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.71	8.48	9.11	9.11	8.73	8.55	8.81	8.28	8.40	8.97	8.66	8.51	8.79	8.41
	BEHI root density ind	3.14	3.73	4.05	4.05	3.52	3.36	2.97	3.22	2.92	2.70	2.99	3.18	3.40	3.28
	BEHI surface% index	3.36	4.65	6.20	6.20	4.19	3.36	2.99	2.06	1.58	2.65	2.65	2.65	4.19	2.65
	BEHI +/- factor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	BEHI Index	30.71	32.36	34.85	34.85	31.94	30.78	30.26	24.06	28.39	29.82	29.81	24.84	31.88	29.85
Avg. BEHI left bank		**31.04**	**28.92**	**30.27**	**31.47**	**39.94**	**36.40**	**32.25**	**33.25**	**35.32**	**35.51**	**28.56**	**28.17**	**33.76**	**29.21**
Avg. BEHI right bank		**31.44**	**31.32**	**34.61**	**33.07**	**30.09**	**32.57**	**35.20**	**27.54**	**30.89**	**30.88**	**31.19**	**30.86**	**36.33**	**35.35**

Table 6
Bank Conditions
Irwin Creek Restoration Reach

Segment	Attribute / *Distance (meters)*	29 *560-580*	30 *580-600*	31 *600-620*	32 *620-640*	33 *640-660*	34 *660-680*	35 *680-700*	36&37 *700-880*	38 *880-944*	39 *944-1008*	40 *1008-1034*	41 *1034-1154*	42 *1154-1171*	43 *1171-1191*
	SLOPE BEHI Index	8.5	8.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	8.5	8.5	OUTFALL	3.5
	% TREES	15	15	30	20			10				0.1	0.1	OUTFALL	5
	% SHRUB	30	35	30	60	30	10	70	60	90	90			OUTFALL	80
	% GRASS	15	20	20	10		70		20					OUTFALL	15
	% No Plant Cover	40	30	20	10									OUTFALL	
	% Rock					70	20	20	20	10	10	99.9	99.9	OUTFALL	
	Saprolite													OUTFALL	
Top 1/3 Left Bank	**Bedrock**													OUTFALL	
	Riprap					1	1	1				1		OUTFALL	
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1		1	OUTFALL	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.80	8.66	8.18	8.11	9.52	9.37	8.38	8.78	8.40	8.40	10.13	10.13	#VALUE!	8.27
	BEHI root density ind	3.08	2.99	3.27	3.20	2.99	2.16	3.18	2.73	2.99	2.99	4.65	4.65	#VALUE!	2.91
	BEHI surface% index	3.36	2.65	2.06	1.58	1.22	1.22	1.22	1.22	1.22	1.22	1.22	1.22	#VALUE!	1.22
	BEHI +/- factor	3.00	2.25	1.50	0.75	5.25	1.50	1.50	1.50	0.75	0.75	7.49	7.49	#VALUE!	0.00
	BEHI Index	33.75	32.06	25.51	24.13	12.52	20.10	20.12	20.09	21.55	21.55	7.52	7.52	#VALUE!	22.90
	SLOPE BEHI Index	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	OUTFALL	3.5
	% TREES	25	20	20	10	5		5	5	10	10	10	15	OUTFALL	
	% SHRUB	15	10	30	50	45	50	50	60	80	80	80	5	OUTFALL	50
	% GRASS	5		20	10		25						60	OUTFALL	20
	% No Plant Cover	55	70	30	30	10	15						20	OUTFALL	
	% Rock					40	10	45	35	10	10	10		OUTFALL	30
	Saprolite													OUTFALL	
Middle 1/3 Left Bank	**Bedrock**													OUTFALL	
	Riprap					1	1	1	1					OUTFALL	1
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	OUTFALL	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.77	9.11	8.56	8.66	9.03	8.93	8.93	8.75	8.21	8.21	8.21	8.93	#VALUE!	8.97
	BEHI root density ind	3.72	4.05	3.10	3.04	3.14	2.65	3.12	3.10	3.15	3.15	3.15	2.49	#VALUE!	2.70
	BEHI surface% index	4.65	6.20	2.65	2.65	1.58	1.80	1.22	1.22	1.22	1.22	1.22	2.06	#VALUE!	1.22
	BEHI +/- factor	4.13	5.25	2.25	2.25	3.75	1.88	3.38	2.63	0.75	0.75	0.75	1.50	#VALUE!	2.25
	BEHI Index	31.76	35.10	27.06	27.11	18.30	23.37	16.45	17.95	21.53	21.53	21.53	25.48	#VALUE!	18.62
	SLOPE BEHI Index	8.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	8.5	8.5	8.5	8.5	OUTFALL	3.5
	% TREES	5	10	20	5			5	5	40	40	40	5	OUTFALL	
	% SHRUB		5		10	20	5	5	20	40	40	40	15	OUTFALL	
	% GRASS	5	25		10		10			10	10	10	30	OUTFALL	10
	% No Plant Cover	85	60	70	60	20	45		35	10	10	10	30	OUTFALL	
	% Rock	5		10	15	60	40	90	40				20	OUTFALL	90
	Saprolite	1		1						1				OUTFALL	
Lower 1/3 Left Bank	**Bedrock**		1	1	1			1						OUTFALL	
	Riprap					1	1	1	1				1	OUTFALL	1
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	OUTFALL	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.88	9.41	9.30	9.64	9.72	9.95	9.82	9.51	7.72	7.72	7.72	9.37	#VALUE!	10.06
	BEHI root density ind	3.18	2.69	4.65	2.85	2.99	2.34	3.76	3.29	3.54	3.54	3.54	2.52	#VALUE!	2.06
	BEHI surface% index	8.02	5.14	6.20	5.14	2.06	3.76	1.22	2.99	1.58	1.58	1.58	2.65	#VALUE!	1.22
	BEHI +/- factor	6.75	4.50	6.00	5.63	6.00	6.38	6.75	5.63	0.75	0.75	0.75	3.75	#VALUE!	6.75
	BEHI Index	41.50	32.24	33.59	29.53	16.11	22.31	9.28	21.40	29.09	29.09	29.09	27.79	#VALUE!	9.13
	SLOPE BEHI Index	8.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	8.5	8.5	8.5	8.5	8.5	3.5
	% TREES	5	5	10	10		5	5	40	10	5	5	5		0.1
	% SHRUB	30	25	5		35		20	10	60	50	50	50	20	0.1
	% GRASS	10	20	30	15	5	10	5	20	10	5	5	5	10	0.1
	% No Plant Cover	50	50	40	60	20	10	40	20	20	40	40	40	70	
	% Rock	5		15	15	40	75	30	10						99
	Saprolite	1	1	1						1				1	
Bottom 1/3 Right Bank	**Bedrock**				1	1									
	Riprap				1	1	1	1	1						1
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.24	9.25	9.37	9.59	9.38	9.84	9.47	8.16	8.48	8.89	8.89	8.89	9.64	10.13
	BEHI root density ind	2.92	2.72	2.62	2.92	2.86	2.76	3.05	3.53	3.04	3.02	3.02	3.02	2.65	3.11
	BEHI surface% index	4.19	4.19	3.36	5.14	2.06	1.58	3.36	2.06	2.06	3.36	3.36	3.36	6.20	1.22
	BEHI +/- factor	4.13	3.75	4.13	5.63	4.50	6.38	5.25	2.25	1.50	3.00	3.00	3.00	5.25	7.43
	BEHI Index	34.38	30.41	26.10	29.56	19.38	12.55	23.72	24.08	30.57	33.78	33.78	33.78	39.24	7.67
	SLOPE BEHI Index	3.5	2.5	3.5	2.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	2.5	3.5
	% TREES	5	15	20	5			5	50	25	15	15	15	10	0.1
	% SHRUB	30	50	30	25	20		55	20	50	85	85	85	20	0.1
	% GRASS	20	5	20	25	60	20	10	5	15				20	0.1
	% No Plant Cover	35	30	30	30	5	5	10	20	10				50	0.1
	% Rock				15	15	75	20	5						99
	Saprolite														
Middle 1/3 Right Bank	**Bedrock**														
	Riprap				1	1	1	1							1
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.16	8.51	8.56	9.21	9.24	9.98	8.76	7.73	8.05	7.95	7.95	7.95	9.15	10.13
	BEHI root density ind	2.74	3.23	3.10	2.65	2.27	2.06	2.94	3.96	3.22	3.21	3.21	3.21	2.85	3.11
	BEHI surface% index	2.99	2.65	2.65	2.65	1.39	1.39	1.58	2.06	1.58	1.22	1.22	1.22	4.19	1.22
	BEHI +/- factor	2.63	2.25	2.25	3.38	1.50	6.00	2.25	1.88	0.75	0.00	0.00	0.00	3.75	7.43
	BEHI Index	28.02	26.14	27.06	23.79	21.38	11.98	21.28	24.92	24.10	22.88	22.88	22.88	29.45	7.67
	SLOPE BEHI Index	2.5	2.5	3.5	2.5	3.5	3.5	3.5	3.5	2.5	2.5	2.5	2.5	8.5	3.5
	% TREES	15	35	40	5	10			50	60	40	40	40	10	0.1
	% SHRUB	70	45	35	30	40	35	70	40	20	60	60	60	50	60
	% GRASS	15	10	15	35	35	40	10	10					10	30
	% No Plant Cover		10	10	5	5				20				30	0.1
	Rock				25	10	25	20							10
	Saprolite														
Top 1/3 Right Bank	**Bedrock**														
	Riprap				1		1	1							1
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.08	7.81	7.76	9.04	8.65	9.10	8.68	7.36	7.41	7.47	7.47	7.47	8.66	8.70
	BEHI root density ind	3.05	3.45	3.47	2.58	2.73	2.46	2.86	3.64	4.19	3.60	3.60	3.60	3.04	2.65
	BEHI surface% index	1.22	1.58	1.58	1.39	1.39	1.22	1.22	1.22	2.06	1.22	1.22	1.22	2.65	1.22
	BEHI +/- factor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	BEHI Index	21.84	22.35	23.32	16.88	20.93	17.46	18.61	22.72	23.17	21.79	21.79	21.79	29.86	20.77
Avg. BEHI left bank		**35.67**	**33.14**	**28.72**	**26.92**	**15.64**	**21.93**	**15.28**	**19.81**	**24.06**	**24.06**	**19.38**	**20.26**	**NA**	**16.88**
Avg. BEHI right bank		**28.08**	**26.30**	**25.49**	**23.41**	**20.57**	**14.00**	**21.20**	**23.91**	**25.95**	**26.15**	**26.15**	**26.15**	**32.85**	**12.04**

Table 6
Bank Conditions
Irwin Creek Restoration Reach

Segment	Attribute	44	45	46	47	48	49	50	51	52	53	54	55	56	57
	Distance (meters)	*1191-1250*	*1250-1292*	*1292-1312*	*1312-1332*	*1332-1352*	*1352-1372*	*1372-1392*	*1392-1412*	*1412-1432*	*1432-1452*	*1452-1472*	*1472-1492*	*1492-1512*	*1512-1532*
Top 1/3 Left Bank	SLOPE BEHI Index	2.5	2.5	2.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	8.5	8.5
	% TREES	30	5	15	20	40	40	40	50	15	10	10	10	25	20
	% SHRUB	60	65	5	30	10	30	20	40	60	40	25	20	30	35
	% GRASS	10	20	10	10	5	10	5	10	20	10	50	10	10	20
	% No Plant Cover			30	10	35	10	5		5	40	15	20	25	25
	% Rock		10		30	10	10	30					30	10	
	Saprolite														
	Bedrock				1	1	1						1		
	Riprap		1					1							
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	7.74	8.50	9.33	8.64	8.28	7.89	8.10	7.36	8.21	8.84	8.81	9.23	8.45	8.47
	BEHI root density ind	3.33	2.84	3.36	3.30	4.03	3.61	3.86	3.64	2.99	3.05	2.56	3.08	3.39	3.09
	BEHI surface% index	1.22	1.22	2.65	1.58	2.99	1.58	1.39	1.22	1.39	3.36	1.80	2.06	2.34	2.34
	BEHI +/- factor	0.00	0.75	2.25	3.00	3.38	1.50	2.63	0.00	0.38	3.00	1.13	3.75	2.63	1.88
	BEHI Index	21.79	20.60	27.09	19.82	26.60	22.72	19.32	22.72	23.46	28.76	24.80	21.16	29.34	31.28
Middle 1/3 Left Bank	SLOPE BEHI Index	3.5	3.5	8.5	8.5	8.5	8.5	3.5	2.5	2.5	3.5	3.5	8.5	3.5	3.5
	% TREES	5		5		20	25	40	40	25	10	10	10	15	10
	% SHRUB	50	70	30	15	5	20	15	20	20	5	50			5
	% GRASS	5	20	5		10		5	30	5	5	10			15
	% No Plant Cover	40		60	20	50	15	10	10	50	80	30	40	20	70
	% Rock		10		65	15	40	30					50	75	
	Saprolite														
	Bedrock				1	1	1						1	1	
	Riprap		1					1							
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.89	8.60	9.28	9.82	9.12	8.72	8.19	7.90	8.68	9.57	8.66	9.71	9.51	9.49
	BEHI root density ind	3.02	2.76	3.04	2.99	3.53	3.86	3.94	3.28	3.64	3.46	3.04	4.65	4.65	2.93
	BEHI surface% index	3.36	1.22	5.14	2.06	4.19	1.80	1.58	1.58	4.19	7.38	2.65	3.36	2.06	6.20
	BEHI +/- factor	3.00	0.75	4.50	6.38	4.88	4.13	3.00	0.75	3.75	6.00	2.25	6.75	7.13	5.25
	BEHI Index	28.78	21.52	37.45	17.01	32.37	22.05	19.95	23.01	29.76	36.92	27.11	23.36	13.80	34.38
Lower 1/3 Left Bank	SLOPE BEHI Index	8.5	8.5	3.5	3.5	3.5	8.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	2.5
	% TREES	10	5	5			15	20			5		0.1		0.1
	% SHRUB	50	30	30	5	5		5		5		20			
	% GRASS		10	5	5	10	5	5	10	5	5	5		5	
	% No Plant Cover	40	35	60		70	20	20	90	90		75	30	20	100
	% Rock		20		90	15	60	50			90		70	75	
	Saprolite	1													
	Bedrock			1	1	1	1	1		1			1	1	
	Riprap		1					1							
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.74	9.24	9.28	9.99	9.95	9.47	9.16	10.06	9.99	9.88	9.68	10.13	10.10	10.13
	BEHI root density ind	3.24	2.92	3.04	2.49	2.34	3.87	3.83	2.06	2.49	3.18	2.79	4.65	2.06	4.65
	BEHI surface% index	3.36	2.99	5.14	1.22	6.20	2.06	2.06	8.68	8.68	1.22	6.78	2.65	2.06	10.10
	BEHI +/- factor	3.00	4.13	4.50	6.75	6.38	6.00	5.25	6.75	6.75	6.75	5.63	7.50	7.13	7.50
	BEHI Index	33.84	28.64	32.45	9.17	31.02	18.36	18.03	38.04	38.41	9.23	35.37	15.88	13.30	41.88
Bottom 1/3 Right Bank	SLOPE BEHI Index	8.5	2.5	2.5	2.5	3.5	3.5	3.5	3.5	3.5	2.5	2.5	3.5	3.5	3.5
	% TREES		30	5	5	10	15		10	10	5		0.1	5	5
	% SHRUB	20	30	5	5	5	5			5	10	5		5	5
	% GRASS	10	20			30	10	10	5	10	50	25			40
	% No Plant Cover	70	10	90	90	40	30	75	85	75	20	60	95	90	50
	% Rock		20			15	40	15			15	10	5		
	Saprolite	1													
	Bedrock					1	1	1		1					
	Riprap		1					1							
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.64	8.18	9.82	9.82	9.37	9.33	10.06	9.67	9.53	9.32	9.83	10.13	9.82	9.50
	BEHI root density ind	2.65	3.27	3.76	3.76	2.62	3.36	2.06	3.63	3.14	2.34	2.20	4.65	3.76	2.34
	BEHI surface% index	6.20	1.58	8.68	8.68	3.36	2.65	6.78	8.02	6.78	2.06	5.14	9.37	8.68	4.19
	BEHI +/- factor	5.25	2.25	6.75	6.75	4.13	5.25	6.75	6.38	5.63	2.63	5.25	7.50	6.75	3.75
	BEHI Index	39.24	20.27	38.51	38.51	26.10	20.76	31.73	38.19	35.57	22.36	29.25	40.42	39.51	30.28
Middle 1/3 Right Bank	SLOPE BEHI Index	2.5	2.5	2.5	3.5	3.5	8.5	3.5	3.5	3.5	2.5	3.5	6	3.5	3.5
	% TREES	10	30	5	15	10	15	10	20	30	10			10	
	% SHRUB	20	25	20	40	10	40	15	5	10	10	25	60	5	30
	% GRASS	20	5	10	5	30	25	30	15	30	20	5	10	15	20
	% No Plant Cover	50	30	65	40	40	10	40	60	30	60	65	30	70	50
	% Rock		10			10	10	5				5			
	Saprolite														
	Bedrock						1								
	Riprap							1							
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	9.15	8.39	9.43	8.69	9.27	8.53	9.17	9.08	8.47	9.35	9.58	8.86	9.49	9.36
	BEHI root density ind	2.85	3.66	2.89	3.27	2.65	2.93	2.68	3.32	3.15	2.82	2.82	2.84	2.93	2.59
	BEHI surface% index	4.19	2.65	5.66	3.36	3.36	1.58	3.36	5.14	2.65	5.14	5.66	2.65	6.20	4.19
	BEHI +/- factor	3.75	3.00	4.88	3.00	3.75	1.50	3.38	4.50	2.25	4.50	5.25	2.25	5.25	3.75
	BEHI Index	29.45	24.78	32.36	28.82	26.96	27.19	27.81	32.54	27.02	31.31	32.37	29.61	34.38	30.39
Top 1/3 Right Bank	SLOPE BEHI Index	3.5	8.5	3.5	2.5	8.5	3.5	3.5	3.5	8.5	3.5	3.5	3.5	3.5	3.5
	% TREES	15	30	5	25	5	40	10	45	30	30	5	15	30	15
	% SHRUB	70	20	70	60	25	30	60	15	40	50	60	80	50	50
	% GRASS	15	10	5	15	60		20	30	20	10	15	5	5	10
	% No Plant Cover		40	20		10			10	10	10	20		15	25
	Rock						30	10							
	Saprolite														
	Bedrock														
	Riprap						1	1							
	Floodplain Sediment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	BEHI BH/BfH index	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	BEHI Root D/BH inde	8.08	8.44	8.53	7.88	8.93	7.97	8.40	7.81	8.00	7.91	8.63	7.99	7.95	8.47
	BEHI root density ind	3.05	3.56	3.02	3.19	2.41	3.88	2.92	3.36	3.24	3.36	2.88	3.16	3.46	3.14
	BEHI surface% index	1.22	3.36	2.06	1.22	1.58	1.22	1.22	1.58	1.58	1.58	2.06	1.22	1.80	2.34
	BEHI +/- factor	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	BEHI Index	22.84	30.87	24.10	21.80	28.42	16.50	20.73	23.25	28.32	23.36	24.07	22.87	23.71	24.45
Avg. BEHI left bank		**28.14**	**23.59**	**32.33**	**15.33**	**30.00**	**21.04**	**19.10**	**27.93**	**30.55**	**24.97**	**29.09**	**20.14**	**18.82**	**35.84**
Avg. BEHI right bank		**30.51**	**25.31**	**31.66**	**29.71**	**27.16**	**21.48**	**26.76**	**31.33**	**30.31**	**25.67**	**28.56**	**30.96**	**32.53**	**28.37**

Table 7
Sediment Size Information
Irwin Creek, Mecklenburg County

GRAIN SIZE DATA BARS (Meander point bars & lateral bars on runs)

Sample/Station	Fine Sieved Fraction			Coarse Field Measured Fraction			Integrated Bulk Grain	
	D16 (mm)	D50 (mm)	D84 (mm)	D16 (mm)	D50 (mm)	D84 (mm)	D16 (mm)	D50 (mm)
SB-1-A	0.90	2.60	7.00	10.00	18.00	21.00	6.59	12.23
SB-1-B	1.00	2.60	6.00				1.00	2.60
SB-1-C	0.48	0.80	1.50				0.48	0.80
SB-1 Avg							2.69	5.21
SB-2-A	1.00	2.10	6.00	17.00	27.00	37.00	11.82	18.93
SB-2-B	0.60	1.70	6.10				0.60	1.70
SB-2-C	0.40	0.81	1.90				0.40	0.81
SB-2 Avg							4.27	7.15
LB-1-A	0.80	2.00	4.80				0.80	2.00
LB-1-B	0.80	1.60	3.80	6.20	9.20	15.00	2.83	4.45
LB-1-C	0.61	1.20	3.00				0.61	1.20
LB-1 Avg							1.41	2.55
LB-2-A	0.60	1.10	2.80	17.00	30.00	40.00	13.82	24.39
LB-2-B	0.79	1.80	5.10				0.79	1.80
LB-2-C	0.83	1.90	3.10				0.83	1.90
LB-2 Avg							5.15	9.36
Average for all Bars*							3.38	6.07

GRAIN SIZE DATA RIFFLES (Armour)

Sample/Station	Fine Sieved Fraction						Integrated Bulk Grain	
	D16 (mm)	D50 (mm)	D84 (mm)				D16 (mm)	D50 (mm)
Riffle 1	52.00	70.00	110.00				52.00	70.00
Riffle 2	51.00	69.00	110.00				51.00	69.00
Riffle 3	52.00	81.00	110.00				52.00	81.00
Average	51.67	73.33	110.00				51.67	73.33

INTEGRATED BAR & RIFFLE GRAIN SIZE DATA

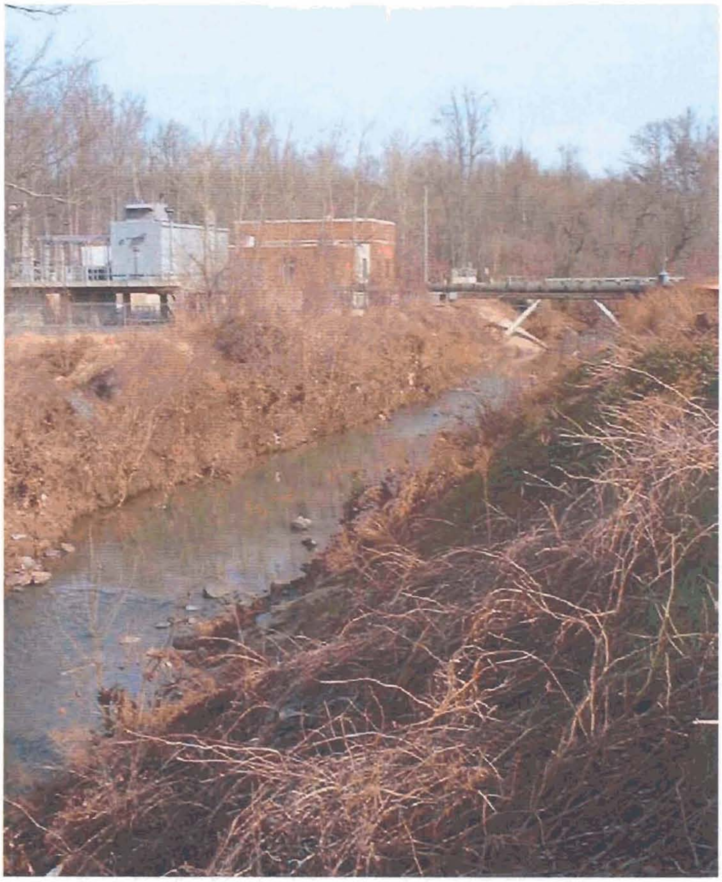
	Integrated Bulk Grain	
	D16 (mm)	D50 (mm)
Bulk Stream Bed Avg**	9.18	14.15

*Average for all bars calculated from fine sieved fraction data & coarse field measured fraction data (armour), each weighted according to p
armour coverage. Percent armour coverage found for SB-1 = 62.5%, SB-2 = 67.6%, LB-1 = 37.5%, LB-2 = 80.6%.
**Bulk Stream Bed Average weighted according to Irwin Creek total riffle coverage percentage = 12.02%

Photo 1. View looking north (upstream) along Irwin Creek north of the Irwin Creek WWTP, reach has no significant sinuosity, and has been widened and deepened by dredging operations early in the 21st Century authorized by the former Meck. Co. Drainage Commission.

Photo 2. View looking south (downstream) along Irwin Creek north of the Irwin Creek WWTP, Lateral bars interspersed with bedrock nickpoints (granitoids with northwest striking diabase dikes) forming short riffle zones. Otherwise, reach is a sand to fine gravel bed run.

Photos 3 & 4. Views looking upstream along Irwin Creek within the Irwin Creek WWTP. Reach has been constricted in the upper half of this area (photo at right) compared to reach up- and downstream, probably by placement of additional rip-rap for bank protection within the WWTP area. New flood control levee built at top edge of east bank. Lower portion of this reach has lateral bars similar to areas north of the WWTP.



Photos 5 & 6. Bank exposures of the early Paleozoic granitoid rock formations that dominate the Irwin Creek watershed. Photo at left shows a series of 3 sub-parallel diabase dikes of probable Triassic or Early Jurassic age. Foam seen in view at top originates from the WWTP discharge point.

Photo 7. View of meander bend in Zone 4 south of Irwin Creek WWTP. The downed tree has acted as a flow deflector on eroding outer banks to meander and caused siltation downstream (tire dropout area).

March 3 - Photo 35: Taken at Segment 9, 160-180 m., Left Bank

March 3 - Photo 40: Taken at Segment 10, 180-200 m., Right Bank

March 4 - Photo 29: Taken at Segment 21, 400-420 m., Left Bank

March 4 - Photo 31: Taken at Segment 21, 400-420 m., Right Bank

March 4 - Photo 87: Taken at Segment 34, 660-680 m., Right Bank

March 4 - Photo 92: Taken at Segment 35, 680-700 m., Right Bank

March 5 - Photo 17: Taken at Segment 51, 1392-1412 m., Right Bank

March 5 - Photo 21: Taken at Segment 52, 1412 -1432 m., Right Bank

March 5 - Photo 64: Taken at Segment 63, 1632-1652 m., Left Bank

March 5 - Photo 64: Taken at Segment 63, 1652 m., Left & Right Banks

Fish and Macroinvertebrates Data

MECKLENBURG COUNTY
Land Use and Environmental Services Agency
Water Quality Program

May 19, 2003

Jaime Henkels
HDR
128 S. Tryon St., Suite 1400
Charlotte, NC 28202-5001

Dear Ms. Henkels:

Please find enclosed copies of Stream Bioassessment data for the Mecklenburg County Water Quality Program (MCWQP) Irwin/Sugar Creek monitoring sites located at Statesville Avenue, West Boulevard, Westmont Drive (@ Irwin WWTP), York Road, and Arrowood Road. Sampling methodologies used to collect Benthic Macroinvertebrates and Fish were adapted from those developed by the North Carolina Department of Environment and Natural Resources Bioassessment Group. Please note that prior to 2002, Oligochaete and Leaches were not identified and prior to 2000, Chironomidae were not identified. The collection of the benthic macroinvertebrates and fish samples were conducted under the supervision of Mecklenburg County's NC State Certified Biological Laboratory (Biological Certification #036).

If you have any questions about the data or need more detailed information, please call me at (704) 336-5500 or e-mail me at *rouxtj@co.mecklenburg.nc.us*.

Sincerely,

Anthony J. Roux
Environmental Hygienist II
Water Quality Program

ajr
enclosures

FISH IDENTIFICATION SHEET

LOG NO: 2002 -00032 **SURVEY DATE:** 10/05/2001
SITE: BASIN 14 BASIN 14 - UPPER IRWIN CREEK
STATION: MC19 IRWIN CREEK AT STATESVILLE AVE
BASIN: 14
LOCATION: MC19

TAXONOMIST: Anthony J. Roux
COLLECTORS: Anthony J. Roux
Chris F. Elmore

FAMILY	GENUS/SPECIES	NO.	TOT WT	LENGTHS
CATOSTOMIDAE	ERIMYZON OBLONGUS	29	0	4(1), 8(1), 9(3), 10(5), 11(5), 12(6), 13(4), 14(3), 15(1)
CENTRARCHIDAE	LEPOMIS AURITUS	242	0	3(47), 4(23), 5(19), 6(42), 7(41), 8(26), 9(10), 10(9), 11(8), 12(6), 13(6), 14(1), 15(4)
CENTRARCHIDAE	LEPOMIS MACROCHIRUS	9	0	6(1), 7(1), 8(2), 9(2), 10(2), 15(1)
CENTRARCHIDAE	MICROPTERUS SALMOIDES	1	0	23(1)
CLUPEIDAE	DOROSOMA CEPEDIANUM	1	0	14(1)
CYPRINIDAE	CLINOSTOMUS FUNDULOIDES	13	0	5(5), 7(1), 8(6), 10(1)
CYPRINIDAE	CYPRINELLA CHLORISTIA	5	0	3(1), 4(3), 5(1)
CYPRINIDAE	NOTEMIGONUS CRYSOLEUCAS	2	0	5(1), 10(1)
CYPRINIDAE	NOTROPIS HUDSONIUS	36	0	5(1), 6(8), 7(14), 8(13)
CYPRINIDAE	NOTROPIS PROCNE	182	0	3(47), 4(46), 5(83), 6(5), 7(1)
CYPRINIDAE	SEMOTILUS ATROMACULATUS	36	0	4(6), 5(4), 6(3), 7(2), 8(3), 9(5), 10(2), 11(5), 12(2), 13(4)
POECILIDAE	GAMBUSIA HOLBROOKI (AFFINIS)	2	0	2(1), 3(1)

IBI SCORE: 42 **WATER QUALITY RATING:** 5 FAIR

FISH IDENTIFICATION SHEET

STREAM: BASIN IR18 - UPPER IRWIN CREEK WATERSHED
IRWIN CREEK AT WEST BLVD
BASIN:
LOCATION: MC22
Other collectors: D. Peine, K. Joyce & J. Brzorad

LOG NO: 95-02005
SURVEY DATE: 11/01/95
TAXONOMIST: Anthony J. Roux
COLLECTORS: Anthony J. Roux
Kimberly

FAMILY	GENUS/SPECIES	NO.	TOT WT	LENGTHS
CYPRINIDAE	NOCOMIS LEPTOCEPHALUS	3	0	4 cm (1), 5(2)
CYPRINIDAE	NOTROPIS PROCNE	32	0	3(10), 4(15), 5(6), 6(1)
CATOSTOMIDAE	CATOSTOMUS COMMERSONI	1	0	17(1)
CATOSTOMIDAE	ERIMYZON OBLONGUS	3	0	18(1), 19(2)
ICTALURIDAE	AMEIURUS CATUS	2	0	6(2)
ICTALURIDAE	AMEIURUS NATALIS	3	0	8(1), 19(2)
POECILIDAE	GAMBUSIA HOLBROOKI (AFFINIS)	4	0	2(1), 3(2), 4(1)
CENTRARCHIDAE	LEPOMIS AURITUS	111	0	3(10), 4(3), 5(3), 6(4), 7(8), 8(18), 9(22), 10(14), 11(6), 12(6), 13(7), 14(6), 15(3), 17(1)
CENTRARCHIDAE	LEPOMIS CYANELLUS	5	0	6(2), 9(1), 10(1), 11(1)
CENTRARCHIDAE	LEPOMIS MACROCHIRUS	37	0	3(2), 4(9), 5(20), 6(4), 7(2)
CENTRARCHIDAE	MICROPTERUS SALMOIDES	2	0	6(1), 8(1)

IBI SCORE: 40 WATER QUALITY RATING: 5 FAIR

MACROINVERTEBRATE IDENTIFICATION SHEET

STREAM: BASIN 14 - UPPER IRWIN CREEK
IRWIN CREEK AT STATESVILLE AVE
BASIN:
LOCATION: MC19

LOG NO: 2002 - 01235
SURVEY DATE: 05/24/2001

TAXONOMIST: Mark Popinchalk
COLLECTORS: Anthony J. Roux, Jay Wilson, John McCulloch, Derrick A. Harris

ORDER	FAMILY	GENUS/SPECIES	TV	NO.	ABUNDANCE
COLEOPTERA	DYTISCIDAE	THERMONECTUS SPP.	2.0	1	R
COLEOPTERA	HYDROPHILIDAE	HELOPHORUS SPP.	7.6	1	R
COLEOPTERA	HYDROPHILIDAE	SPERCHOPSIS TESSELLATUS	6.1	1	R
DIPTERA	CHIRONOMIDAE	CHIRONOMUS SPP.	9.6	58	A
DIPTERA	CHIRONOMIDAE	CONCHAPELOPIA GROUP	8.3	12	A
DIPTERA	CHIRONOMIDAE	CRICOTOPUS/ORTHOCLADIUS GROUP	9.9	28	A
DIPTERA	CHIRONOMIDAE	POLYPEDILUM SPP.	5.8	27	A
DIPTERA	CHIRONOMIDAE	PSECTROTANYPUS DYARI	10.0	2	R
DIPTERA	CHIRONOMIDAE	RHEOCRICOTOPUS SPP.	7.3	1	R
DIPTERA	CHIRONOMIDAE	TANYTARSUS SPP.	6.7	2	R
DIPTERA	CULICIDAE	ANOPHELES SPP.	8.6	4	C
DIPTERA	CULICIDAE	CULEX SPP.	10.0	2	R
DIPTERA	SIMULIIDAE	SIMULIUM SPP.	4.0	46	A
DIPTERA	TIPULIDAE	LIMONIA SPP.	9.6	1	R
DIPTERA	TIPULIDAE	TIPULA SPP.	7.3	6	C
EPHEMEROPTERA	BAETIDAE	BAETIS FLAVISTRIGA	6.6	52	A
LIMNOPHILA	ANCYLIDAE	FERRISSIA SPP.	6.6	4	C
LIMNOPHILA	PHYSIDAE	PHYSELLA SPP.	8.8	5	C
LIMNOPHILA	PLANORBIDAE	MENETUS DILATUS	8.3	2	R
ODONATA	AESHNIDAE	BOYERIA VINOSA	5.9	1	R
ODONATA	CALOPTERYGIDAE	CALOPTERYX SPP.	7.8	2	R
ODONATA	COENAGRIONIDAE	ARGIA SPP.	8.2	7	C
ODONATA	GOMPHIDAE	GOMPHUS SPP.	5.8	1	R
ODONATA	GOMPHIDAE	LANTHUS SPP.	1.7	2	R
TRICHOPTERA	HYDROPSYCHIDAE	CHEUMATOPSYCHE SPP.	6.2	43	A
TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE BETTENI	7.8	32	A

TOTAL # ORGANISMS: 343
TOTAL TAXA: 26
TOTAL EPT: 3
SPECIES DIVERSITY: 3.6

METHOD: STD
BIOTIC INDEX: 7.31
WATER QUALITY RATING: 2 FAIR

MACROINVERTEBRATE IDENTIFICATION SHEET

STREAM: BASIN 14 - UPPER IRWIN CREEK
IRWIN CREEK AT STATESVILLE AVE
BASIN:
LOCATION: MC19

LOG NO: 2000 - 01564
SURVEY DATE: 05/21/1999

TAXONOMIST: Anthony J. Roux
COLLECTORS: Lonnie N. Shull, Derrick A. Harris, Shawn K. Tatum, Craig M. Miller

ORDER	FAMILY	GENUS/SPECIES	TV	NO.	ABUNDANCE
DIPTERA	CULICIDAE	ANOPHELES SPP.	8.6	1	R
DIPTERA	SIMULIIDAE	SIMULIUM SPP.	4.0	8	C
DIPTERA	TIPULIDAE	TIPULA SPP.	7.3	6	C
EPHEMEROPTERA	BAETIDAE	BAETIS INTERCALARIS	5.0	79	A
EPHEMEROPTERA	BAETIDAE	CALLIBAETIS SPP.	9.8	1	R
LIMNOPHILA	PHYSIDAE	PHYSELLA SPP.	8.8	4	C
MEGALOPTERA	CORYDALIDAE	CORYDALUS CORNUTUS	5.1	1	R
MEGALOPTERA	SIALIDAE	SIALIS SPP.	7.2	1	R
ODONATA	AESHNIDAE	BOYERIA VINOSA	5.9	4	C
ODONATA	CALOPTERYGIDAE	CALOPTERYX SPP.	7.8	3	C
ODONATA	COENAGRIONIDAE	ARGIA SEDULA	8.5	5	C
ODONATA	GOMPHIDAE	PROGOMPHUS OBSCURUS	8.2	1	R
TRICHOPTERA	HYDROPSYCHIDAE	CHEUMATOPSYCHE SPP.	6.2	3	C

TOTAL # ORGANISMS: 117
TOTAL TAXA: 13
TOTAL EPT: 3
SPECIES DIVERSITY: 2.0

METHOD: EPT
BIOTIC INDEX: [redacted]
WATER QUALITY RATING: 5 POOR

MACROINVERTEBRATE IDENTIFICATION SHEET

STREAM: BASIN ST14 - STEWART CREEK WATERSHED
IRWIN CREEK AT STATESVILLE AVE
BASIN:
LOCATION: MC19

LOG NO: 95-00405
SURVEY DATE: 05/17/94
TAXONOMIST: Anthony J. Roux
COLLECTORS: Anthony J. Roux
Paul M. Brigham
Glenna M. Smith

ORDER/FAMILY	GENUS/SPECIES	TV	NO.	ABUNDANCE
BAETIDAE	ACENTRELLA AMPLA	3.6	60	A
BAETIDAE	BAETIS PLUTO	4.2	15	A
CAENIDAE	CAENIS SPP.	7.4	1	R
EPHEMERELLIDAE	DANNELLA SIMPLEX	3.5	1	R
EPHEMERELLIDAE	EPHEMERELLA CATAWBA (GR)	4.3	1	R
HEPTAGENIIDAE	STENONEMA MODESTUM	5.5	2	R
ISONYCHIIDAE	ISONYCHIA SPP.	3.4	1	R
NEMOURIDAE	AMPHINEMURA SPP.	3.2	1	R
PERLIDAE	PERLESTA PLACIDA	4.7	7	C
HYDROPSYCHIDAE	CHEUMATOPSYCHE SPP.	6.2	31	A
HYDROPSYCHIDAE	HYDROPSYCHE BETTENI	7.8	11	A
DYTISCIDAE	HYDROPORUS SPP.	8.6	1	R
CULICIDAE	ANOPHELES SPP.	8.6	5	C
SIMULIIDAE	SIMULIUM SPP.	4.0	7	C
TIPULIDAE	TIPULA SPP.	7.3	6	C
AESHNIDAE	BOYERIA VINOSA	5.9	1	R
COENAGRIONIDAE	ARGIA SPP.	8.2	4	C
GOMPHIDAE	GOMPHUS SPP.	5.8	2	R
GOMPHIDAE	STYLOGOMPHUS ALBISTYLUS	4.7	1	R

TOTAL # ORGANISMS: 158
TOTAL TAXA (ST): 0
TOTAL EPT (SEPT): ~~8~~ 11

SPECIES DIVERSITY: 2.2
BIOTIC INDEX: [redacted]
WATER QUALITY RATING: 0 FAIR

[redacted]

MACROINVERTEBRATE IDENTIFICATION SHEET

STREAM: BASIN 20 - LOWER IRWIN CREEK
IRWIN CREEK AT IRWIN CRK WWTP

BASIN:

LOCATION: MC22A

LOG NO: 2001 - 01749

SURVEY DATE: ~~07/09/2001~~ 8/16/2000

TAXONOMIST: David Buetow

COLLECTORS: Lonnie N. Shull, Shawn K. Tatum, Craig M. Miller, Derrick A. Harris

ORDER	FAMILY	GENUS/SPECIES	TV	NO.	ABUNDANCE
COLEOPTERA	HALIPLIDAE	PELTODYTES SPP.	8.7	1	R
DIPTERA	CHIRONOMIDAE	ABLABESMYIA MALLOCHI	7.2	2	R
DIPTERA	CHIRONOMIDAE	CHIRONOMUS SPP.	9.6	19	A
DIPTERA	CHIRONOMIDAE	CRICOTOPUS BICINCTUS	8.5	1	R
DIPTERA	CHIRONOMIDAE	CRICOTOPUS/ORTHOCLADIUS GROUP	9.9	5	C
DIPTERA	CHIRONOMIDAE	CRYPTOCHIRONOMUS SPP.	6.4	2	R
DIPTERA	CHIRONOMIDAE	PHAENOPSECTRA SPP.	6.5	1	R
DIPTERA	CHIRONOMIDAE	POLYPEDILUM CONVICTUM	4.9	5	C
DIPTERA	CHIRONOMIDAE	POLYPEDILUM SCALAENUM	8.4	10	A
DIPTERA	CHIRONOMIDAE	RHEOCRICOTOPUS SPP.	7.3	2	R
DIPTERA	CHIRONOMIDAE	TANYTARSUS SPP.	6.7	8	C
DIPTERA	TIPULIDAE	TIPULA SPP.	7.3	4	C
EPHEMEROPTERA	BAETIDAE	BAETIS INTERCALARIS	5.0	49	A
EPHEMEROPTERA	BAETIDAE	BAETIS SPP.	5.0	12	A
EPHEMEROPTERA	TRICORYTHIDAE	TRICORYTHODES SPP.	5.0	2	R
LIMNOPHILA	PHYSIDAE	PHYSELLA SPP.	8.8	4	C
MEGALOPTERA	CORYDALIDAE	CORYDALUS CORNUTUS	5.1	6	C
ODONATA	AESHNIDAE	BOYERIA VINOSA	5.9	1	R
ODONATA	CALOPTERYGIDAE	CALOPTERYX SPP.	7.8	1	R
ODONATA	COENAGRIONIDAE	ARGIA SEDULA	8.5	17	A
ODONATA	COENAGRIONIDAE	ARGIA SPP.	8.2	3	C
ODONATA	COENAGRIONIDAE	ENALLAGMA SPP.	8.9	1	R
ODONATA	GOMPHIDAE	GOMPHUS SPP.	5.8	2	R
ODONATA	GOMPHIDAE	PROGOMPHUS OBSCURUS	8.2	1	R
ODONATA	GOMPHIDAE	STYLOGOMPHUS ALBISTYLUS	4.7	1	R
PELECYPODA	CORBICULIDAE	CORBICULA FLUMINEA	6.1	7	C
TRICHOPTERA	HYDROPSYCHIDAE	CHEUMATOPSYCHE SPP.	6.2	11	A
TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE BETTENI	7.8	79	A
TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE ROSSI	4.7	2	R
TRICHOPTERA	HYDROPTILIDAE	HYDROPTILA SPP.	6.2	21	A

MACROINVERTEBRATE IDENTIFICATION SHEET

STREAM: BASIN 18 - UPPER IRWIN CREEK
IRWIN CREEK AT WEST BLVD
BASIN:
LOCATION: MC22

LOG NO: 98-00659
SURVEY DATE: 06/20/97
TAXONOMIST: Anthony J. Roux
COLLECTORS: Anthony J. Roux
David M.
Anne Loftin
David J. Rimer

ORDER/FAMILY	GENUS/SPECIES	TV	NO.	ABUNDANCE
BAETIDAE	BAETIS PLUTO	4.2	9	A
HYDROPSYCHIDAE	CHEUMATOPSYCHE SPP.	6.2	5	C
HYDROPSYCHIDAE	HYDROPSYCHE BETTENI	7.8	63	A
HYDROPSYCHIDAE	HYDROPSYCHE VENULARIS	4.9	8	C
ELMIDAE	STENELMIS SPP.	5.1	1	R
SIMULIIDAE	SIMULIUM SPP.	4.0	6	C
TIPULIDAE	TIPULA SPP.	7.3	10	A
CORYDALIDAE	CORYDALUS CORNUTUS	5.1	1	R
AESHNIDAE	BOYERIA VINOSA	5.9	1	R
COENAGRIONIDAE	ARGIA SPP.	8.2	61	A
COENAGRIONIDAE	ENALLAGMA SPP.	8.9	2	R
CORDULIIDAE	SOMATOCHLORA SPP.	9.1	1	R
GOMPHIDAE	GOMPHUS SPP.	5.8	1	R
PHYSIDAE	PHYSELLA SPP.	8.8	3	C
CORBICULIDAE	CORBICULA FLUMINEA	6.1	1	R

TOTAL # ORGANISMS: 173
TOTAL TAXA (ST): 0
TOTAL EPT (SEPT): 84

SPECIES DIVERSITY: ****
BIOTIC INDEX: [redacted]7
WATER QUALITY RATING: 8 Poor

MACROINVERTEBRATE IDENTIFICATION SHEET

TREAM: BASIN 21 - LOWER IRWIN CREEK
SUGAR CREEK @ ARROWOOD RD

LOG NO: 2002 - 01118
SURVEY DATE: 06/13/2001

ASIN:
OCATION: MC23A

AXONOMIST: Anthony J. Roux
OLLECTORS: Anthony J. Roux, Mark Popinchalk, Derrick A. Harris, John McCulloch

RDER	FAMILY	GENUS/SPECIES	TV	NO.	ABUNDANCE
DIPTERA	CHIRONOMIDAE	ABLABESMYIA MALLOCHI	7.2	7	C
DIPTERA	CHIRONOMIDAE	CHIRONOMUS SPP.	9.6	1	R
DIPTERA	CHIRONOMIDAE	CONCHAPELOPIA GROUP	8.3	9	C
DIPTERA	CHIRONOMIDAE	CRYPTOCHIRONOMUS SPP.	6.4	1	R
DIPTERA	CHIRONOMIDAE	PHAENOPSECTRA SPP.	6.5	3	C
DIPTERA	CHIRONOMIDAE	POLYPEDILUM ILLINOENSE	9.0	10	A
DIPTERA	CHIRONOMIDAE	POLYPEDILUM SCALAENUM	8.4	4	C
DIPTERA	CHIRONOMIDAE	PROCLADIUS SPP.	9.1	3	C
IPTERA	CHIRONOMIDAE	RHEOCRICOTOPUS ROBACKI	7.3	2	R
IPTERA	CHIRONOMIDAE	RHEOTANYTARSUS SPP.	5.9	1	R
PTERA	EMPIDIDAE	EMPIDIDAE	7.6	1	R
PTERA	SIMULIIDAE	SIMULIUM SPP.	4.0	9	C
PTERA	TIPULIDAE	TIPULA SPP.	7.3	16	A
HEMEROPTERA	BAETIDAE	BAETIS FLAVISTRIGA	6.6	11	A
HEMEROPTERA	BAETIDAE	BAETIS INTERCALARIS	5.0	2	R
HEMEROPTERA	HEPTAGENIIDAE	STENONEMA MODESTUM	5.5	2	R
INOPHILA	PHYSIDAE	PHYSELLA SPP.	8.8	9	C
ONATA	AESHNIDAE	BOYERIA VINOSA	5.9	17	A
ONATA	CALOPTERYGIDAE	CALOPTERYX SPP.	7.8	3	C
ONATA	COENAGRIONIDAE	ARGIA SEDULA	8.5	34	A
ONATA	COENAGRIONIDAE	ARGIA SPP.	8.2	1	R
ONATA	GOMPHIDAE	GOMPHUS SPP.	5.8	4	C
ONATA	GOMPHIDAE	OPHIOGOMPHUS SPP.	5.5	8	C
P LECYPODA	CORBICULIDAE	CORBICULA FLUMINEA	6.1	19	A
TRICHOPTERA	HYDROPSYCHIDAE	CHEUMATOPSYCHE SPP.	6.2	31	A
TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE BETTENI	7.8	64	A
TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE VENULARIS	4.9	20	A
TRICHOPTERA	HYDROPTILIDAE	HYDROPTILA SPP.	6.2	10	A

TAL # ORGANISMS: 302
TAL TAXA: 28
TOTAL EPT: 7
SPECIES DIVERSITY: 4.0

METHOD: STD
BIOTIC INDEX: 6.92
WATER QUALITY RATING: 2 FAIR

MACROINVERTEBRATE IDENTIFICATION SHEET

STREAM: BASIN 21 - LOWER IRWIN CREEK
SUGAR CREEK @ ARROWOOD RD

BASIN:

LOCATION: MC23A

LOG NO: 2000 - 01578
SURVEY DATE: 07/30/1999

TAXONOMIST: Anthony J. Roux

COLLECTORS: Anthony J. Roux; Lonnie N. Shull
Anthony J. Roux; Craig M. Miller

ORDER	FAMILY	GENUS/SPECIES	TV	NO.	ABUNDANCE
COLEOPTERA	ELMIDAE	ANCYRONYX VARIEGATUS	6.5	1	R
COLEOPTERA	HYDROPHILIDAE	BEROSUS SPP.	8.4	2	R
DIPTERA	EMPIDIDAE	EMPIDIDAE	7.6	1	R
DIPTERA	TIPULIDAE	TIPULA SPP.	7.3	4	C
EPHEMEROPTERA	BAETIDAE	BAETIS INTERCALARIS	5.0	9	A
EPHEMEROPTERA	HEPTAGENIIDAE	STENONEMA MODESTUM	5.5	8	C
LIMNOPHILA	PHYSIDAE	PHYSELLA SPP.	8.8	6	C
MEGALOPTERA	CORYDALIDAE	CORYDALUS CORNUTUS	5.1	4	C
ODONATA	AESHNIDAE	BOYERIA VINOSA	5.9	1	R
ODONATA	COENAGRIONIDAE	ARGIA SEDULA	8.5	29	A
ODONATA	COENAGRIONIDAE	ENALLAGMA SPP.	8.9	1	R
ODONATA	GOMPHIDAE	GOMPHUS SPP.	5.8	4	C
ODONATA	GOMPHIDAE	OPHIOGOMPHUS SPP.	5.5	2	R
ODONATA	GOMPHIDAE	PROGOMPHUS OBSCURUS	8.2	11	A
ODONATA	MACROMIIDAE	MACROMIA GEORGINA	6.2	6	C
PELECYPODA	CORBICULIDAE	CORBICULA FLUMINEA	6.1	8	C
TRICHOPTERA	HYDROPSYCHIDAE	CHEUMATOPSYCHE SPP.	6.2	24	A
TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE BETTENI	7.8	47	A
TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE SIMULANS	5.0	8	C
TRICHOPTERA	HYDROPTILIDAE	HYDROPTILA SPP.	6.2	5	C

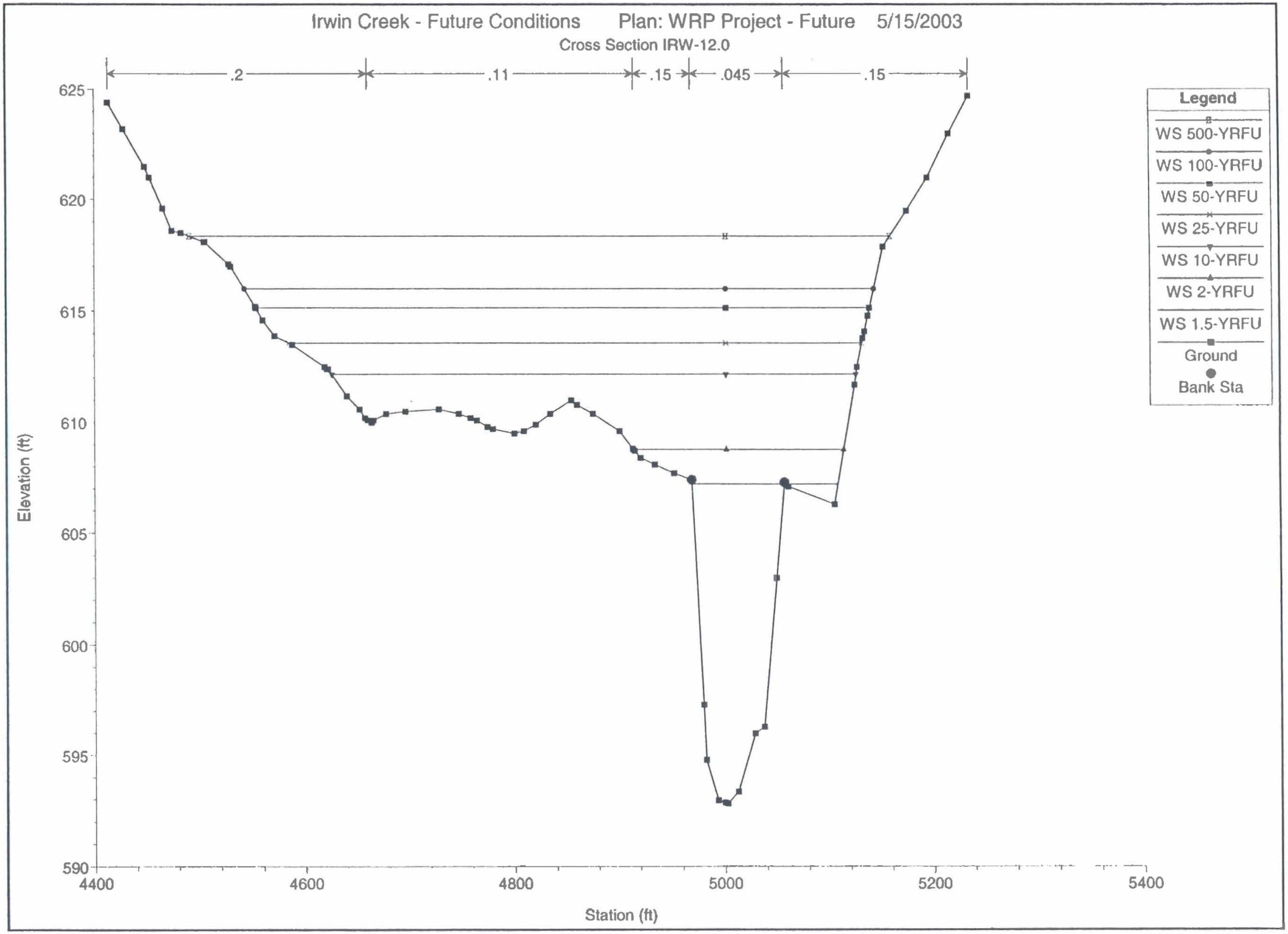
TOTAL # ORGANISMS: 181
TOTAL TAXA: 20
TOTAL EPT: 6
SPECIES DIVERSITY: 3.5

METHOD: EPT
BIOTIC INDEX: [redacted]
WATER QUALITY RATING: Poor

ORDER/FAMILY	GENUS/SPECIES	TV	NO.	ABUNDANCE
BAETIDAE	BAETIS INTERCALARIS	5.0	28	A
BAETIDAE	BAETIS PROPINQUUS	5.7	1	R
HEPTAGENIIDAE	STENONEMA MODESTUM	5.5	2	R
HYDROPSYCHIDAE	CHEUMATOPSYCHE SPP.	6.2	138	A
HYDROPSYCHIDAE	HYDROPSYCHE BETTENI	7.8	40	A
HYDROPTILIDAE	HYDROPTILA SPP.	6.2	1	R
DRYOPIDAE	HELICHUS SPP.	4.6	1	R
ELMIDAE	ANCYRONYX VARIEGATUS	6.5	1	R
ELMIDAE	STENELMIS SPP.	5.1	1	R
HYDROPHILIDAE	BEROSUS SPP.	8.4	2	R
SIMULIIDAE	SIMULIUM SPP.	4.0	2	R
TIPULIDAE	TIPULA SPP.	7.3	1	R
CORYDALIDAE	CORYDALUS CORNUTUS	5.1	2	R
NEPIDAE	RANATRA SPP.	7.8	1	R
AESHNIDAE	BOYERIA VINOSA	5.9	12	A
CALOPTERYGIDAE	CALOPTERYX SPP.	7.8	7	C
COENAGRIONIDAE	ARGIA SPP.	8.2	103	A
COENAGRIONIDAE	ENALLAGMA SPP.	8.9	2	R
GOMPHIDAE	GOMPHUS SPP.	5.8	9	A
GOMPHIDAE	OPHIOGOMPHUS SPP.	5.5	2	R
GOMPHIDAE	PROGOMPHUS OBSCURUS	8.2	16	A
MACROMIIDAE	MACROMIA GEORGINA	6.2	31	A

TOTAL # ORGANISMS: 403 SPECIES DIVERSITY: ****
TOTAL TAXA (ST): 0 BIOTIC INDEX: [redacted]
TOTAL EPT (SEPT): ~~0~~ 6 WATER QUALITY RATING: ~~0~~ POOR

HEC Data



Irwin Creek - Future Conditions Plan: WRP Project - Future 5/15/2003
Cross Section IRW-12.0
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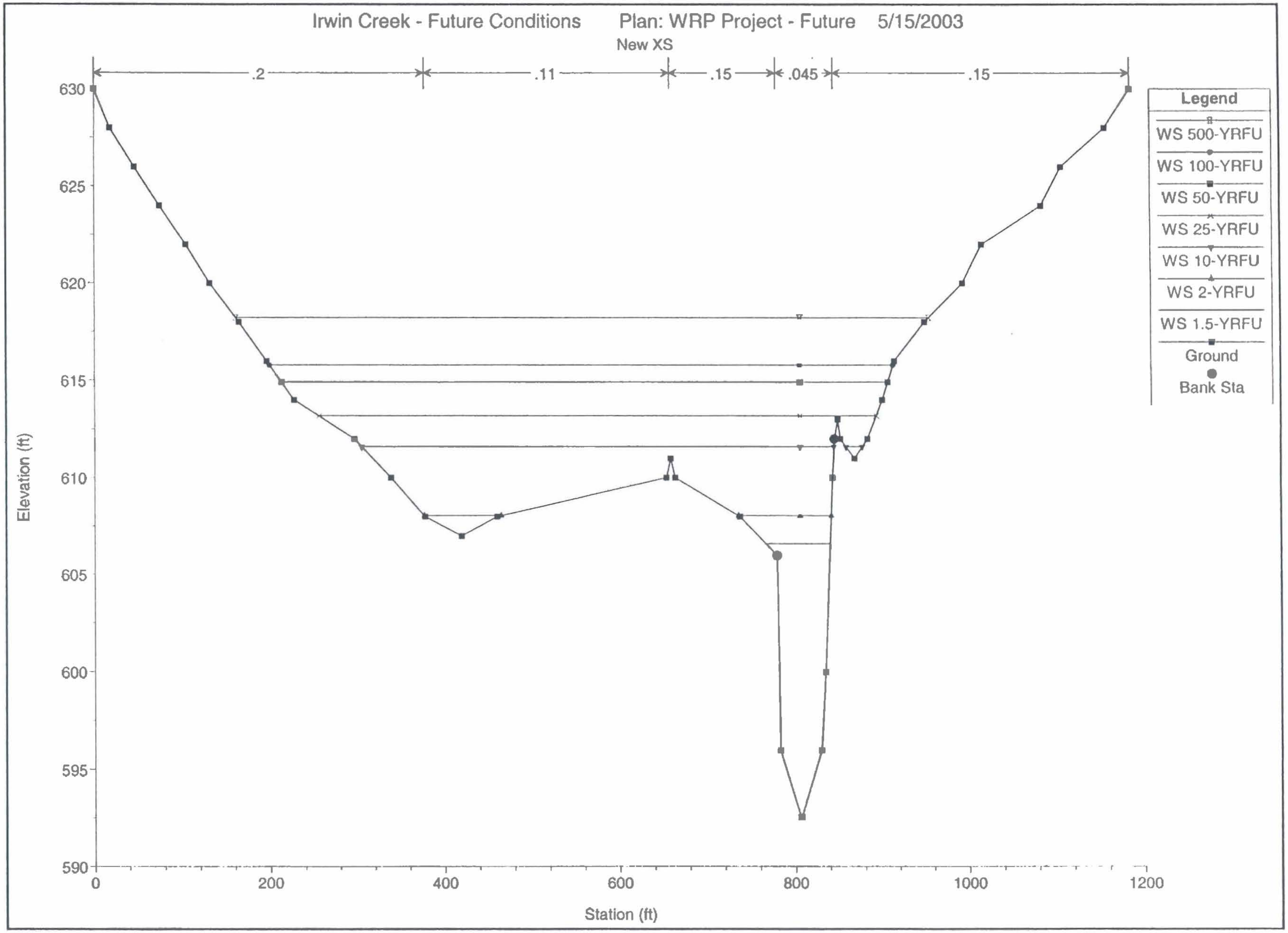

Irwin Creek - Future Conditions Plan: WRP Project - Future 5/15/2003
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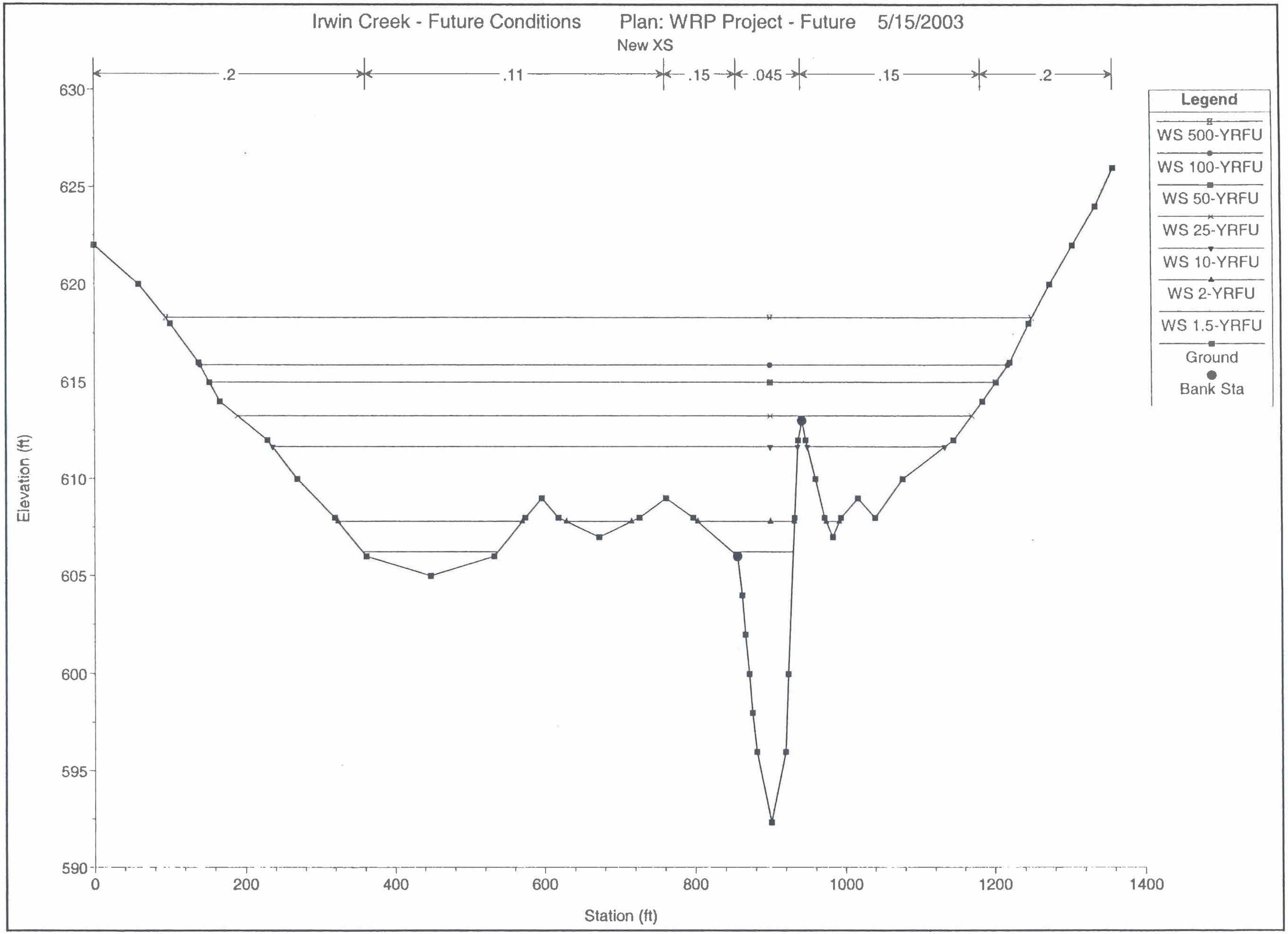

Irwin Creek - Future Conditions Plan: WRP Project - Future 5/15/2003
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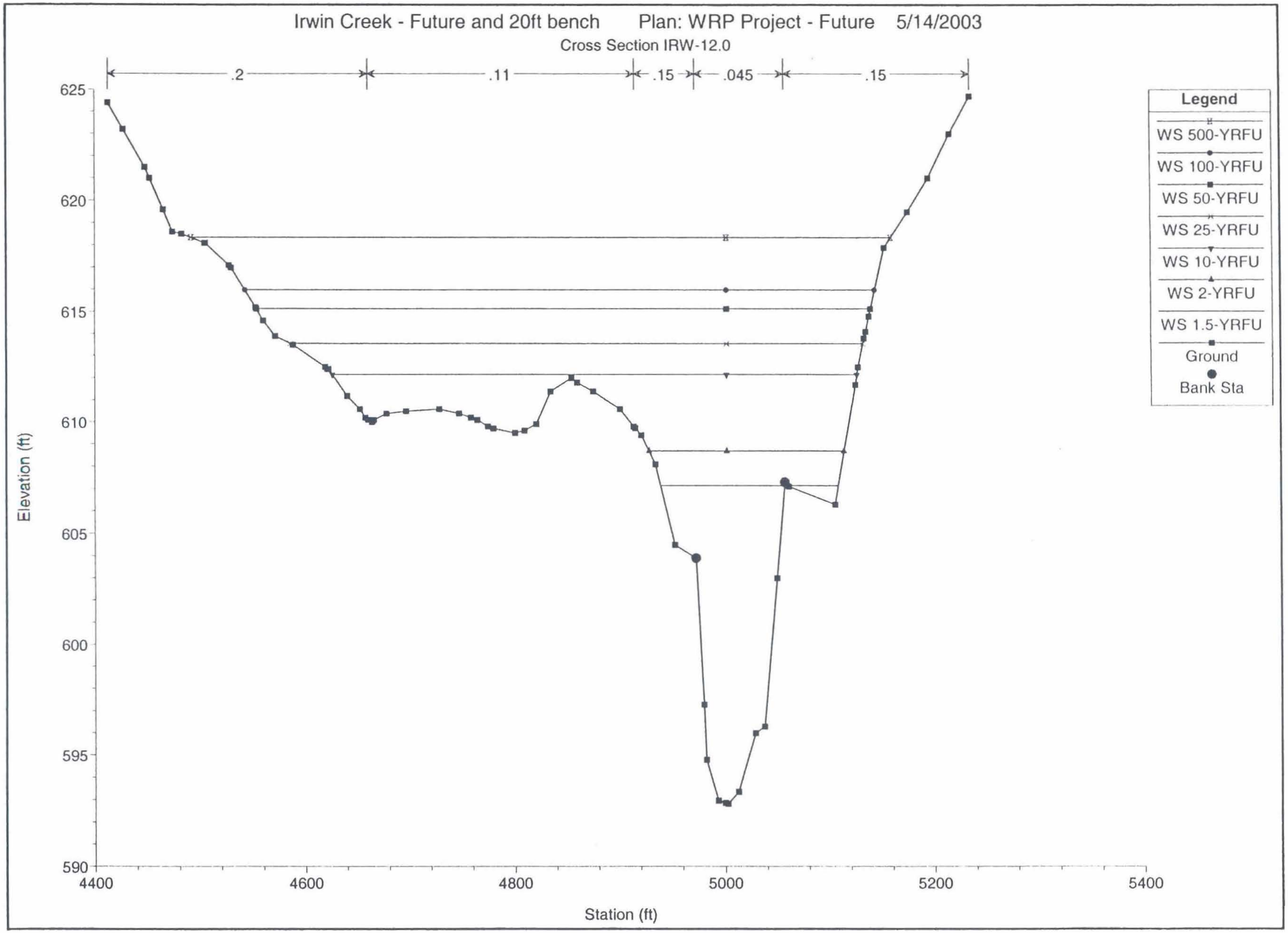

Irwin Creek - Future and 20ft bench Plan: WRP Project - Future 5/14/2003
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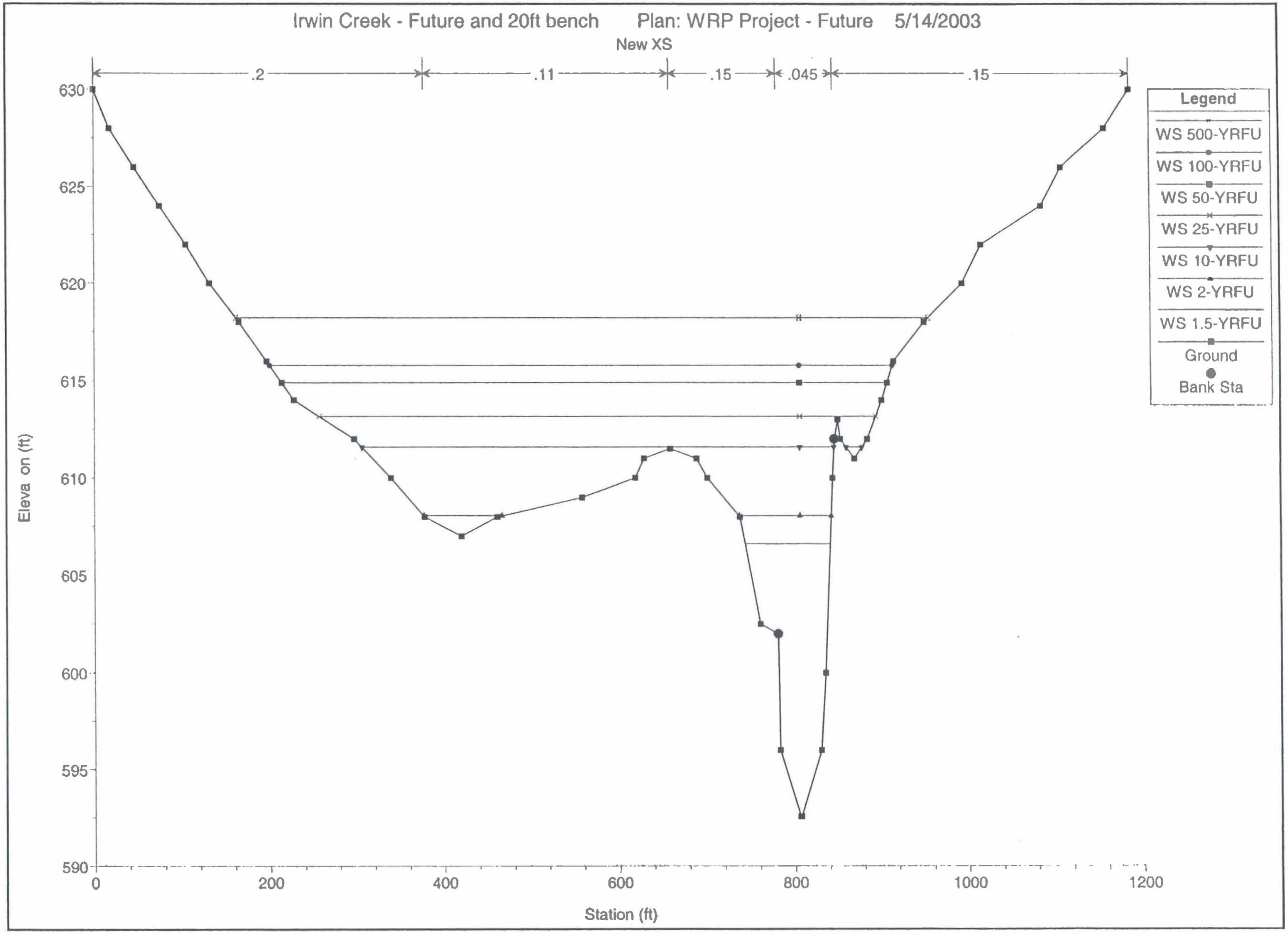

Irwin Creek - Future and 20ft bench Plan: WRP Project - Future 5/14/2003
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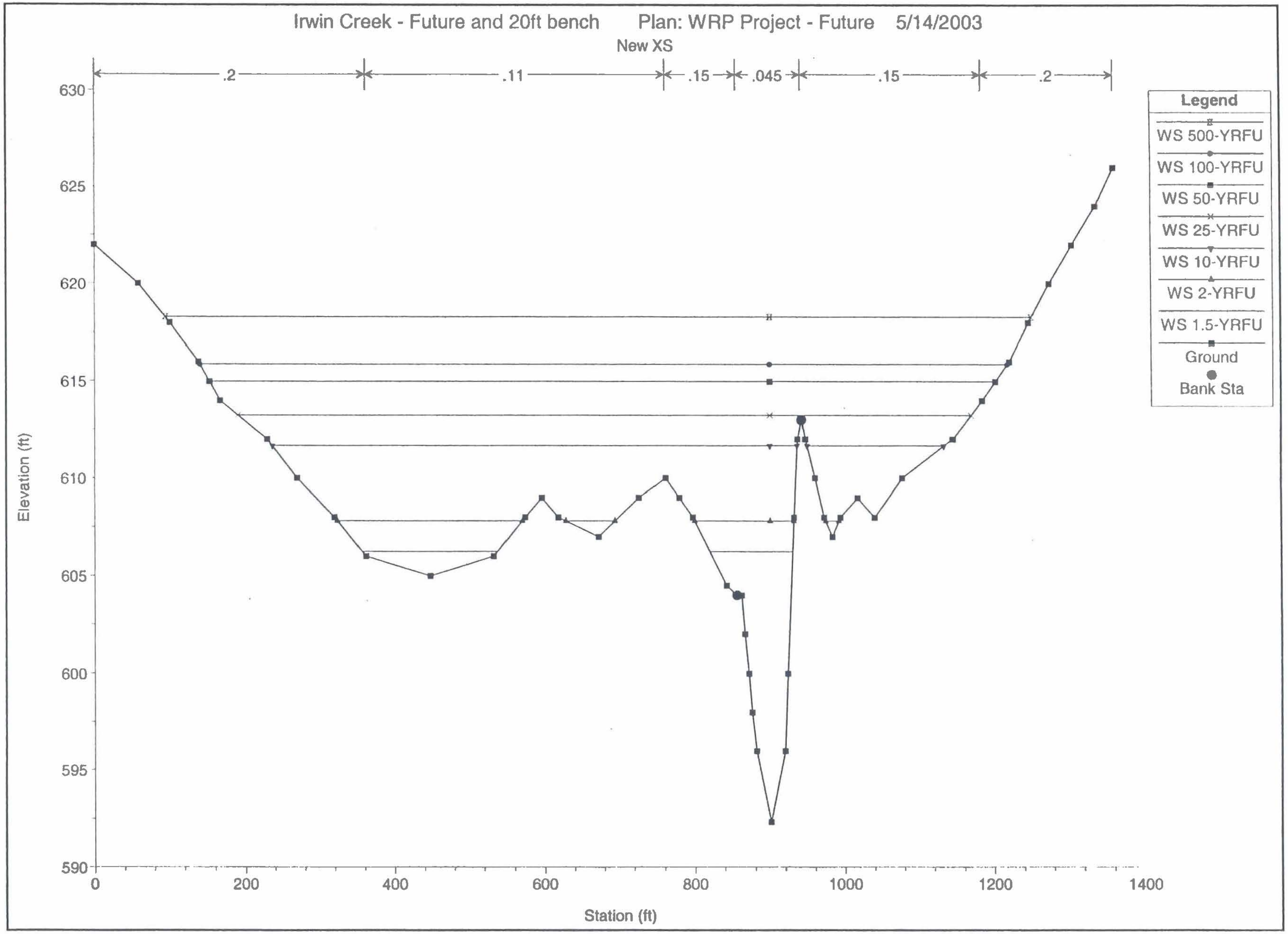

Irwin Creek - Future and 20ft bench Plan: WRP Project - Future 5/14/2003
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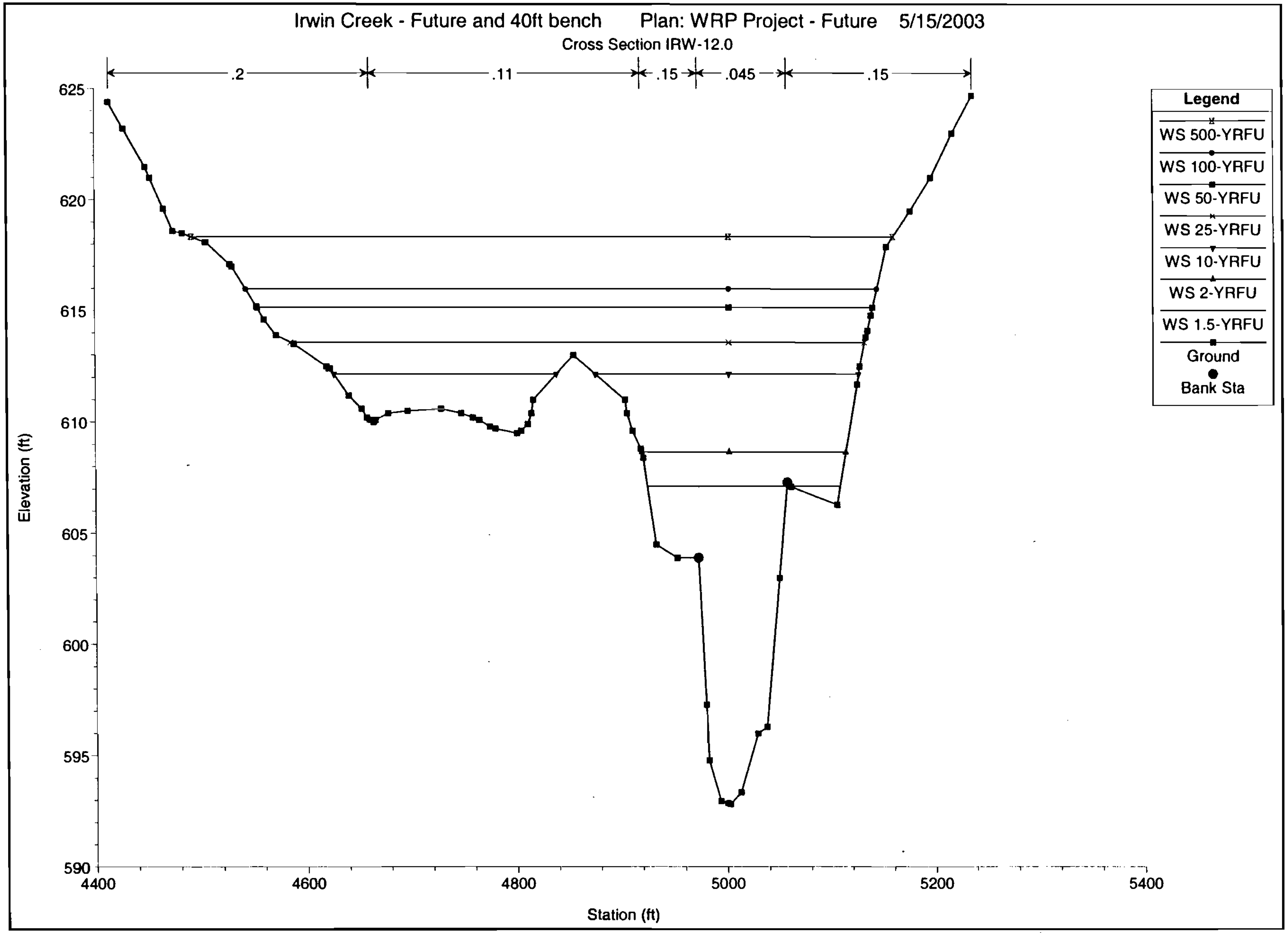

Irwin Creek - Future and 40ft bench Plan: WRP Project - Future 5/15/2003
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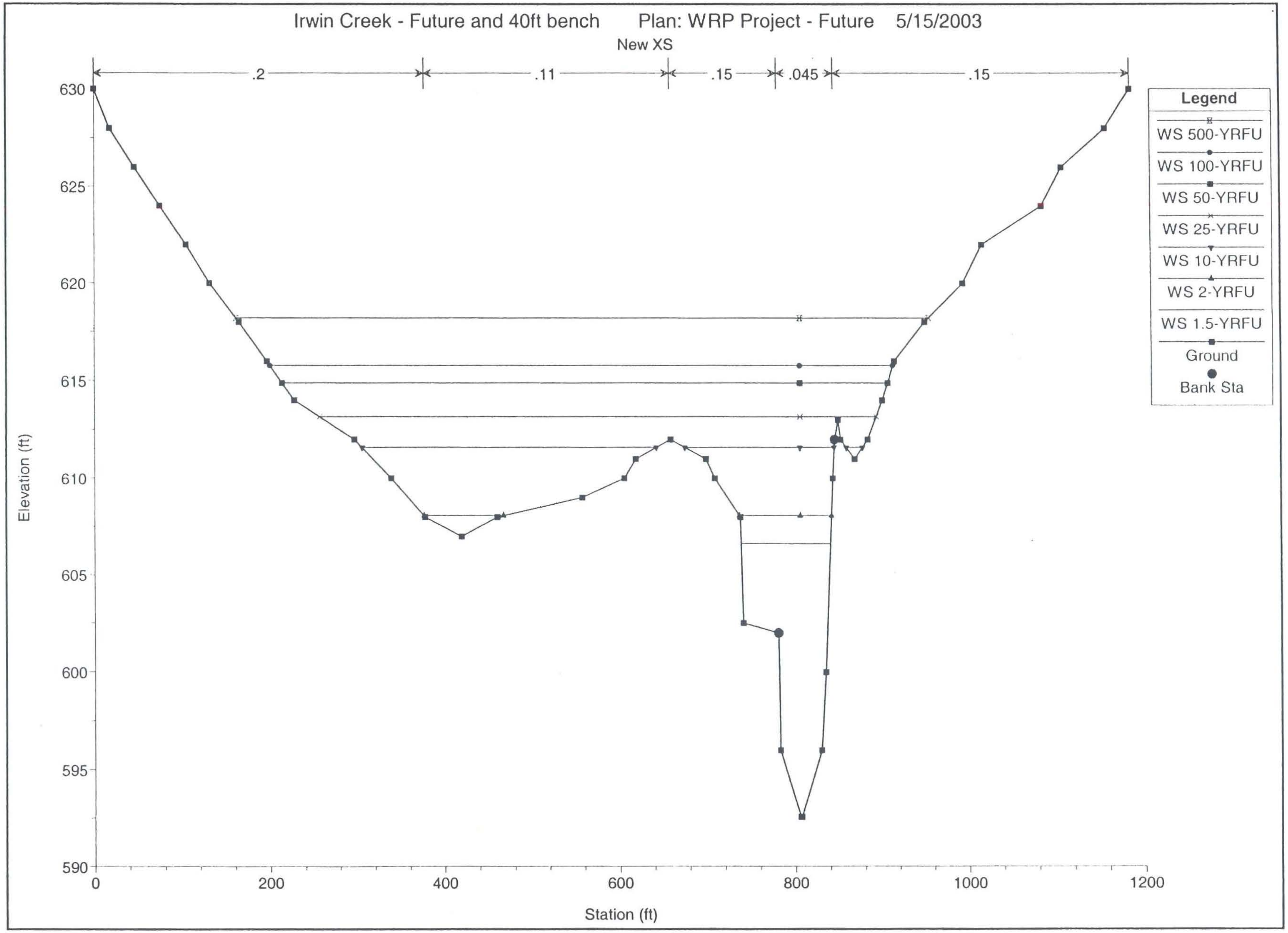

Irwin Creek - Future and 40ft bench Plan: WRP Project - Future 5/15/2003
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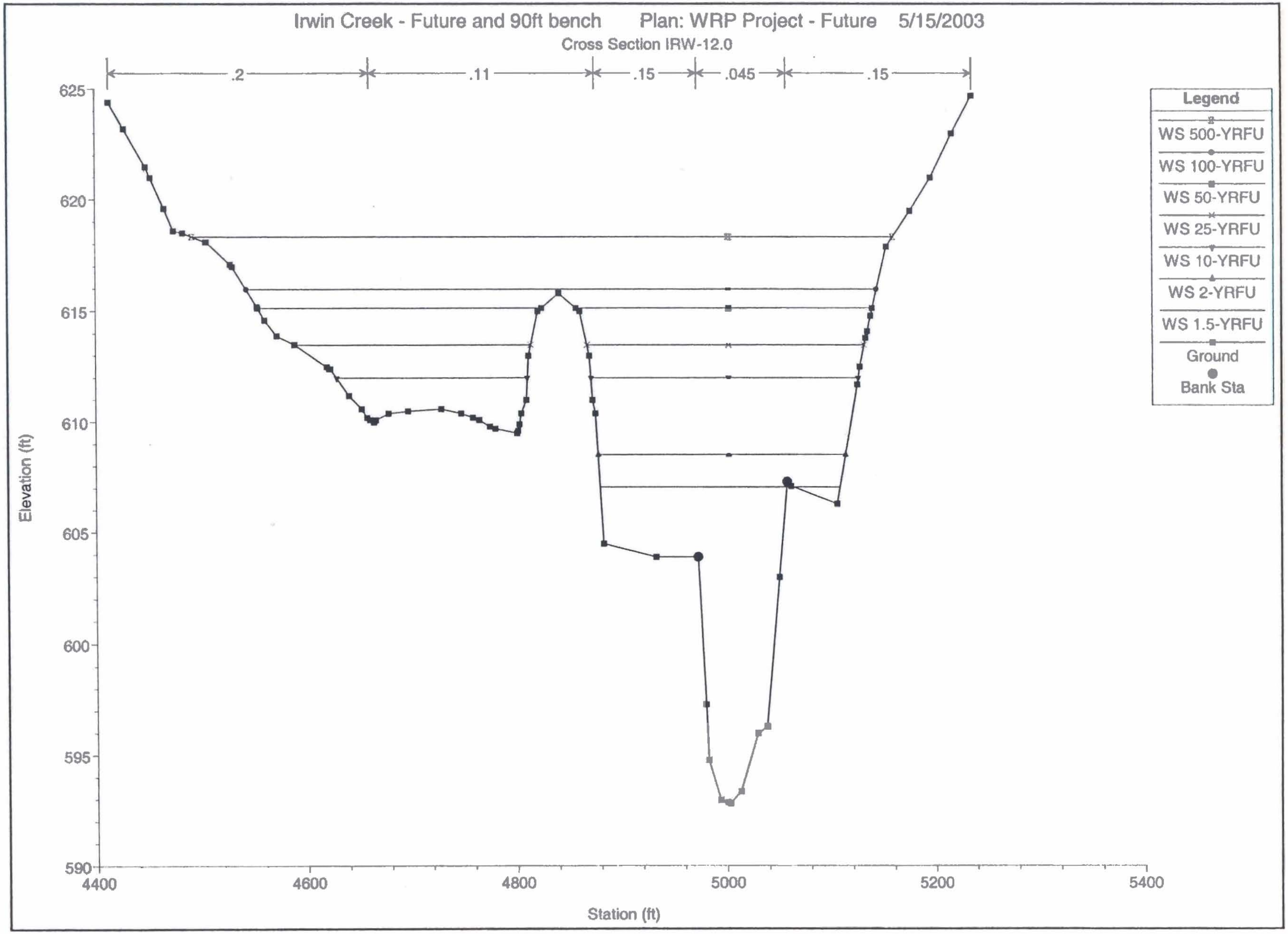
Irwin Creek - Future and 90ft bench Plan: WRP Project - Future 5/15/2003
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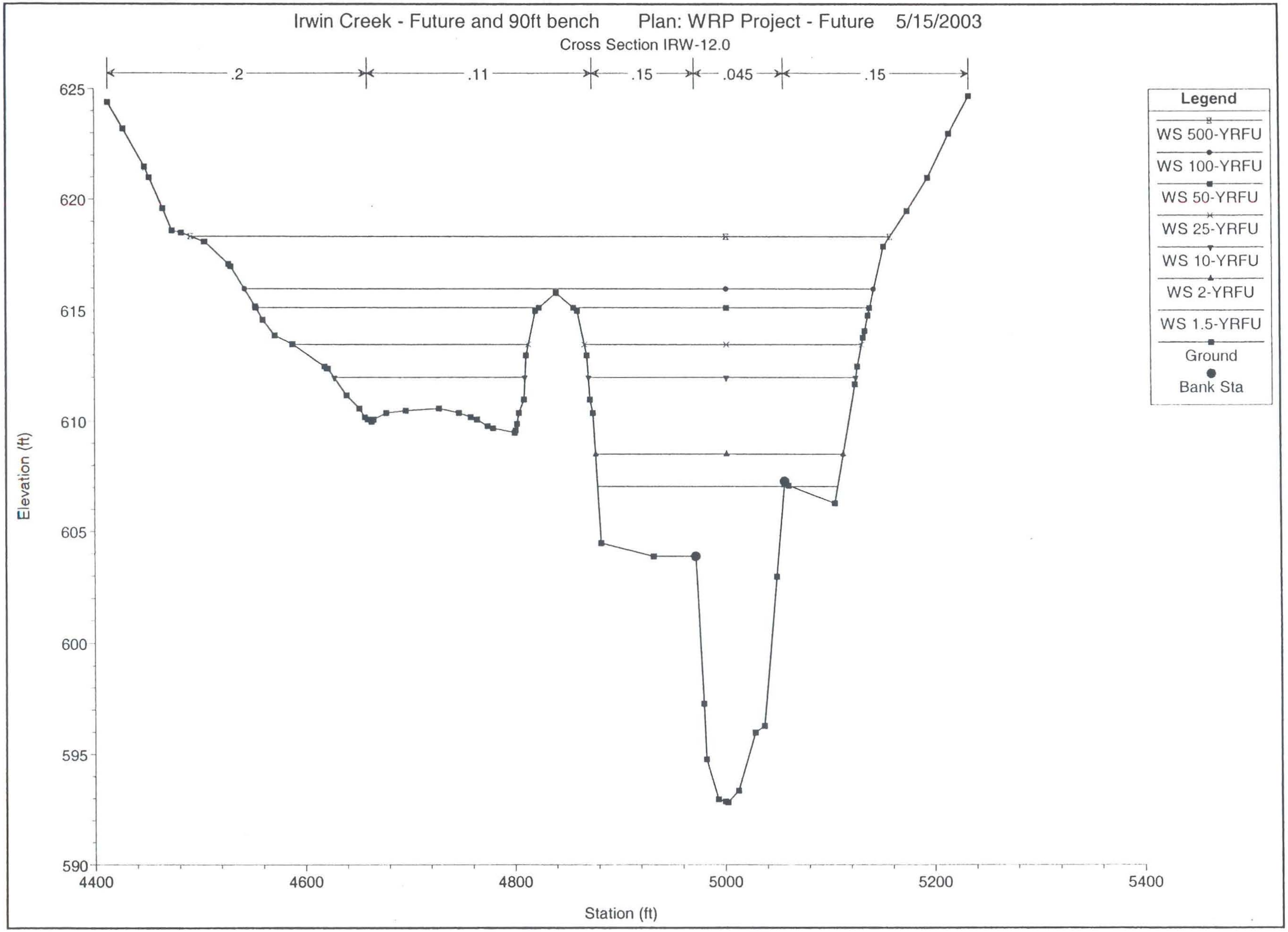

Irwin Creek - Future and 90ft bench
Plan: WRP Project - Future
5/15/2003
Cross Section IRW-12.0
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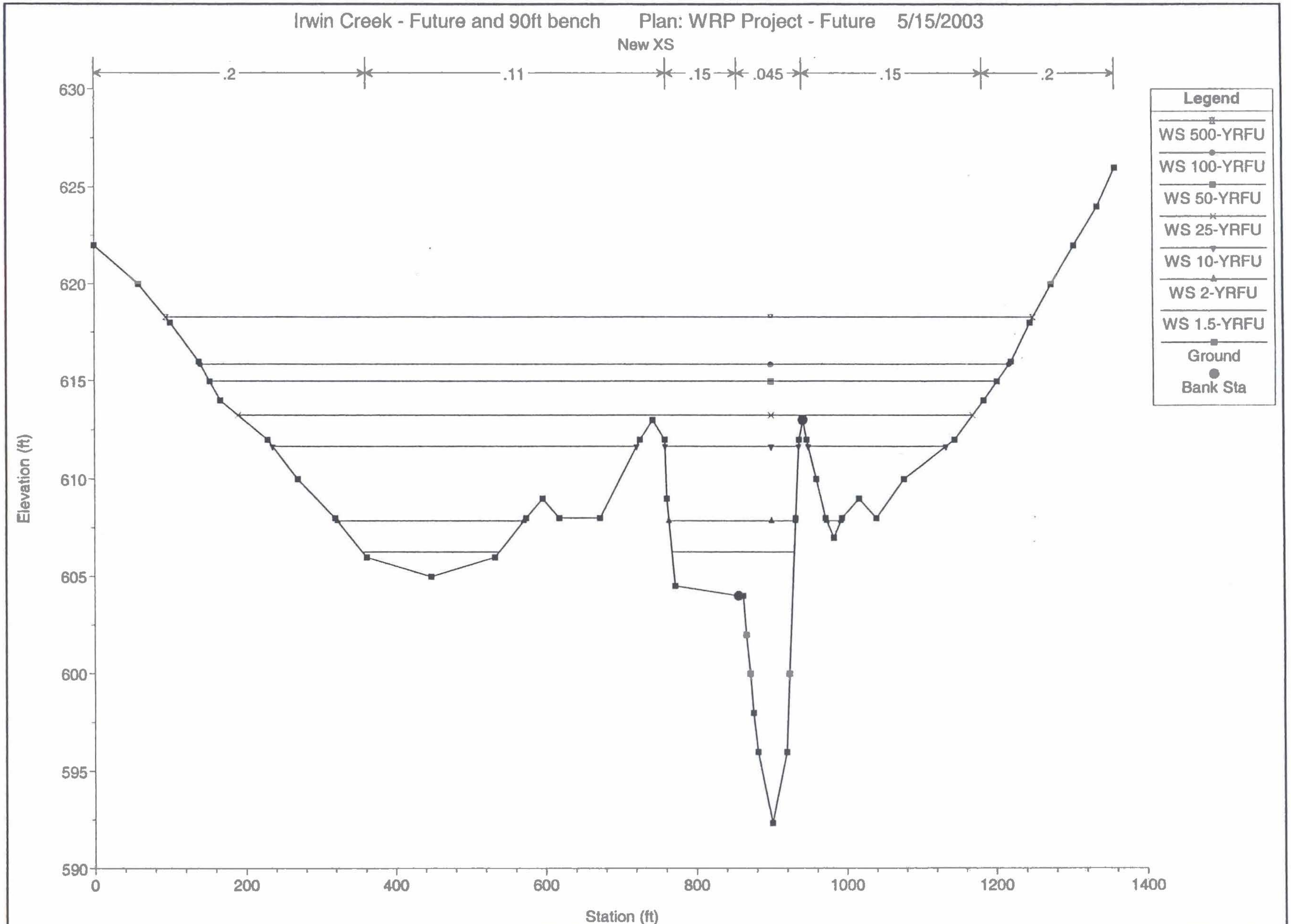

Irwin Creek - Future and 90ft bench Plan: WRP Project - Future 5/15/2003
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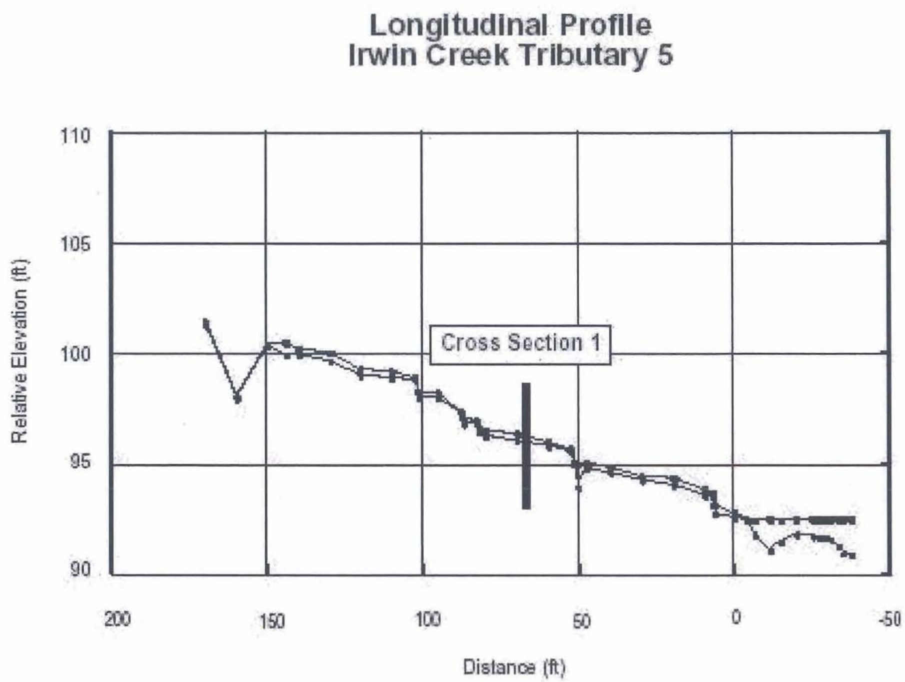
Irwin Creek Tributaries



Not to Scale

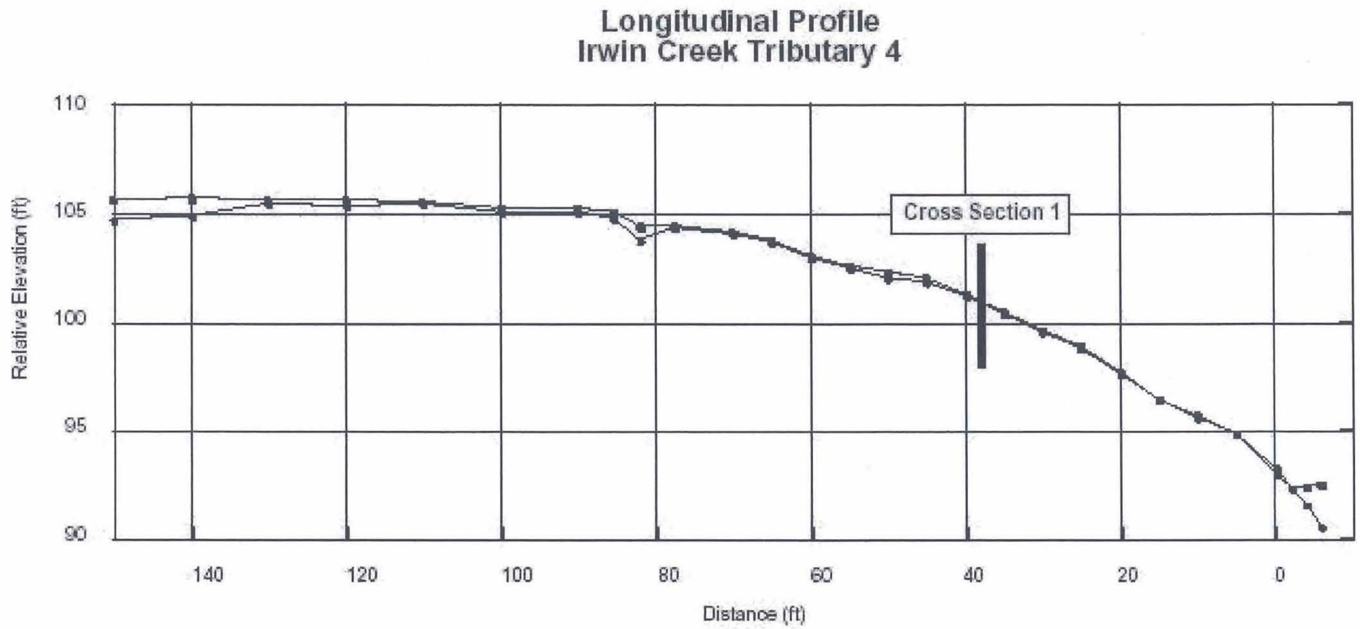
HDR Engineering, Inc.
of the Carolinas

Habitat Assessment and Restoration Program Inc.

Figure 1: Longitudinal Profile
Irwin Tributary 5
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



Not to Scale

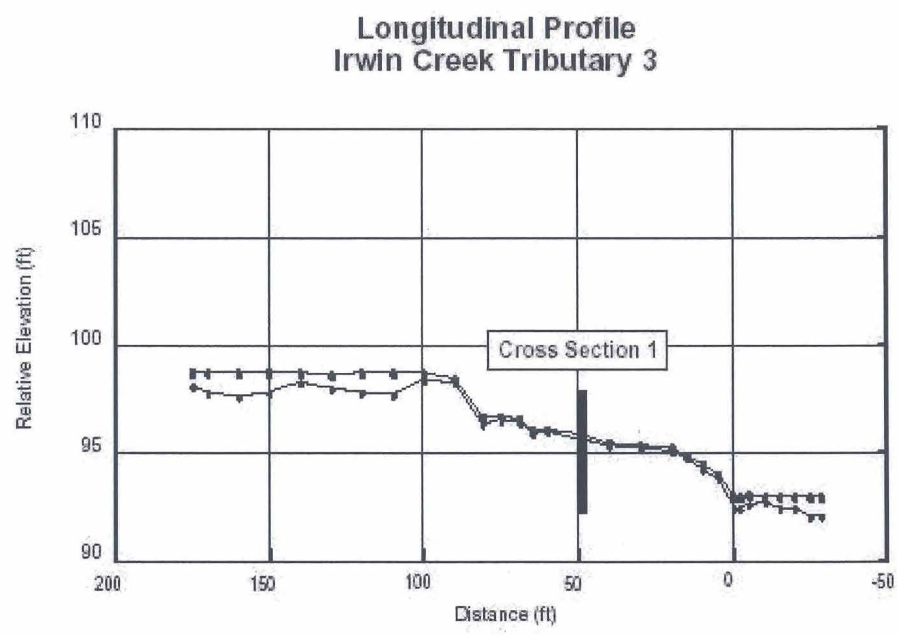
HDR Engineering, Inc.
of the Carolinas

HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.

Figure 2: Longitudinal Profile
Irwin Tributary 4
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



Not to Scale

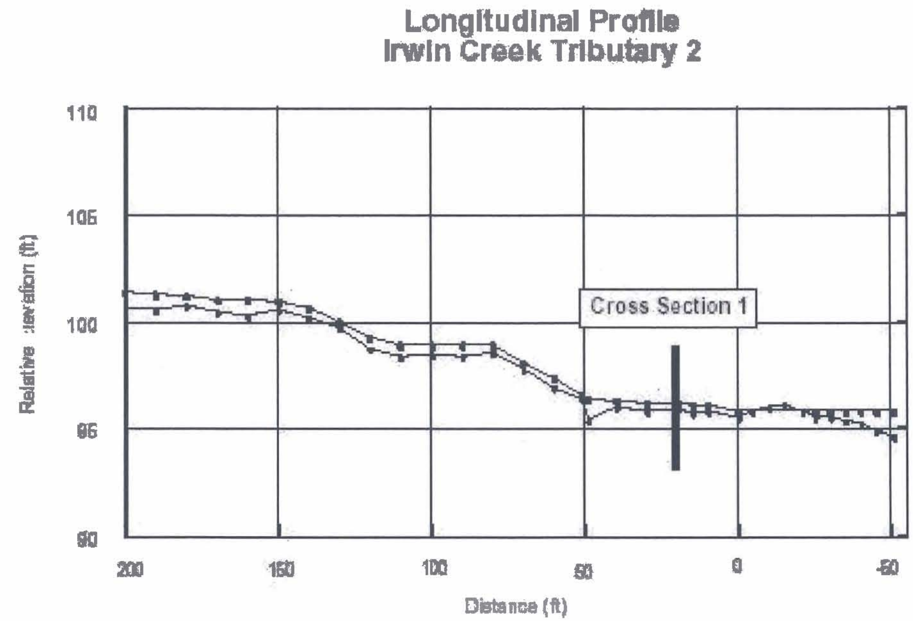
HDR Engineering, Inc.
of the Carolinas

Habitat Assessment and Restoration Program Inc.

Figure 3: Longitudinal Profile
Irwin Tributary 3
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



Not to Scale

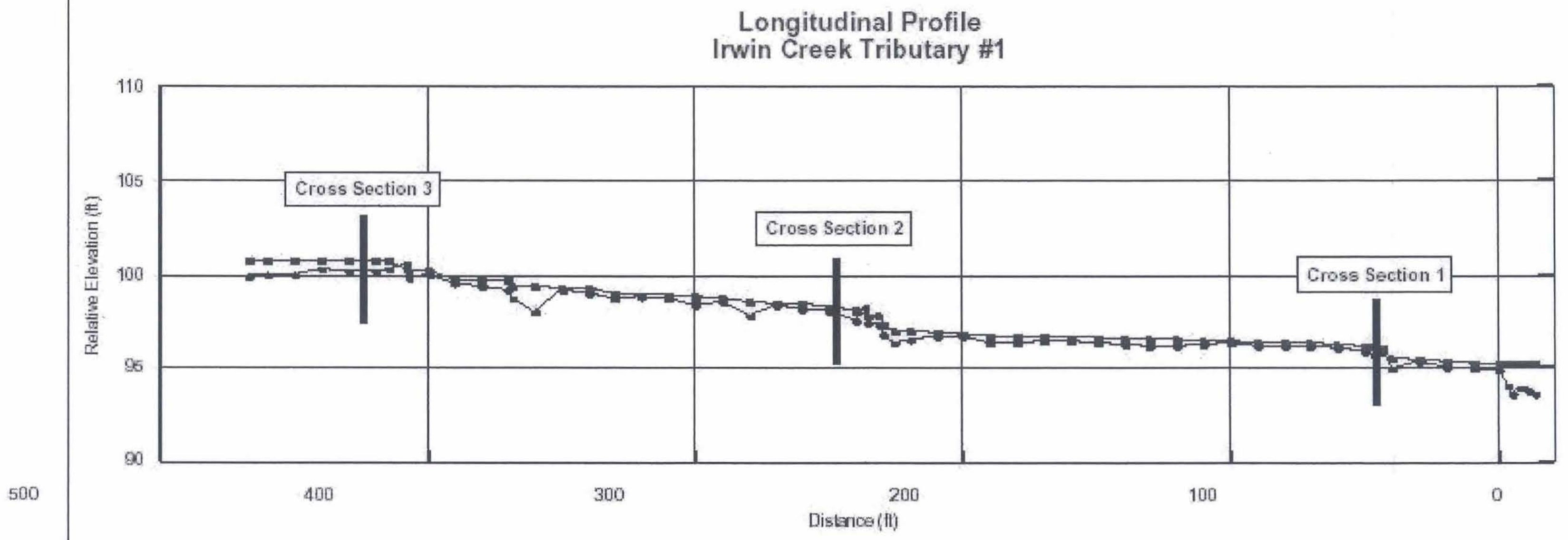
HDR Engineering, Inc.
of the Carolinas

HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.

Figure 4: Longitudinal Profile
Irwin Tributary 2
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



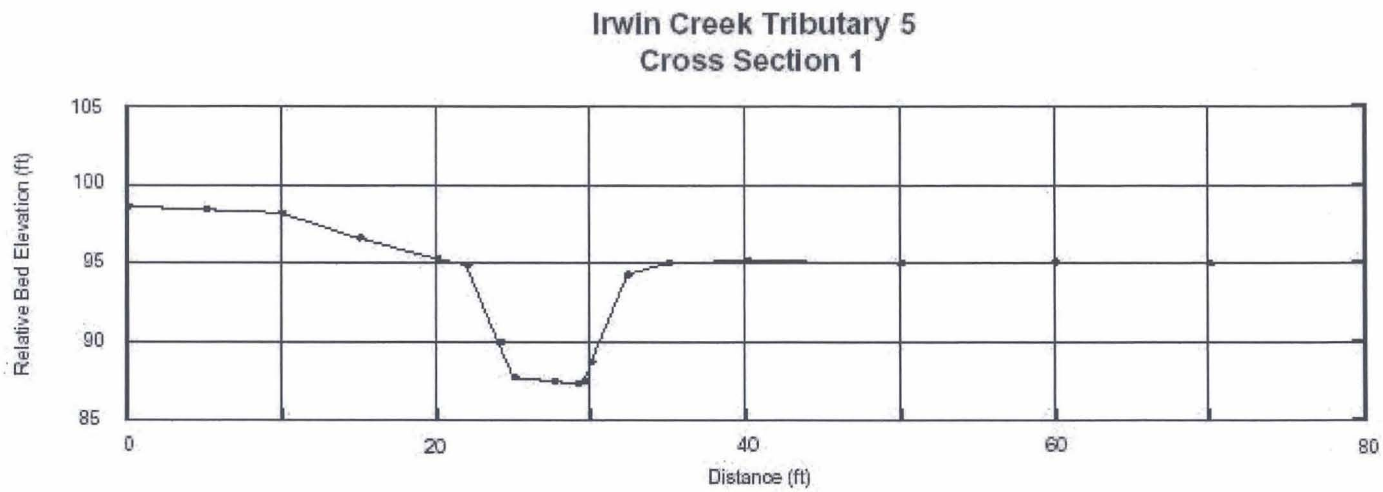
HDR Engineering, Inc.
of the Carolinas

HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.

Figure 5: Longitudinal Profile
Irwin Tributary 1
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



HDR Engineering, Inc.
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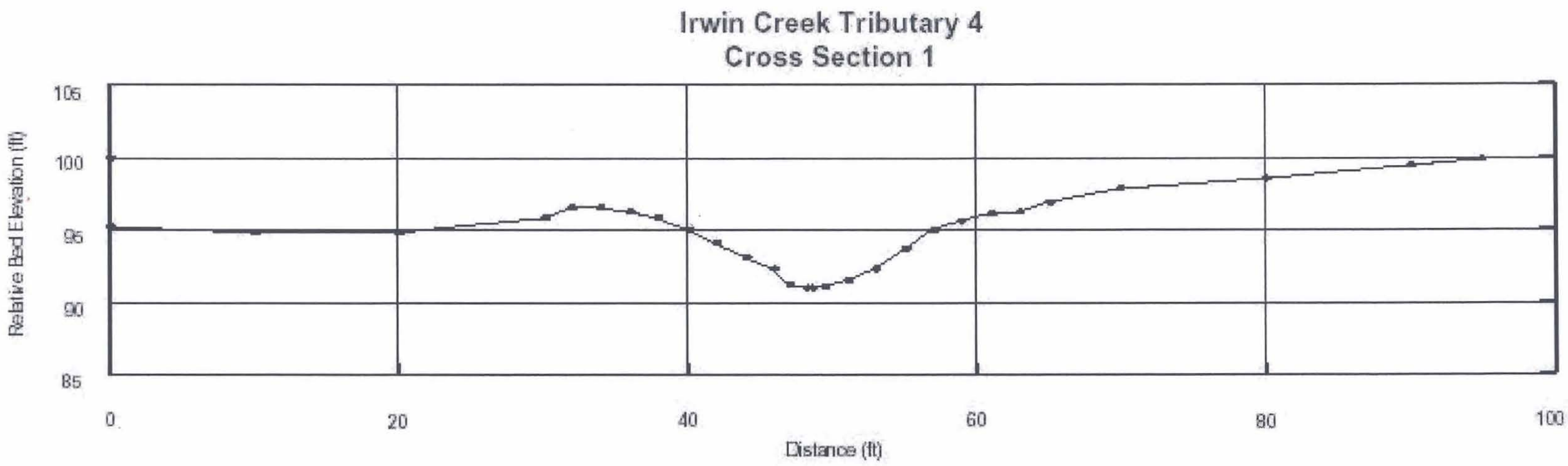
Habitat Assessment and Restoration Program Inc.

Figure 6: Cross Section 1
Irwin Tributary 5
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



HDR Engineering, Inc.
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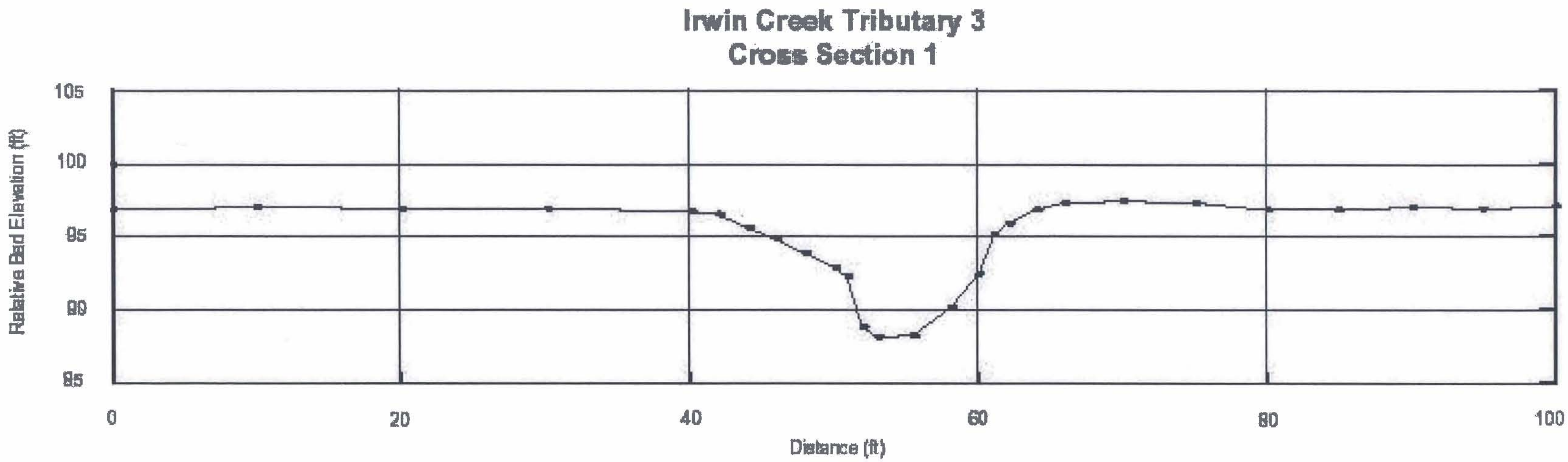
HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.

Figure 7: Cross Section 1
Irwin Tributary 4
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



HDR Engineering, Inc.
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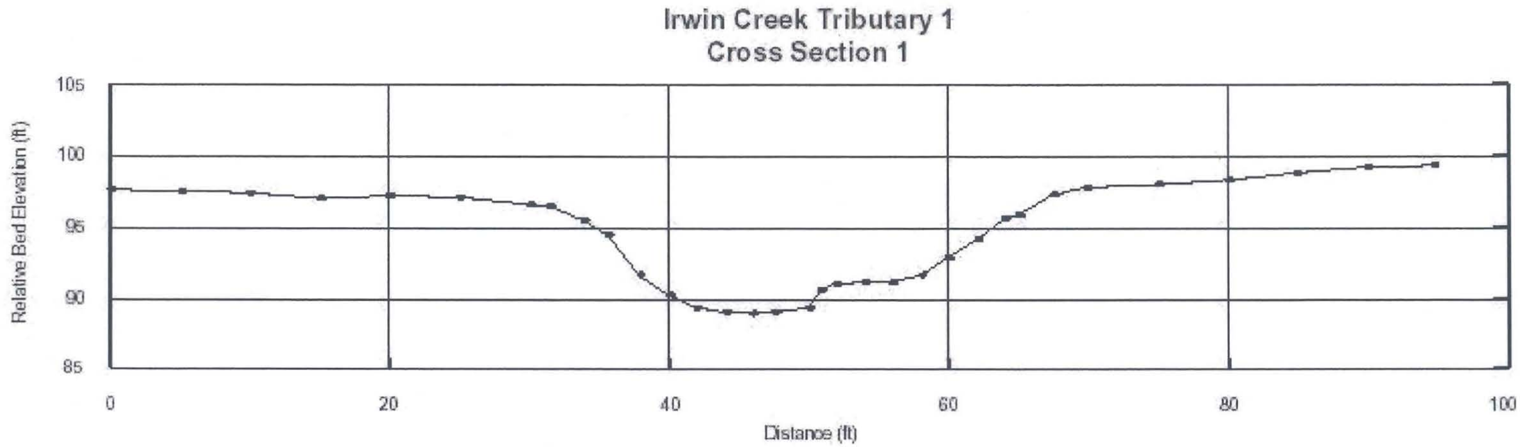
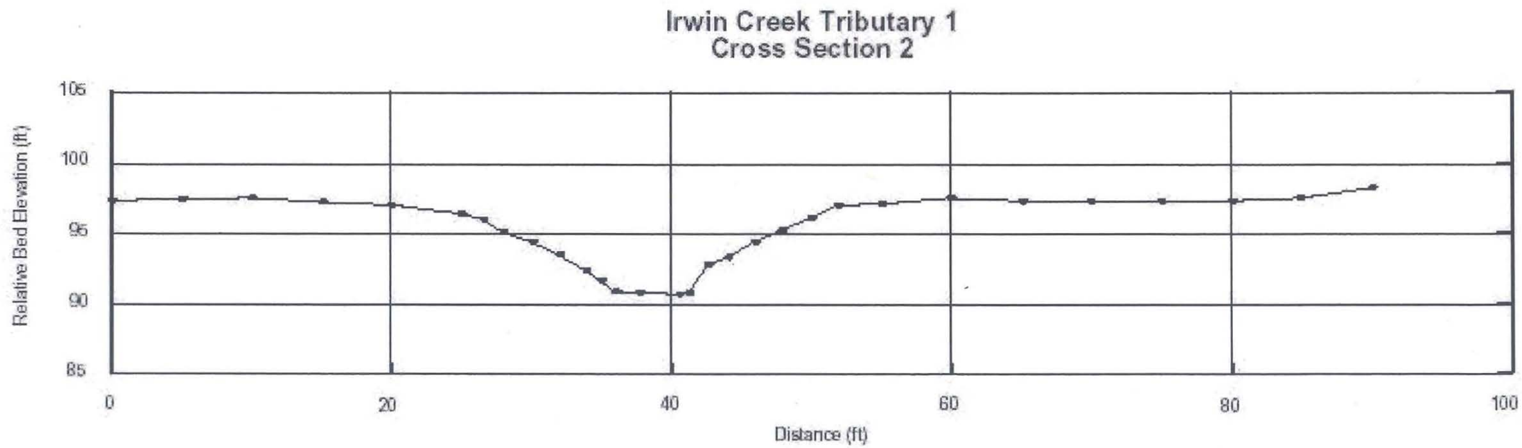
HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.

Figure 8: Cross Section 1
Irwin Tributary 3
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018





HDR Engineering, Inc.
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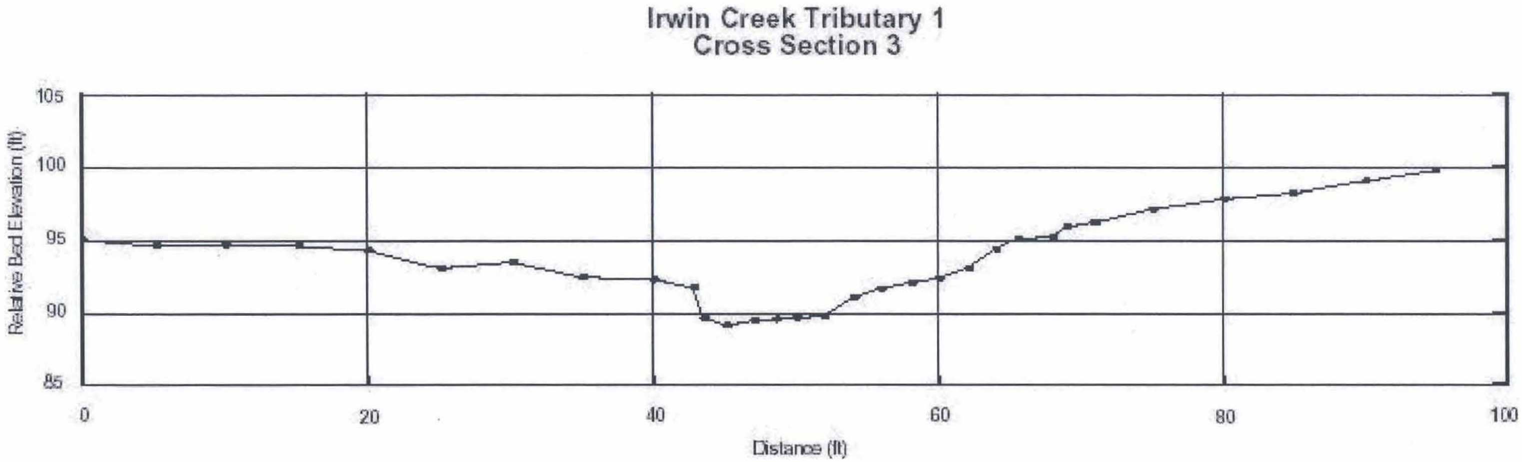
HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.

Figure 9: Cross Sections 1 & 2
Irwin Tributary 1
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



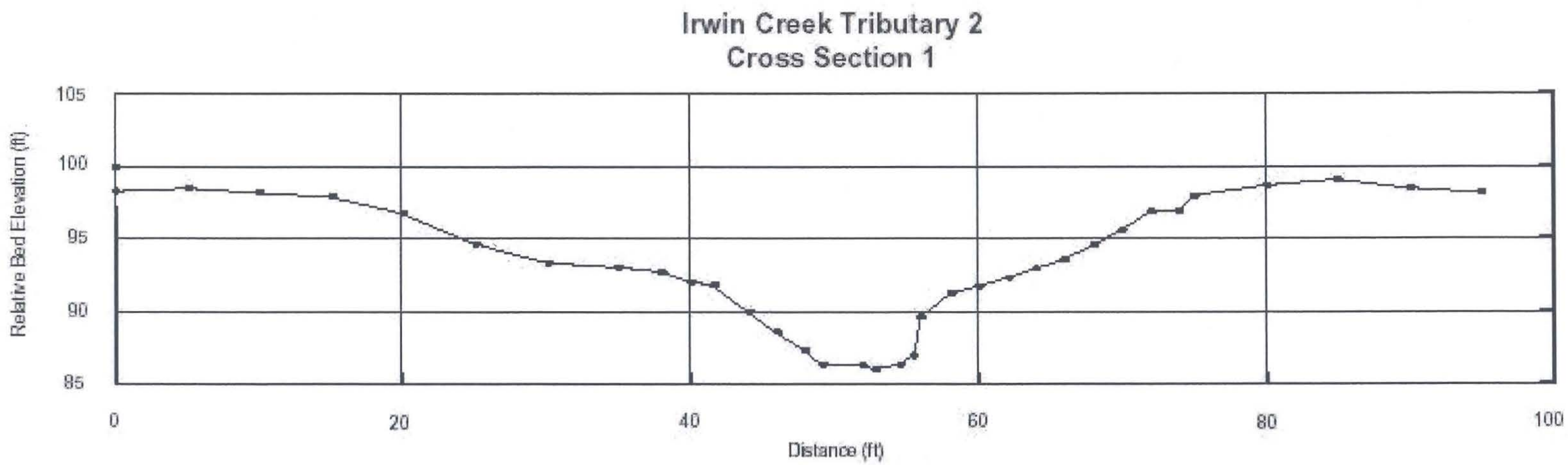
HDR Engineering, Inc.
of the Carolinas

HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.

Figure 10: Cross Section 3
Irwin Tributary 1
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



HDR

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Habitat Assessment and Restoration Program Inc.

Figure 11: Cross Section 1
Irwin Tributary 2
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

Storm Water Outfalls

Irwin Creek Storm Water Outfall Survey
April 28, 2003

Whitehurst Road

1. Catch basin grate. Whitehurst Road
   Depth = 4.45 feet, 15" concrete pipe

2. Manhole. Whitehurst Road
   #1 and #5 enter. Depth = 8.25'
   Could not open.

3. Grate in yard of Whitehurst Road
   #2 enters, pipe is 48"
   Depth = 9.35'

4. Pipe-out to Irwin Creek, left bank
   48" concrete pipe with flared end, bottom elevation even with stream
   Stabilized with rip-rap
   Flow present.

5. Catch basin grate, Whitehurst Road
   Large pipe with flow from behind houses.

**This system was replaced and enlarged approximately 4 years ago. I'm currently working on getting the plans from the City so we have more information.

6. Outlet from Whitehurst Road.
   15" pipe, from #7.
   Outlet is in middle of bank, separated last segment due to erosion. Erosion is not severe, water drains down slope without erosion.

7. Catch basin grate. Whitehurst Road
   Drains to outlet #6.

Irwin Creek WWTP

8. Outlet at top of left bank.
   24" pipe with flared end.
   Drains to stream in rip-rap ditch.

9. Abandoned grate, plugged outlet is buried.

10. Manhole in wall.

11. Main plant storm drain, left bank.

36” pipe protected with valve closure and headwall with wings structure.
Sediment deposition around outlet, outlet just above water surface.

12. Sand filter area storm drain outlet, left bank.
Same type as #11, outlet just above water surface.

13. Secondary clarifier storm drain, left bank.
Pipe is at least 36” and has same valve as #11 and #12.
Box headwall structure to protect outlet, also riprap surrounding.
Sediment deposition in box structure.
Structure is set back approximately 15’ from edge of channel, outlet is higher than water surface.

Table 1
Irwin Creek Storm Water Inventory

ID	Location	Type	Size
1	Whitehurst Road	Catch basin	-
2	Whitehurst Road	Manhole	-
3	Whitehurst Road	Drop inlet	-
4	Whitehurst Road	Outfall	48 inch
5	Whitehurst Road	Catch basin	-
6	Whitehurst Road	Outfall	15 inch
7	Whitehurst Road	Catch basin	-
8	Irwin Creek WWTP	Outfall	24 inch
9	Irwin Creek WWTP	Abandoned Inlet	-
10	Irwin Creek WWTP	Manhole	-
11	Irwin Creek WWTP	Outfall	36 inch
12	Irwin Creek WWTP	Outfall	36 inch
13	Irwin Creek WWTP	Outfall	< 36 inch
14	Irwin Creek WWTP	Abandoned Outfall	-
15	Irwin Creek WWTP	Abandoned Outfall	-

1
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4
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6
7
Irwin Creek Storm Water
Outfall Locations
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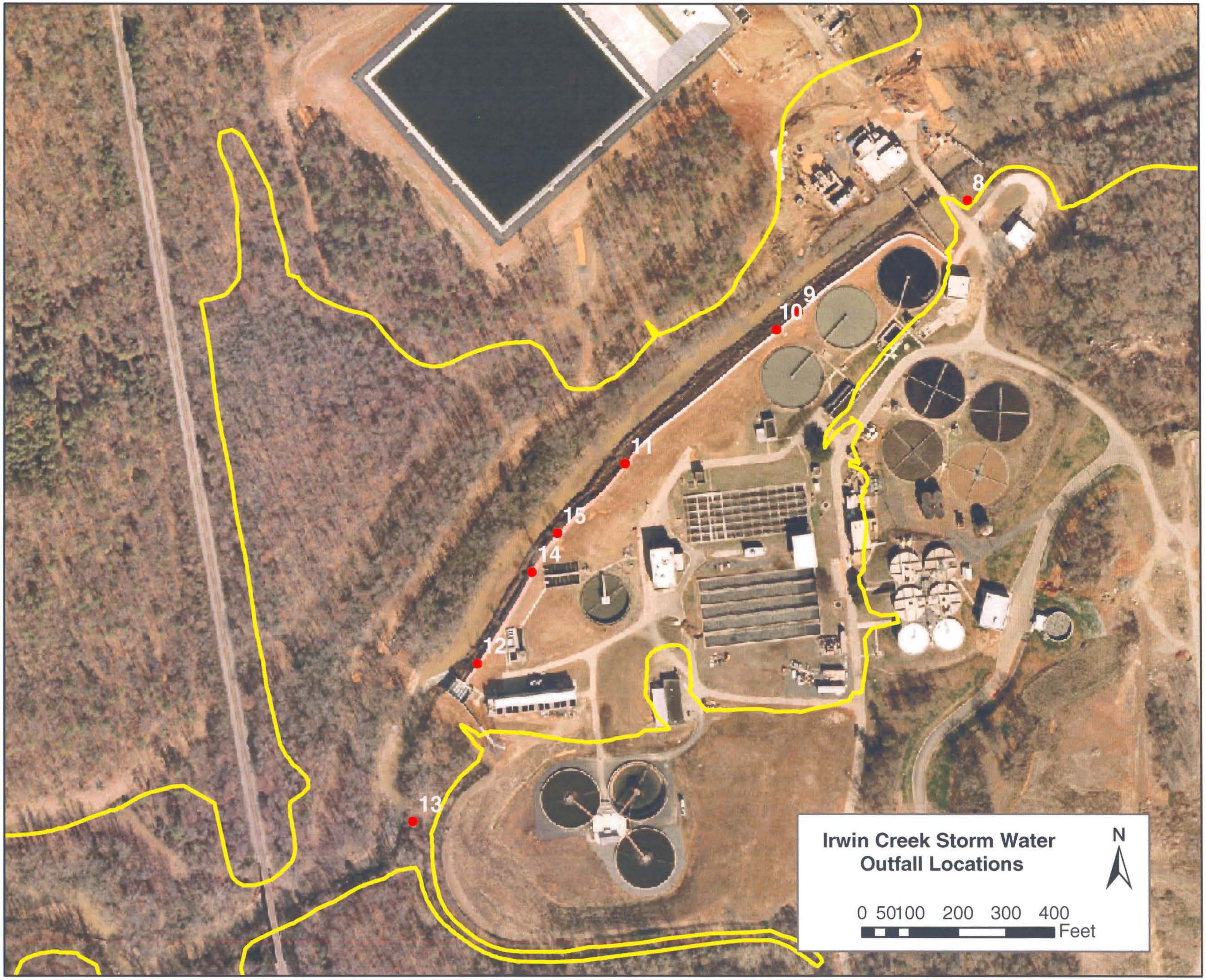
0 25 50 100 150 200 250 300
Feet


8
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13
Irwin Creek Storm Water
Outfall Locations
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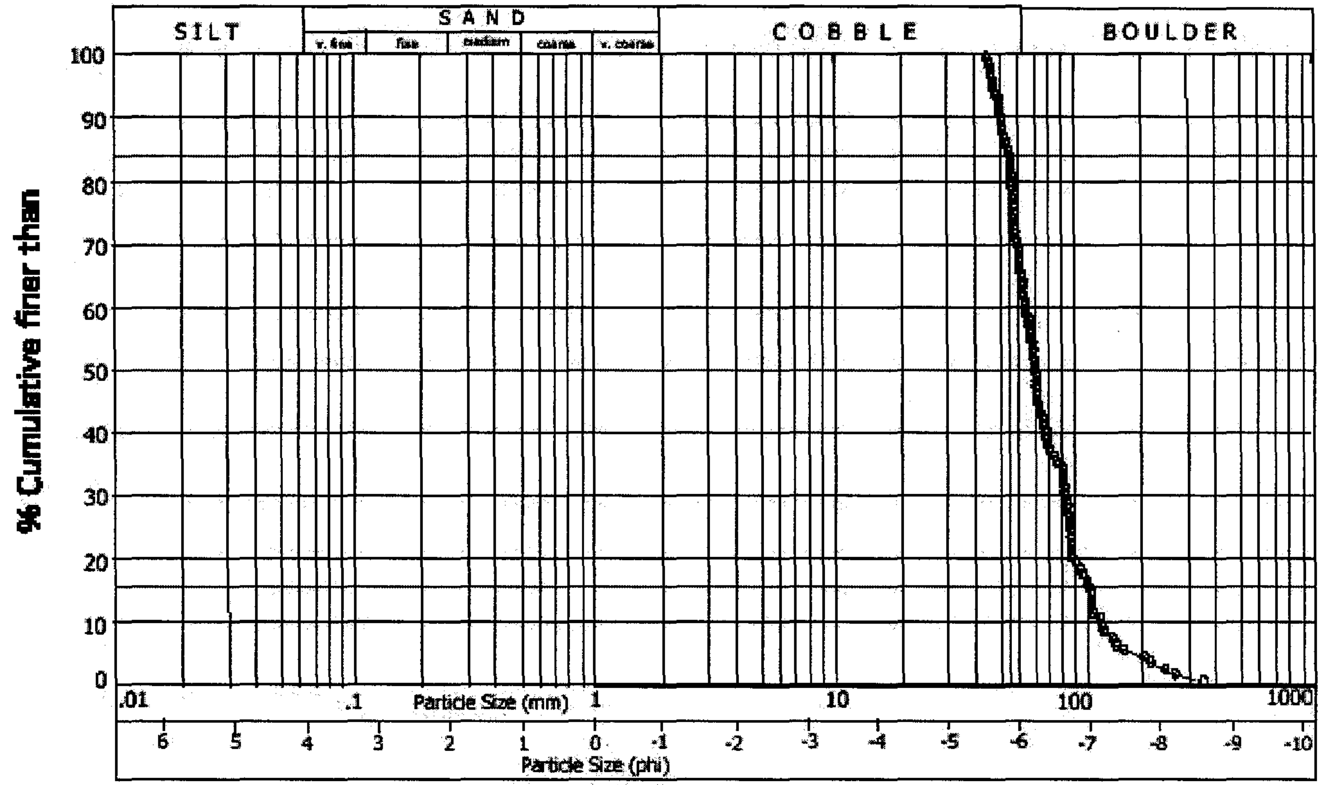
0 50100 200 300 400
Feet

Sediment and Grain Size Distributions

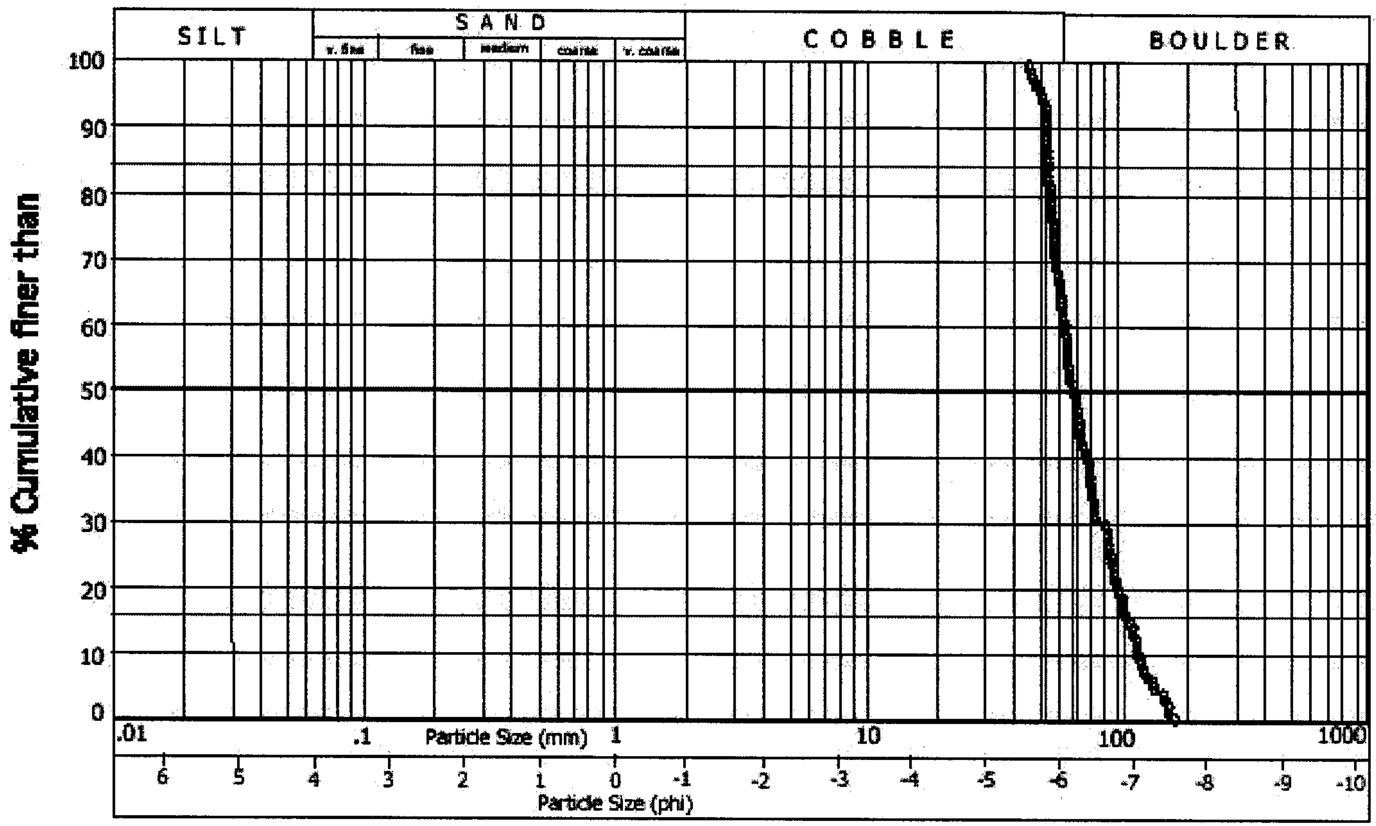
LOCALITY	Irwin Creek Wastewater Treatment Plant
SITE	Irwin Sample Riffle # 1



$D_{84(min)}$ 52 mm D_{50} 70 mm $D_{84(max)}$ 110 mm

HDR HDR Engineering, Inc. of the Carolinas	Habitat Assessment and Restoration Program Inc.	**Figure S1: Sediment Sample** **Irwin Creek Riffle 1** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018

LOCALITY	Irwin Creek Wastewater Treatment Plant
SITE	Irwin Sample Riffle # 2



$D_{84(min)}$ 51 mm D_{50} 69 mm $D_{84(max)}$ 110 mm

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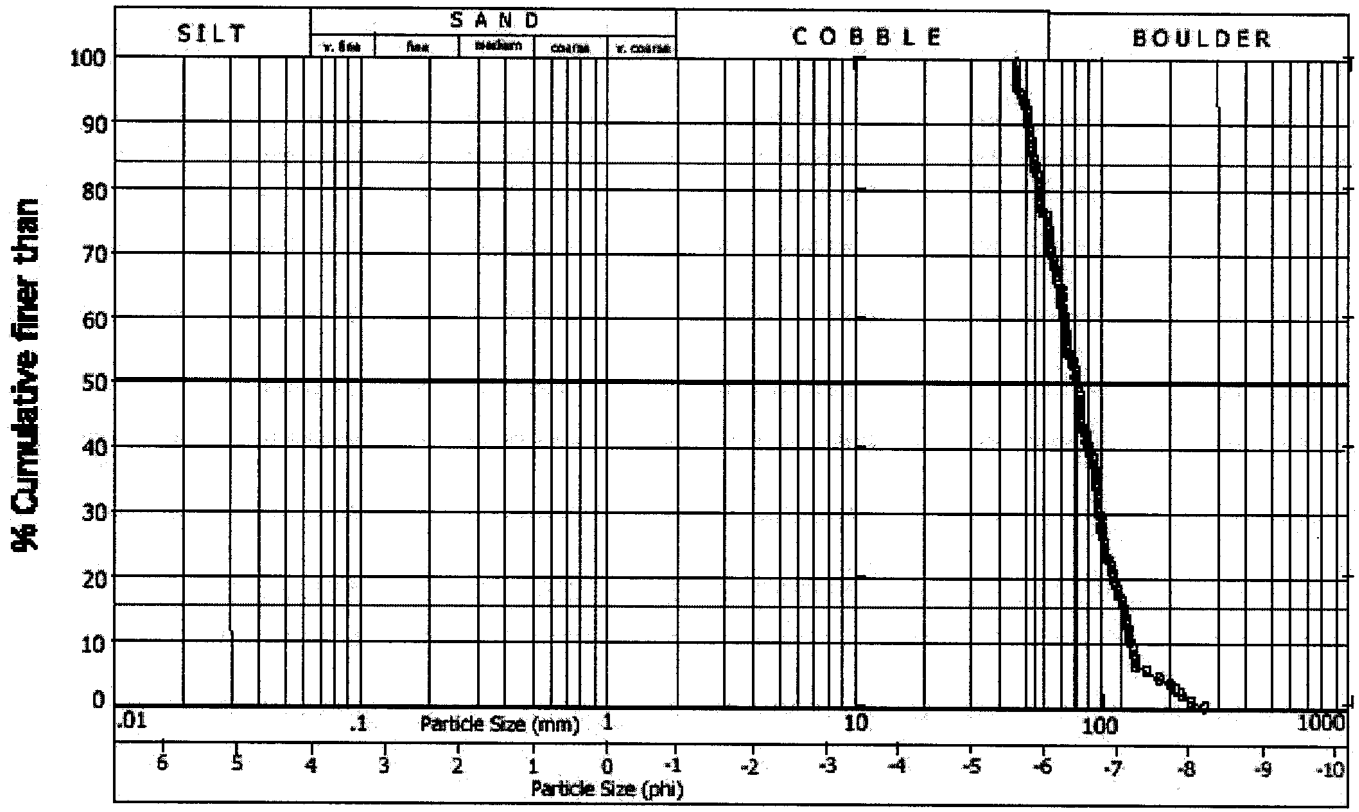
Figure S2: Sediment Sample
Irwin Creek Riffle 2
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Irwin Creek Wastewater Treatment Plant
SITE	Irwin Sample Riffle # 3

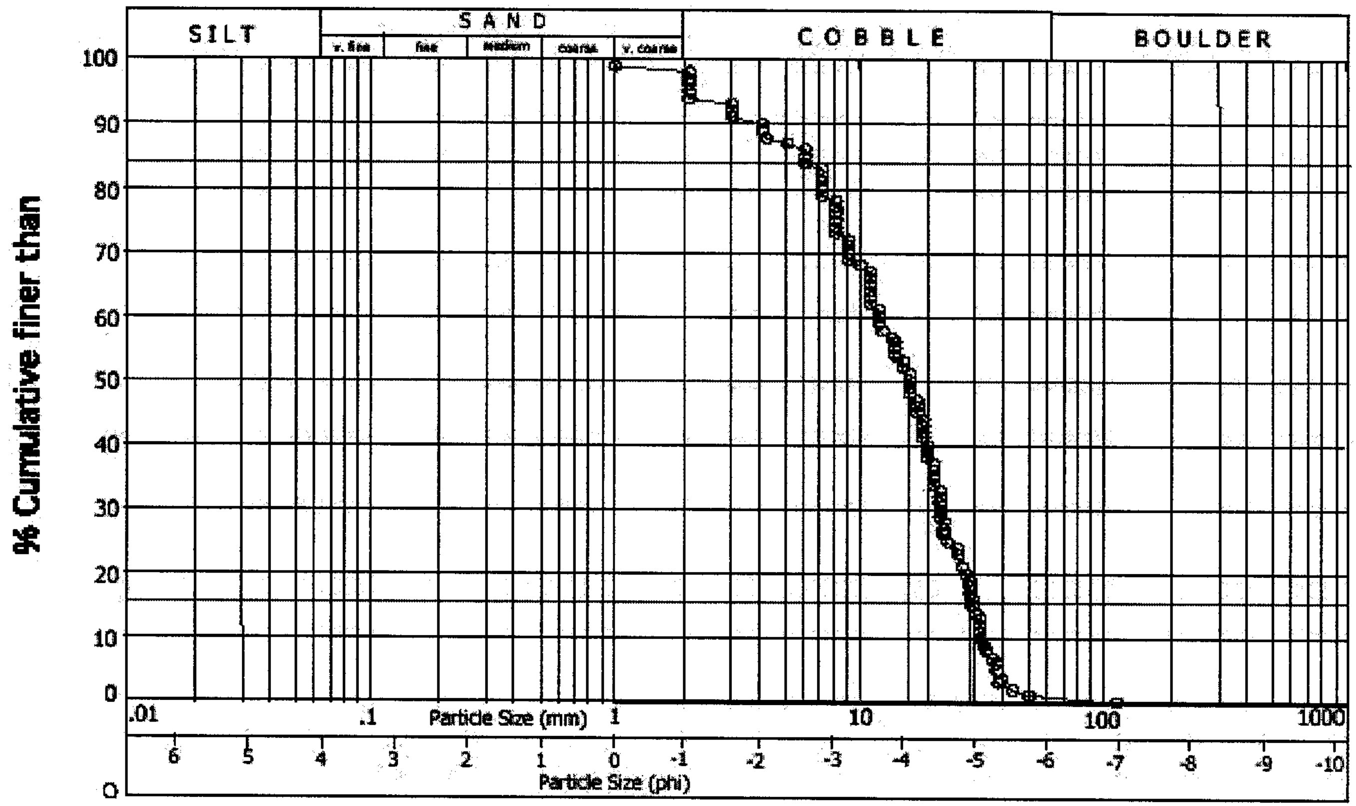


$D_{84(min)}$ 52 mm D_{50} 81 mm $D_{84(max)}$ 110 mm

HDR HDR Engineering, Inc. of the Carolinas	HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.	**Figure S3: Sediment Sample Irwin Creek Riffle 3** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018

LOCALITY Leepers Reference Reach

SITE Leepers Sample Riffle # 1



$D_{84(min)}$ 6.0 mm D_{50} 16 mm $D_{84(max)}$ 29 mm

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Figure S4: Sediment Sample Leepers Creek Riffle 1

Stream Restoration Plan

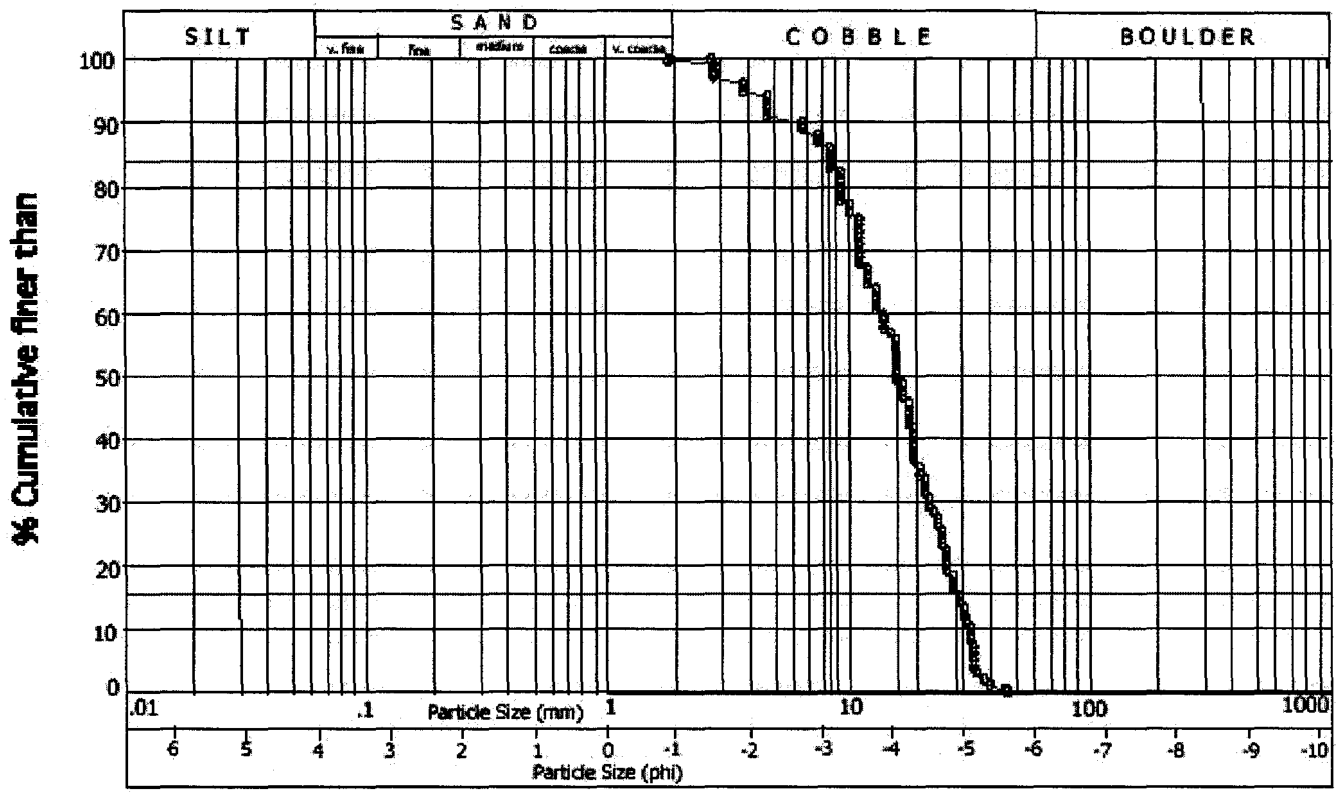
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Leepers Reference Reach

SITE Leepers Sample Riffle # 2

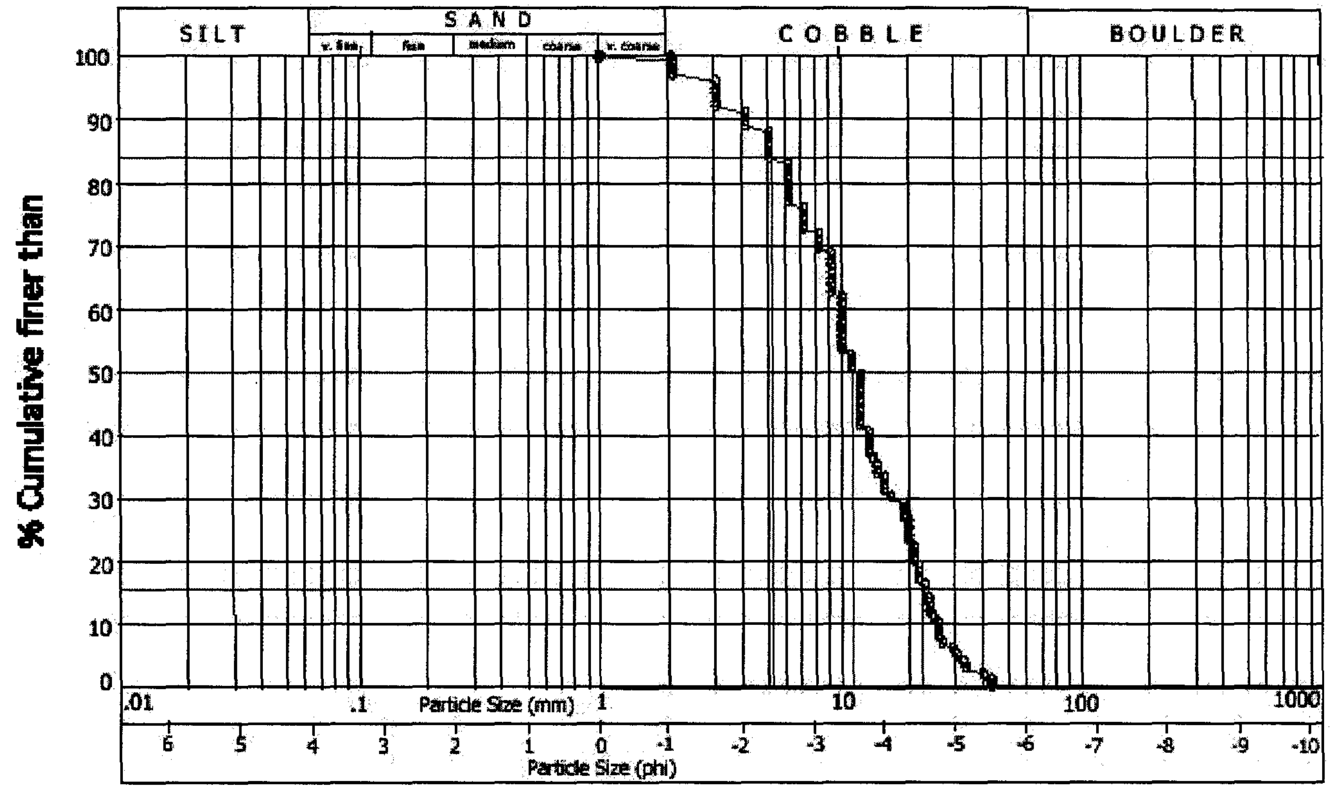


$D_{84(min)}$ 8.5 mm D_{50} 17 mm $D_{84(max)}$ 28 mm

HDR HDR Engineering, Inc. of the Carolinas	Habitat Assessment and Restoration Program Inc.	**Figure S5: Sediment Sample Leepers Creek Riffle 2** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018

LOCALITY Leepers Reference Reach

SITE Leepers Sample Riffle # 3



$D_{84(min)}$ 5.1 mm D_{50} 11 mm $D_{84(max)}$ 22 mm

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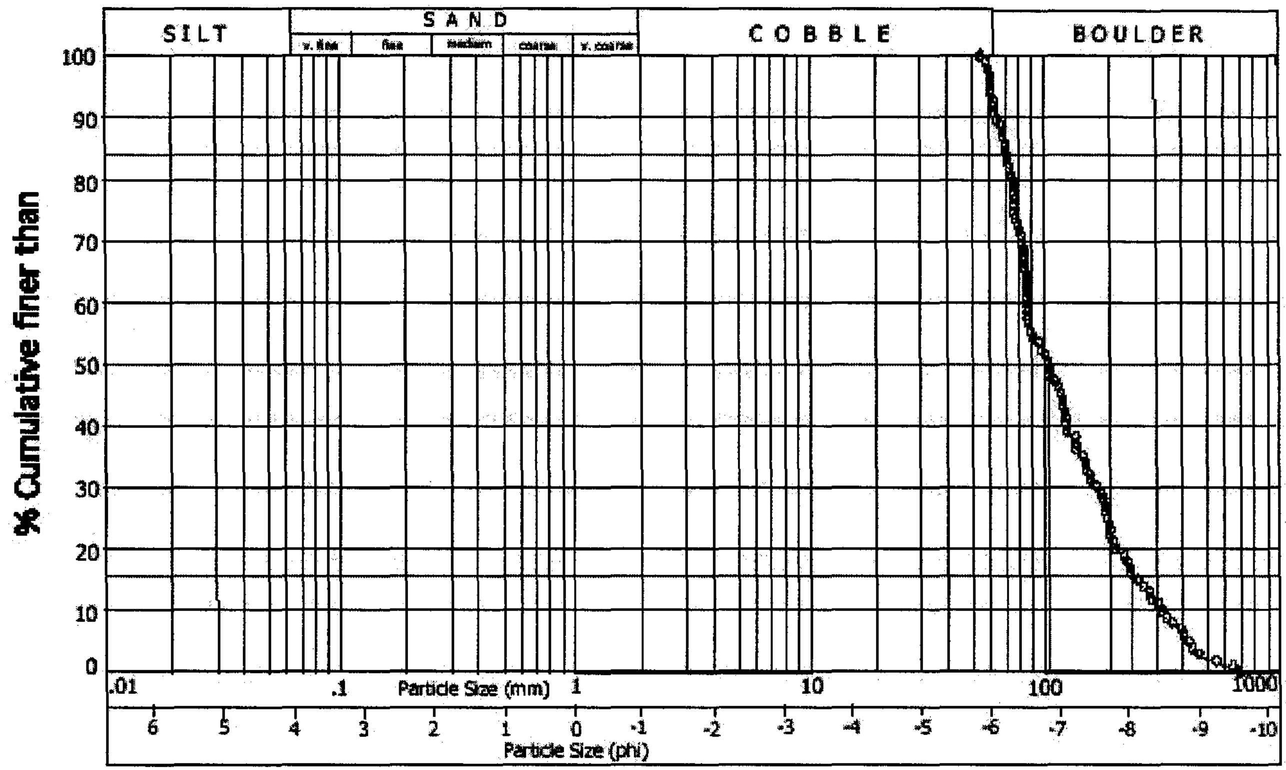
Figure S6: Sediment Sample
Leepers Creek Riffle 3
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Leepers Reference Reach (Alba Mill Downstream Site)

SITE Leepers Sample Riffle # 4



$D_{84(min)}$ 71 mm

D_{50} 100 mm

$D_{84(max)}$ 260 mm

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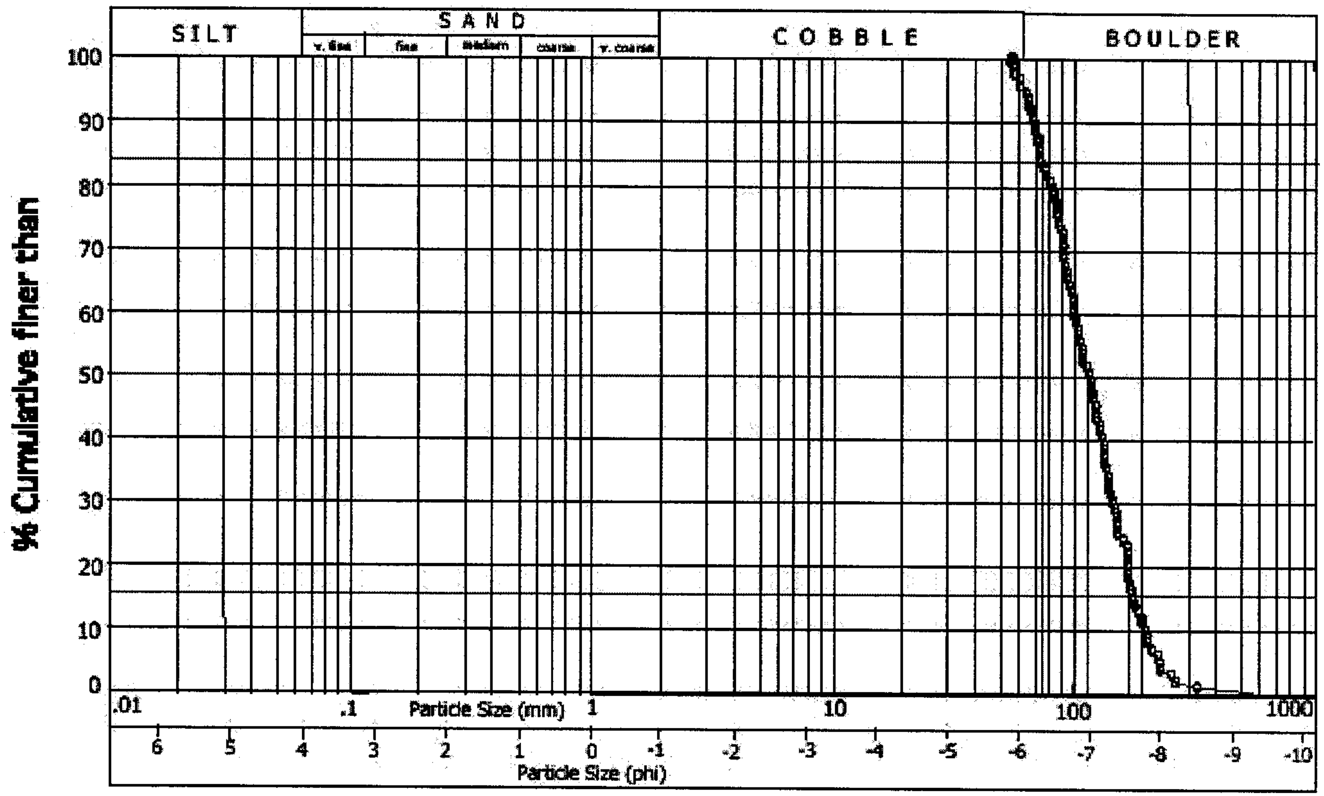
Figure S7: Sediment Sample
Leepers Creek Riffle 4

Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

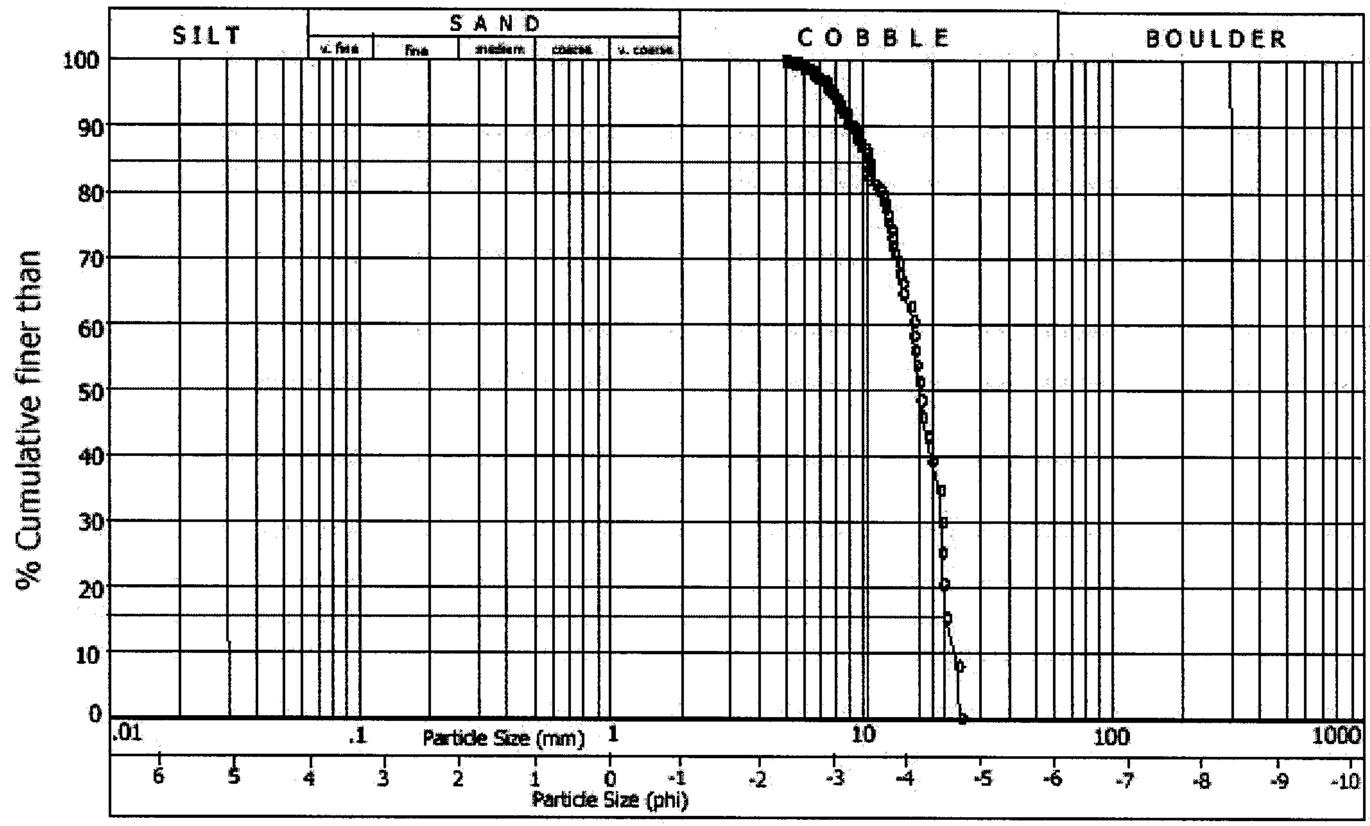
LOCALITY	Leepers Reference Reach (Alba Mill Downstream Site)
SITE	Leepers Sample Riffle # 5



$D_{84(min)}$ 77 mm D_{50} 110 mm $D_{84(max)}$ 180 mm

HDR HDR Engineering, Inc. of the Carolinas	Habitat Assessment and Restoration Program Inc.	**Figure S8: Sediment Sample** **Leepers Creek Riffle 5** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018

LOCALITY	Irwin Creek Sandbar Armor
SITE	SB-1-A



$D_{84(min)}$ 10 mm D_{50} 18 mm $D_{84(max)}$ 21 mm

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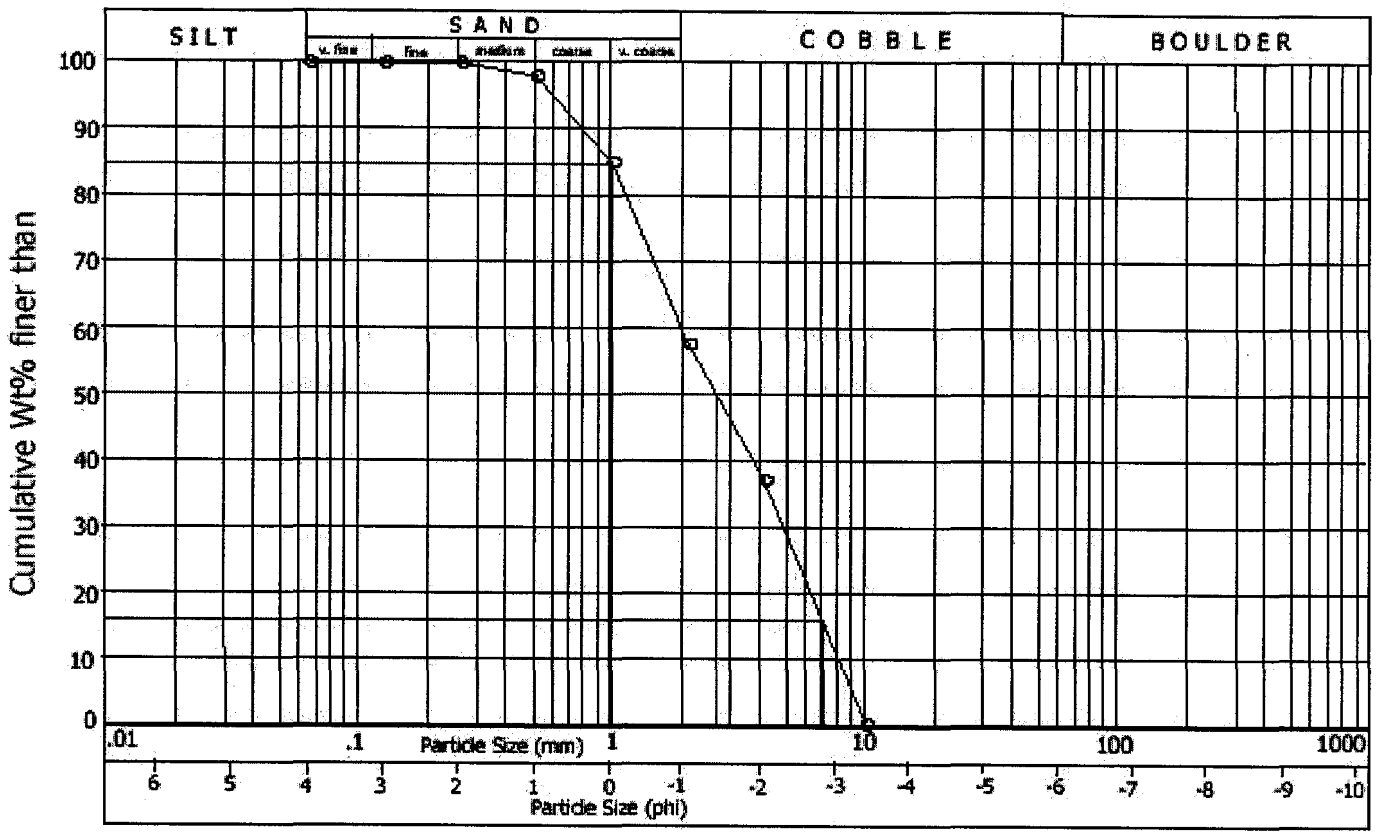
Figure S9: Sediment Sample
Irwin Creek Sand Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Irwin Creek Sandbar

SITE SB-1-B



$D_{84(min)}$ 1 mm D_{50} 2.6 mm $D_{84(max)}$ 6 mm

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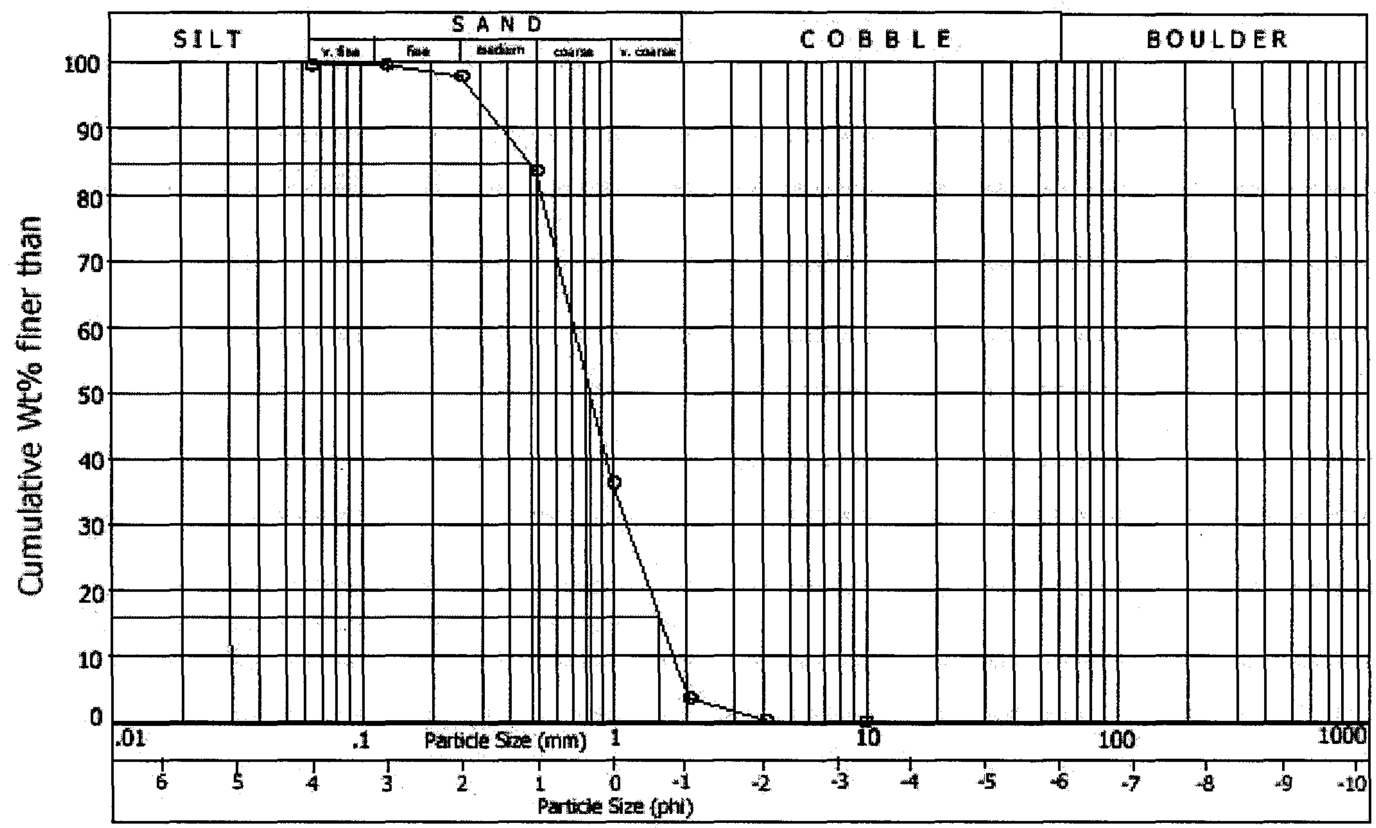
Figure S10: Sediment Sample
Irwin Creek Sand Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Irwin Creek Sandbar
SITE	SB-1-C



$D_{84(min)}$ 0.48mm D_{50} 0.8mm $D_{84(max)}$ 1.5mm

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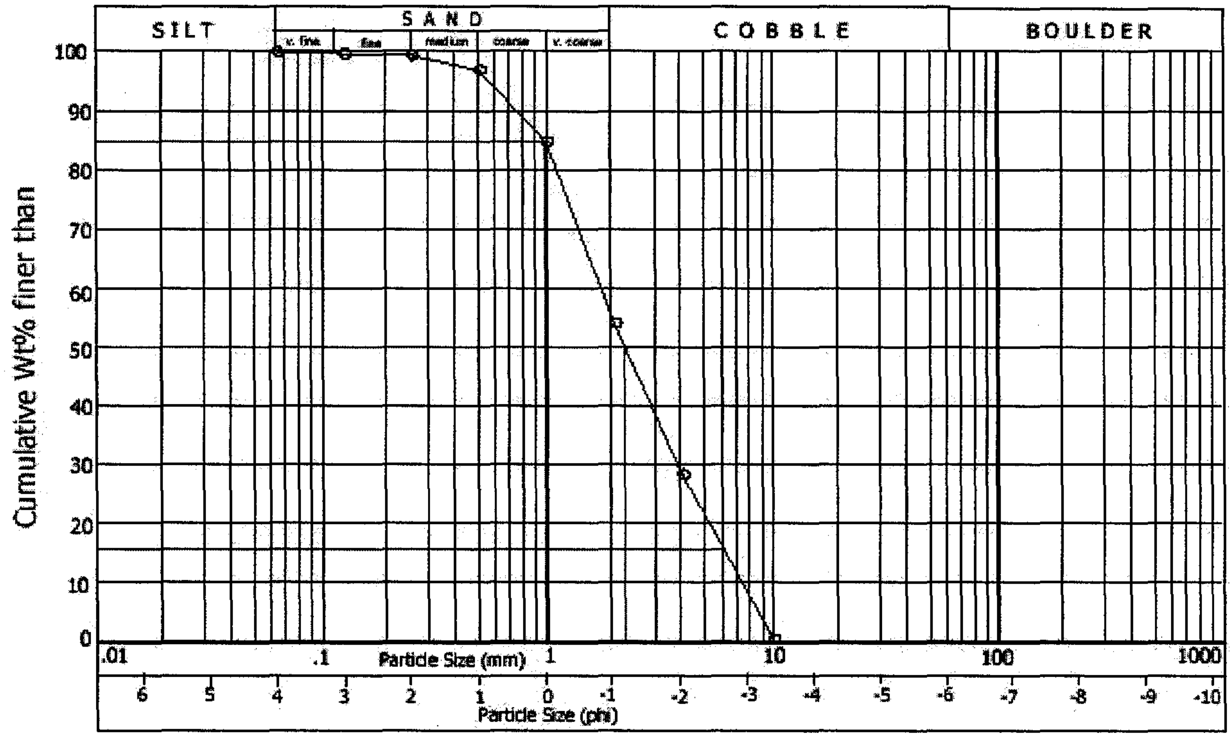
Figure S11: Sediment Sample
Irwin Creek Sand Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Irwin Creek Sandbar

SITE SB-2-A



$D_{84(min)}$ 1.0 mm　　Substrate D_{50} 2.1 mm　　$D_{84(max)}$ 6.0 mm

Armor D_{50} 11.7 mm

Integrated Armor & Substrate D50 Calculation
Armor/Substrate = 1/1.48 = 0.676
Integrated D50 = Substrate D50 (2.1)(0.324) + Armor D50 (11.7)(0.676) = 8.586mm

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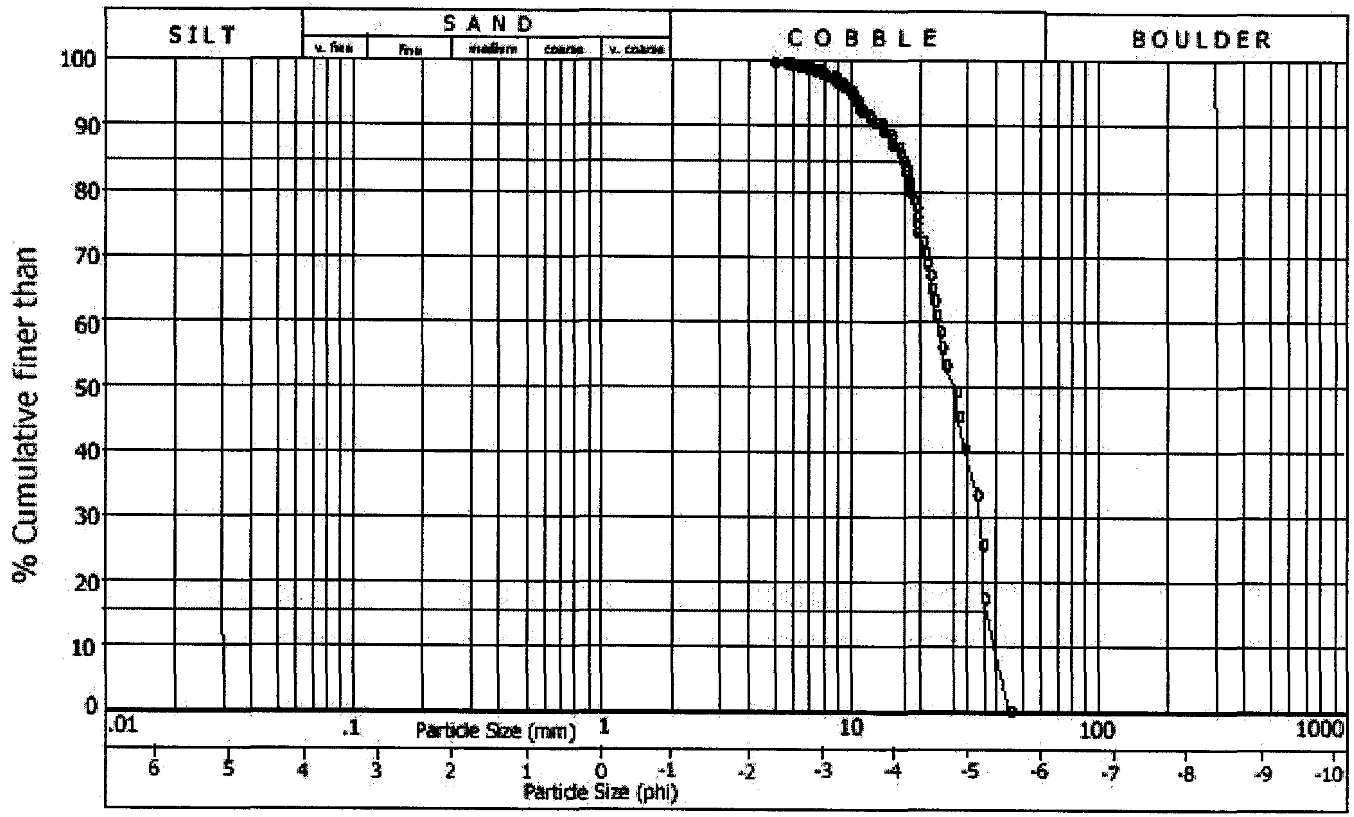
Figure S12: Sediment Sample
Irwin Creek Sand Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Irwin Creek Lateral Bar Armor

SITE SB-2-A



$D_{84(min)}$ 17 mm

D_{50} 27 mm

$D_{84(max)}$ 37 mm

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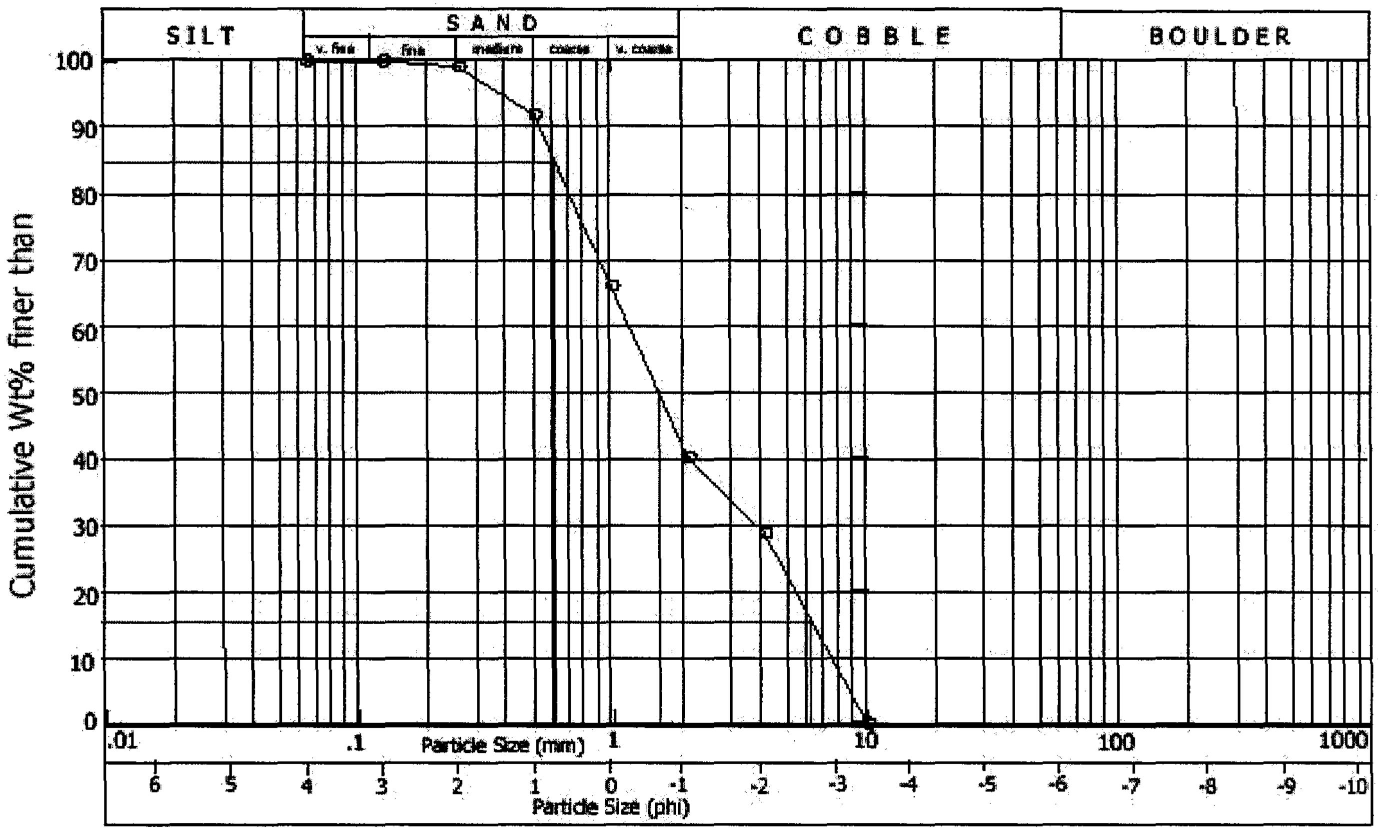
Figure S13: Sediment Sample
Irwin Creek Sand Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Irwin Creek Sandbar
SITE	SB-2-B



$D_{84(min)}$ 0.6 mm D_{50} 1.7 mm $D_{84(max)}$ 6.1 mm

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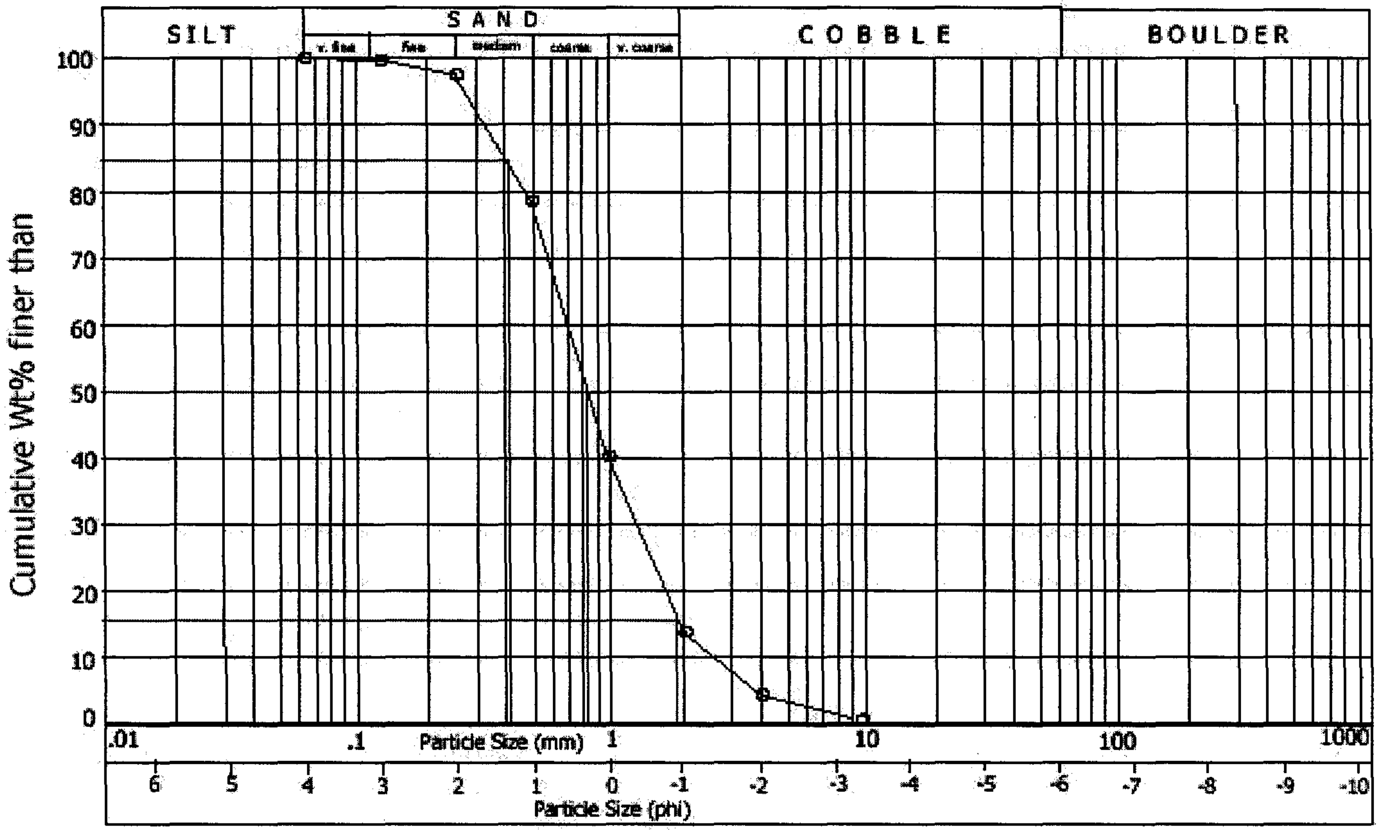
Figure S14: Sediment Sample
Irwin Creek Sand Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Irwin Creek Sandbar
SITE	SB-2-C



$D_{84(min)}$ 0.4 mm D_{50} 0.81 mm $D_{84(max)}$ 1.9 mm

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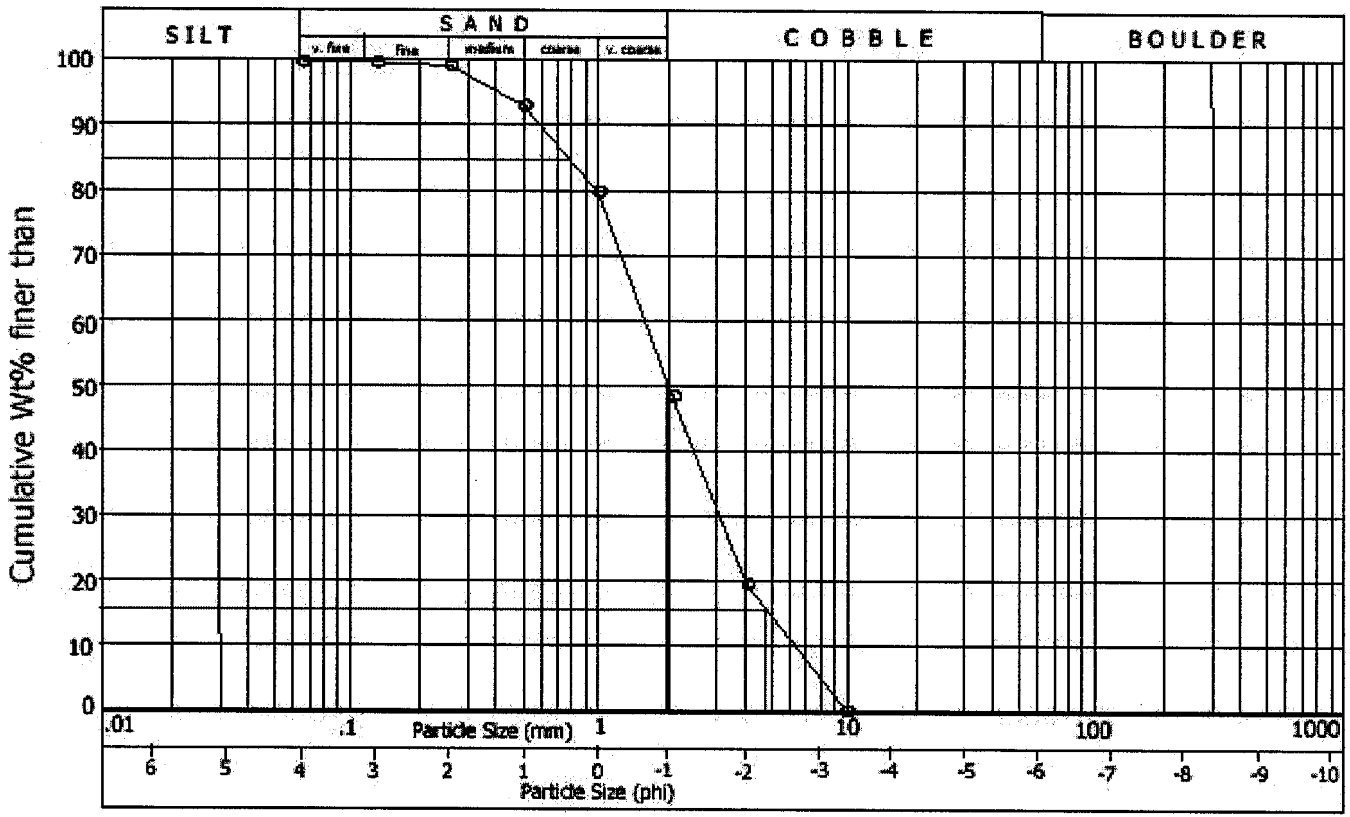
Figure S15: Sediment Sample
Irwin Creek Sand Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Irwin Creek Lateral Bar
SITE	LB-1-A



$D_{84(min)}$ 0.8 mm D_{50} 2.0 mm $D_{84(max)}$ 4.8 mm

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Habitat Assessment and Restoration Program Inc.

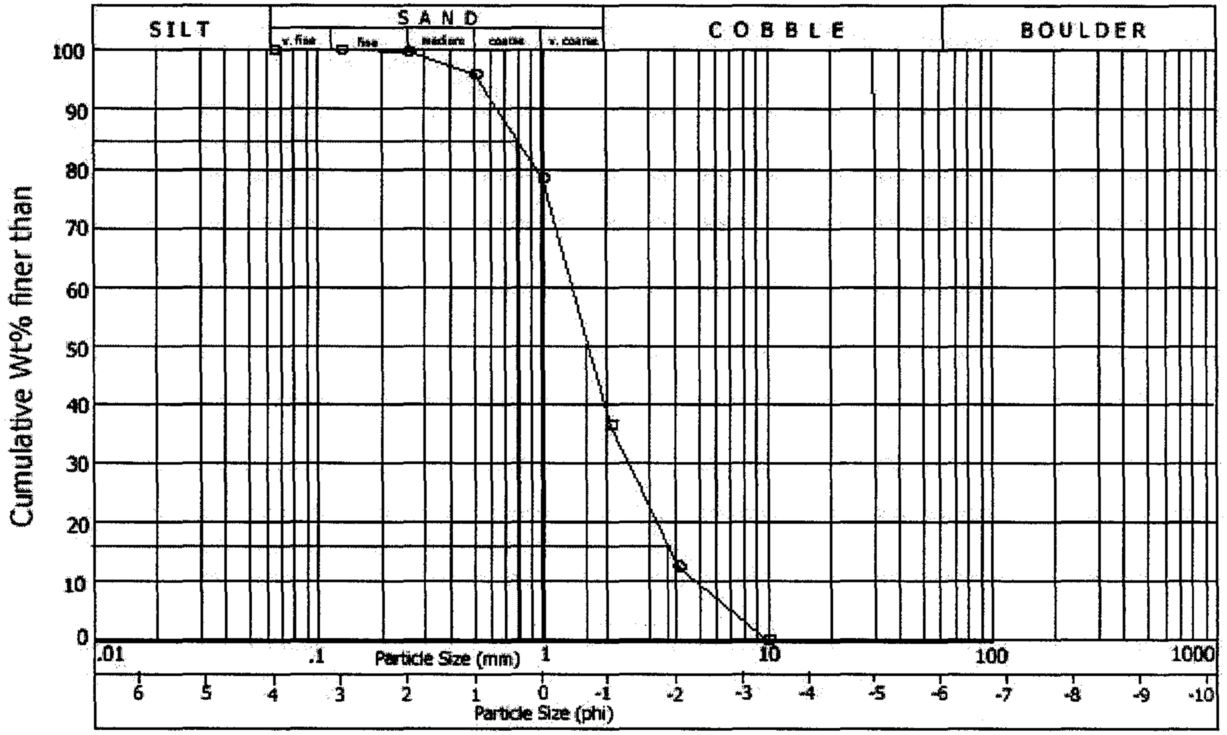
Figure S16: Sediment Sample
Irwin Creek Lateral Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Irwin Creek Lateral Bar

SITE LB-1-B



$D_{84(min)}$ 0.8 mm Substrate D_{50} 1.6 mm $D_{84(max)}$ 3.8 mm

Armor D_{50} 9.2 mm

Integrated Armor & Substrate D50 Calculation
Armor/Substrate = 1/266.67 = 0.375
Integrated D50 = Substrate D50 (1.6)(0.625) + Armor D50 (9.2)(0.375) = 4.45mm

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Figure S17: Sediment Sample Irwin Creek Lateral Bar

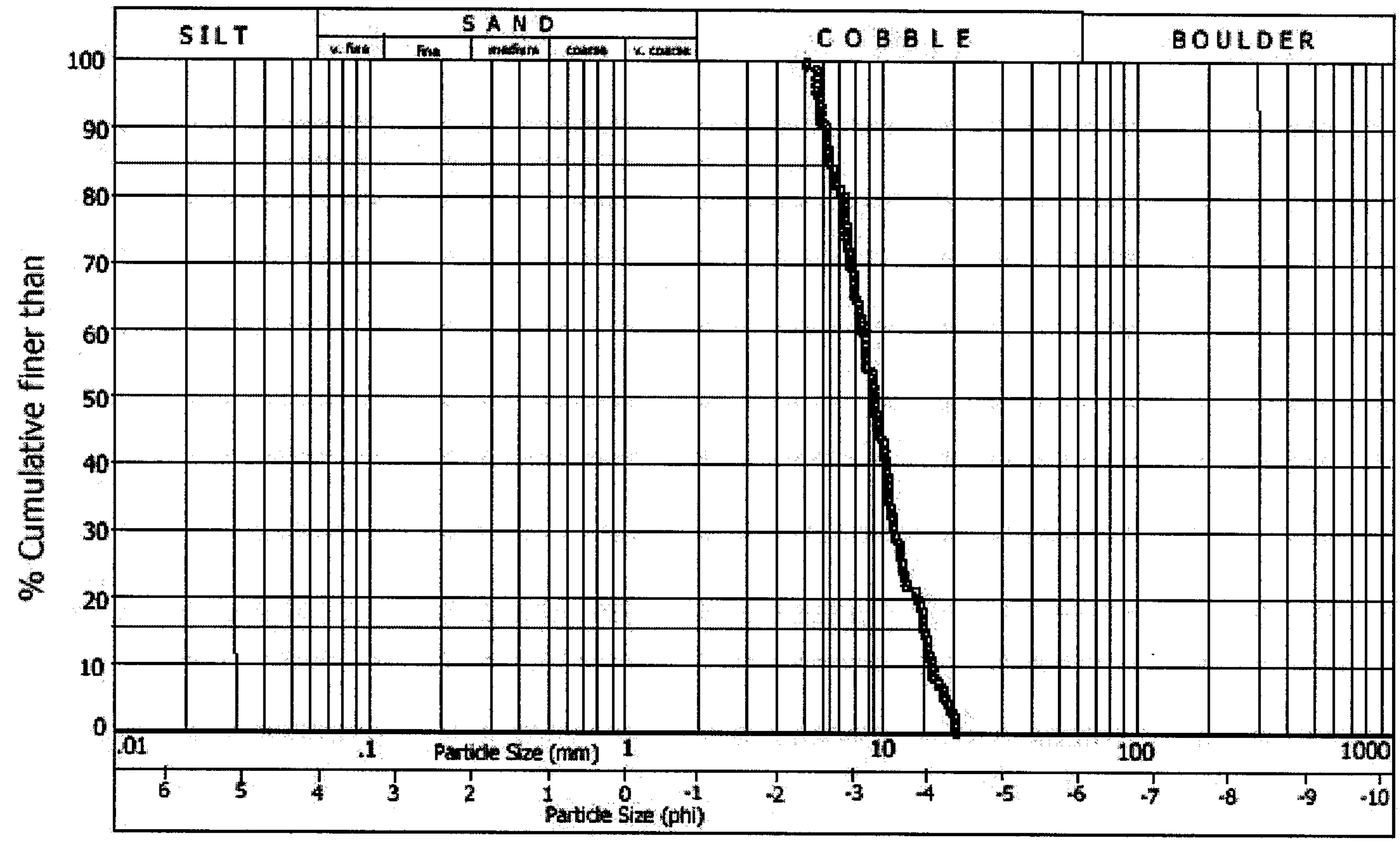
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Irwin Creek Lateral Bar Armor

SITE LB-1-B



$D_{84(min)}$ 6.2 mm D_{50} 9.2 mm $D_{84(max)}$ 15 mm

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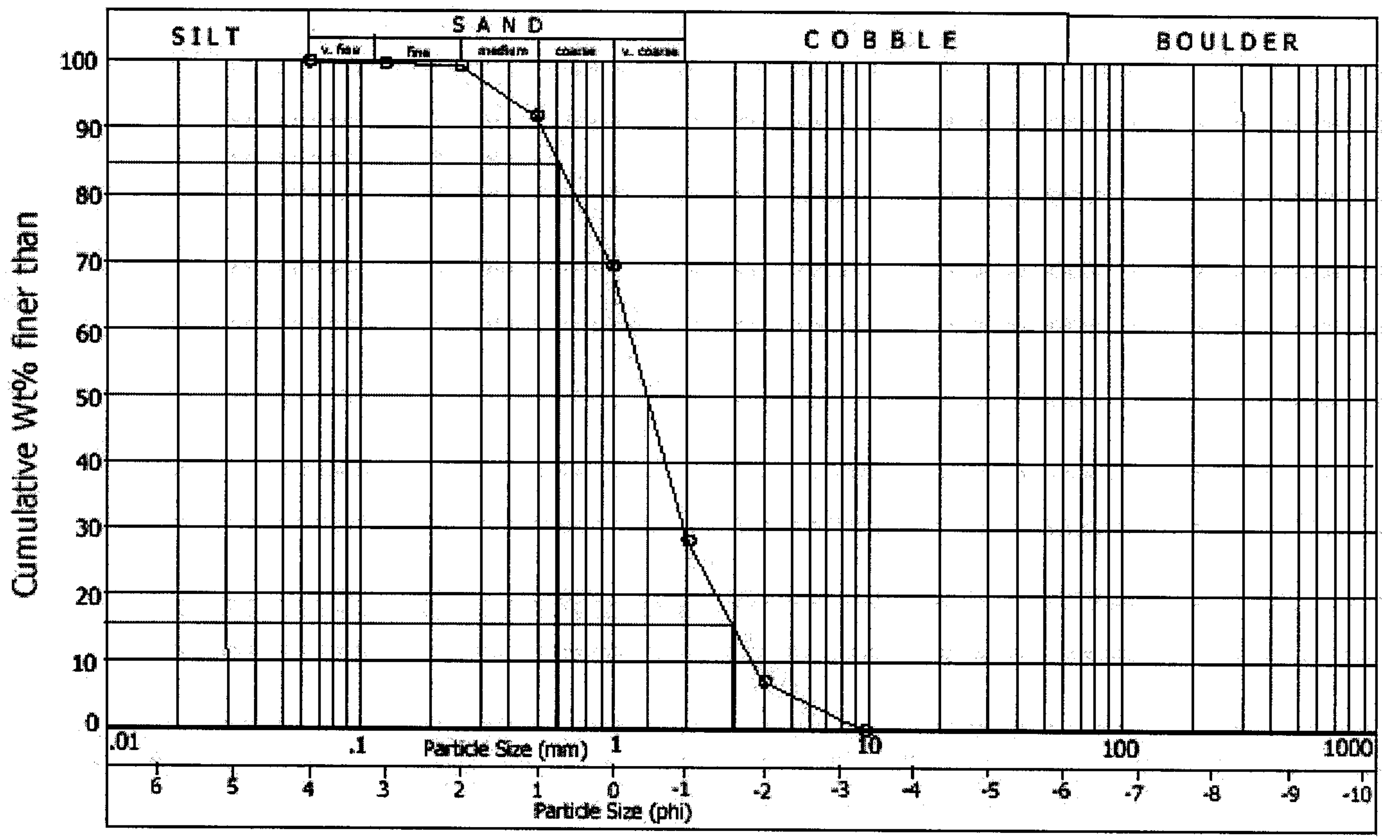
Figure S18: Sediment Sample
Irwin Creek Lateral Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Irwin Creek Lateral Bar

SITE LB-1-C



$D_{84(min)}$ 0.61 mm D_{50} 1.2 mm $D_{84(max)}$ 3.0 mm

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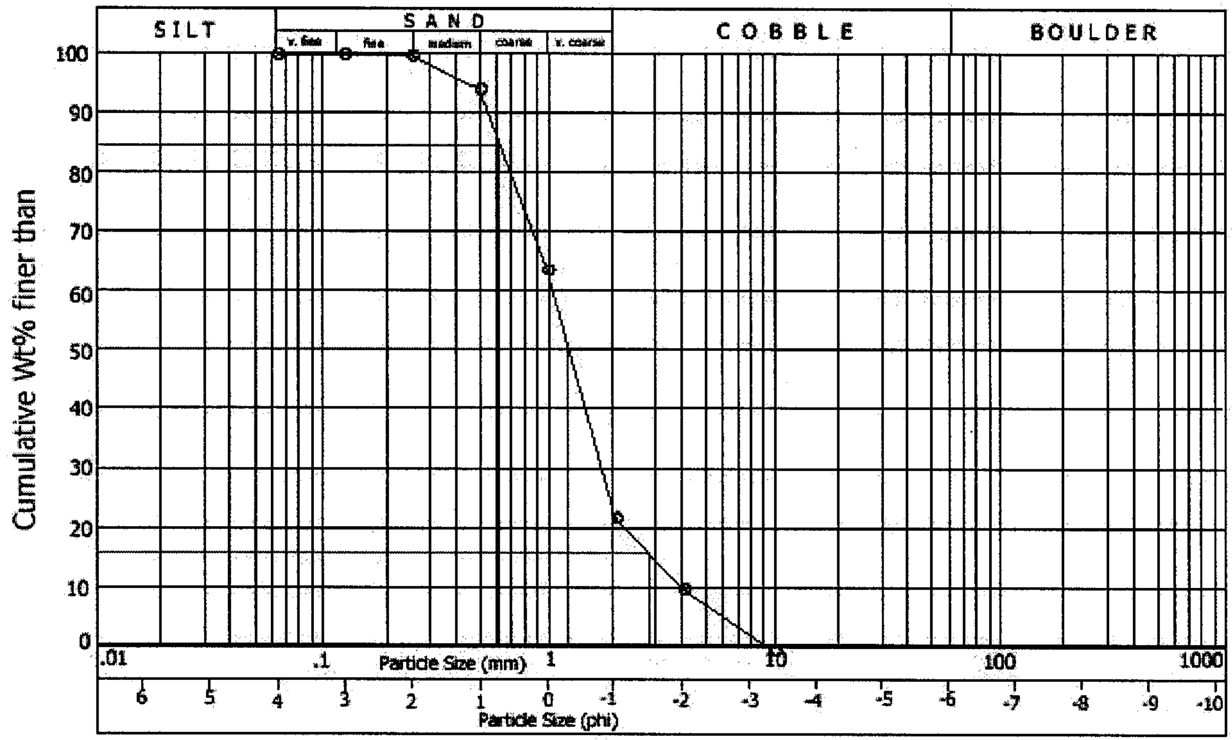
Figure S19: Sediment Sample
Irwin Creek Lateral Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Irwin Creek Lateral Bar

SITE LB-2-A



$D_{84(min)}$ 0.6 mm

Substrate D_{50} 1.1 mm

$D_{84(max)}$ 2.8 mm

Armor D_{50} 13.0 mm

Integrated Armor & Substrate D50 Calculation
Armor/Substrate = 1/1.24 = 0.806
Integrated D50 = Substrate D50 (1.1)(0.194) + Armor D50 (13.0) (0.806) = 10.697mm

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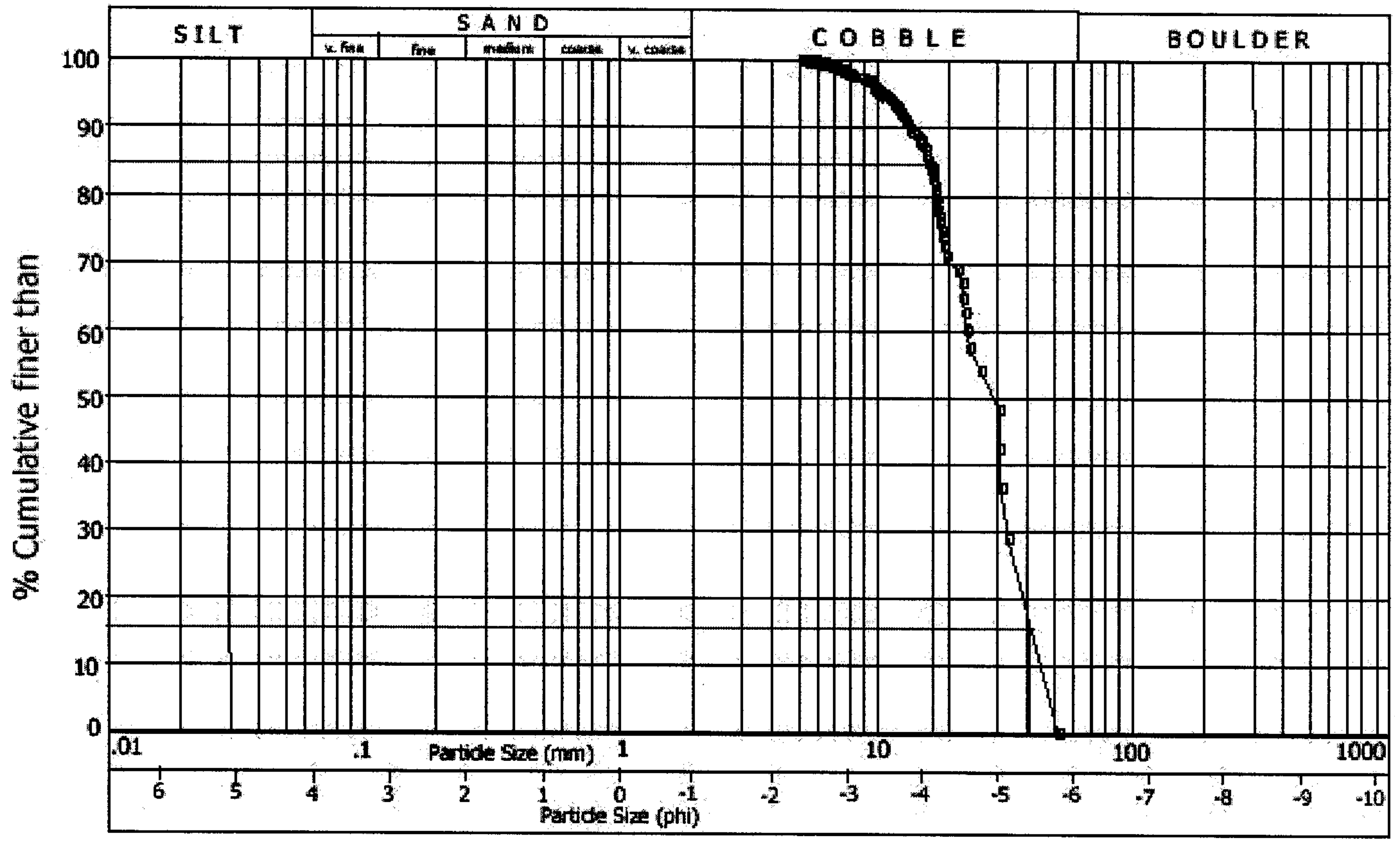
Figure S20: Sediment Sample
Irwin Creek Lateral Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Irwin Creek Lateral Bar Armor
SITE	LB-2-A



$D_{84(min)}$ 17 mm D_{50} 30 mm $D_{84(max)}$ 40 mm

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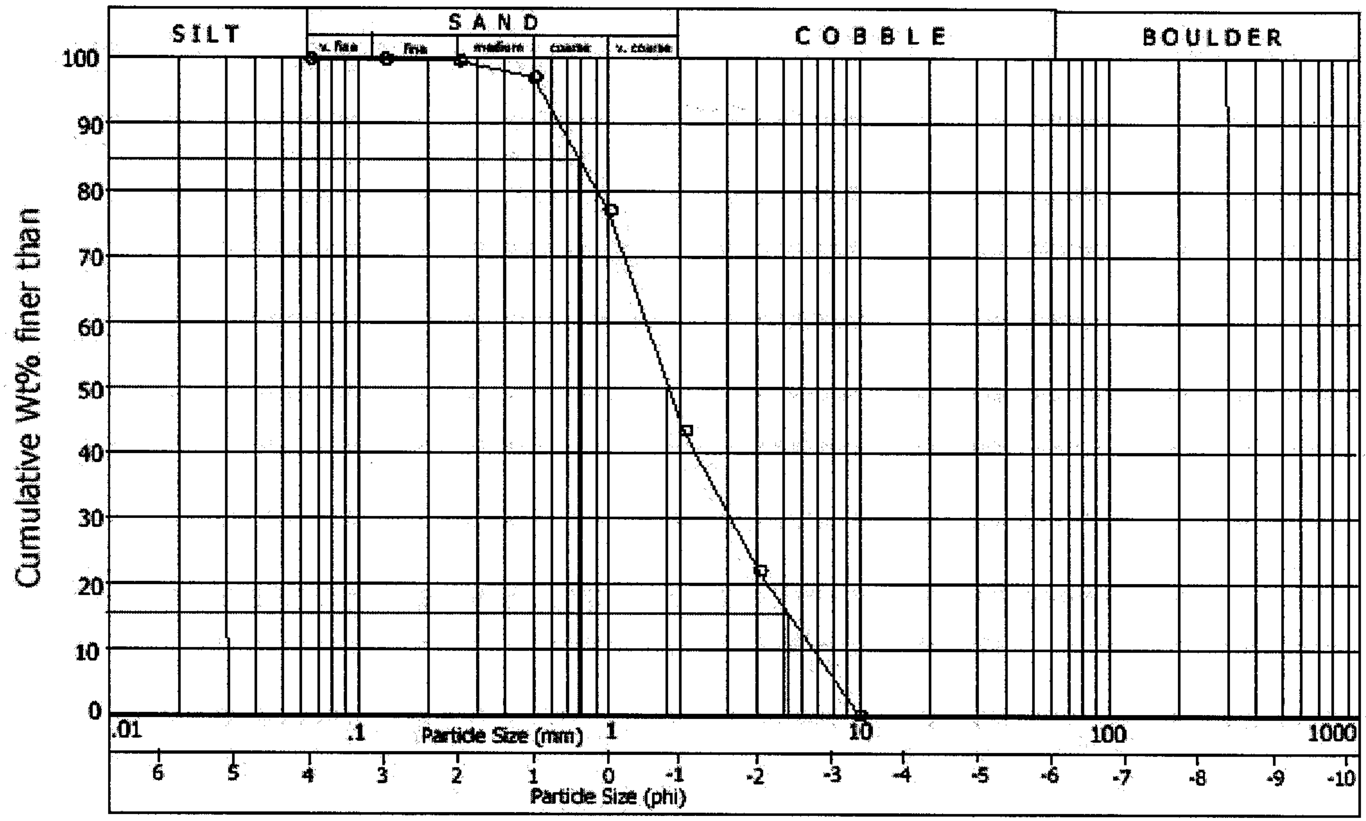
Habitat Assessment and Restoration Program Inc.

Figure S21: Sediment Sample
Irwin Creek Lateral Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Irwin Creek Lateral Bar
SITE	LB-2-B



$D_{84(min)}$ 0.79 mm D_{50} 1.8 mm $D_{84(max)}$ 5.1 mm

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Figure S22: Sediment Sample Irwin Creek Lateral Bar

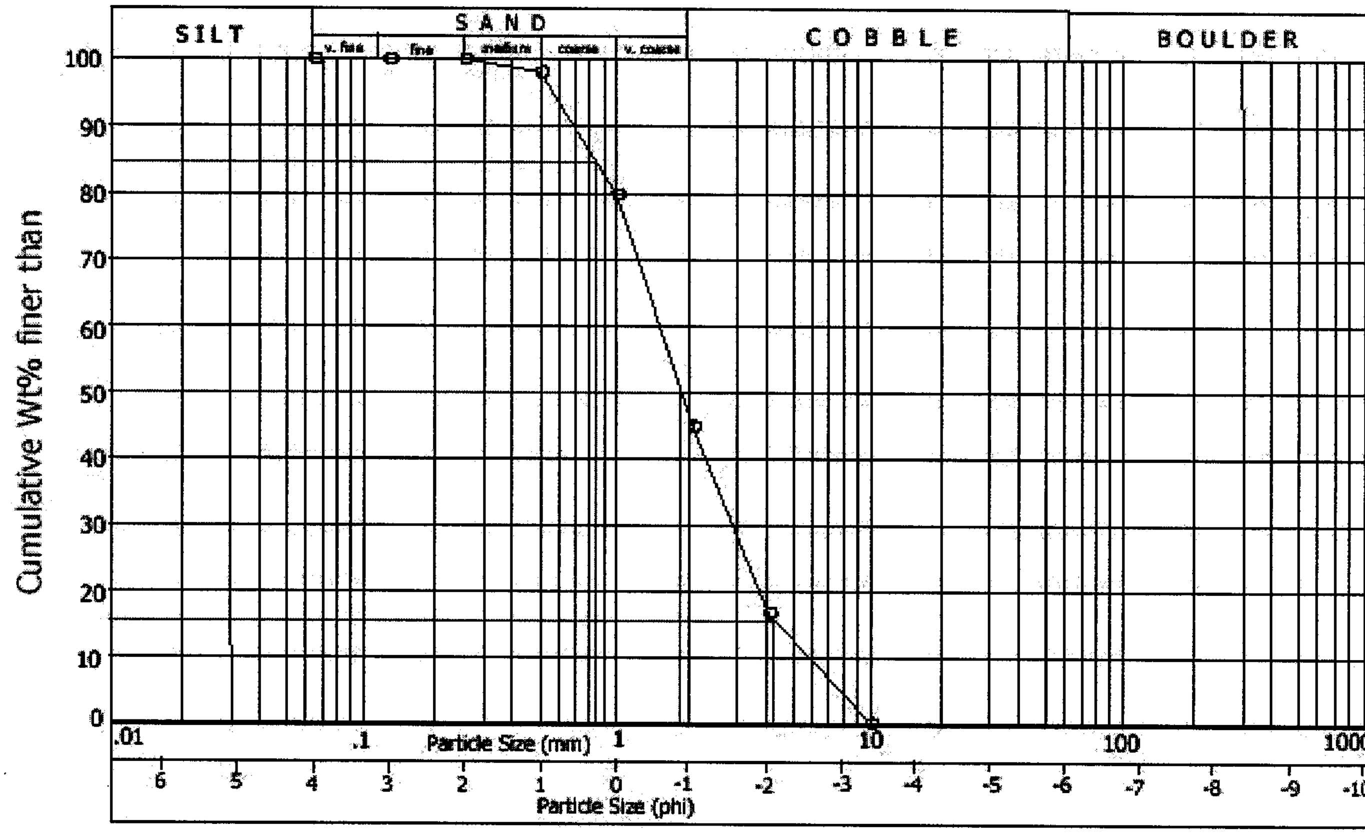
Stream Restoration Plan

Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Irwin Creek Lateral Bar
SITE	LB-2-C

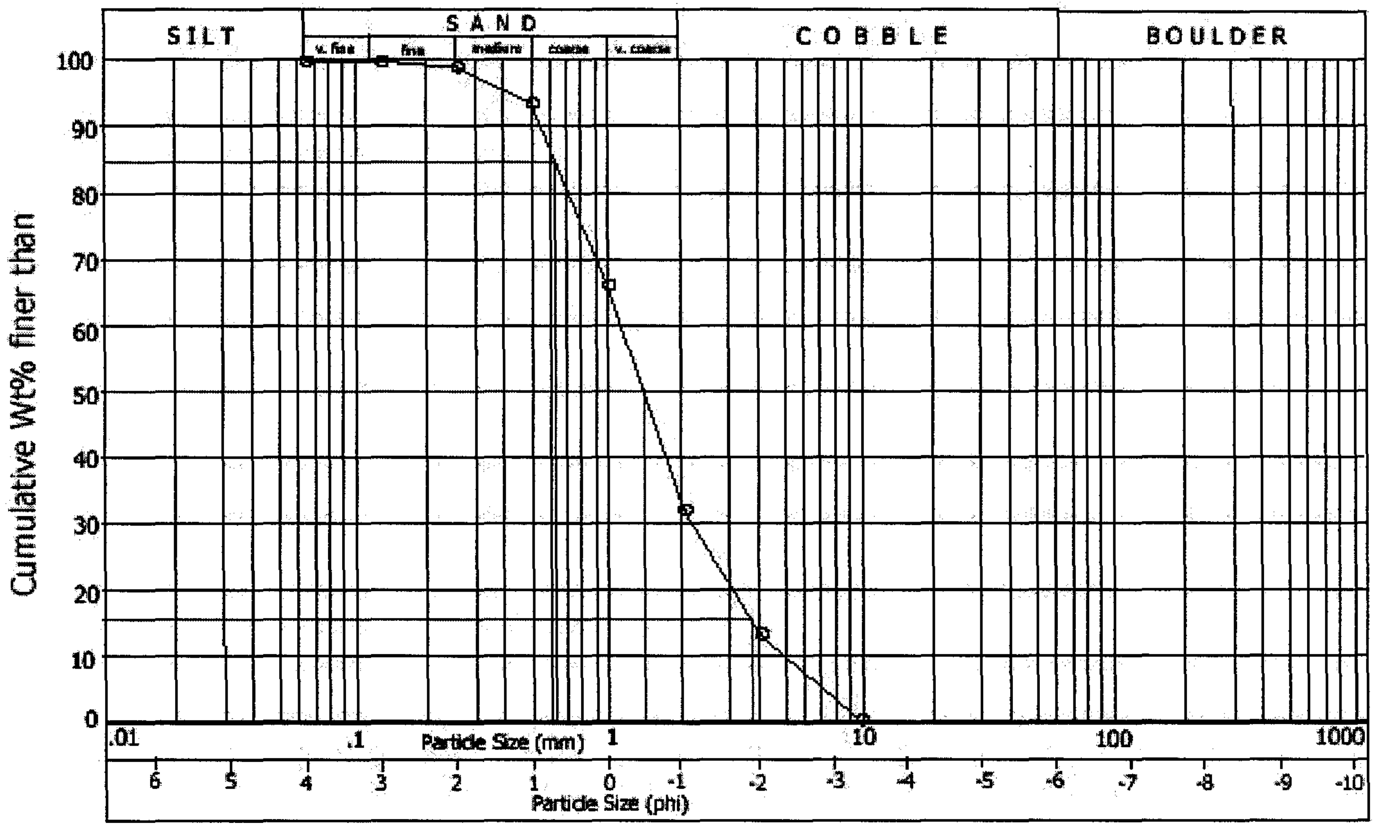


$D_{84(min)}$ 0.83 mm D_{50} 1.9 mm $D_{84(max)}$ 3.1 mm

HDR HDR Engineering, Inc. of the Carolinas	Habitat Assessment and Restoration Program Inc.	**Figure S23: Sediment Sample Irwin Creek Lateral Bar** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018

LOCALITY Leepers Creek Point Bar

SITE LC-1-A



$D_{84(min)}$ 0.62 mm D_{50} 1.2 mm $D_{84(max)}$ 3.8 mm

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Habitat Assessment and Restoration Program Inc.

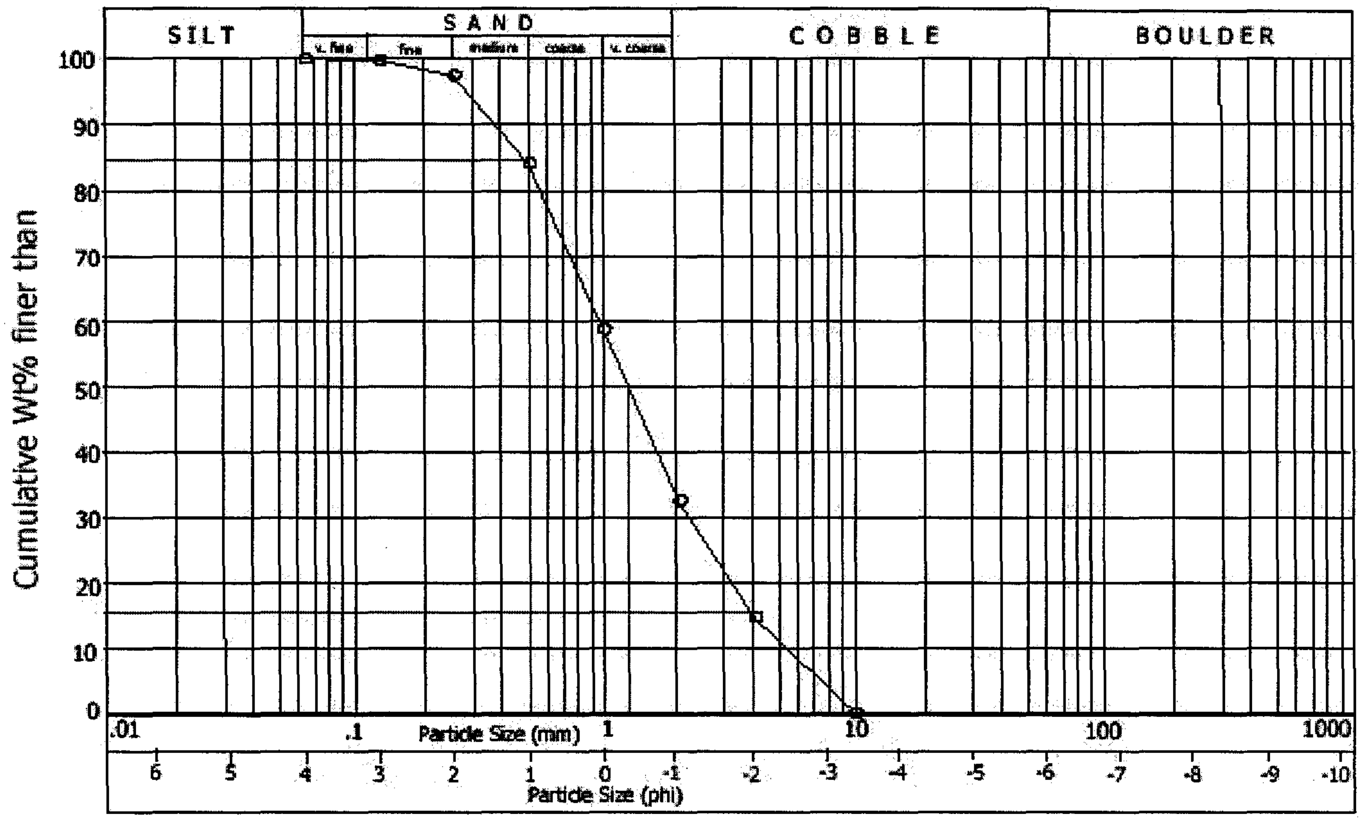
Figure S24: Sediment Sample
Leepers Creek Point Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Leepers Creek Point Bar

SITE LC-1-B



$D_{84(min)}$ 0.5 mm D_{50} 1.1 mm $D_{84(max)}$ 4.0 mm

HDR

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Figure S25: Sediment Sample Leepers Creek Point Bar

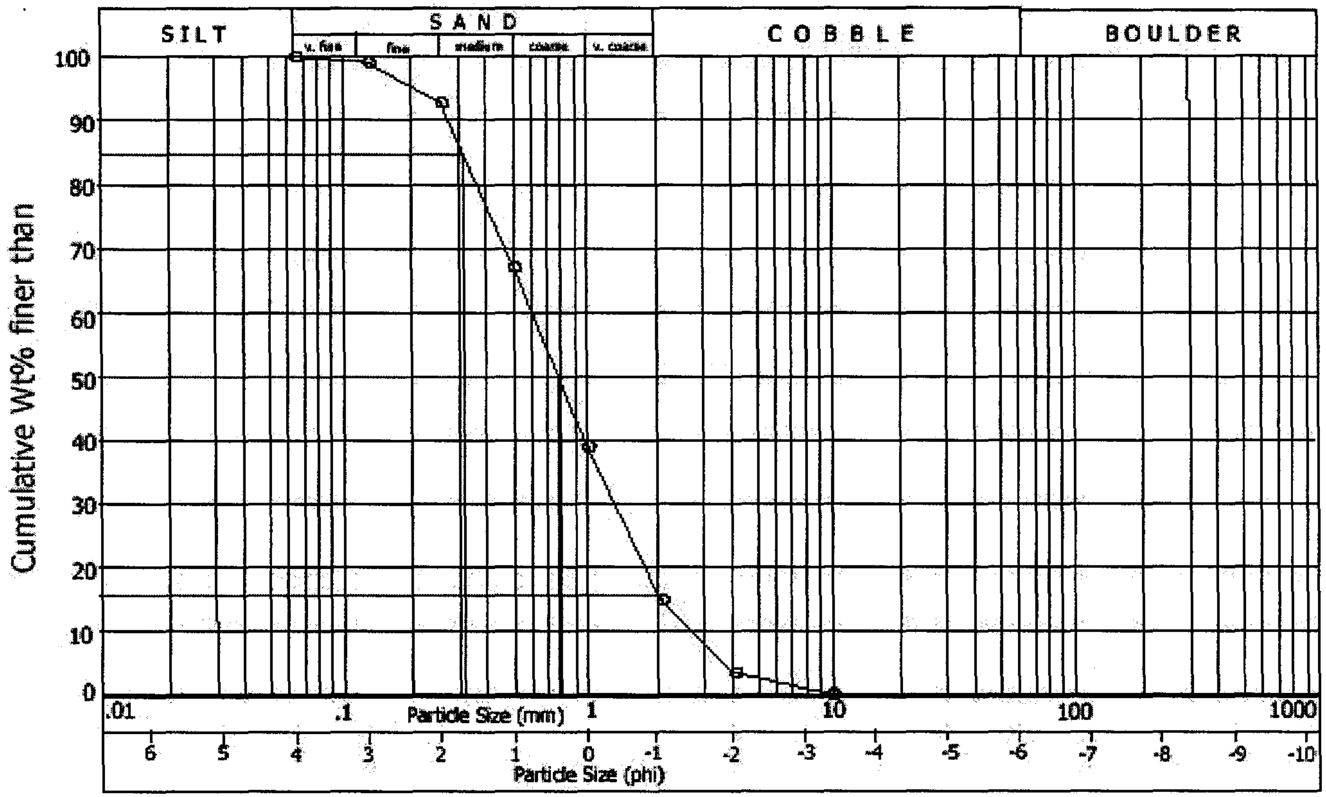
Stream Restoration Plan

Irwin Creek

October 2003

Project: 09177-021-018

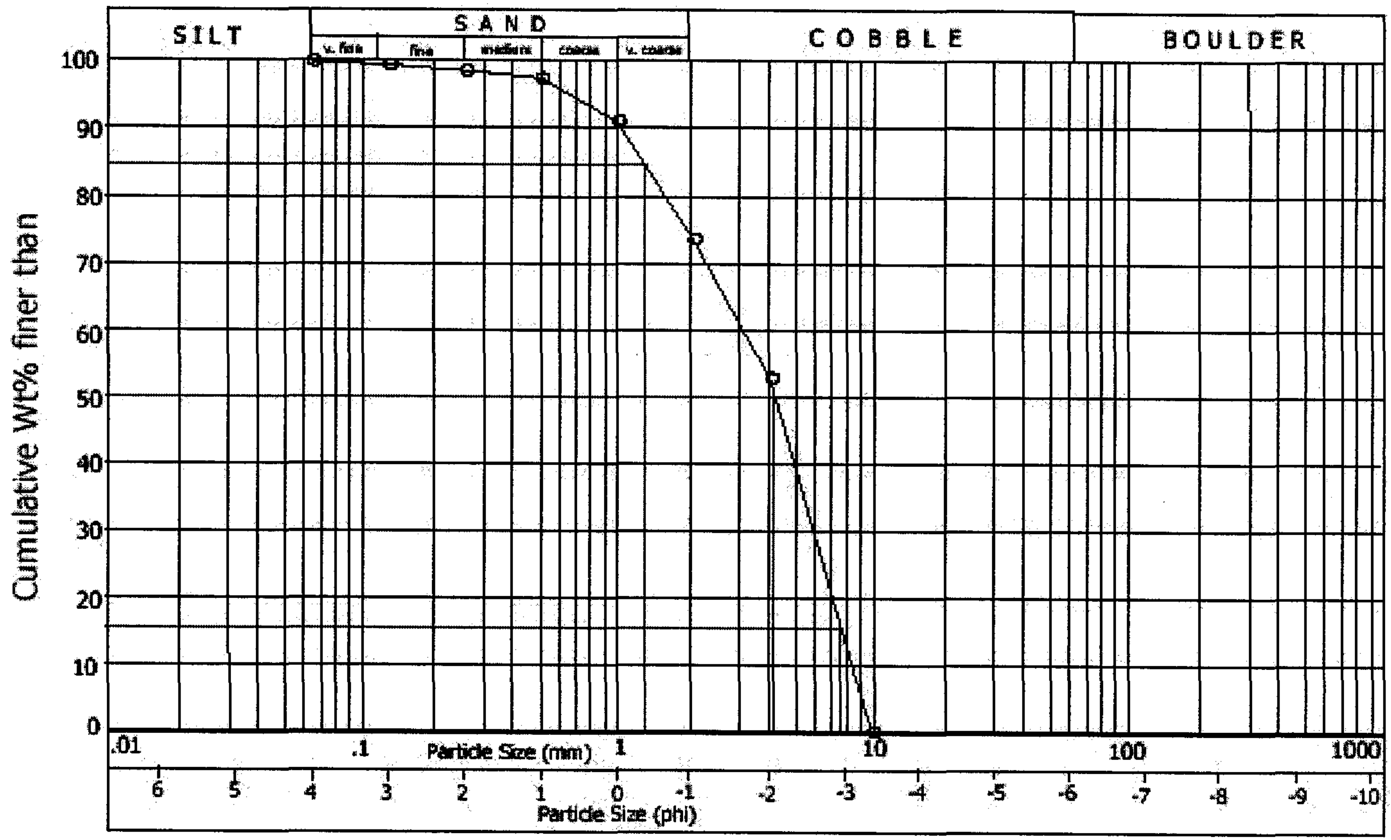
LOCALITY	Leepers Creek Point Bar
SITE	LC-1-C



$D_{84(min)}$ 0.3 mm D_{50} 0.79 mm $D_{84(max)}$ 2.0 mm

HDR HDR Engineering, Inc. of the Carolinas	HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.	**Figure S26: Sediment Sample** **Leepers Creek Point Bar** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018

LOCALITY	Leepers Creek Lateral Bar
SITE	LC-2-A



$D_{84(min)}$ 1.2 mm D_{50} 4.1 mm $D_{84(max)}$ 7.8 mm

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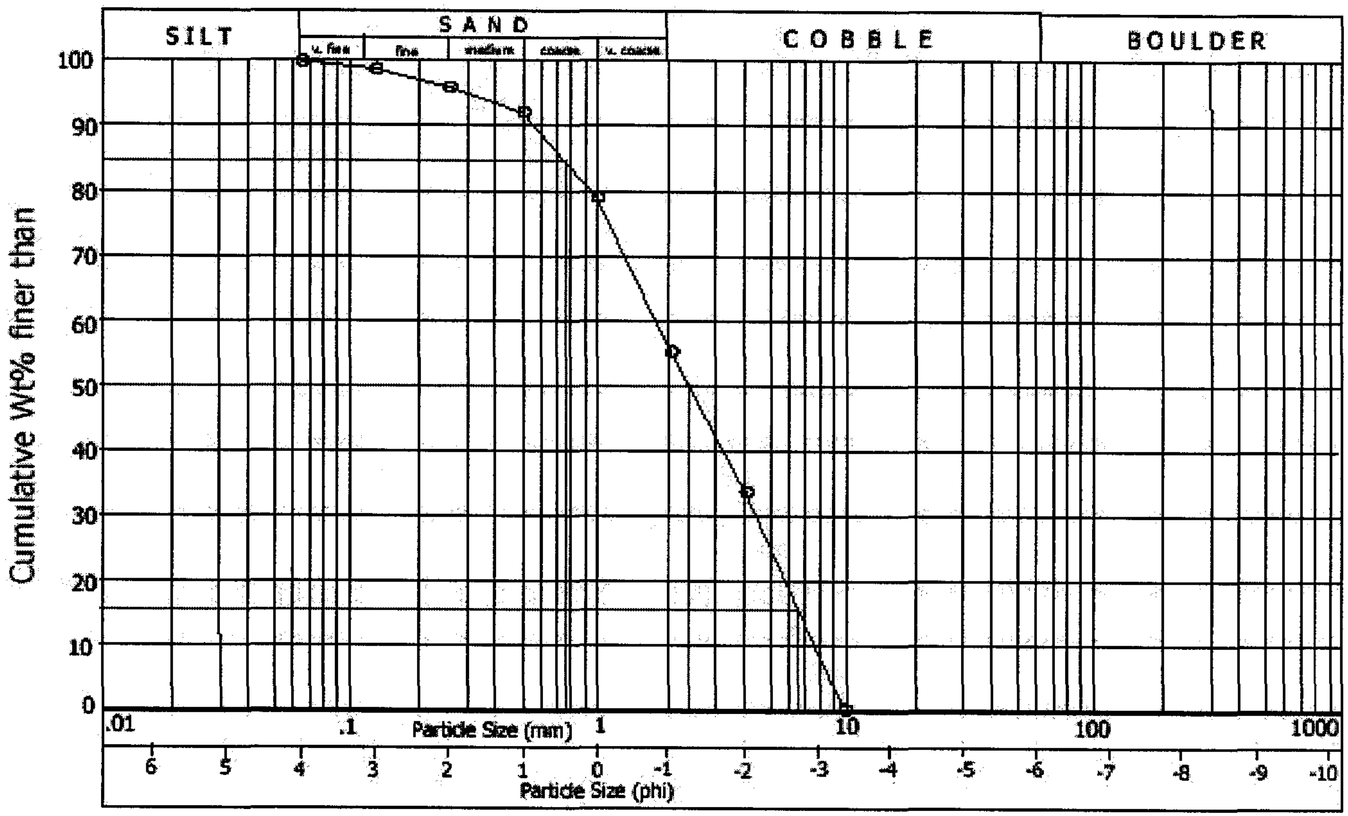
Figure S27: Sediment Sample
Leepers Creek Lateral Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Leepers Creek Lateral Bar

SITE LC-2-B



$D_{84(min)}$ 0.78 mm D_{50} 2.2 mm $D_{84(max)}$ 6.4 mm

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Habitat Assessment and Restoration Program Inc.

Figure S28: Sediment Sample Leepers Creek Lateral Bar

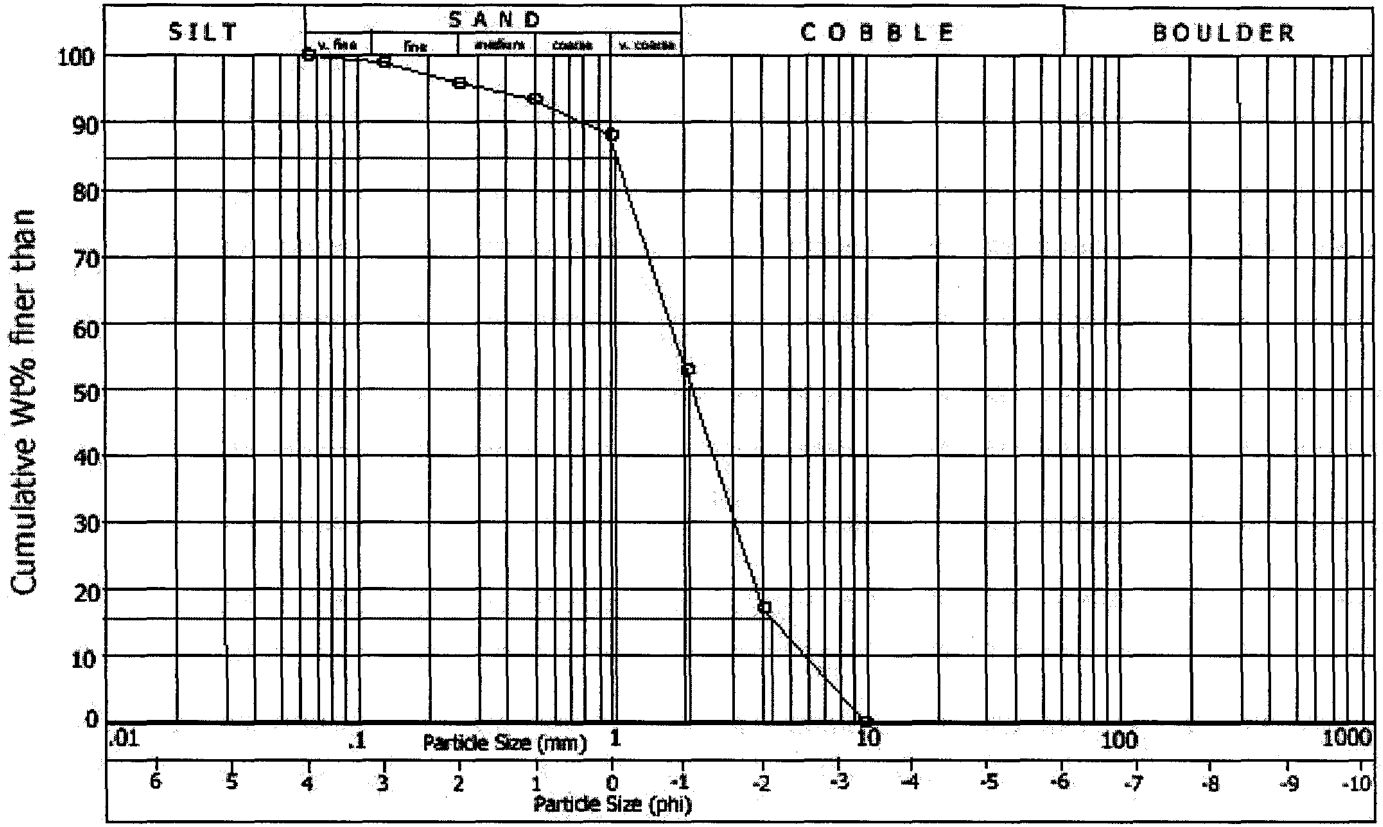
Stream Restoration Plan

Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Leepers Creek Lateral Bar
SITE	LC-2-C



$D_{84(min)}$ 1.0 mm D_{50} 2.0 mm $D_{84(max)}$ 4.1 mm

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Habitat Assessment and Restoration Program Inc.

Figure S29: Sediment Sample Leepers Creek Lateral Bar

Stream Restoration Plan

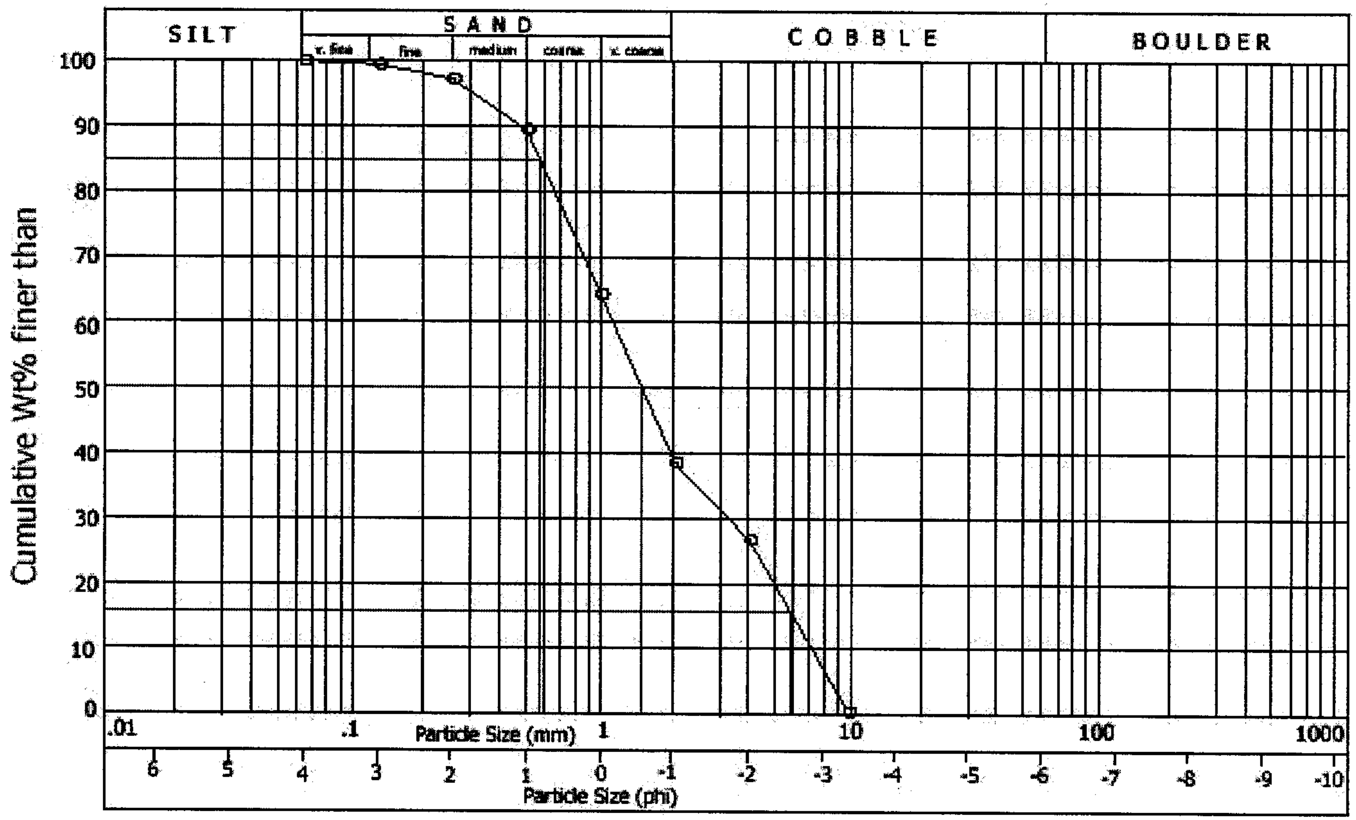
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Leepers Creek Sand Bar

SITE LC-3-A



$D_{84(min)}$ 0.58 mm D_{50} 1.3 mm $D_{84(max)}$ 5.9 mm

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Habitat Assessment and Restoration Program Inc.

Figure S30: Sediment Sample Leepers Creek Sand Bar

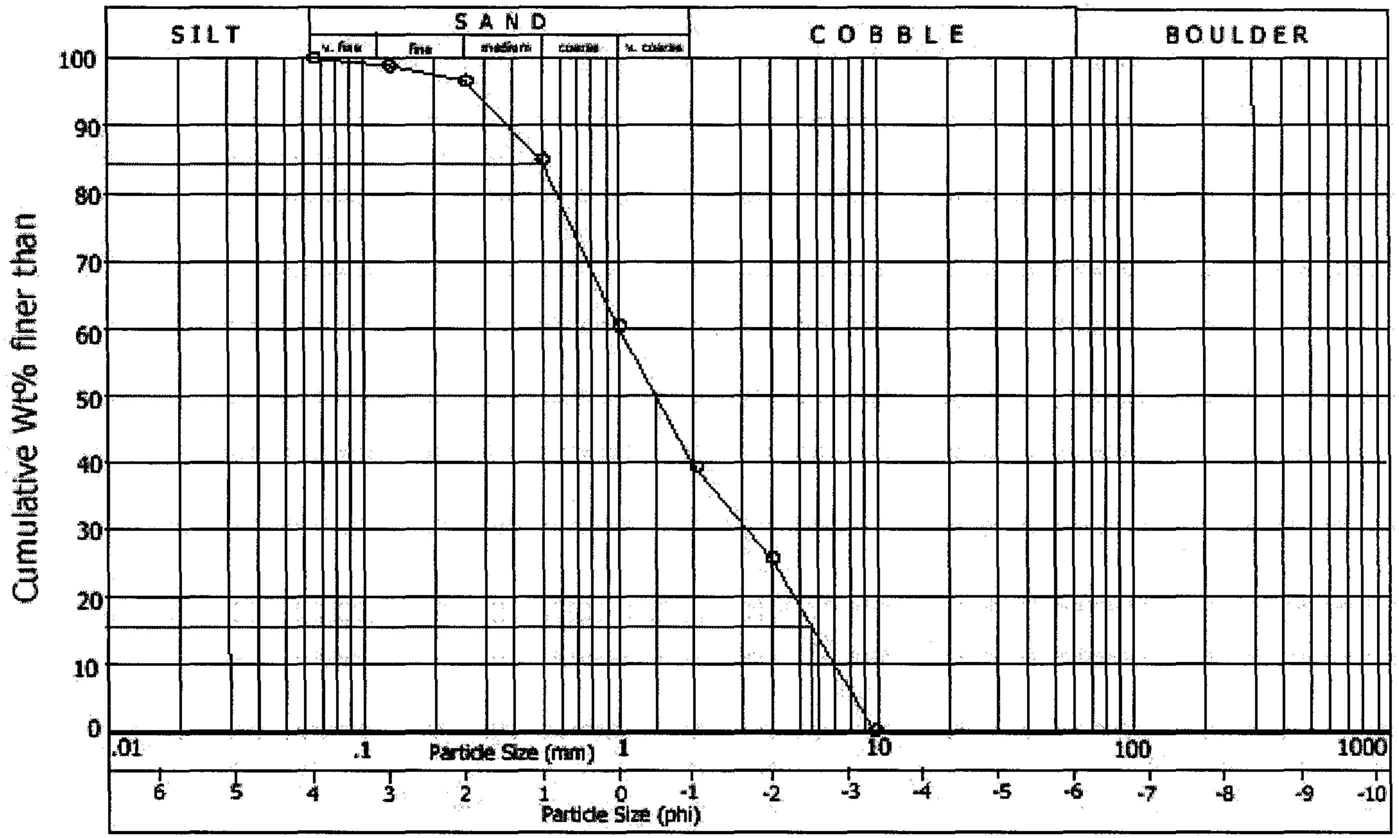
Stream Restoration Plan

Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY	Leepers Creek Sandbar
SITE	LC-3-B



$D_{84(min)}$ 0.5 mm D_{50} 1.2 mm $D_{84(max)}$ 5.7 mm

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Habitat Assessment and Restoration Program Inc.

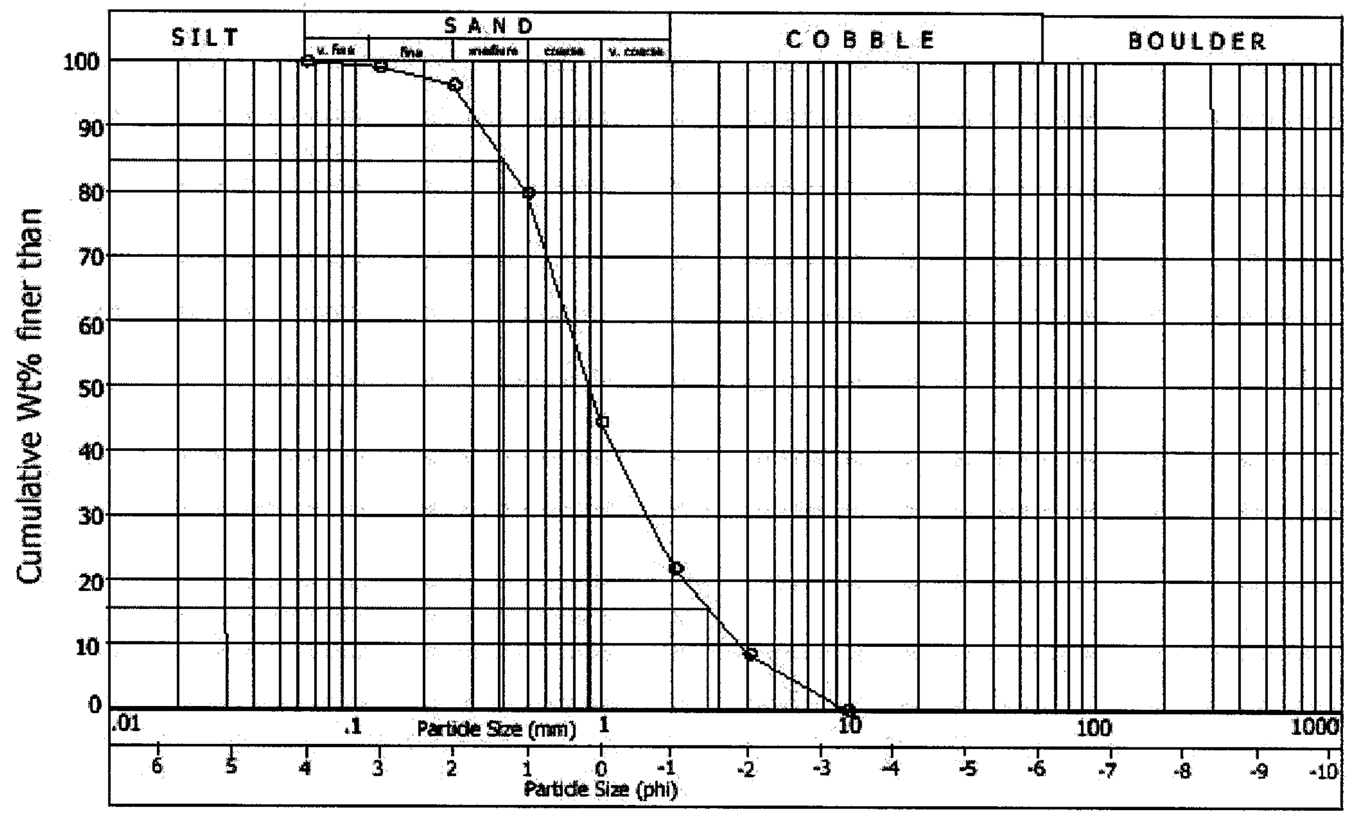
Figure S31: Sediment Sample
Leepers Creek Sand Bar
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018

LOCALITY Leepers Creek Sandbar

SITE LC-3-C



$D_{84(min)}$ 0.4 mm D_{50} 0.89 mm $D_{84(max)}$ 2.7 mm

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Figure S32: Sediment Sample Leepers Creek Sand Bar

Stream Restoration Plan

Irwin Creek

October 2003

Project: 09177-021-018

Reference Reach Data

Watershed Area of Leepers Creek

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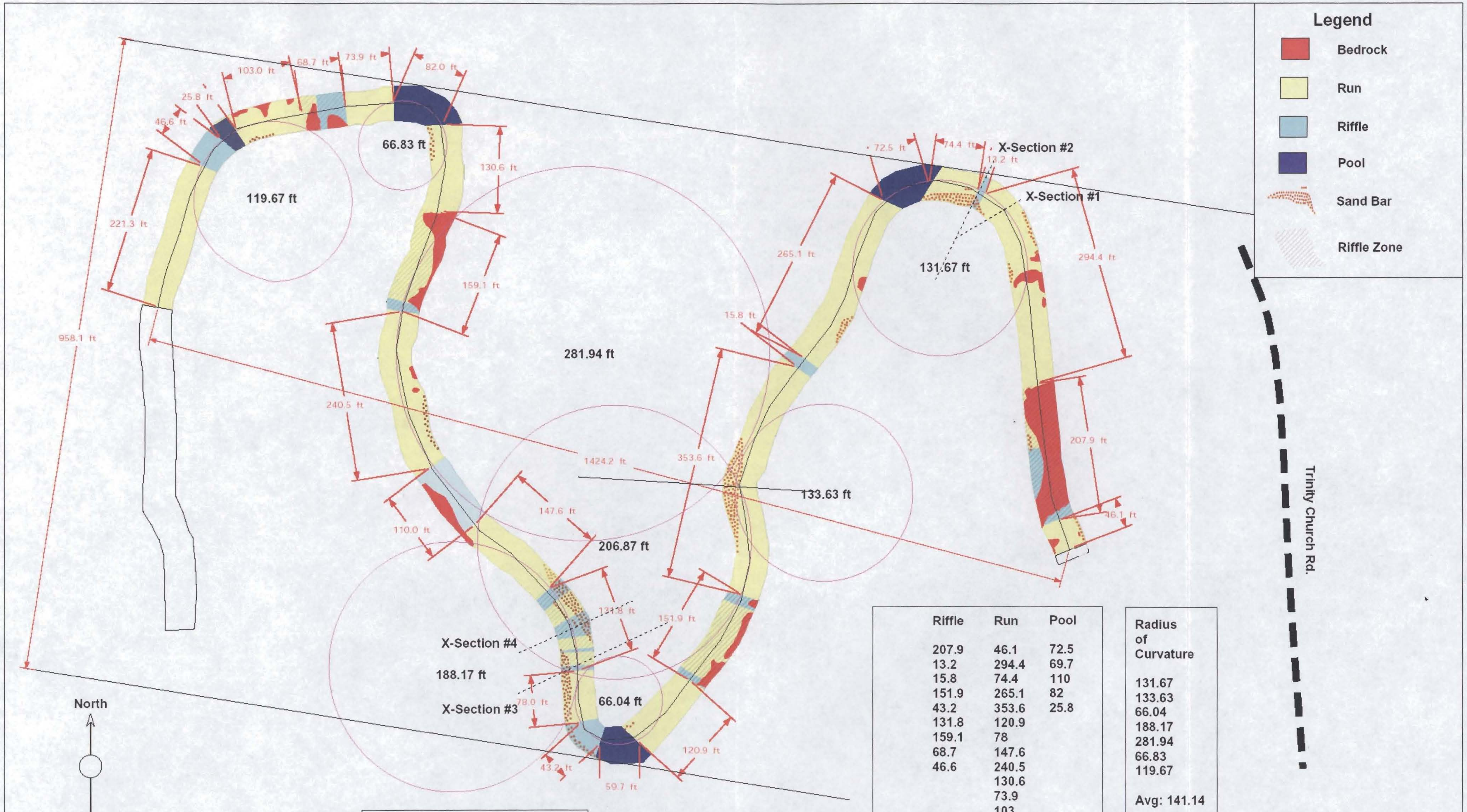
Figure L1: Leepers Watershed
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



Meander Wavelength:	
min:	336 ft
max:	700 ft
mean:	512 ft

Sinuosity = 3371.5 ft / 1424.2 ft = 2.367

	Riffle	Run	Pool
	207.9	46.1	72.5
	13.2	294.4	69.7
	15.8	74.4	110
	151.9	265.1	82
	43.2	353.6	25.8
	131.8	120.9	
	159.1	78	
	68.7	147.6	
	46.6	240.5	
		130.6	
		73.9	
		103	
		221.3	
Avg:	93.1	165.3	72
Tot:	838.2	2149.4	360

Radius of Curvature
131.67
133.63
66.04
188.17
281.94
66.83
119.67
Avg: 141.14

Meander Belt Width: 958.1 ft

Planform Map of Leepers Creek

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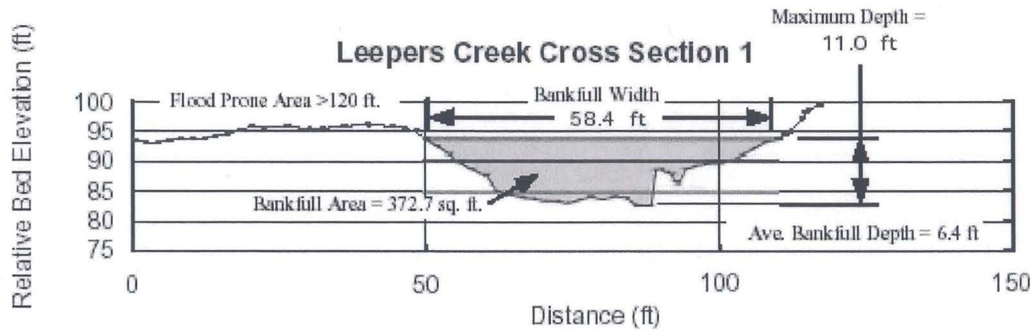
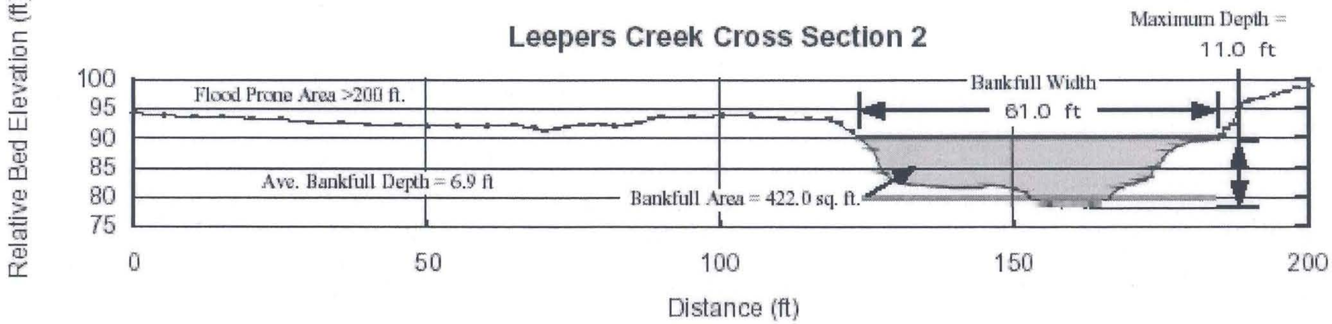
Figure L2: Planform for Leepers Creek
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018





Leepers Creek Cross Sections

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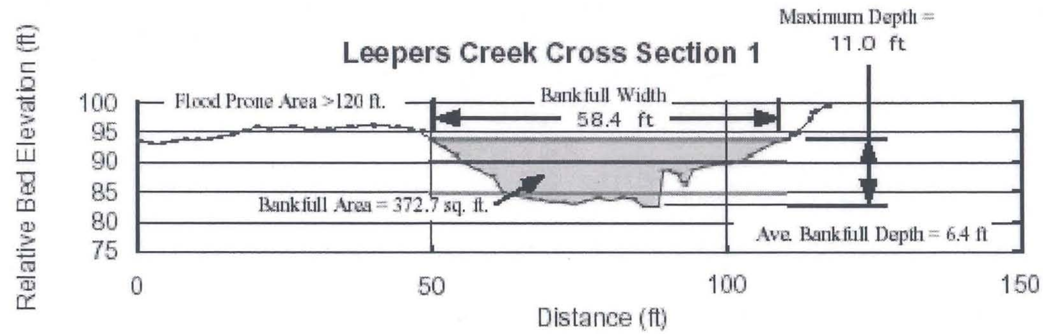
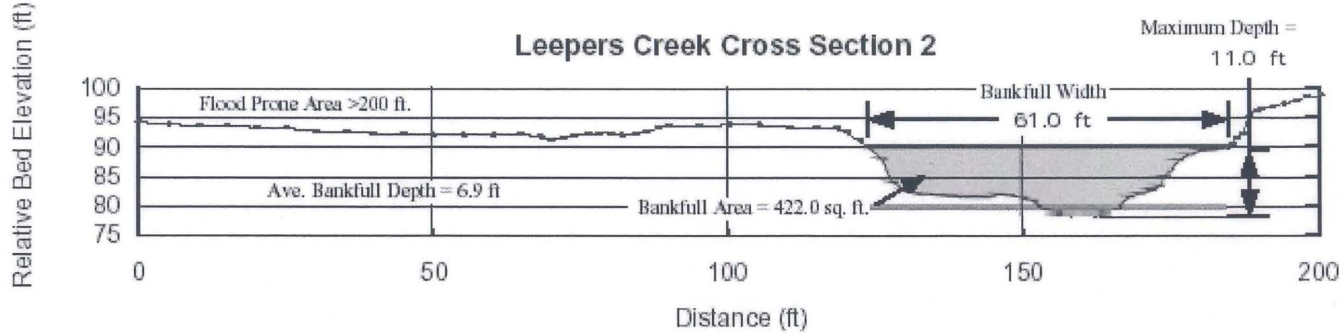
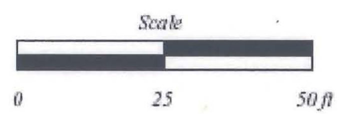
Figure L3: Cross Sections 1 & 2
Leepers Creek
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018







Leepers Creek Cross Sections

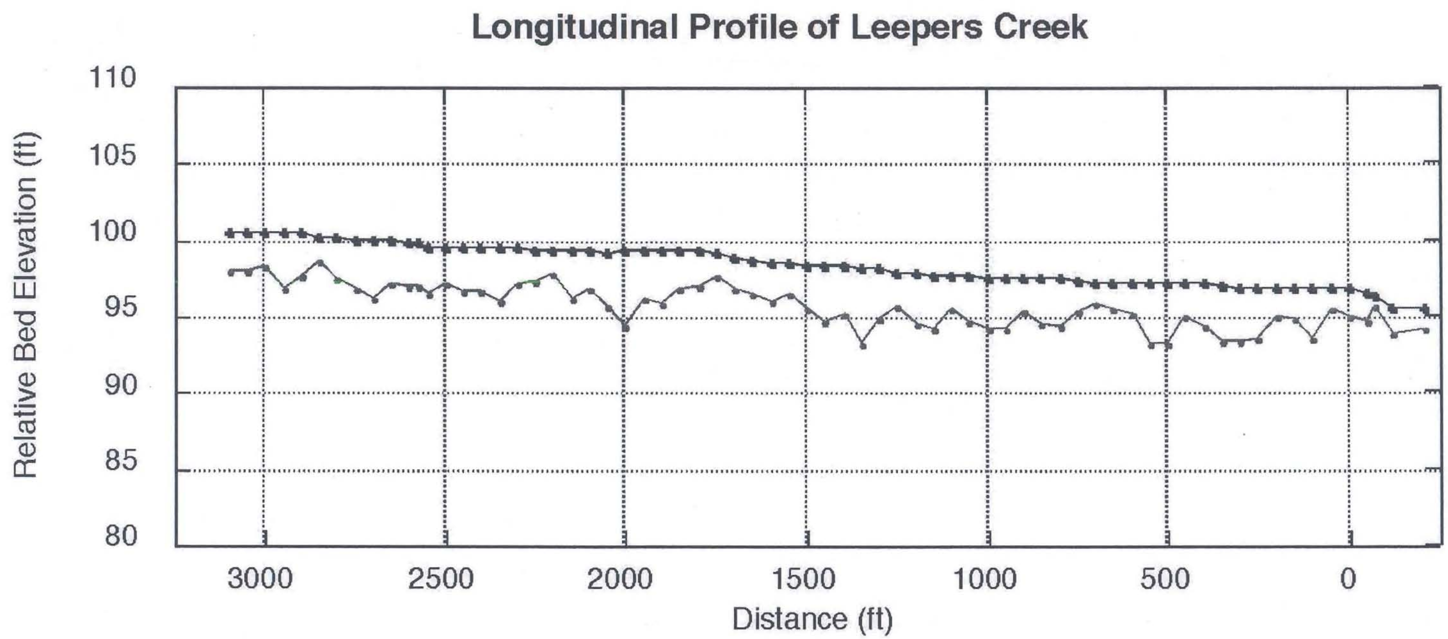
HDR Engineering, Inc.
of the Carolinas

HABITAT ASSESSMENT AND RESTORATION PROGRAM INC.

Figure L4: Cross Sections 3 & 4
Leepers Creek
Stream Restoration Plan
Irwin Creek

October 2003

Project: 09177-021-018



Longitudinal Profile of Leepers Creek

Data collected using WAAS-enable (2-3 meter) GPS and laser range finder (+/- 1 m) for horizontal positioning and Lasermark laser level (1/8" at 100') for vertical positions.

HDR HDR Engineering, Inc. of the Carolinas	Habitat Assessment and Restoration Program Inc.	**Figure L5: Longitudinal Profile Leepers Creek** Stream Restoration Plan Irwin Creek	October 2003 Project: 09177-021-018

Table L-1
Leepers Creek Reference Reach Longitudinal Profile Calculations

STA	Water Depth ft	Water Depth in	Water Elevation	Notes/Comments	Character	Distance	Riffle Slope	Run Slope	Pool Slope
TBM									
-207	1	3.5	95.46	Run	Run				
-160.9			95.46	Run	Run	46.1		0.0000	
-120	1	6	95.44	Riffle	Riffle				
-72		9	96.38	Riffle	Riffle				
-50	1	10	96.48	Riffle	Riffle				
0	1	9	96.77	Riffle	Riffle				
47			96.86	Riffle	Riffle	207.9	0.0067		
50	1	3.5	96.85	Run	Run				
100	3	4.5	96.83	Run	Run				
150	2	11.5	96.83	Run, This water level is not calculated from data	Run				
				Run	RUN				
200	1	9.25	96.83	Run	Run				
250	3	4.5	96.90	Run	Run				
300	3	6.25	96.88	Run	Run				
341.4			96.88	Run	Run	294.4		0.0001	
350	3	7.5	96.98	Riffle	Riffle				
354.6			97.13	Riffle	Riffle	13.2	0.0189		
400	2	8.5	97.13	Run	Run				
429			97.19	Run	Run	74.4		0.0008	
450	2	2.5	97.19	Pool	Pool				
			97.19	Pool	Pool				
500	3	11.5	97.19	Pool	Pool				
501.5			97.19	Pool X-SECTION #1 (526 ft)	Pool	72.5			0.0000
550	4	0.5	97.17	Run X-SECTION #2 (573.5 ft)	Run				
600	2	1	97.19	Run	Run				
650	1	8	97.19	Run	Run				
700	1	4	97.21	Run	Run				
				Run	Run	248.5		0.0006	
750	1	11.5	97.33	Riffle	Riffle				
766.6			97.33	Riffle	Riffle	16.6	0.0100		
774				Run	Run				
782.4			97.50	Run	Run				
800	3	1	97.50	Run	Run				
850	3	0.5	97.54	Run	Run				
900	2	1.75	97.54	Run	Run				
950	3	4	97.54	Run	Run				
1000	3	3.5	97.56	Run	Run				
1050	2	10.5	97.58	Run	Run				
				Run	Run				
1100	2	1.5	97.63	Run	Run				
1136			97.63	Run	Run	369.4		0.0008	
1150	3	5.5	97.69	Riffle	Riffle				
1200	3	3.5	97.79	Riffle	Riffle				
1250	2	0.5	97.79	Riffle	Riffle				
1287.9			98.17	Riffle	Riffle				
				Riffle	Riffle	164	0.0035		
1300	3	3	98.15	Run	Run				
1350	4	11	98.17	Run	Run				
1400	3	0.5	98.23	Run	Run				
1408.8			98.25	Run	Run				
1450	3	6	98.25	Run	Run				
1478.5			98.25	Run	Run	178.5		0.0006	
				Pool	Pool				
1500	2	10	98.35	Pool	Pool				
1521.7			98.42	Pool	Pool	71.5			0.0023
1550	1	10.5	98.42	Riffle	Riffle				
1590			98.42	Riffle	Riffle				
1600	2	6.5	98.46	Riffle	Riffle	50	0.0038		
1650	2	1	98.65	Run	Run				
1700	1	11.5	98.81	Run	Run	100		0.0035	
1731.5			99.19	Riffle	Riffle				
1750	1	6.5	99.21	Riffle	Riffle				
1800	2	4.25	99.27	Riffle	Riffle				
1850	2	5.25	99.33	RiffleX-SECTION #3 (1823 ft)	Riffle	150	0.0035		
1879.1			99.35	RunX-SECTION #4 (1878 ft)	Run				
				Run	Run				
1900	3	5.5	99.35	Run	Run				
1950	3	2	99.35	Run	Run				
1989.1			99.35	Run	Run				
2000	5	1	99.38	Run	Run	150		0.0003	
				Pool	Pool				
2050	3	5.75	99.15	Pool	Pool				
2100	2	4.5	99.23	Pool	Pool	100			-0.0015
2150	3	1.5	99.27	Run	Run				
2200	1	6.25	99.31	Run	Run				
2229.6			99.33	Run	Run				
2250	2	1	99.35	Run	Run				
2300	2	2	99.40	Run	Run				
2350	3	5	99.44	Run	Run	250		0.0008	
2388.7			99.46	Riffle	Riffle				
			99.79	Riffle	Riffle				
2400	2	10.25	99.46	Riffle	Riffle				
2450	2	8.75	99.44	Riffle	Riffle				
2500	2	4.5	99.48	Riffle	Riffle				
2519.3			99.50	Riffle, bedrock	Riffle	169.3	0.0011		
2550	2	11.5	99.50		Run				
2575	2	9	99.73		Run				
2600	2	9.75	99.83		Run				
2601.3			99.83		Run				
2650	2	9.5	99.90		Run	130.7		0.0030	
2675.2			99.90		Pool				
2700	3	8.25	99.90		Pool				
2743.9			99.90		Pool	93.9			0.0000
			100.21		Run				
2750	3	0.75	99.90		Run				
2800	2	7	100.06		Run				
2846.9			100.19		Run				
2850	1	6	100.19		Run	106.1		0.0027	
2872.7			100.19		Riffle				
2900	2	10	100.46		Riffle	50	0.0098		
2919.3			100.46		Run				
2950	3	7.5	100.42		Run				
3000	2	2	100.46		Run	100		0.0000	
3025	2	6	100.46		Pool	25			0.0000
3050			100.46		Riffle				
3070	2	5	100.46		Riffle	45	0.0000		
3100			100.46		Run				
3120			100.46		Run				
3140.6					Run			0.0000	
						Minimum	0.0011	0.0003	-0.0015
						Maximum	0.0189	0.0035	0.0023
						Points	9.0000	12.0000	5.0000
						Mean	0.0064	0.0011	0.0002

Table L-2 Sediment Size Information Leepers Creek, Lincoln County			
GRAIN SIZE DATA BARS (Meander point bars & lateral bars on runs			
Sample/Station	**D16** (mm)	**D50** (mm)	**D84** (mm)
LC-1-A	0.62	1.20	3.80
LC-1-B	0.50	1.10	4.00
LC-1-C	0.30	0.79	2.00
LC-1 Avg	0.47	1.03	3.27
LC-2-A	1.20	4.10	7.80
LC-2-B	0.78	2.20	6.40
LC-2-C	1.00	2.00	4.10
LC-2 Avg	0.99	2.77	6.10
LC-3-A	0.58	1.30	5.90
LC-3-B	0.50	1.20	5.70
LC-3-C	0.40	0.89	2.70
LC-3 Avg	0.49	1.13	4.77
Average for all Bars	0.65	1.64	4.71
GRAIN SIZE DATA RIFFLES (Armour)			
Sample/Station	**D16** (mm)	**D50** (mm)	**D84** (mm)
Riffle 1	6.00	16.00	29.00
Riffle 2	8.50	17.00	28.00
Riffle 3	5.10	11.00	22.00
Riffle 4	71.00	100.00	260.00
Riffle 5	77.00	110.00	180.00
Average	33.52	50.80	103.80
INTEGRATED BAR & RIFFLE GRAIN SIZE DATA			
	D16 (mm)	**D50** (mm)	**D84** (mm)
Bulk Stream Bed Avg	8.88	13.95	29.52

*Bulk Stream Bed Average weighted according to Irwin Creek total riffle coverage percentage = 25.04%

Photo 1

Looking upstream from Leepers Creek cross-section two, a lower berm feature can be seen in the pro - file of the point bar along the inner bank of the meander.

Photo 2

A view of the right bank at Leepers Creek cross-section one. The creek flows around a meander from the top right and off to the left. A lower berm exists halfway up the bank here, as indicated by the topography.

Photo 3

An image downstream of Leepers Creek cross-section one. This image shows typical creek condi - tions for the reference reach.

Photo 4

A view of the left bank at Leepers Creek cross-section one. The creek flows around a meander from the left across the image and to the right. Here is an example of a typical bedrock outcrop, a feature which characterizes much of this stream.

Photo 5

Looking upstream at Leepers Creek from the old Mariposa Rd. bridge.

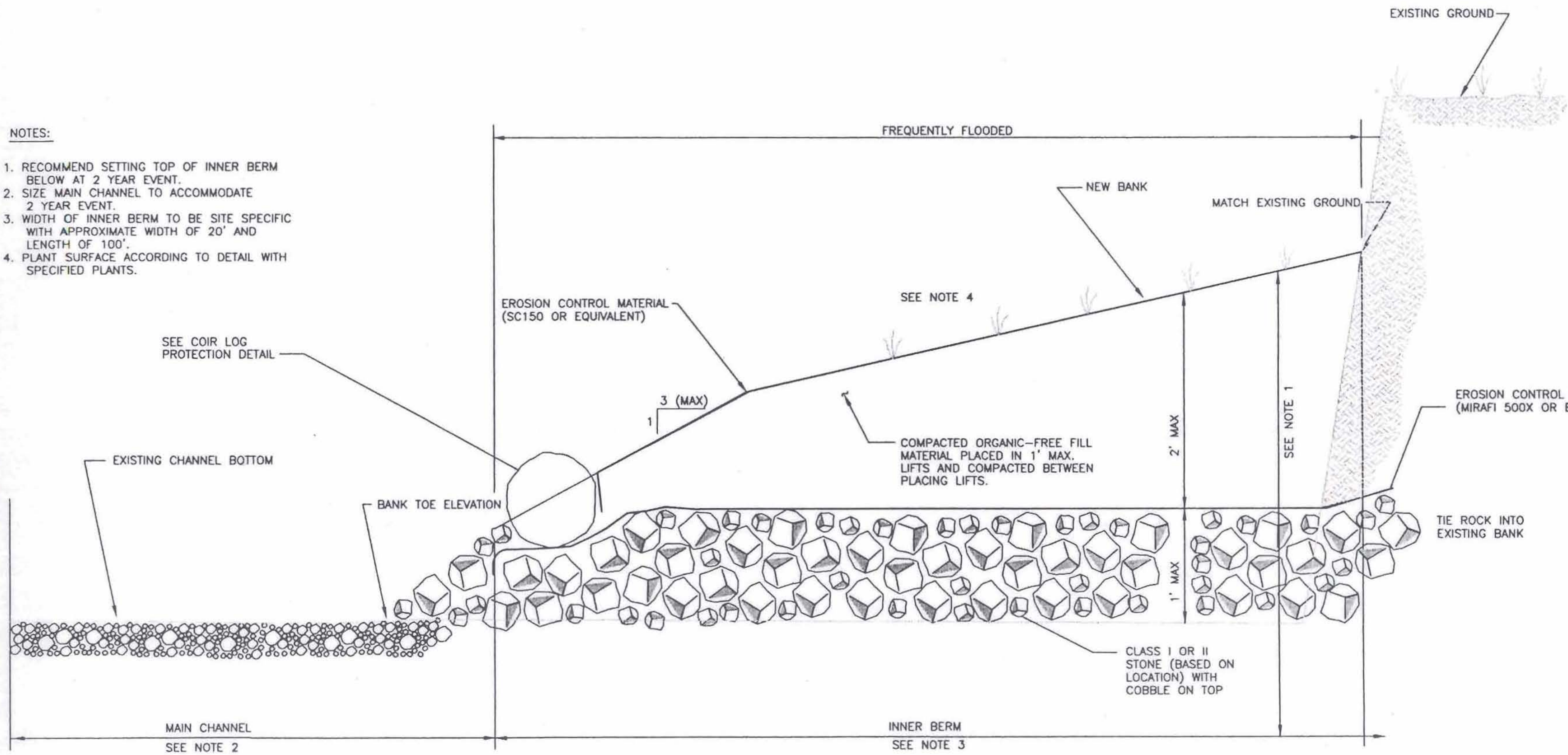
Photo 6

A view of Leepers Creek downstream of the old Mariposa Rd. bridge. This section of Leepers is down - stream of the reference reach and thus, has a much larger watershed. This riffle zone was found to have a mean D50 of 28 cm.

Standard Details

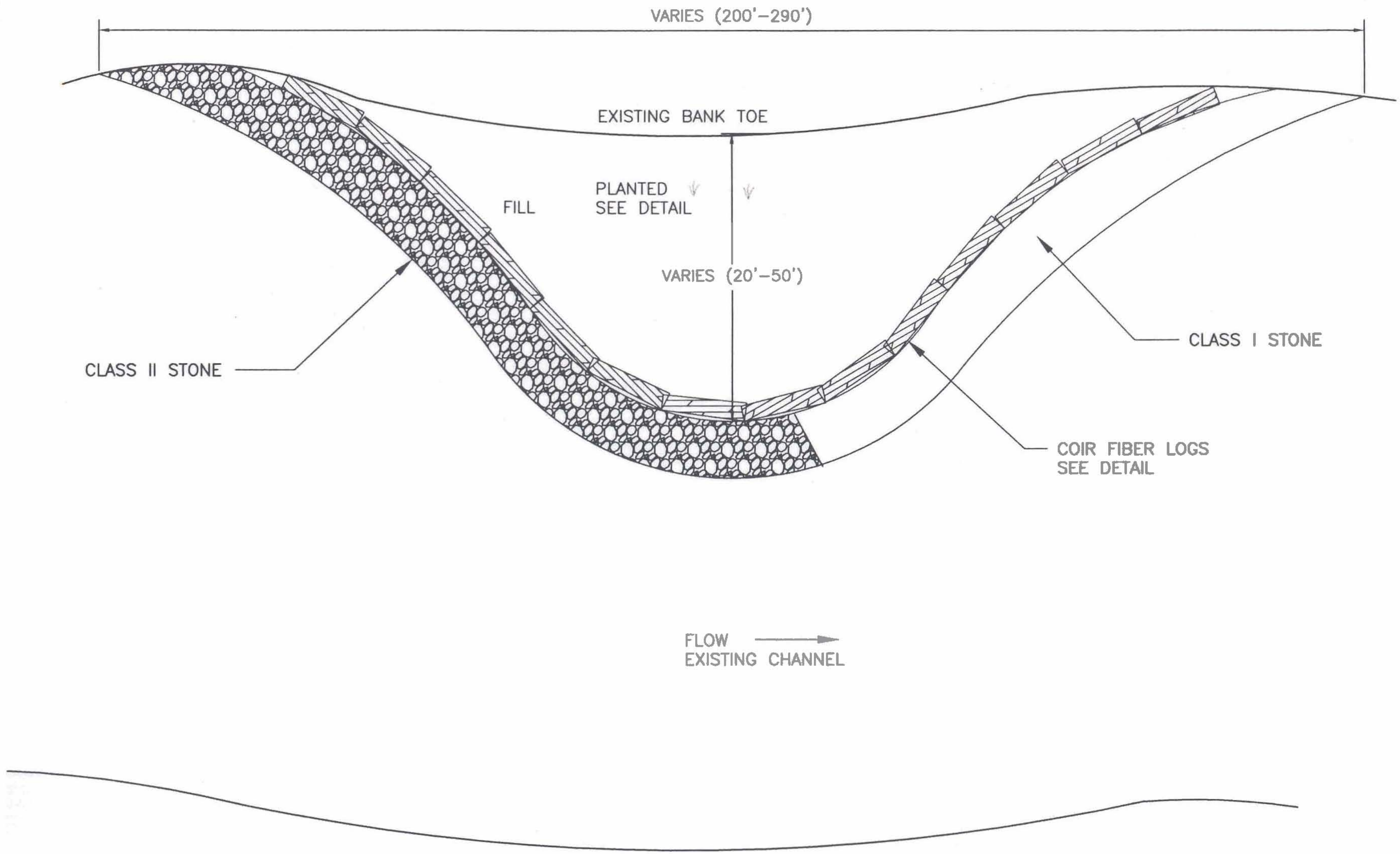
NOTES:

1. RECOMMEND SETTING TOP OF INNER BERM BELOW AT 2 YEAR EVENT.
2. SIZE MAIN CHANNEL TO ACCOMMODATE 2 YEAR EVENT.
3. WIDTH OF INNER BERM TO BE SITE SPECIFIC WITH APPROXIMATE WIDTH OF 20' AND LENGTH OF 100'.
4. PLANT SURFACE ACCORDING TO DETAIL WITH SPECIFIED PLANTS.



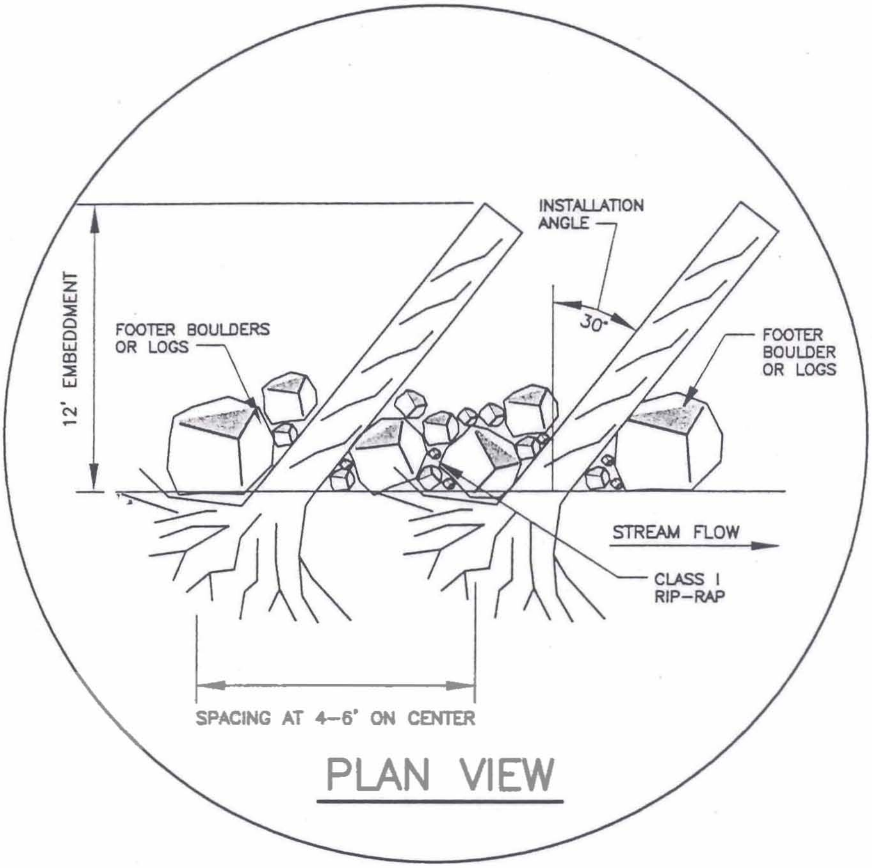
INNER CHANNEL BERM

NO SCALE

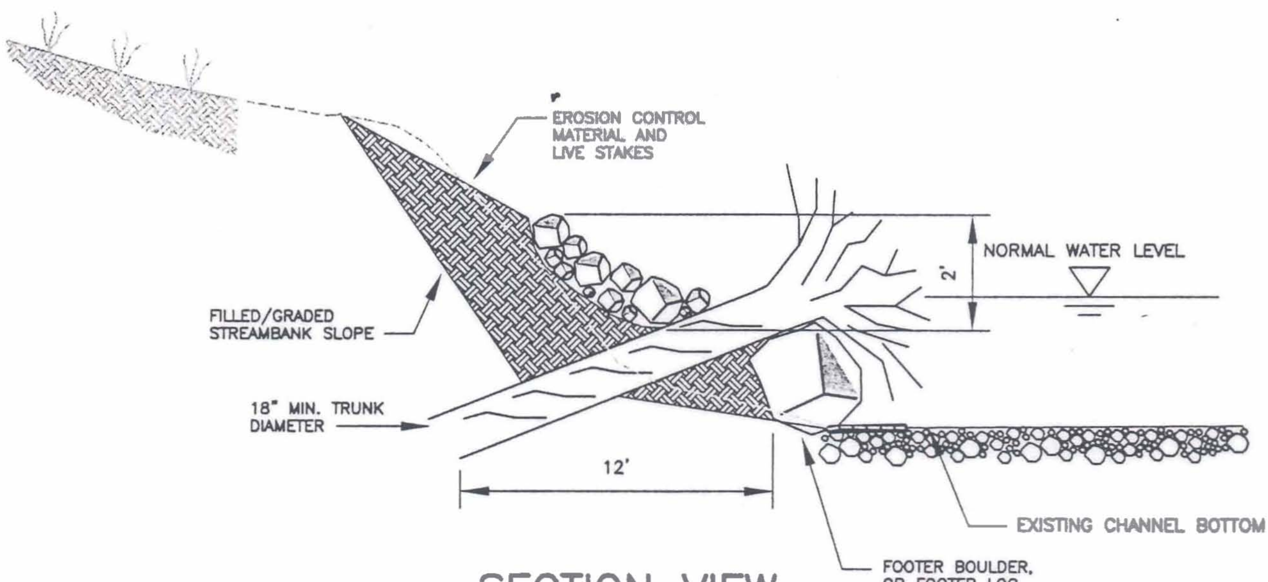


NOTES

1. WIDTH AND LENGTH OF BERM TO BE SITE SPECIFIC.
2. EXPOSED STONE TO BE DRESSED WITH RIVER COBBLE.



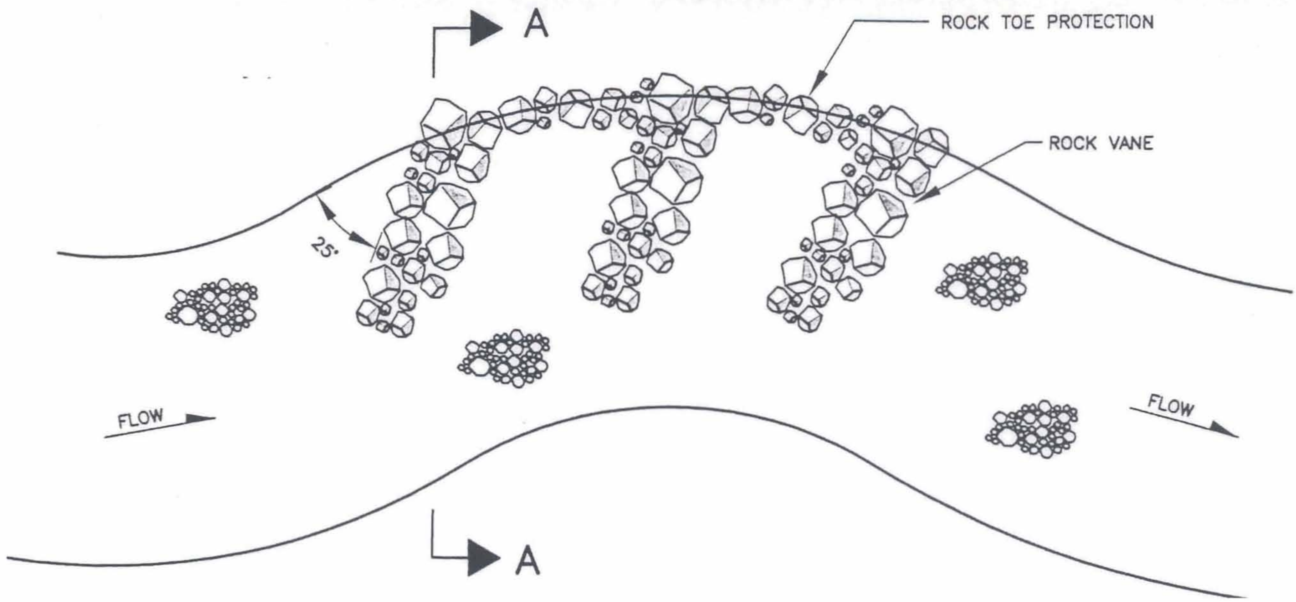
PLAN VIEW



SECTION VIEW

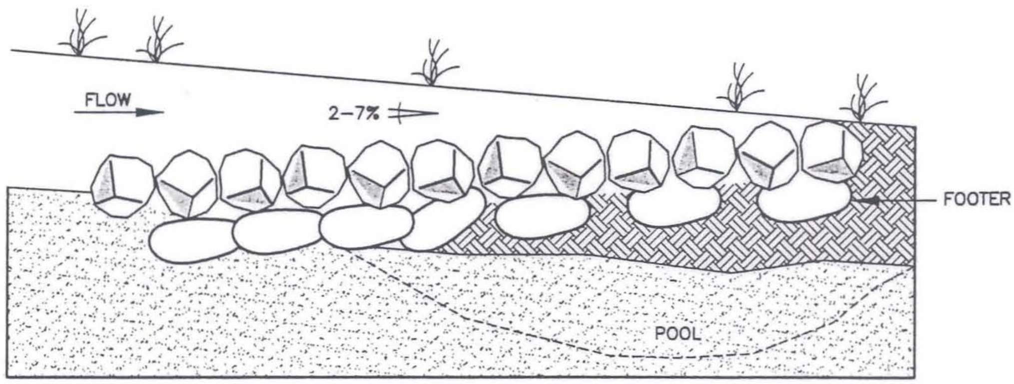
ROOT WAD

NO SCALE



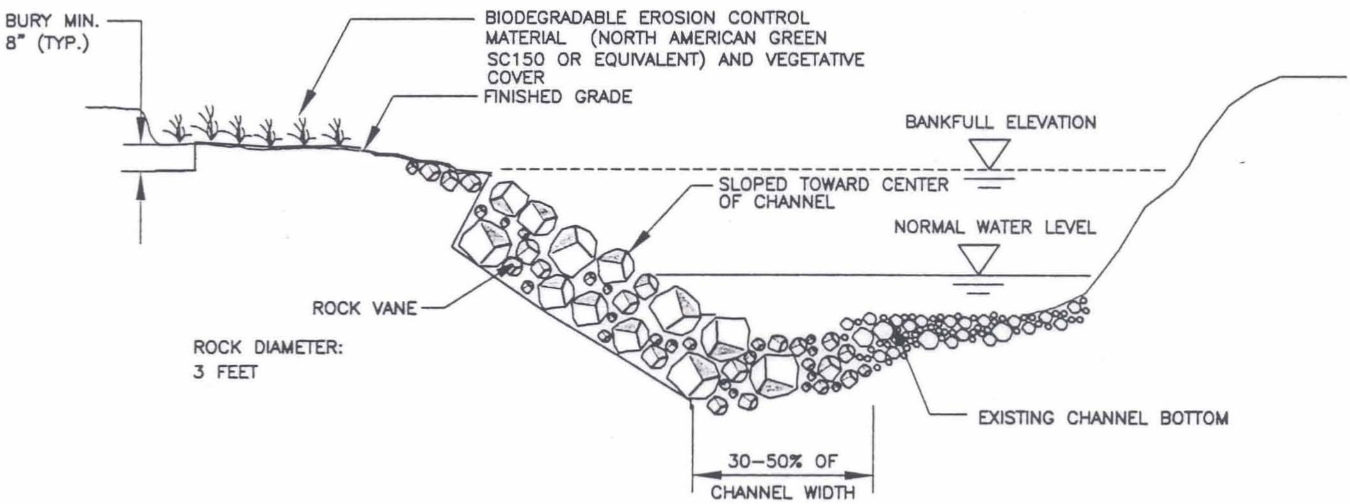
PLAN VIEW

NOT TO SCALE



PROFILE

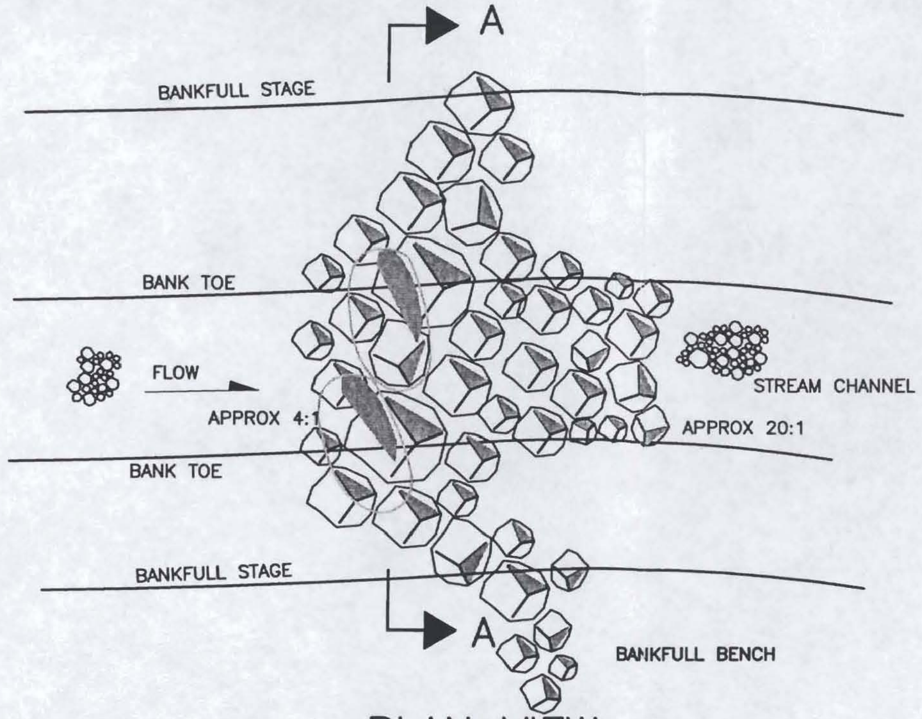
NOT TO SCALE



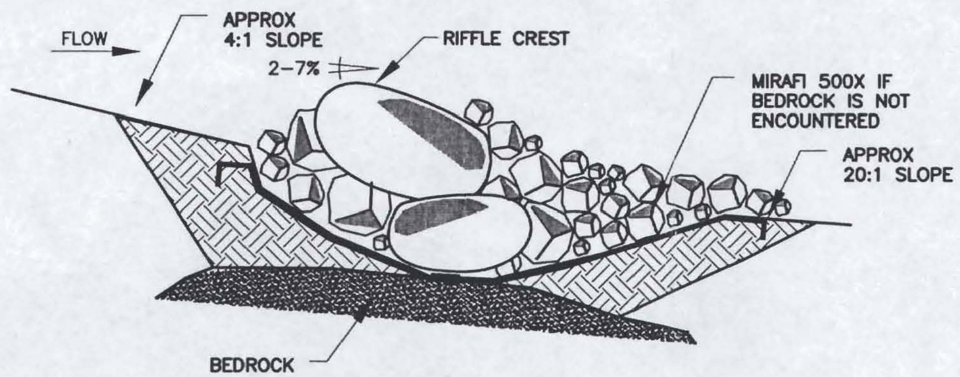
SECTION A-A

ROCK VANE

NO SCALE



PLAN VIEW



PROFILE

CONSTRUCTION NOTES:

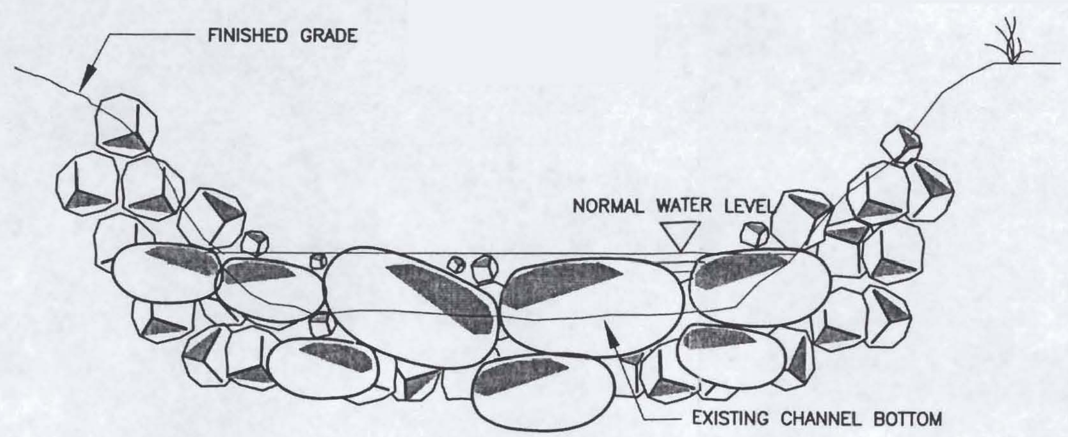
1. PLAN: BUILD RIFFLE TO EXTEND ACROSS BASE OF STREAM WITH LARGEST DIAMETER BOULDERS AT CREST LINE AND REDUCE SIZES PROGRESSIVELY DOWNSTREAM. CREST BOULDERS SIZED 1.5 TO 2 TIMES MAXIMUM SIZE TRANSPORTABLE WITH TOP–OF–BANK EVENT. RIFFLE CREST HAS SIMILAR SIZED FOOTERS TO COHESIVE SAPROLITE OR BEDROCK.

2. PROFILE: CONSTRUCT DOWNSTREAM FACE OF RIFFLE AT APPROXIMATELY 20:1 AND UPSTREAM FACE AT APPROXIMATELY 4:1 SLOPE. SLOPE SHOULD BE ADJUSTED TO MEET DESIGN RIFFLE:POOL RATIO, AND RIFFLE SLOPES.

3. CROSS SECTION: V–SHAPED CREST CUT DOWN TOWARDS CENTER OF CHANNEL.

4. SURFACE: SPACE LARGE SURFACE ROCKS 20 TO 30 CM APART ON THE DOWNSTREAM FACE OF THE RIFFLE TO FORM LOW FISH PASSAGE CHANNELS.

5. BANKS: EXTEND RIFFLE SIDE SLOPE UP BANK TO LEVELS EQUAL TO HEIGHT OF COIR FIBER LOGS, AND THEN EXTEND CREST BACK WITH ROCK PLACED WITHIN BANDS AT 20 TO 30° ANGLE FROM BANK, AND WITH RISE ANGLE OF 2–7° (AS SEEN IN THE CROSS VANE STRUCTURE).



SECTION A–A

CONSTRUCTED BEDROCK RIFFLE

NO SCALE

Geotechnical Report

500-K Clanton Road
Charlotte, North Carolina 28217
(704) 525-2003
(704) 525-2051-Fax

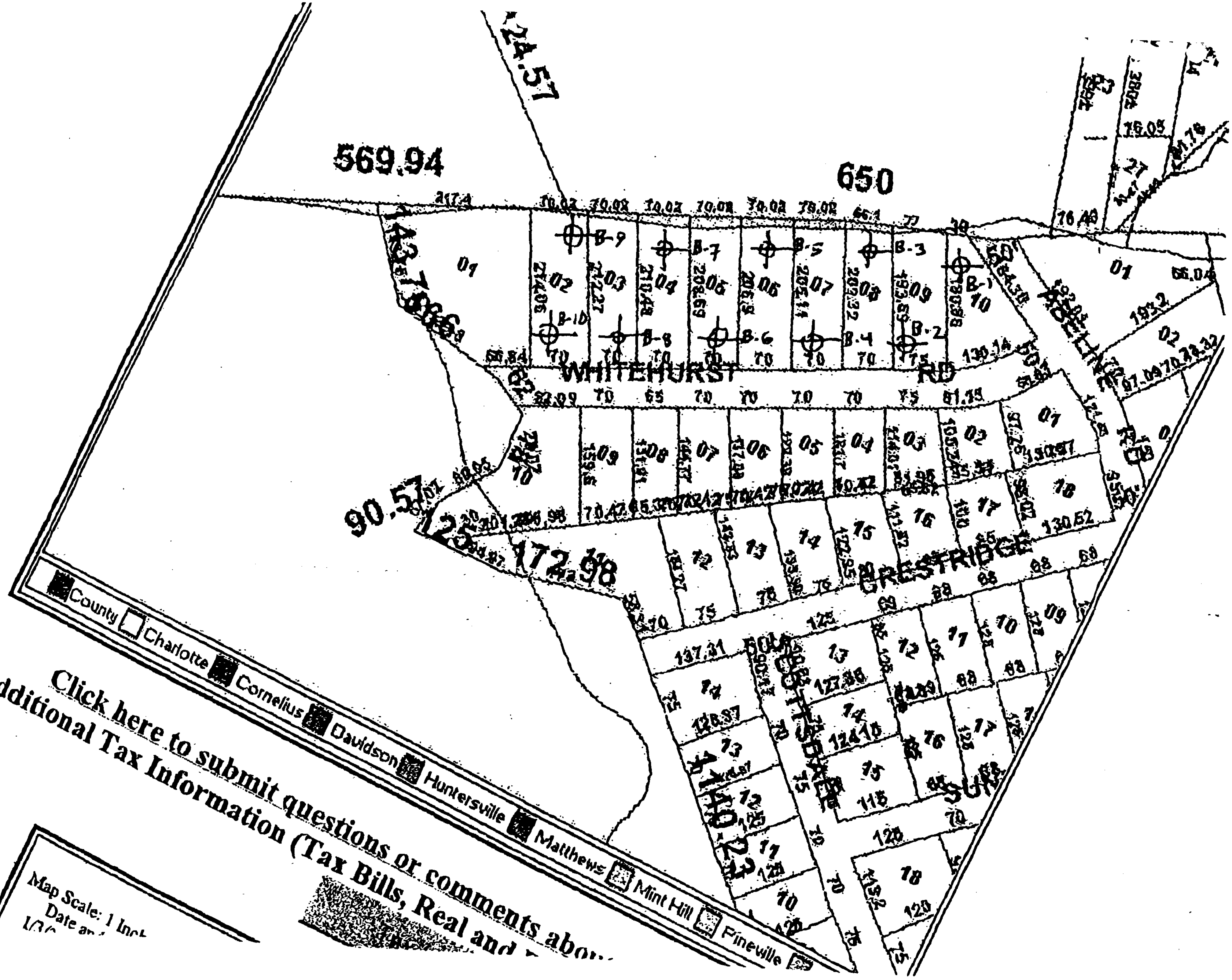
GEOSCIENCE GROUP, INC.

Fax

To: TIM TRAUTMAN | From: DANIEL
Fax: 704.336.3846 | Pages: 2
Phone: | Date:
Re: BORING LOGS - WHITEHURST RD. | CC:

☐ Urgent ☐ For Review ☐ Please Comment ☐ Please Reply ☐ Please Recycle

• Comments:



Click here to submit questions or comments abou

Additional Tax Information (Tax Bills, Real and

Map Scale: 1 Inch

Date and

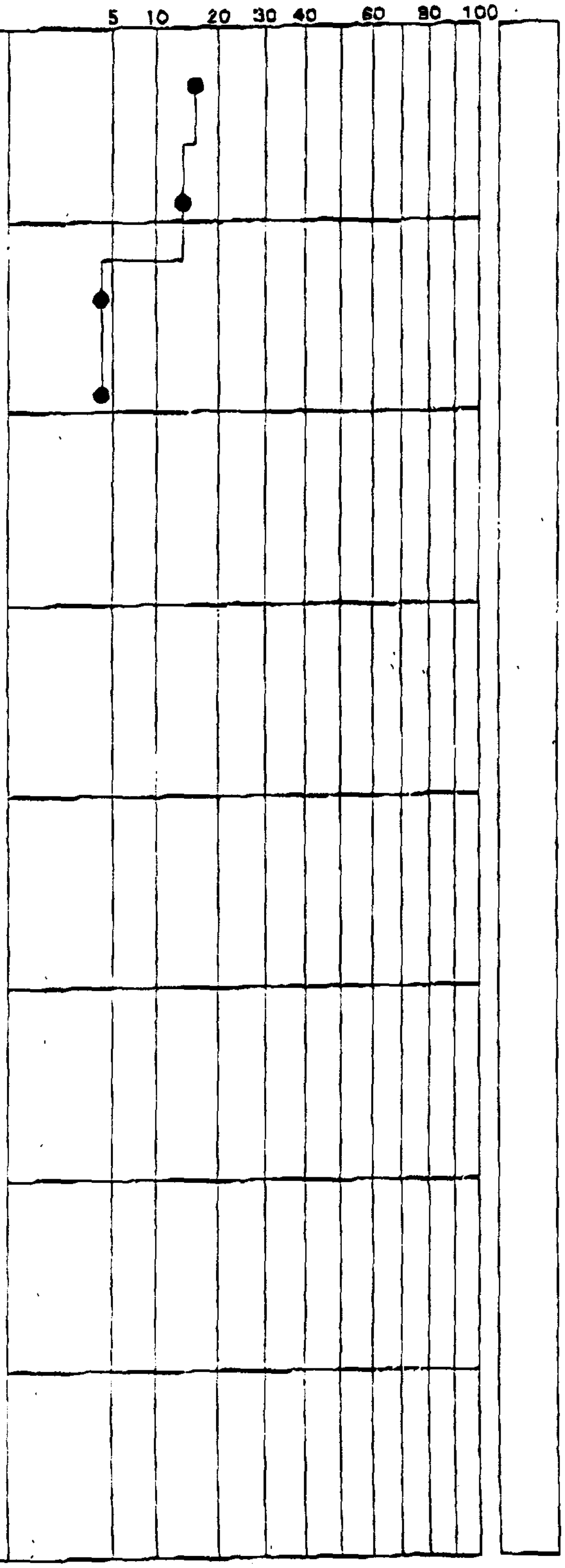
BORING NO.: B-1
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmeriDrill
PROJECT NO.: CH02-0844-GE
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev. 100.0±	Blow Count
0.0			
0.3	Topsoil And Roots		
	Very Stiff Reddish-Brown And Brown Medium To Fine Sandy Very Silty CLAY With Small Rock Fragments And Trace Organics - Fill		16
3.0		97.0	
	Stiff Brown And Grey Silty Medium To Fine Sandy CLAY With Trace Organics - Fill		14
6.0		94.0	
	Very Loose Brown And Tan Silty Medium To Fine SAND With Clay Seams - Alluvial Note: Sample Moist		4
10.0		90.0	4
	Boring Terminated No Groundwater Encountered		

● PENETRATION - BLOW COUNT*



BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE A 1.4 IN. (3.6cm) I.D. SAMPLER 1 FT. (30.5cm)

UNDISTURBED SAMPLER TEST
ROCK CORE RECOVERY
WOH: WEIGHT OF HAMMER
HOUR WATER LEVEL
24 HOUR WATER LEVEL
CAVE DEPTH LEVEL

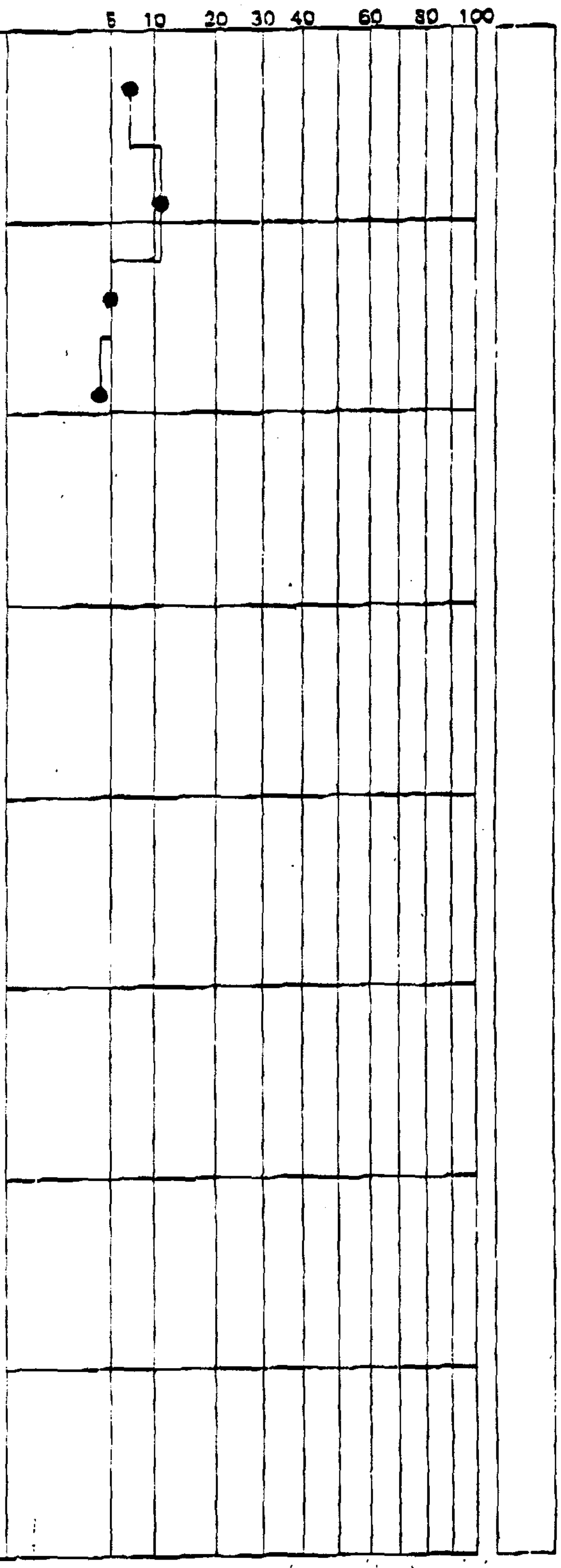
BORING NO.: B-2
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmenDrill
PROJECT NO.: CR02.0844.GE
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev. 100.0±	Blow Count
0.0			
0.3	Topsoil And Roots		
3.0	Firm Brown, Tan And Grey Medium To Fine Sandy Clayey SILT With Rock Fragments, Concrete Pieces And Trace Organics - Fill	97.0	7
6.0	Stiff Reddish-Brown, Brown And Tan Medium To Fine Sandy Very Clayey SILT With Trace Organics - Fill	94.0	11
8.0	Loose Brown Silty Medium To Fine SAND - Alluvial Note: Sample Moist	92.0	5
10.0	Very Loose Brown And Tan Silty Medium To Fine SAND - Alluvial Note: Sample Moist	90.0	4
	Boring Terminated No Groundwater Encountered		

● PENETRATION - BLOW COUNT*



BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE A 1.4 IN. (3.6cm) I.D. SAMPLER 1 FT. (30.5cm)

PRESSUREMETER TEST
60% ROCK CORE RECOVERY
WOH WEIGHT OF HAMMER
0-HOUR WATER LEVEL
24-HOUR WATER LEVEL
CAVE DEPTH LEVEL

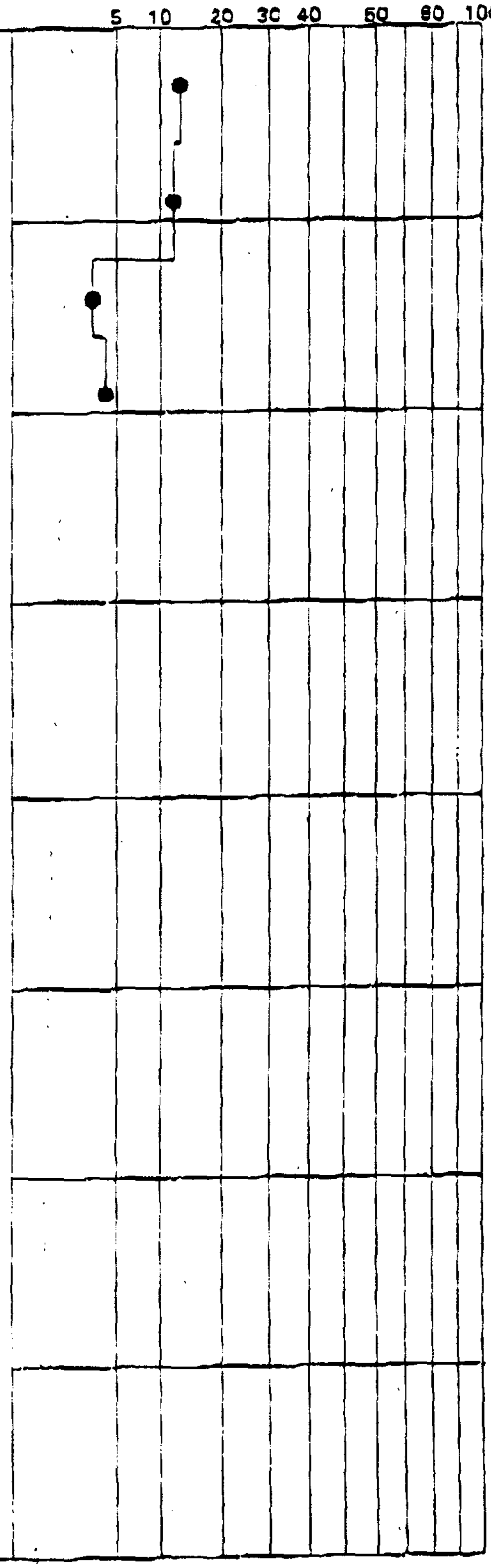
BORING NO. B-1
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmeriDrill
PROJECT NO.: CH02.0545.GE
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev. 100.0±	Blow Count
0.0			
0.2	Topsoil And Roots		
3.0	Stiff Reddish-Brown, Brown And Tan Medium To Fine Sandy Very Silty CLAY With Small Rock Fragments - Fill	97.0	13
6.0	Firm Brown Silty Medium To Fine SAND - Fill Note: Sample Moist	94.0	12
8.0	Very Loose Brown And Grey Silty Medium To Fine SAND With Clay Seams - Alluvial Note: Sample Moist	92.0	3
10.0	Very Loose Brown And Grey Silty Coarse To Fine SAND With Small Rock Fragments - Alluvial	90.0	4
	Boring Terminated No Groundwater Encountered		

● PENETRATION - BLOW COUNT*



BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE A 1.4 IN. (3.6cm) I.D. SAMPLER 1 FT. (30.5cm)

PRESSUREMETER TEST
50% ROCK CORE RECOVERY
WOH WEIGHT OF HAMMER
EOD WATER LEVEL
24 HOUR WATER LEVEL
CAVE DEPTH LEVEL

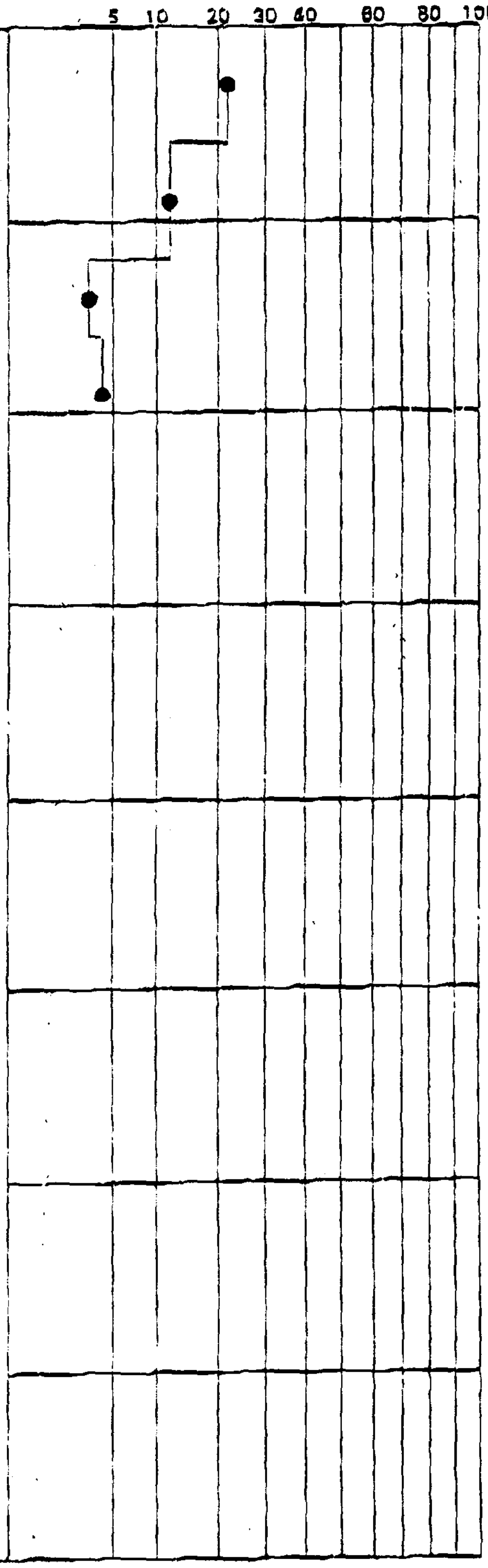
BORING NO.: B-4
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmeriDrill
PROJECT NO.: CH02-0541.GE
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev. 100.0±	Blow Count
0.0			
0.2	Topsoil And Roots		
3.0	Very Stiff Brown And Grey Medium To Fine Sandy Very Silty CLAY With Trace Organics - Fill Note: Sample Moist	97.0	22
6.0	Stiff Reddish-Brown, Brown And Grey Medium To Fine Sandy Clayey SILT With Small Rock Fragments And Trace Organics - Fill	94.0	12
8.0	Soft Brown And Grey Silty Medium To Fine Sandy CLAY - Alluvial Note: Sample Moist	92.0	3
0.0	Very Loose Brown And Grey Silty Medium To Fine SAND With Rock Fragments - Alluvial Note: Sample Moist	90.0	4
	Boring Terminated No Groundwater Encountered		

● PENETRATION - BLOW COUNT*



BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE A 1.4 IN. (3.6cm) I.D. SAMPLER 1 FT. (30.5cm)

PRESSUREMETER TEST
ROCK CORE RECOVERY
WOH WEIGHT OF HAMMER
EQUIL WATER LEVEL
24 HOUR WATER LEVEL
CAVE DEPTH LEVEL

BORING NO.: B-[illegible]
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmeriDrill
PROJECT NO.: CH02.0544.GE
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev. 100.0±	Blow Count
0.0			
0.2	Topsoil And Roots		
3.0	Stiff Reddish-Brown And Brown Medium To Fine Sandy Clayey SILT And Trace Organics - Fill	97.0	12
6.0	Firm Reddish-Brown And Brown Silty Coarse To Fine Sandy CLAY With Small Rock Fragments And Trace Organics - Fill Note: Sample Moist	94.0	5
8.0	No Sample Recovery	92.0	50/0.4
10.0	Stiff Brown, Tan And Grey Silty Medium To Fine Sandy CLAY With Rock Fragments - Alluvial Note: Blow Count Influenced By Rock Fragments	90.0	50/0.3

● PENETRATION - BLOW COUNT* (5, 10, 20, 30, 40, 60, 80, 100)

Boring Terminated
No Groundwater Encountered

BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE A 1.4 I.D. (3.6cm) I.D. SAMPLER 1 FT. (30.5cm)

PRESSUREMETER TEST — 0-HR WATER LEVEL
50% ROCK CORE RECOVERY — 24-HOUR WATER LEVEL
WOH WEIGHT OF HAMMER — CAVE-DEPTH LEVEL

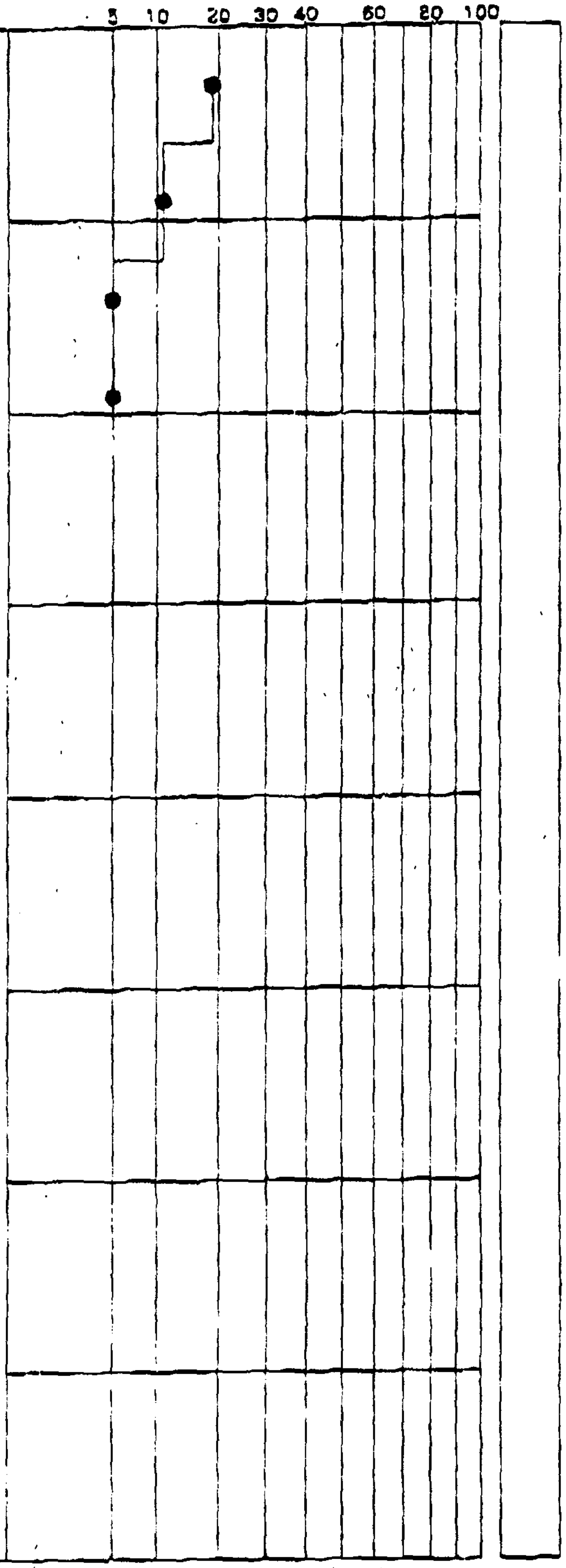
BORING NO.: B-6
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmeriDrill
PROJECT NO.: CH02-0544-GT
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev. 100.0±	Blow Count
0.0 – 0.2	Topsoil And Roots		
0.2 – 3.0	Very Stiff Brown, Tan And Grey Clayey Coarse To Fine Very Sandy SILT With Small Rock Fragments - Fill	97.0	19
3.0 – 6.0	Stiff Brown, Tan And Grey Medium To Fine Sandy Very Silty CLAY With Small Rock Fragments - Fill	94.0	11
6.0 – 8.0	Loose Brown And Tan Silty Medium To Fine SAND - Alluvial	92.0	5
8.0 – 10.0	Firm Brown, Tan And Grey Silty Medium To Fine Sandy CLAY - Alluvial Note: Sample Moist	90.0	5
	Boring Terminated No Groundwater Encountered		

● PENETRATION - BLOW COUNT*



BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE A 1.4 IN. (3.6cm) I.D. SAMPLER 1 FT. (30.5cm)

PRESSUREMETER TEST — EOD WATER LEVEL
50/5 ROCK CORE RECOVERY — 24 HOUR WATER LEVEL
WOH WEIGHT OF HAMMER — CAVE DEPTH LEVEL

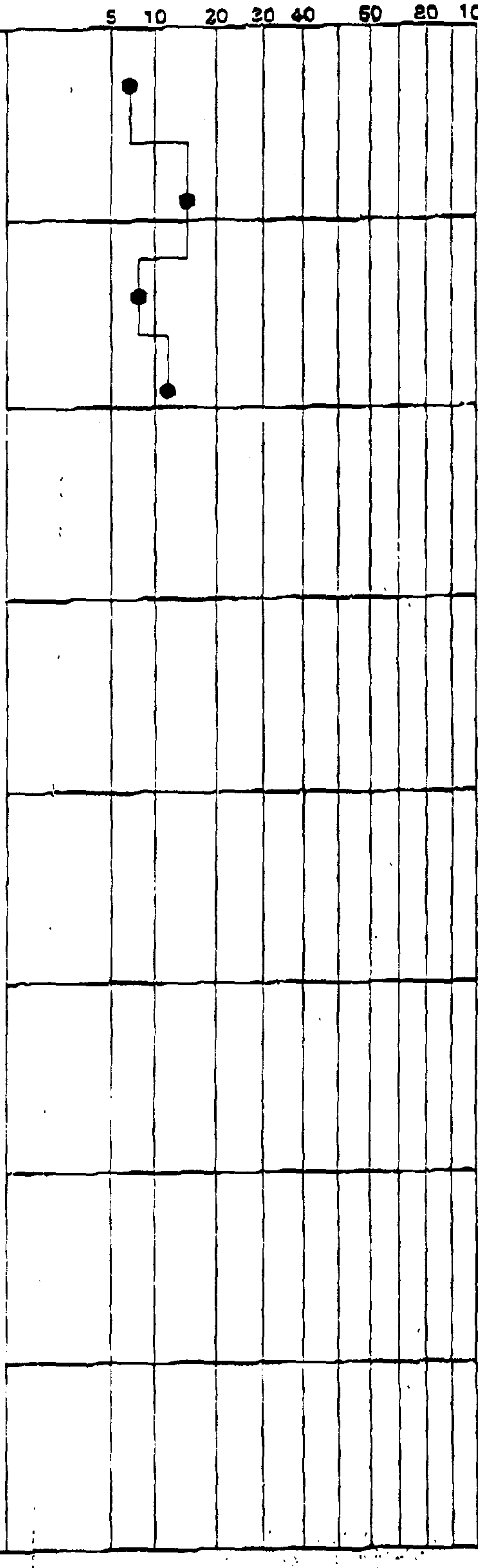
BORING NO.: B-7
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmeriDrill
PROJECT NO.: CH02-0544-GE
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev. 100.0±	Blow Count
0.0			
0.2	Topsoil And Roots		
3.0	Firm Brown, Tan And Grey Medium To Fine Sandy Clayey SILT With Small Rock Fragments And Trace Organics - Fill	97.0	7
5.5	Stiff Reddish-Brown, Brown And Tan Clayey Medium To Fine Sandy SILT - Fill	94.5	15
8.0	Firm Brown, Tan And Grey Silty Medium To Fine Sandy CLAY With Trace Organics - Alluvial Note: Sample Moist	92.0	8
10.0	Stiff Brown, Tan And Grey Medium To Fine Sandy Very Silty CLAY - Alluvial	90.0	12
	Boring Terminated No Groundwater Encountered		

● PENETRATION - BLOW COUNT*



BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE 1.4 IN. (3.6cm) I.D. SAMPLER 1 FT. (30.5cm)

PRESSUREMETER TEST — EOD WATER LEVEL
40% ROCK CORE RECOVERY — 24 HOUR WATER LEVEL
WOH WEIGHT OF HAMMER — CAVE DEPTH LEVEL

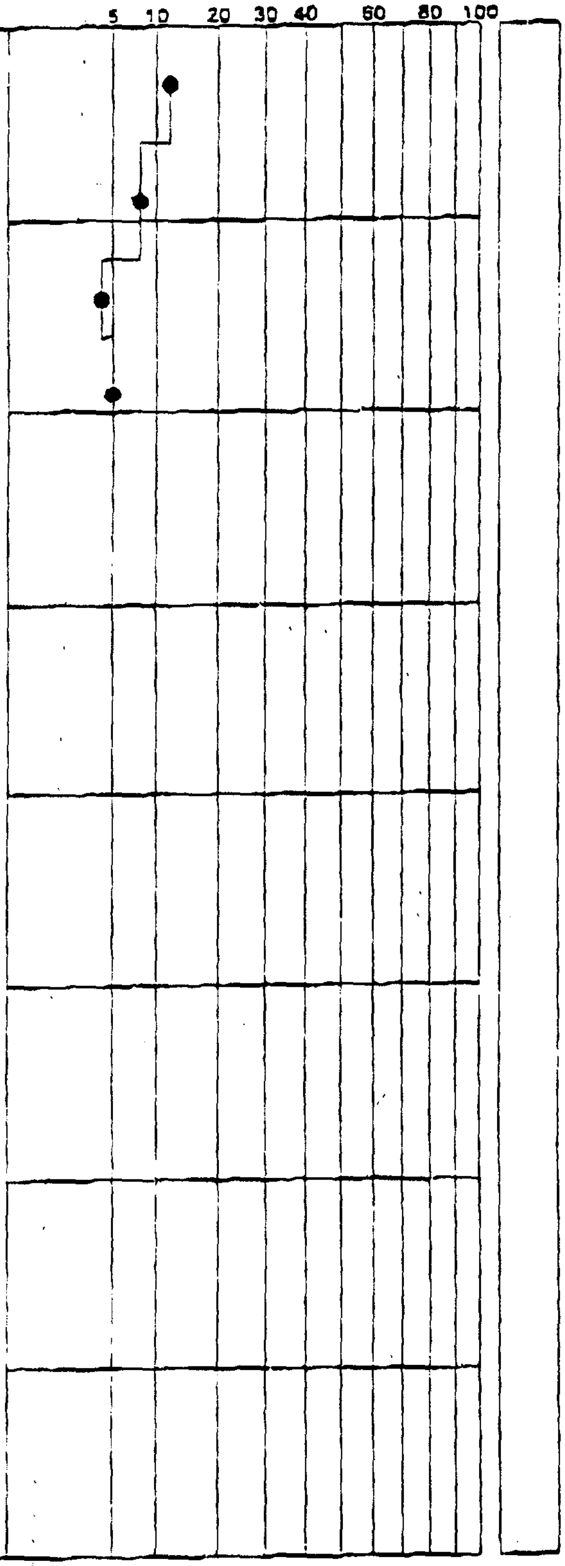
BORING NO.: B-3
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmeriDrill
PROJECT NO.: CH02-0646 GE
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev. 100.0±	Blow Count
0.0			
0.3	Topsoil And Roots		
3.0	Stiff Brown, Tan And Grey Medium To Fine Sandy Very Clayey SILT With Small Rock Fragments - Fill	97.0	12
6.0	Firm Brown, Tan And Grey Medium To Fine Sandy Clayey SILT With Small Rock Fragments And Trace Organics - Fill	94.0	8
8.0	Very Loose Grey Clayey Silty Medium To Fine SAND - Alluvial	92.0	4
10.0	Firm Brown And Grey Silty Medium To Fine Sandy CLAY - Alluvial Note: Sample Moist	90.0	5
	Boring Terminated No Groundwater Encountered		

● PENETRATION - BLOW COUNT*



BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE A 1.4 IN. (3.6cm) I.D. SAMPLER 1 FT. (30.5cm)

PRESSUREMETER TEST
ROCK CORE RECOVERY
WOH WEIGHT OF HAMMER

EOD WATER LEVEL
24 HOUR WATER LEVEL
CAVE DEPTH LEVEL

PAGE 1 of 1

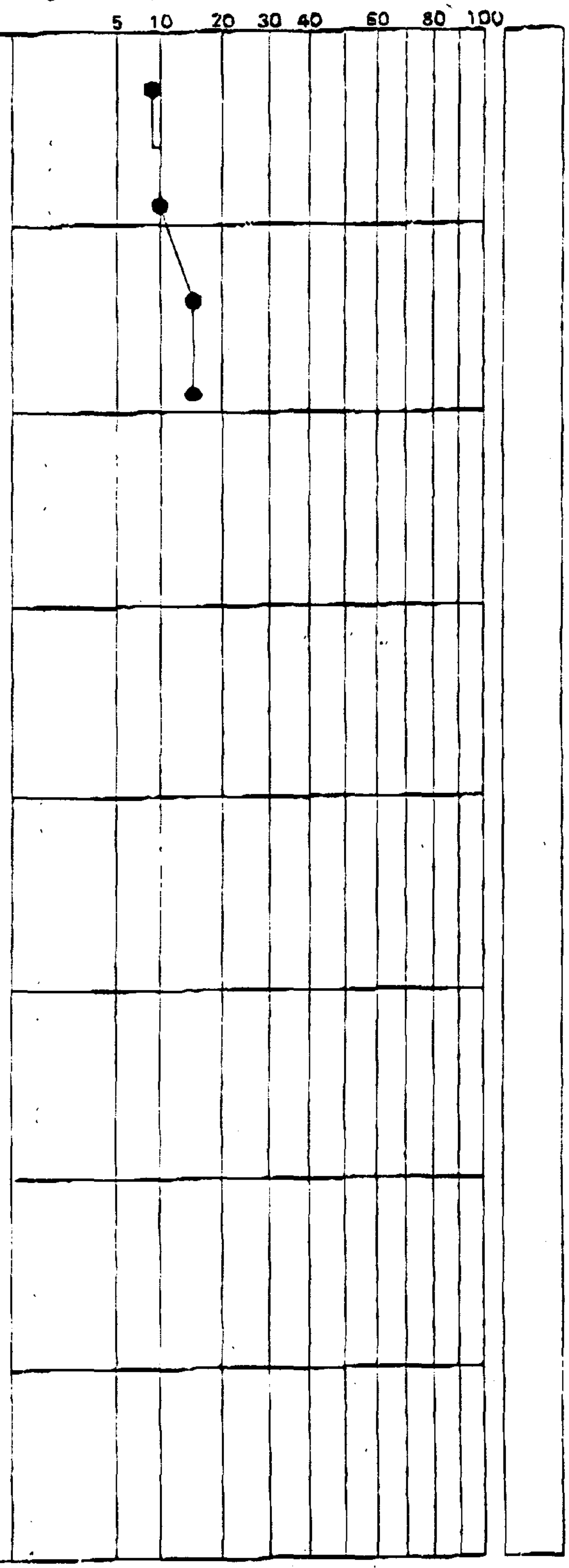
BORING NO.: B-[illegible]
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmeriDrill
PROJECT NO.: GH02-[illegible]-GE
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev. 100.0±	Blow Count
0.0			
0.3	Topsoil And Roots		
	Stiff Brown, Tan And Grey Medium To Fine Sandy Very Silty CLAY With Small Rock Fragments - Fill		9
3.0		97.0	
	Stiff Brown And Tan Medium To Fine Sandy Very Silty CLAY - Alluvial		10
			15
8.0		92.0	
	Stiff Brown, Tan And Grey Medium To Fine Sandy Very Silty CLAY With Trace Organics - Alluvial		
10.0		90.0	15
	Boring Terminated		
	No Groundwater Encountered		

● PENETRATION - BLOW COUNT*



BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE A 1.4 IN. (3.5cm) I.D. SAMPLER 1 FT. (30.5cm)

PENETROMETER TEST
50% ROCK CORE RECOVERY
WOH WEIGHT OF HAMMER
GROUNDWATER LEVEL
24 HOUR WATER LEVEL
CAVE DEPTH LEVEL

PAGE 1 OF 1

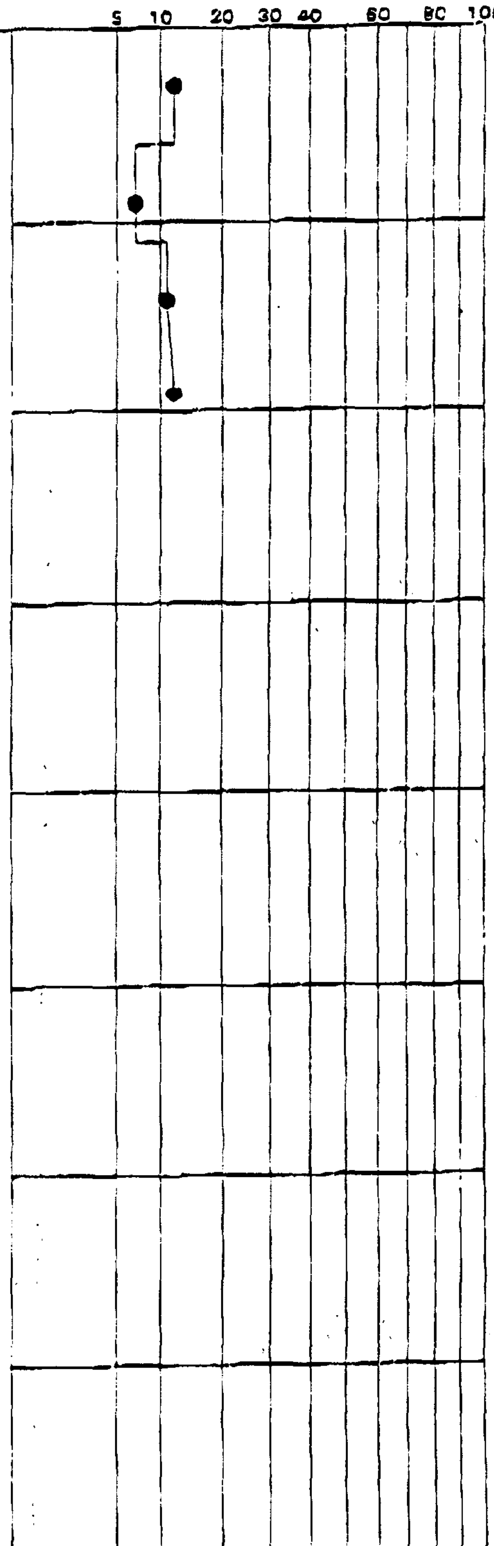
BORING NO.: B-10
DATE DRILLED: 11/20/02
DRILLING CONTRACTOR: AmeriDrill
PROJECT NO.: GH02-0544 GE
PROJECT: WHITEHURST ROAD SITE

TEST BORING RECORD

GEOSCIENCE GROUP, INC.

DEPTH, FT.	DESCRIPTION	Elev 100.0±	Blow Count
0.0			
0.3	Topsoil And Roots		
3.0	Stiff Brown, Tan And Grey Medium To Fine Sandy Very Clayey SILT With Small Rock Fragments - Fill Note: Sample Moist	97.0	12
5.5	Firm Reddish-Brown And Brown Medium To Fine Sandy Very Silty CLAY With Trace Organics - Fill	94.5	7
	Stiff Brown, Tan And Grey Medium To Fine Sandy Very Silty CLAY - Alluvial		11
10.0	Boring Terminated No Groundwater Encountered	90.0	12

● PENETRATION - BLOW COUNT*



BORING AND SAMPLING MEETS ASTM D-1586
CORE DRILLING MEETS ASTM D-2113

*PENETRATION IS THE NUMBER OF BLOWS OF A 140 LB. (63.5kg) HAMMER FALLING 30 IN. (76.2cm) REQUIRED TO DRIVE A 1.4 IN. (3.6cm) I.D. SAMPLER 1 FT. (30.5cm)

PRESSUREMETER TEST
ROCK CORE RECOVERY
WOH WEIGHT OF HAMMER

EOD WATER LEVEL
24 HOUR WATER LEVEL
CAVE DEPTH LEVEL

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