Appendix F

Environmental Appendix

Flat Creek Watershed
Aquatic Ecosystem Restoration
Detailed Project Report

Environmental Appendix

US Army Corps of Engineers
Mobile District

June 2011

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1. Introduction

1.1 Background

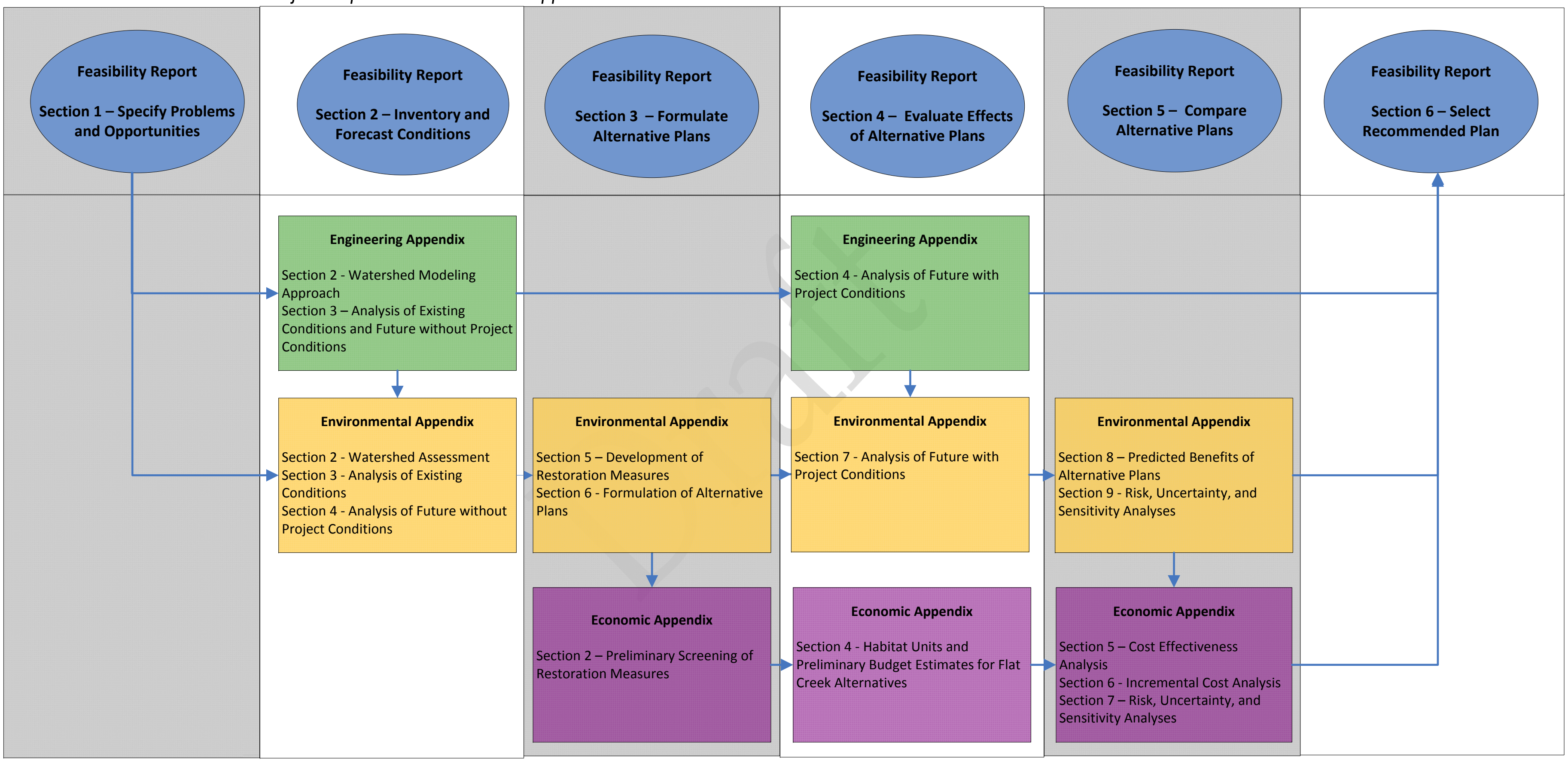
Through a partnership between the U.S. Army Corps of Engineers (USACE); the City of Gainesville, Georgia; and Hall County, Georgia, a plan was developed to restore the aquatic ecosystem of the Flat Creek watershed under Section 206 of the Water Resources Development Act of 1996 (WRDA 96), as amended. The USACE objective in federal ecosystem restoration planning (one of the primary missions of the Civil Works program) is to contribute to increase the net quantity and/or quality of ecosystem resources. The watershed was identified for an aquatic ecosystem restoration study based on degraded habitat throughout the watershed, which does not support a diverse, robust, biological community. Instream and riparian habitat have been adversely affected by changes to the natural stream hydrology, which has led to a scarcity of riffle/pool habitat, limited availability of woody debris and shade, and increased instream sedimentation and substrate embeddedness.

The *Flat Creek Aquatic Ecosystem Restoration Detailed Project Report* (Detailed Project Report) was developed to identify, evaluate, and recommend to decision makers an appropriate, coordinated, and implementable solution to the identified water resources problems and opportunities in the Flat Creek watershed. The Detailed Project Report outlined ecosystem restoration problems and opportunities in the Flat Creek watershed and recommended the most cost-effective strategy for ecosystem restoration. The study incorporated a systematic approach that follows the six-step planning process outlined in the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&G), adopted by the Water Resource Council and required for all federal water resource projects.

1.2 Organization of Detailed Project Report

The six planning steps are presented in Figure 1-1 and detailed in the Detailed Project Report. The Environmental Appendix was associated with Steps 2 – 5, as shown in Figure 1-1. The Environmental Appendix utilized information from the Engineering Appendix to: inventory and forecast conditions, formulate alternative plans, and evaluate the effects of alternative plans. This information was then used in the Economics Appendix to recommend the most cost-effective ecosystem restoration alternative for the Flat Creek watershed.

FIGURE 1-1
Organization of the Detailed Project Report in Relation to the Six Planning Steps
Flat Creek Watershed Detailed Project Report – Environmental Appendix



2. Watershed Assessment

2.1 Study Area Description

The study area for this Detailed Project Report included the Flat Creek watershed, which is located in the Chattahoochee River Basin in Hall County, Georgia, upstream of Lake Sidney Lanier. The Chattahoochee River Basin is part of the larger Apalachicola-Chattahoochee-Flint Rivers Basin (ACF Basin), which flows south to the Gulf of Mexico and also drains portions of Alabama and Florida (Figure 2-1). Flat Creek is an eastern tributary to Lake Lanier, the largest lake (38,500 acres) located entirely within the State of Georgia.

The Flat Creek watershed is located entirely within Hall County, which is part of the upper Piedmont physiographic province. The watershed encompasses 7,337 total acres (698 acres of which are inundated by Lake Lanier) and contains a total of 31 stream miles (6 miles of main stem and 25 miles of tributaries). Roughly 38 percent of the watershed is located in the City of Gainesville and less than 1 percent is in the City of Oakwood. This correlates to incorporated areas of the watershed totaling 2,617 acres, of which 2,553 are located in Gainesville and 64 in Oakwood (Figure 2-2). For the purposes of this study, the watershed was divided into three subwatersheds: Upper Flat Creek (headwaters), Lower Flat Creek, and the Flat Creek Embayment (includes Lake Lanier backwaters). The three areas were roughly equal in size, but have notable land use differences. A delineation of these subwatersheds is shown in Figure 2-2.

2.1 Prior Studies, Projects, and Programs

Prior reports/studies associated with the Flat Creek watershed outline problems identified in the watershed. These studies, as well as historical data for the watershed (CH2M HILL, 2000; CH2M HILL, 2003; Brown and Caldwell, 2006; and CH2M HILL, 2007b) were reviewed and incorporated into multiple steps of the six-step planning process. Applicable prior studies are summarized below.

2.1.1 Flat Creek 319(h) Stream Restoration

Upon receipt of funding from a 319(h) grant administered through the GA EPD, the City of Gainesville restored 500 feet of degraded stream channel and regional stormwater detention facility in an upstream part of the Flat Creek watershed east of Queen City Parkway. The design used a natural channel design or reference reach approach in which the pattern, dimension, and profile were developed based on a stable stream channel with similar characteristics. The stream channel was enhanced with in-stream structures, such as cross-vanes and log sills, and a robust planting plan that will control exotic species and reintroduce native vegetation to the area. The regional stormwater detention facility provided substantial hydrologic benefits for a heavily urbanized watershed through offline stormwater treatment and attenuation of peak storm flows. The regional detention facility was integrated with a diversion structure to convey the "first flush" of stormwater runoff to the detention facility.

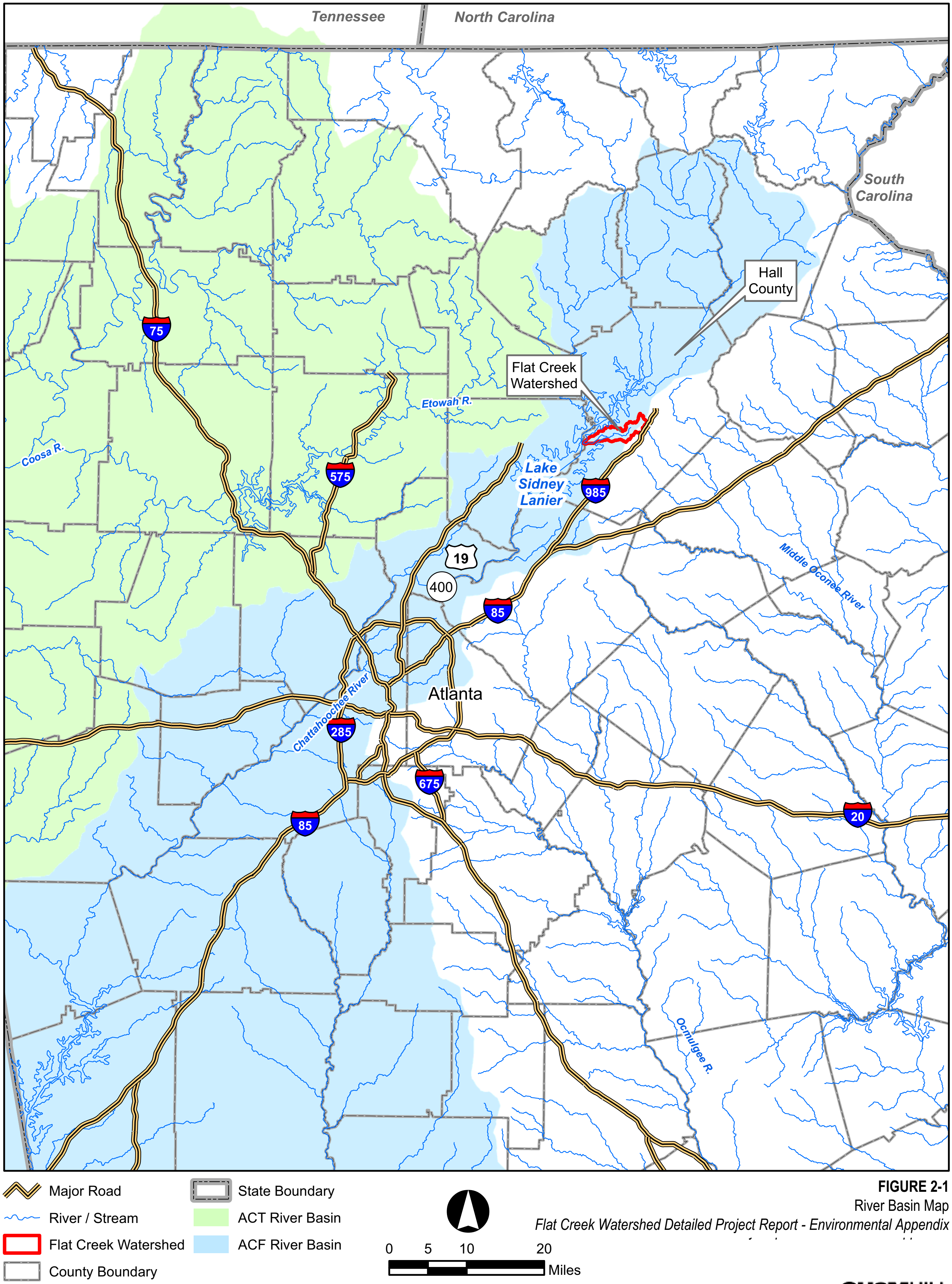


FIGURE 2-1
River Basin Map
Flat Creek Watershed Detailed Project Report - Environmental Appendix

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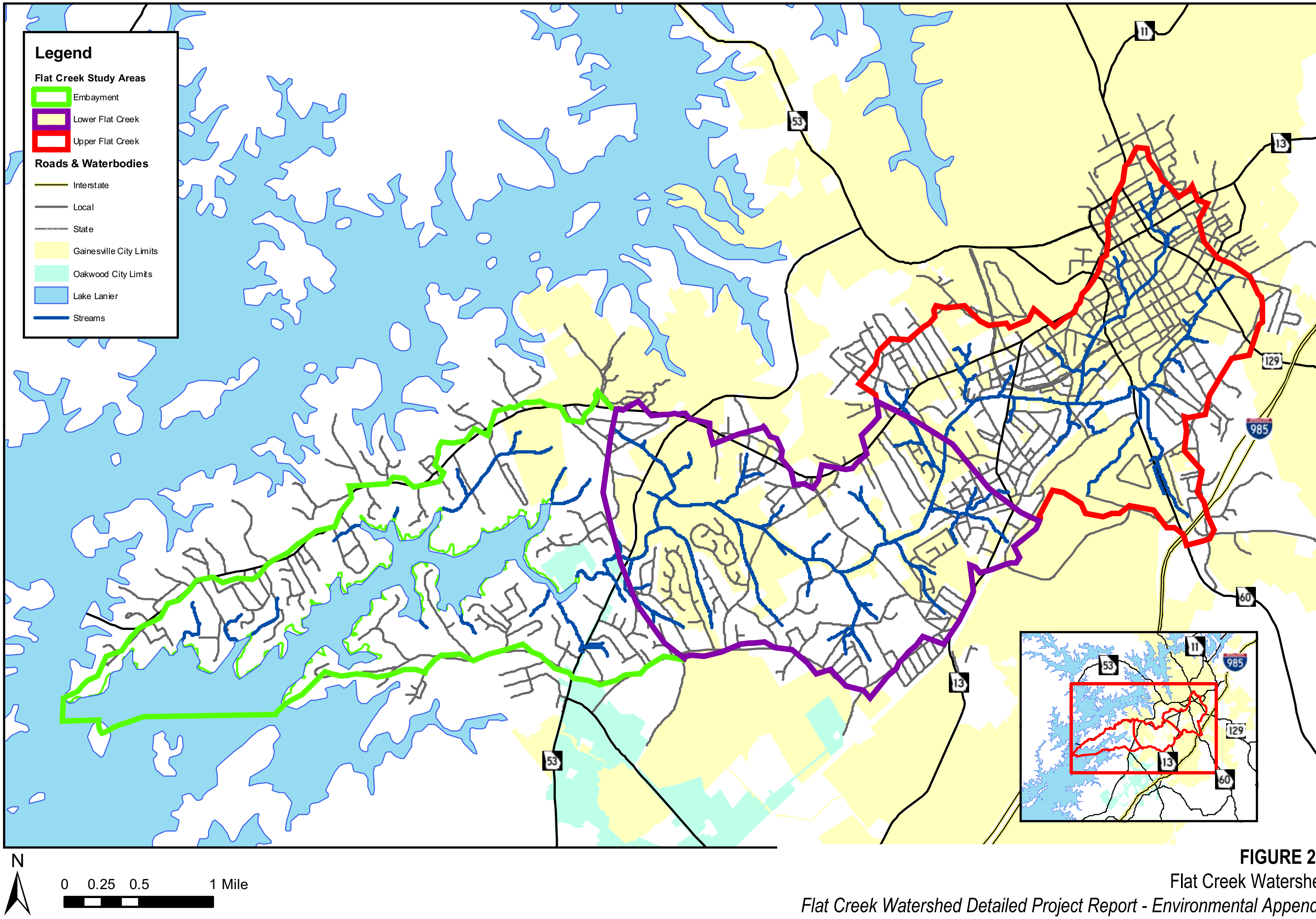

FIGURE 2-2
Flat Creek Watershed
Flat Creek Watershed Detailed Project Report - Environmental Appendix
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The City of Gainesville selected the project for implementation as a proactive approach to address the damage to water quality and aquatic habitat caused by years of development and past land use practices. The project made significant strides toward addressing these impacts, and also introduced an aesthetic element that will enhance the surrounding community through construction of a perimeter trail around the pond. The trail was designed to be incorporated with plans for the future Midtown Greenway construction.

Regional stormwater detention facility adjacent to stream restoration partially funded by a 319(h) grant in the headwaters part of Flat Creek.

2.1.2 Ongoing Local Programs

Additional watershed management activities being implemented by the City of Gainesville will enhance the long-term success of the Tentatively Selected Plan. The City's ultimate watershed management goals are to implement an adaptive management approach to improve streams that are listed in Georgia's Integrated 305(b)/303(d) List of Waters for not meeting their designated uses, maintain watersheds that are meeting designated uses, and conserve and potentially restore the environment of watersheds across the City. Other activities that the City has undertaken towards this goal are discussed as part of several plans, including the Community Watershed Assessment and Management Plan (WAMP), Watershed Protection Plan (WPP), and Flat Creek Watershed Improvement Plan (WIP). As demonstrated in biannual reports submitted to GAEPD since 2003, the City has taken steps to meet the goals of the WAMP and WPP, comply with regulatory guidelines, and adapt watershed management activities based on issues identified through monitoring and inspections. Note that many of these activities are further described as nonstructural restoration measures in Section 5.1. The City currently conducts the following activities:

- Stormwater Management
  - Adoption and enforcement of protective ordinances, including litter control, floodplain management, illicit discharge and illegal connection, post-development stormwater management for new development and redevelopment, stream buffer protection, and conservation subdivision development
  - Public education/outreach and public involvement activities, including: participation in Adopt-A-Stream, public meetings, development of NPDES stormwater steering committee, and televised appearances
  - Development of an illicit discharge detection elimination program that involves dry weather screenings of outfalls, stream walks, stormwater mapping, and maintenance of a hotline for reporting illicit discharge/illegal dumping
  - Post-construction stormwater management, including enforcement of a post-development stormwater management ordinance, enforcement of the *Georgia*

Stormwater Management Manual (ARC, 2001) for all new development, plan reviews, and annual inspections of public stormwater ponds
  - Pollution prevention/Good housekeeping practices, including inspection and maintenance of the storm sewer system, stormwater management trainings, ongoing street cleaning program, adoption of the *Georgia Stormwater Management Manual*, and enforcement of proper disposal of waste
- Watershed Improvement
  - Watershed improvement project planning and implementation, including the completion of the Flat Creek WIP and completion of the first phase of the stream restoration and stormwater treatment project identified in the WIP
  - TMDL activities, including the focus of stream walks, illicit discharge detection, long-term monitoring, watershed improvement plans, public education, and short-term water quality studies in watersheds identified as impaired and not meeting a designated use
- Environmental Monitoring Program (EMP)
  - Annual water quality monitoring at six locations
  - Biannual biological monitoring at six locations
  - Quarterly stream walks and illicit discharge detection monitoring
  - Weekly site inspections at stream crossings and other areas with historical water quality problems or identified potential pollutant sources, such as commercial/industrial areas
  - Annual reporting of watershed management activities to GAEPD

2.1.3 Preliminary Restoration Plan Report

A Preliminary Restoration Plan (PRP) Report for the Flat Creek watershed was developed in 2002 (USACE, 2002). The report documents that Hall County and the City of Gainesville have experienced substantial growth and development over the past 20 years, and this trend is expected to continue. The PRP Report further states that urban growth and development has adversely affected the biological integrity and water quality of streams within Hall County, like Flat Creek and its tributaries. Major contributors to stream degradation were identified as sedimentation and erosion, as well as certain metals and fecal coliform.

2.1.4 Total Maximum Daily Load (TMDL) Development

The Georgia Environmental Protection Division (GAEPD) of the Georgia Department of Natural Resources (GADNR) identifies segments of state streams in Georgia's Integrated 305(b)/303(d) List of Waters in accordance with Section 305(b) of the Clean Water Act (CWA). Six miles of Flat Creek, from the headwaters to Lake Lanier, are identified in Georgia's Draft 2010 Integrated 305(b)/303(d) List of Waters. This stream segment is listed for violating both fecal coliform standards and biological criteria for fish bioassessments, with urban runoff the potential source of degradation (GAEPD, 2010). For streams not supporting a designated use, GAEPD develops a Total Maximum Daily Load (TMDL), or an estimate of the amount of a pollutant that can be introduced to a stream without causing the stream to violate its designated use. A TMDL for fecal coliform in mainstem Flat Creek was developed in 2003 and revised in 2008, during TMDL development for 79 stream segments in the Chattahoochee River Basin (GAEPD, 2008a).A TMDL focusing on sediment as the measurable pollutant of concern was developed for 25 segments of the basin, including Flat Creek, to address impacted biological communities (GAEPD, 2008b).

Following the development of the fecal coliform TMDL, a TMDL Implementation Plan was developed for Flat Creek (GAEPD, 2004). The Plan identifies a set of actions to improve water quality with the goal of meeting water quality standards and supporting its designated use. Urban nonpoint source runoff was identified as the source of water quality impairment. The primary contributors of fecal coliform include failing septic systems, leaking sewer systems, and runoff from urban development. Lesser contributors include wildlife, domestic pets, industrial development, and illicit discharges. Management actions identified in the TMDL Implementation Plan include the formation of a stakeholders group, ordinance revisions, ongoing monitoring, and public outreach.

2.1.5 Community Watershed Assessment and Management Plan (WAMP) and City of Gainesville Watershed Protection Plan (WPP)

The Community Watershed Assessment and Management Plan (WAMP), was prepared by CH2M HILL in 2000 for Hall County and the City of Gainesville. The purpose of the WAMP was to evaluate the environmental health of community streams and develop a management plan to control pollution in selected watersheds. The City of Gainesville Watershed Protection Plan (WPP), prepared by CH2M HILL in 2006, further described watershed degradation and updated strategies to protect water quality and natural stream conditions.

The Flat Creek watershed was one of three areas identified in both the WAMP and the WPP as not meeting the desired level of health for reasons attributable to urban growth, unstable stream banks, and degraded stream quality. Residential and commercial development associated with urbanization generates increased demand on existing utility infrastructure, such as wastewater collection and treatment facilities, and generates additional nonpoint source pollution. The WPP outlined steps to protect water quality given that as less-developed areas of the watershed transition to residential areas, efforts must be made to prevent further stream degradation and to improve water quality by implementing watershed improvement projects.

2.1.6 Flat Creek Watershed Improvement Plan (WIP)

In 2008, the Flat Creek Watershed Improvement Plan (WIP) was completed by the City of Gainesville. To meet multiple community objectives, the City leveraged efforts for the WIP to also complete much of the technical components of this study. On behalf of the City, CH2M HILL prepared the WIP by using a Section 319(h) grant, administered by the GAEPD, and developed it to meet three major goals:

- Develop a restoration plan for the Flat Creek watershed, in accordance with Section 319(h) funding, which will improve water quality and channel stability in Flat Creek and will enhance aquatic habitat and ecosystem integrity.
- Follow Metropolitan North Georgia Water Planning District (District) guidelines for watershed improvement activities, as enforced by GAEPD as a component of the National Pollutant Discharge Elimination System (NPDES) permitting process. The

District had previously classified Flat Creek as a substantially impacted watershed in 2003 due to high effective imperviousness estimates.

- Conduct watershed investigations, involve agencies and other stakeholders, and develop site-specific restoration alternatives with a technical approach that could also support a Section 206 study.

Through development of the WIP, the City of Gainesville and Hall County cooperatively identified and prioritized potential watershed improvement projects to stabilize and restore specific reaches of Flat Creek. These projects were identified through analysis of current and historical watershed data and through field assessments of Flat Creek and its tributaries and stormwater detention structures in the watershed. Two potential projects were identified: (1) stormwater detention structure retrofit project, aimed at improving structures to retain and treat stormwater, and (2) stream restoration projects, intended to stabilize streambanks and restore aquatic habitats and riparian corridors to improve water quality, promote ecological integrity, and reduce erosion and sedimentation. The projects were then prioritized, according to existing conditions at the project sites, cost-benefit analysis, and feasibility studies, to ultimately develop a capital improvement plan for Flat Creek.

2.2 Land Use

The Flat Creek watershed has experienced significant growth and development over the last 20 years, and this trend is expected to continue. According to the US Census Bureau, the 1990 population estimate for Hall County was 95,428, and the 2006 population estimate was 173,256. This 82 percent increase is primarily due to growth in and around the City of Gainesville, as well as growth on the south side of the County associated with the metropolitan Atlanta area. Correspondingly, according to the 2004 *Gainesville and Hall County Comprehensive Plan*, the 1990 population estimate for the City of Gainesville was 17,785, and the 2006 population projection was 35,052, for an overall increase of 97 percent within the City of Gainesville. These population increases were associated with more intensive land uses, which can increase nonpoint source pollution and potentially impact streams. Thus, land uses throughout the Flat Creek watershed were reviewed for this assessment.

2.2.1 Existing Land Use

Existing land use data can be used to characterize potential sources of contaminants from nonpoint source pollutants to aquatic ecosystems. Table 2-1 lists land use data for Flat Creek watershed, based on the Atlanta Regional Commission's (ARC's) LandPro 2009 Geographic Information System (GIS) database. The watershed was divided into three subwatersheds to further characterize specific portions of the watershed. Land use in the Flat Creek watershed was reduced to the six categories shown in Table 2-1 and in Figure 2-3.

TABLE 2-1
Current (2009) Land Use in the Flat Creek Watershed
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Land Use Category	Subwatershed			Total Flat Creek Watershed
	Embayment	Lower Flat Creek	Upper Flat Creek	
Residential	41.3	48.0	20.4	37.3
Commercial/Industrial	2.4	25.0	64.4	28.0
Reservoirs	24.4[a]	0.0	0.0	9.3
Parks/cemeteries	14.1	3.4	0.8	6.7
Forests/wetlands	15.6	14.0	1.7	11.0
Utilities, communications, transportation	2.2	9.7	12.6	7.7
Percent Total	100	100	100	100
Percent Impervious Cover[b]	8[c]	18	51	25

Source*:* Atlanta Regional Commission (2009)
[a] Includes Lake Sidney Lanier
[b] Percent impervious cover was calculated from City of Gainesville data
[c] Impervious cover in the Embayment was calculated excluding the "Reservoirs" land use category

The dominant land uses in the Flat Creek watershed were residential (37.3 percent) and industrial/commercial (28.0 percent). The Upper Flat Creek subwatershed is dominated by industrial and commercial areas, while the Lower Flat Creek and Embayment subwatersheds were predominantly residential (Table 2-1). Another 7.7 percent of the watershed is categorized as transportation, communication, utilities, transitional, and institutional which consists primarily of roads, railroads, and rail stations; the largest contiguous areas in this category were rail stations in the Lower and Upper Flat Creek subwatersheds. Industrial and commercial areas in the Upper Flat Creek subwatershed comprise 64 percent of the subwatershed, which is a factor in the high percent impervious cover (51 percent). The Upper Flat Creek subwatershed contains a number of poultry processing plants and feed mills, contributing to the high percentage of industrial areas.

Both the Lower Flat Creek and Embayment subwatersheds were dominated by medium-density residential land use, which is defined as areas developed for single-family residential use in which most houses were situated on ¼-acre to 2-acre lots. As a result, the percent of impervious cover in these subwatersheds is much less than in the Upper Flat Creek subwatershed. Because of the presence of Lake Lanier backwaters, 24.4 percent of the Embayment subwatershed is characterized as reservoir. If the lake were unaccounted for in this subwatershed, the percentage of total residential areas (45 percent) in the Embayment would be comparable to that of Lower Flat Creek (which is 48 percent residential). One difference between the Lower Flat Creek and Embayment subwatersheds is the much higher percentage of commercial land use in the Lower Flat Creek subwatershed (25.0 in Lower Flat Creek versus 2.4 percent in the Embayment).

The data for forest land use illustrate a notable difference among the three subwatersheds. Forest land use accounts for 15.6 percent of the Embayment, 14.0 percent of Lower Flat Creek, but only 1.7 percent of the Upper Flat Creek subwatershed (Table 2-1). Of the 892 acres of forested land in the Flat Creek watershed, over 370 acres, surrounding Lake Lanier, is protected and classified as undevelopable land. While all three subwatersheds exhibit a high degree of development, the Upper Flat Creek subwatershed is almost completely built out. Land use in the Upper Flat Creek subwatershed is over 50 percent impervious, significantly higher than the average imperviousness in the watershed as a whole (25 percent) (Table 2-1). Figure 2-4, which shows the percent imperviousness of watershed areas, exhibits the highly developed nature of the Upper Flat Creek subwatershed.

2.2.2 Projected Future Land Use

Projected land use utilized in the future without project analysis was obtained from the *City of Gainesville and Hall County Comprehensive Plan* (2004). Figure 2-5 shows projected future land use patterns. Table 2-2 summarizes the projected future land use in the City of Gainesville, as provided in the *City of Gainesville and Hall County Comprehensive Plan* (2004). The percentages shown in Table 2-2 provide insight into changes in the Flat Creek watershed, as a majority is located in the City. As the population in Hall County continues to grow, facilitated by available transportation routes (I-985 and an improved Highway 365 corridor) and increased sewer system availability and capacity, land use changes were projected to occur. Land use plans for the county indicate a projected increase in commercial and industrial development in the Flat Creek watershed (CH2M HILL, 2004). Growth projections for the next 30 years indicate a conversion of forest and agricultural land to commercial and industrial uses (Figure 2-5). The County intends to include the floodplains of streams such as Flat Creek in its conservation plans and greenspace preservation planning.

TABLE 2-2
Projected Future (2030) Land Use for the City of Gainesville
Flat Creek Watershed Detailed Project Report - Environmental Appendix

Future Land Use Category	Acres	Percent of City
Commercial	939	6.7
Conservation/Parks/Recreation	3,986	28.4
Industrial	1,077	7.7
Mixed Use Downtown	71	<1
Mixed Use Midtown	314	2.2
Mixed Use	1,032	7.4
Suburban Medium Density (Residential)	4,825	34.4
Suburban High Density (Residential)	1,252	8.9
Urban Residential Low Density	124	<1
Urban Residential Medium Density	131	<1
Urban Residential High Density	274	2.0
Total	**14,025**	**100%**

Source: 2004 Update to the Land Use Plan, MDC in CH2M HILL, 2004

Note: Not all land uses illustrated on the accompanying map are presented in this table, land uses not designated in the in the incorporated portions of the City of Gainesville have not been included

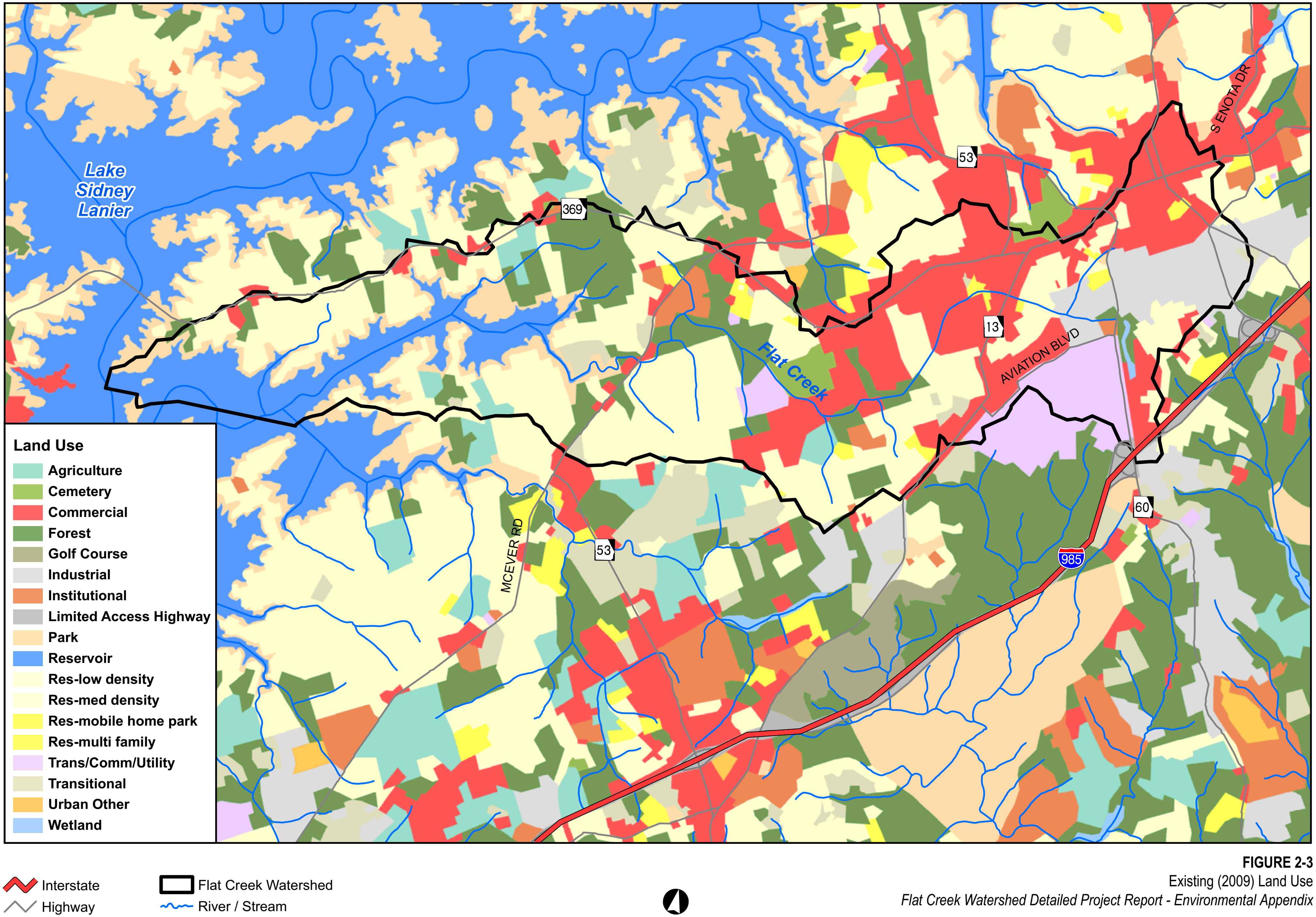

FIGURE 2-3
Existing (2009) Land Use
Flat Creek Watershed Detailed Project Report - Environmental Appendix

Source: Atlanta Regional Commission, 2009.

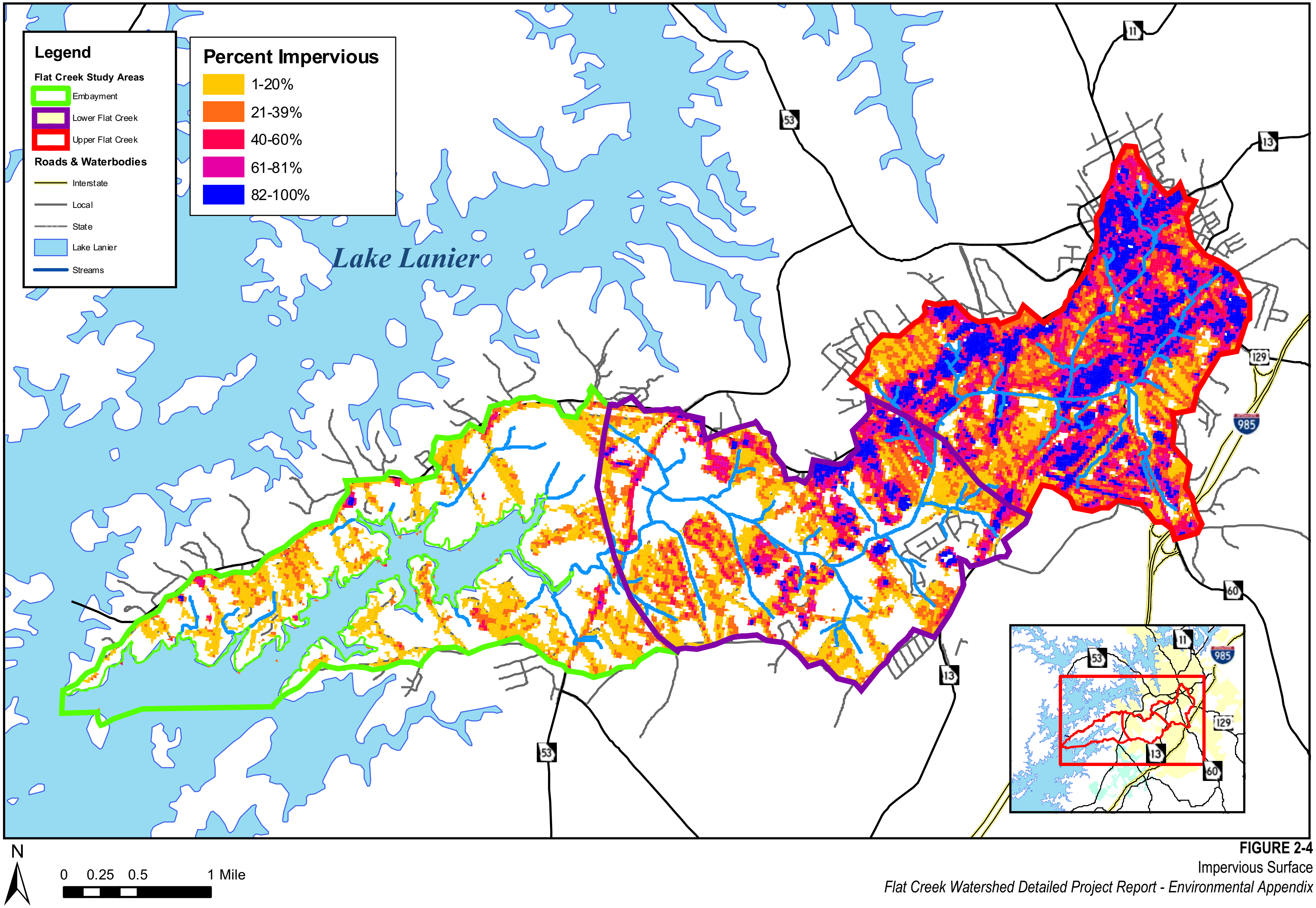

FIGURE 2-4

Impervious Surface

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Gainesville/Hall County

Comprehensive Plan Update 2004

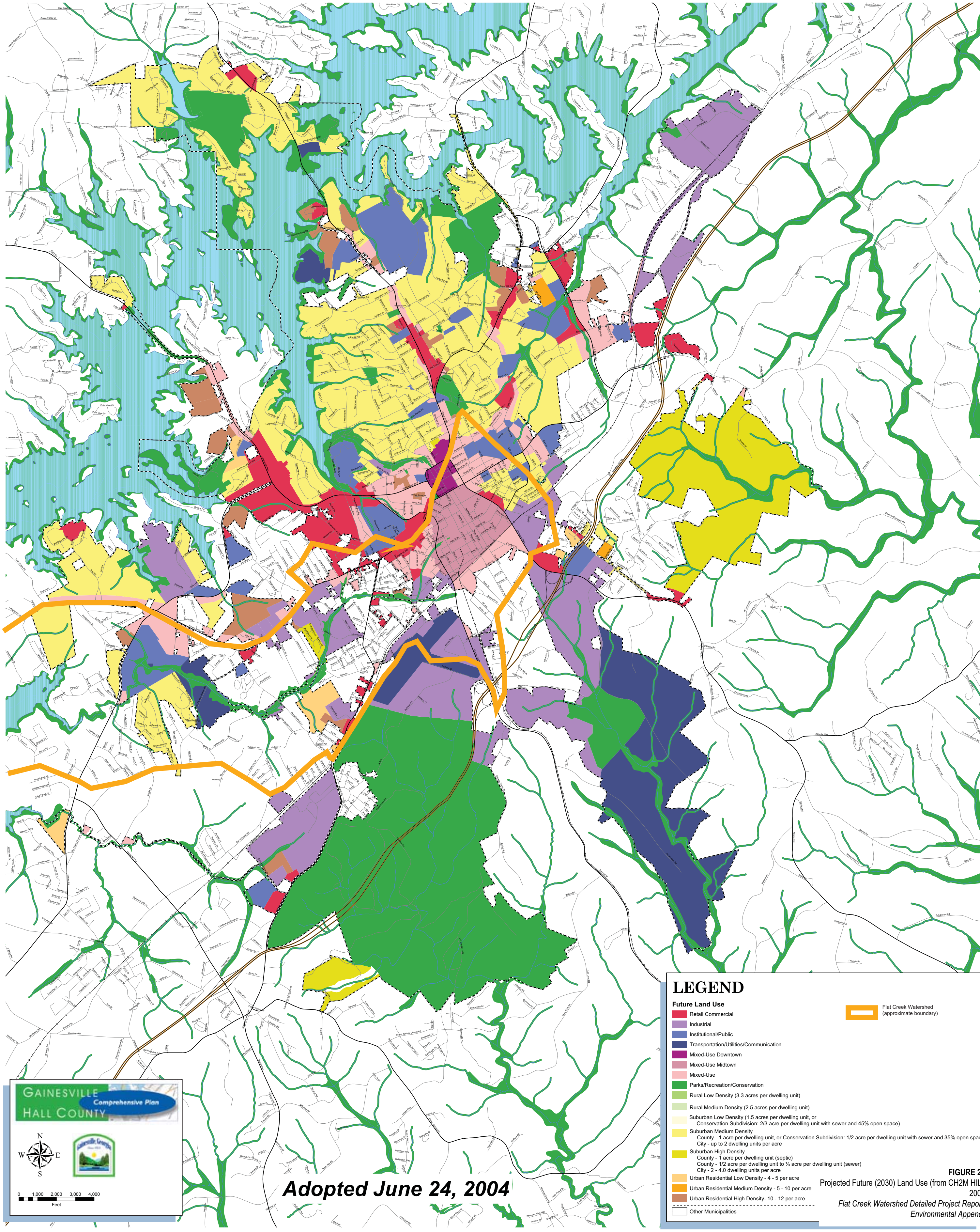

FIGURE 2-5

Projected Future (2030) Land Use (from CH2M HILL, 2004)

Flat Creek Watershed Detailed Project Report - Environmental Appendix

2.3 Pollution Sources

Water quality and aquatic integrity in the watershed were affected by both point and nonpoint sources of pollutants. Point sources were identifiable, fixed locations (such as pipe outfalls) where pollutants were discharged, and nonpoint sources were those that cannot be traced to a specific location, such as stormwater runoff. The City of Gainesville routinely performs stormwater monitoring in connection with both the City of Gainesville Surface Water Quality Program and Environmental Monitoring Plan; these results are presented in Section 3.2 (Biological and Water Quality Monitoring). Potential pollutant sources specific to Flat Creek are shown on Figure 2-6 and include point sources and non-point sources as shown below:

Potential Point Sources

- **Wastewater Dischargers**— The Gainesville Flat Creek Water Reclamation Facility (WRF) operates under a National Pollutant Discharge Elimination System (NPDES) permit to discharge effluent (treated wastewater) to Flat Creek, just south of Old Flowery Branch Road. The Flat Creek WRF is permitted to discharge 10.2 million gallons per day (mgd) and is therefore considered a major NPDES discharger. In 2007, the Flat Creek WRF received EPA's Region 4 2007 Clean Water Act Operations & Maintenance Award for the Large Advanced Wastewater Treatment Plant category, recognizing its efforts to go beyond the minimum requirements needed to meet the Clean Water Act.

- **Toxic Release Inventory (TRI) and Resource Conservation and Recovery Information System (RCRIS) Sites:** There were 62 RCRIS facilities and 13 TRI facilities within the Flat Creek watershed. The facilities were used to store, release, or transfer toxic chemicals or hazardous waste. There is no reason to believe those facilities were contributing contaminants of concern to the watershed. However, because the facilities store, release, or transfer toxic chemicals or hazardous waste, they were included in the evaluation of potential sources of pollution. TRI facilities in the watershed include Cargill, Inc. (a food provider), BorgWarner Cooling Systems, LaFarge Gainesville Concrete Plant, Siemens VDO Automotive (a manufacturer of automobile fuel systems and parts), and Mincey Marble Manufacturing, Inc. RCRIS facilities include Home Depot, Goodyear Auto Service Center, Bell's Drycleaners, Penske Truck Leasing Company, and various auto parts stores, gas stations, and manufacturing plants. Industries can be categorized as both TRI and RCRIS facilities. Note that a comprehensive search of environmental records, including 43 federal databases, 21 state and local databases, and 5 tribal databases, was conducted as part of the requirements for selection of the Tentatively Selected Plan for restoration in the Flat Creek watershed. These results are included in Appendix J to the Detailed Project Report.

- **Industrial / Commercial:** As indicated by the land use data in Table 2-1, industrial and commercial development encompasses 28 percent of the Flat Creek watershed. In addition to the Flat Creek WRF, two other industrial sites within the watershed operate under NPDES permits: Dixie Mobile Home Park and PrimePak Foods, Inc., a beef, poultry, and pork processor. These facilities were classified as Permit Compliance System (PCS) locations by the USEPA Envirofacts database and were permitted to discharge to Flat Creek under specified limitations. Another type of common commercial development, including gas stations and automobile dealerships, stores petroleum products in permitted underground storage tanks. Many leaking underground storage tanks have also been cited in the watershed (see Appendix J to the Detailed Project Report).

- **Septic Tanks**: In 2000, it was estimated that 60 percent of the Flat Creek watershed was served by septic tanks. The City of Gainesville conducts quarterly stream walks and routine water quality monitoring that can help identify any septic system failures or illicit discharges. Data and follow-up activities are reported to GAEPD on a biannual basis. Septic system data specific to Flat Creek were not available, but according to the City of Gainesville and Hall County Comprehensive Plan (City of Gainesville and Hall County, 2004), nearly 15,000 septic permits were issued between 1995 and 2001, including authorization for either new construction or repair to existing septic tanks. Between July of 2002 and June 2003, 1,618 septic permits were issued on a County-wide basis, providing 49 additional septic tanks and 539 repairs.
- **Landfills:** The Flat Creek watershed does not contain any landfills.

Potential Non-Point Sources

- **Stormwater Runoff from Non-stabilized Sites:** Land clearing and development have occurred as part of urbanization in the Flat Creek watershed. As part of their ongoing watershed management activities, the City of Gainesville conducts construction plan reviews and site inspections to enforce proper erosion and sedimentation control practices according to local ordinances. If erosion and sedimentation control practices are not applied correctly during land disturbance, nonpoint source pollution can result. Inadequate erosion control measures may contribute large quantities of sediment to the stream channel.
- **Stormwater Runoff from Stabilized Sites:** Due to the highly impervious nature of some intensive land uses in the Flat Creek watershed, stormwater runoff can carry significant loads of pollutants into the stream channel. These include animal waste, vegetative matter, pesticides, herbicides, fertilizer, and trace metals from urban surfaces such as roofing materials, flashing, galvanized pipes, brake linings, and tires. In addition, atmospheric pollutants can be deposited on impervious surfaces and delivered to the stream. A summary of stormwater sampling conducted by the City of Gainesville is presented in Section 3.2.
- **Channel Erosion:** The large percentage of imperviousness in the Flat Creek watershed decreases the infiltration and storage capacity of the soils in the watershed. This results in a shorter time of concentration as well as an increase in the volume and the velocity of stormwater runoff that is delivered to stream channels. This increase in runoff volume and velocity erodes stream channels and banks and adds to sediment loading in the stream. See Section 3.3 (Stream Assessment) for a bank erosion assessment of Flat Creek.

The majority of the pollution sources in the Flat Creek watershed were located in the Upper Flat Creek subwatershed. Of the 78 potential pollution sources identified, more than 75 percent were located in the Upper Flat Creek subwatershed. Twenty-two percent of the sources were in the Lower Flat Creek subwatershed, including the Flat Creek WRF. Only one pollution source, a TRI facility, is located in the Embayment subwatershed.

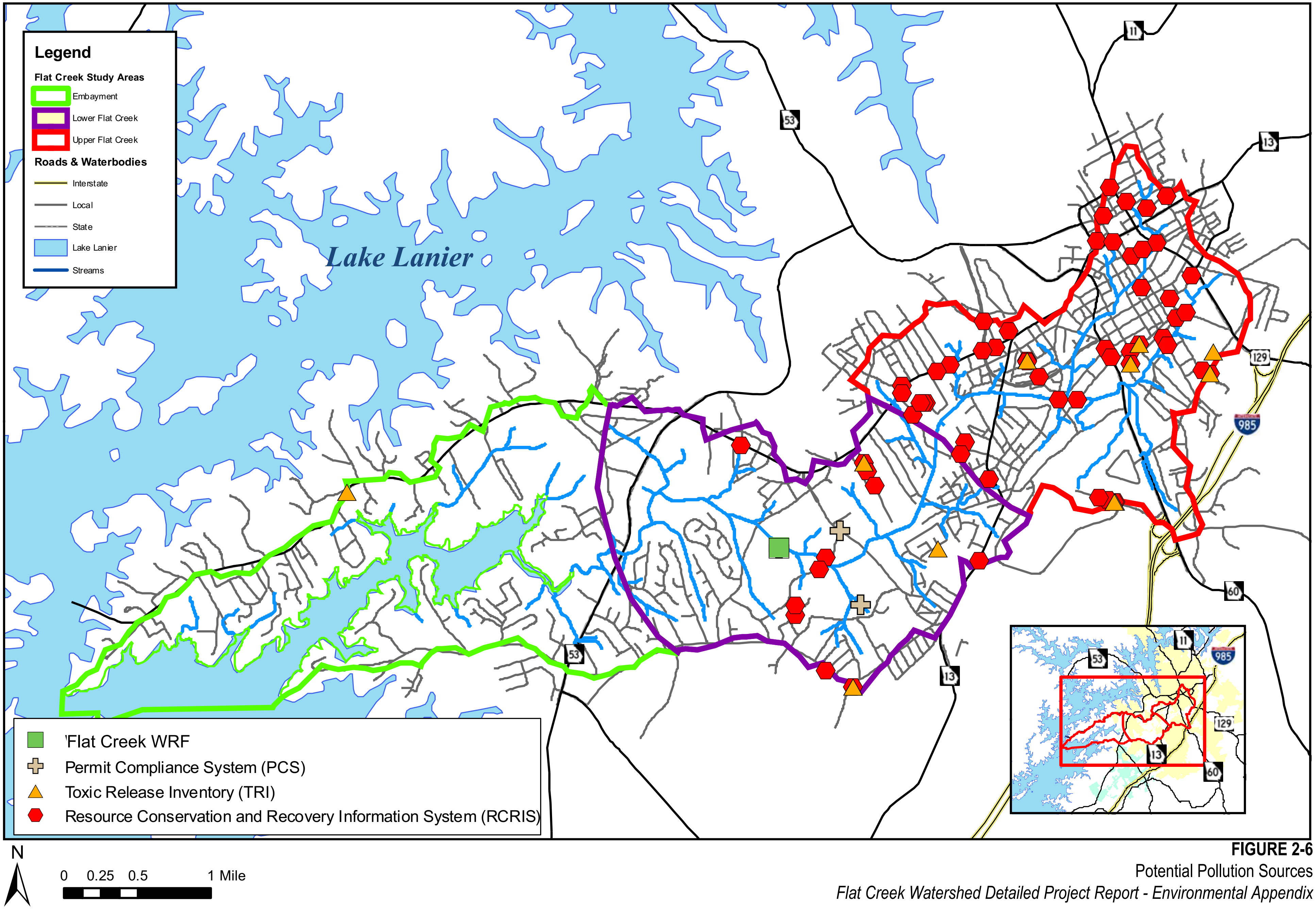

FIGURE 2-6
Potential Pollution Sources
Flat Creek Watershed Detailed Project Report - Environmental Appendix
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3. Analysis of Existing Conditions

3.1 Existing Conditions Assessment

To document existing conditions in the watershed, physical conditions of stream channels and adjacent riparian ecosystems as well as aquatic biological communities were assessed at various representative locations in the project area. The following sections discuss how sampling locations were selected within the project area, how stream assessments were used to identify problem areas, and how these data were used in the analysis of existing conditions using the Ecosystem Response Model (ERM). In 2007, sampling stations in the Flat Creek watershed were chosen based on guidance for the ERM. The procedure for identifying sampling stations aims to be representative of the watershed as a whole, with sampling stations representing the changes in watershed area. Four stations in the Flat Creek watershed were selected. Existing conditions provided a strong indication of the health of aquatic communities in Flat Creek and were used to identify areas that would benefit from ecosystem restoration efforts. Biological field sampling and analysis methods, and the results, are described in this section.

3.1.1 Representative Monitoring Stations

To ensure that ERM outputs were representative of conditions of a watershed as a whole, data must be analyzed at various locations, chosen carefully using a stratified selection procedure. The ERM guidance document, developed by the North Georgia Water Resources Agencies (NGWRA) interagency team, outlines a procedure for selecting locations to be appropriately representative of a watershed. Following this guidance, and based on the size of the Flat Creek watershed, four sites were selected as representative of the watershed (Figure 3-1; Table 3-1). The City of Gainesville had previously established two of the four chosen sites as long-term monitoring stations (FLG-4 and FLG-5). The two additional sampling station sites were established based on ERM guidance (FLG-A and FLG-B). The four sites (total) were selected to represent a range of headwater streams, each associated with an approximate doubling of drainage area (Table 3-1) (NGWRA, 2007). Observed characteristics for each site are based on a single field effort completed in 2007. Representative photographs for each site are provided in Figure 3-2.

Station FLG-A

Station FLG-A was located in the headwaters of Flat Creek, just downstream of its intersection with Dorsey Street. This station was selected to represent the smallest drainage area, for the ERM, and was affected by industrial and commercial land use. Riparian habitat quality has been affected on both banks by the removal of native vegetation, with a power line on the left bank and residential lawns on the right bank. Overall, habitat diversity at the site was fair, with the dominant habitat structure being large woody debris and undercut banks. Stream substrates were dominated by gravel and sand, with a majority being substantially embedded. Sediment deposition has caused the formation of sand bars and has reduced riffle habitat.

A few riffles were present in the reach, although the reach contains no fast currents. Bank stability on both sides of the channel was poor, and some areas have been covered in riprap. The sparse riparian vegetation and large amount of erosion on both banks have the potential to result in further sedimentation to the stream and a further reduction in habitat diversity. In addition, the surrounding riparian areas receive frequent foot traffic and have been impacted by human stressors. These include large amounts of trash, which were adding nonpoint source pollution to the stream during storm events. The City of Gainesville was aware of this problem, and its Environmental Services Department conducts quarterly stream-walks and weekly site inspections at stream crossings and other areas with the potential for pollution problems.

TABLE 3-1
Summary of Sampling Stations
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Summary Category	Station ID			
	FLG-A	**FLG-4**	**FLG-B**	**FLG-5**
Location	Flat Creek at Dorsey St.	Flat Creek at Hilton Dr.	Flat Creek at Old Flowery Branch Rd.	Flat Creek at McEver Rd.
Type	Station added for ERM	Long-term monitoring station	Station added for ERM	Long-term monitoring station
Drainage Area (sq. mi.)	2.4	3.4	5.4	7.1
Surrounding Land Use	Industrial/ commercial	Industrial/ commercial	Commercial and high-density residential	Commercial and high-density residential
Riparian Condition	Severely disrupted	Right-of-way on right bank	Right-of-way on right bank	Minimally impacted, well-vegetated
Physical Habitat Characteristics	Increased sediment deposition, unstable banks; dominated by large woody debris and undercut banks	Poor riffle habitat, unstable banks; dominated by undercut banks	Good habitat diversity, moderately stable banks	Diverse habitat, good riffle and pool habitat, minimally eroded banks

Station FLG-4

Station FLG-4 was located just downstream of Station FLG-A at Hilton Drive. It was chosen as a long-term monitoring station to represent a relatively small drainage area with a prevalence of commercial and high density residential land uses. Current land use in the drainage area was highly industrial. This station also was selected to monitor water quality upstream of the Flat Creek WRF. The stream was a straightened channel with approximately 25 percent sand and 60 percent gravel substrates. Deep pools with sand and cobble substrates were present; however, the reach was predominantly flat water, with a few slow riffles. A narrow range of velocity/depth regimes was present, resulting in poor riffle habitat. The dominant habitat structure included undercut banks and submerged logs. Both banks were moderately unstable, with a high potential for erosion during storm events. The riparian buffer on the left bank was in optimal condition, being well protected by vegetation; however, the right riparian buffer zone has been affected by a sewer line right-of-way (ROW).

Station FLG-B

Station FLG-B was located approximately 400 feet downstream of Old Flowery Branch Road. It was selected according to the random sampling guidelines, in accordance with the ERM guidance document (NGWRA, 2007), and was located in an area with commercial and high-density residential land use. This station was the most first station downstream of the Flat Creek WRF, which discharges to Flat Creek. In the past, effluent from the WRF was found to contribute to high levels of specific conductance in Flat Creek downstream of the plant, which may affect aquatic communities in this reach. The City was aware of these water quality conditions and continues to monitor plant effluent and submit discharge monitoring reports to EPD. The City, like many of its municipal neighbors, was in the process of identifying ways to reduce the impact of its effluent and was focusing efforts on optimizing plant operations and maintenance.

Physical habitat at FLG-B was highly diverse, including large woody debris, undercut banks, root wads, good riffle and pool habitat, and a stable mix of bottom substrates. Both banks exhibit a moderate amount of erosion, although more than 70 percent of their surfaces were covered by vegetation. The left bank riparian zone has not recently been impacted by anthropogenic sources, so habitat quality remains good. However, the right bank riparian area has little vegetation due to clearing and creation of a grassed sewer line ROW.

Station FLG-5

Station FLG-5, the most downstream station, was located upstream of McEver Road. This station was selected for long-term monitoring to represent a relatively large drainage area with high-density residential land use and to monitor water quality downstream of the WRF discharge. Station FLG-5 received the highest physical habitat rating of the Flat Creek stations during the 2007 biological monitoring. The reach was dominated by gravel and cobble, and also contains bedrock and boulders, providing excellent epifaunal substrate and cover for benthic macroinvertebrates and fish. The layering of the substrate provides a diversity of habitat and also results in the presence of a wide variety of velocity/depth regimes. Both riffle and pool habitats were optimal in this reach. The banks were only slightly eroded and were covered, almost entirely, by native vegetation. Both riparian areas were minimally impacted, with small breaks on the right bank resulting from power line clearing.

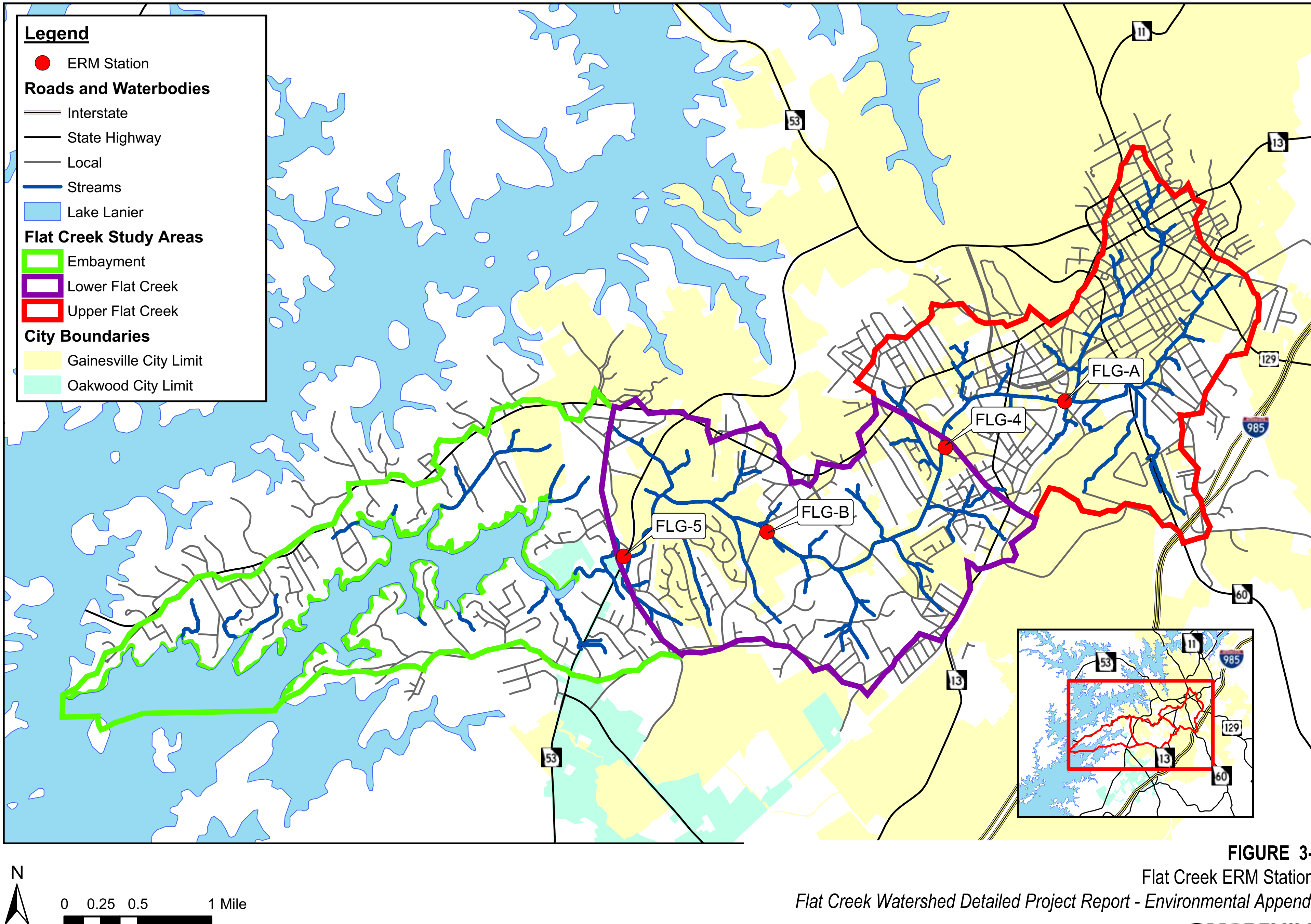

FIGURE 3-1

Flat Creek ERM Stations

Flat Creek Watershed Detailed Project Report - Environmental Appendix

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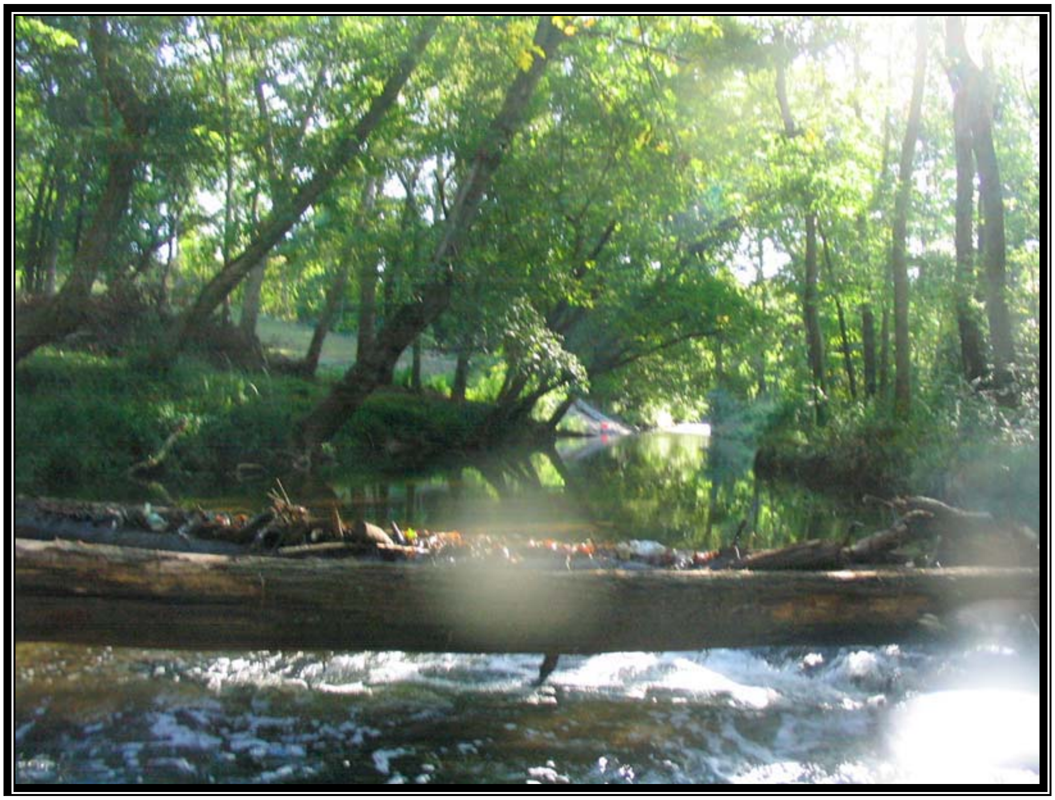

Photograph 1 Representative view of Flat Creek (FLG-5) facing upstream

Photograph 2 Representative view of Flat Creek (FLG-5) facing downstream

FIGURE 3-2a
Representative Photographs of ERM Sampling Stations in 2007

Photograph 3 Representative view of Flat Creek (FLG-4) facing upstream

Photograph 4 Representative view of Flat Creek (FLG-4) facing downstream

FIGURE 3-2b
Representative Photographs of ERM Sampling Stations in 2007
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Photograph 5 Representative view of Flat Creek (FLG-A) facing upstream

Photograph 6 Representative view of Flat Creek (FLG-A) facing downstream

Photograph 7 Representative view of Flat Creek (FLG-B) facing upstream

Photograph 8 Representative view of Flat Creek (FLG-B) facing downstream

FIGURE 3-2d
Representative Photographs of ERM Sampling Stations in 2007

3.2 Biological and Water Quality Monitoring

Biological assessments and water quality monitoring were conducted in 2007 to inventory existing conditions. Fish monitoring was conducted in April 2007, while macroinvertebrate monitoring was conducted in October 2007. Biological monitoring data were then used in the ERM to establish the existing conditions of the Flat Creek watershed, for comparison to future conditions both with and without alternative implementation. Analysis of existing conditions included the following steps:

- **Step 1**: **Biological Monitoring Data Inputs**—Bioassessment data, collected from four stations selected to be representative of the watershed, were input into the ERM, including assessment scores for the fish community, benthic macroinvertebrate community, and physical habitat.
- **Step 2: Existing Conditions Score Outputs**—ERM outputs single fish, macroinvertebrate, and physical habitat scores representative of the entire watershed by averaging scores, representing the averages as a fraction of the total possible scores, and calculating a weighted average of these scores.

In 2007, four stations on Flat Creek were sampled for fish and benthic macroinvertebrates and evaluated for physical habitat conditions (Figure 3-1). Two of these stations (FLG-4 and FLG-5) were selected as part of the Hall County and City of Gainesville WAMP conducted by CH2M HILL in 1999. The two stations were sampled for biological parameters every 2 years due to Flat Creek's status on recent and current Georgia 305(b)/303(d) Reports. Two additional stations on Flat Creek (FLG-A and FLG-B) were included in the 2007 biological monitoring, for the purpose of ERM data collection. The purpose of biological monitoring was to collect data for use in the ERM to determine the existing conditions of Flat Creek watershed. Existing conditions provided a strong indication of the health of aquatic communities in Flat Creek and were used to identify areas that would benefit from ecosystem restoration efforts. Biological field sampling and analysis methods, and the results, are described in this section.

Biological monitoring provides an indication of the long-term health of aquatic ecosystems, but water quality measurements can help determine short-term water quality concerns that may affect aquatic communities. Additionally, when water quality measurements are assessed over a long period of time, water quality measurements may also be a helpful indicator of the long-term health of aquatic ecosystems. Water quality measurements can signify the relative health of ecosystems across areas of a watershed and can be used to further identify locations which would benefit from ecosystem restoration projects. During the benthic macroinvertebrate sampling conducted in October 2007, in situ water quality measurements were made, and grab samples were collected for water chemistry analysis. Although historical water quality data were necessary for trend analysis and determination of the long-term health of the stream, the October sampling results provide useful information regarding instantaneous stream health. The methods and results of the water quality sampling are discussed below.

3.2.1 Fish Community Assessment Methods

Fish sampling was conducted at the four Flat Creek sampling stations in accordance with the *Standard Operating Procedures for Conducting Biomonitoring on Fish Communities in Wadeable Streams in Georgia* (GADNR, 2005). The Index of Biotic Integrity (IBI; Karr et al., 1986) was used to evaluate the health of the fish communities at the sampling stations. The IBI, which is used as the model for USEPA's Rapid Bioassessment Protocol (RBP) (Barbour et al., 1999; Plafkin et al., 1989), integrates a broad range of fish community attributes into an assessment of stream biotic integrity. The methodology involves a fish community survey using standard field techniques, species identification, enumeration, and external examination of the fish collected. Ratings were assigned to various fish community attributes (metrics), which were summed to obtain an overall measure of biotic integrity. For the ERM, each of the individual metrics rated in the fish IBI assessment were analyzed and a range of future scores were predicted based on the projected future environmental condition categories.

3.2.2 Macroinvertebrate Community Assessment Methods

Benthic macroinvertebrates were sampled at each station in accordance with the *Standard Operating Procedures for Conducting Macroinvertebrate Biological Assessment of Wadeable Streams in Georgia, Standard Operating Procedures* (GADNR, 2007). This assessment was consistent with USEPA's RBPs (Barbour et al., 1999) and involved collecting samples from the various habitats for analysis and data evaluation. Benthic macroinvertebrate samples were identified to the lowest taxonomic level practical, and a benthic macroinvertebrate index (BMI) score was calculated based on five metric categories specific to the Southern Inner Piedmont (45a) sub-ecoregion of Georgia. Each metric category represents a different component of community structure and/or function and provides a measure of biotic integrity. For the purposes of future score prediction, similar to the fish IBI procedure, each of the individual metrics rated in the BMI assessment was analyzed and a range of future scores were predicted based on the projected future environmental condition categories.

3.2.3 Physical Habitat Assessment Methods

As a component of biological monitoring, physical habitat assessments were conducted on Flat Creek, using protocols and worksheets provided in the current draft guidance (GADNR, 2007). The procedures include an evaluation of the local watershed, channel substrates, stream width, and general habitat quality conditions. The 2007 guidance included habitat assessment protocols for riffle/run and glide/pool prevalent systems. Following the guidance, all streams located in the Piedmont region of Georgia historically were riffle/run streams and should be evaluated as such, leaving glide/pool reaches only in coastal areas (GADNR, 2007). The riffle/run habitat assessment protocols involve rating each of 10 metrics that measure various riparian and in-stream parameters. The results of each of these metrics were evaluated separately to develop a range of future score predictions, assuming no project was implemented in Flat Creek.

3.2.4 Water Quality Monitoring Methods

For this assessment, water quality data from the City of Gainesville's Surface Water Quality Program and the Environmental Monitoring Program (EMP) from January 2005 through June 2007 were compiled. Comprehensive data and further analyses were presented in the

City of Gainesville quarterly reports and in the biannual reports from 2003, 2005, and 2007. The variability within the 2-year range of data is partially due to seasonal trends, especially as a result of water quality differences during dry and wet weather. In general, nonpoint sources of pollution tend to impact water quality during wet weather events, while point sources of pollution have the greatest potential to impact water quality during dry weather. Nonpoint source pollution results during wet weather when stormwater runoff enters streams, and point source pollution is generally slightly lower during wet weather due to increased flows which dilute pollutant concentrations. Data were summarized by dry and wet weather means for each station to characterize pollutant loads under both dry and wet weather conditions. In order to account for these differences, data were categorized as dry weather (less than 0.25 inch of rain in the 24 hours prior to sampling) or wet weather (greater than 0.25 inch of rain in the 24 hours prior to sampling).

The City of Gainesville monitors water quality, for parameters listed in Table 3-2, at six stations (see Figure 3-3) in the Flat Creek watershed as part of its Surface Water Quality Program. In addition to monitoring conducted for the Surface Water Quality Program, the City of Gainesville staff also conducts monitoring according to the EMP. Of the stations included in the EMP, two (FLG-4 and FLG-5) were located in the Flat Creek watershed (Figure 3-3). Station FC-5 (from the Surface Water Quality Program) was in the same location as the EMP station, FLG-5. As part of the EMP, the City conducts monthly water quality sampling, biannual biological monitoring, and quarterly stream-walks. The EMP included only some of the parameters that were included in the Surface Water Quality Program, and TOC was included in the EMP, but not included in the Surface Water Quality Program. In 2007, some additional parameters were included in the EMP, such as metals analysis. Metals were not discussed in this document because of the limited dataset (four samples since February 2007). However, all metals results in 2007 were below the reportable limit.

3.2.5 Conditions at the Time of Sampling

Droughts or floods can affect stream base and peak flows, water quality, erosion and sedimentation, and other instream conditions, which can affect habitat, and in turn, affect fish and benthic macroinvertebrate communities. The 2007 biological and water quality monitoring event were conducted during a severe drought in the north Georgia region, which can have a notable effect on results. In general, smaller watersheds with a higher impervious cover would be expected to be more susceptible to drought impacts than larger watersheds with less impervious cover. This potential effect must be considered when evaluating the 2007 biological data as a representation of existing watershed conditions and using these conditions to forecast future biological communities. Thus, 2007 monitoring data were compared with data collected from Flat Creek and from other monitoring stations in Hall County with similar drainage areas during other years with weather having less extreme influences on stream flow.

TABLE 3-2
Summary of City of Gainesville Montioring Acitvities
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Monitoring Program	Description	Study/Program Leader	Sampling Period	Parameters Monitored	Flat Creek Stations	Sampling Frequency
Surface Water Quality Program[a]	Monitor changes in the watershed due to the onset of WRF discharges in the City of Gainesville	City of Gainesville	1987-present	Temperature, dissolved oxygen (DO), pH, specific conductance, turbidity, fecal coliform, Escherichia coli (*E. coli*), biochemical oxygen demand (BOD), total suspended solids (TSS), total solids, total phosphorus (TP), Total Kjeldahl Nitrogen (TKN), ammonia, nitrate, nitrite, hardness, alkalinity	FC-1,FC-2, FC-3, FC-4, FC-5c, FC-6	Monthly
Environmental Monitoring Plan (Water Quality)[a]	City staff collects water quality samples based on requirements of the WAMP and WPP for compliance with GAEPD and MNGWPD guidelines	City of Gainesville	2001-present	Temperature, DO, pH, specific conductance, fecal coliform, TSS, TP, total organic carbon (TOC), nitrate, nitrite, turbidity, BOD, ammonia, TKN, hardness, total dissolved solids (TDS), phosphate (PO4), total and dissolved cadmium, total and dissolved lead, total and dissolved zinc, chemical oxygen demand (COD), *E. coli*	FLG-4, FLG-5c	8 times per year
Environmental Monitoring Plan (Biological)[a]	Physical habitat assessments, benthic macroinvertebrate, and fish sampling	City of Gainesville	2003-present	Physical habitat, benthic macroinvertebrates, fish species	FLG-4, FLG-5 c	Biannually
Stream Assessment[b]	Document current physical conditions in the stream channel and riparian areas; identify restoration potential	City of Gainesville/Hall County	May 2007	Man-made and hydrologic channel alterations, bank erosion, riparian buffers, physical habitat,	Over 20 miles of streams walked	Once
Stormwater Detention Structure Assessment[b]	Based on GIS analysis, field verify stormwater detention structures for retrofitting opportunities and potential benefit	City of Gainesville/Hall County	May 2007	Water quality protection, channel protection	30 locations	Once

[a] These monitoring activities include stations in other City/County watersheds
[b] These monitoring activities were conducted as part of the Flat Creek WIP/ERR
[c] Stations FC-5 and FLG-5 were in the same location
[d] As of January 2007
[e] As of February 2007
[f] As of April 2007
[g] As of June 2007

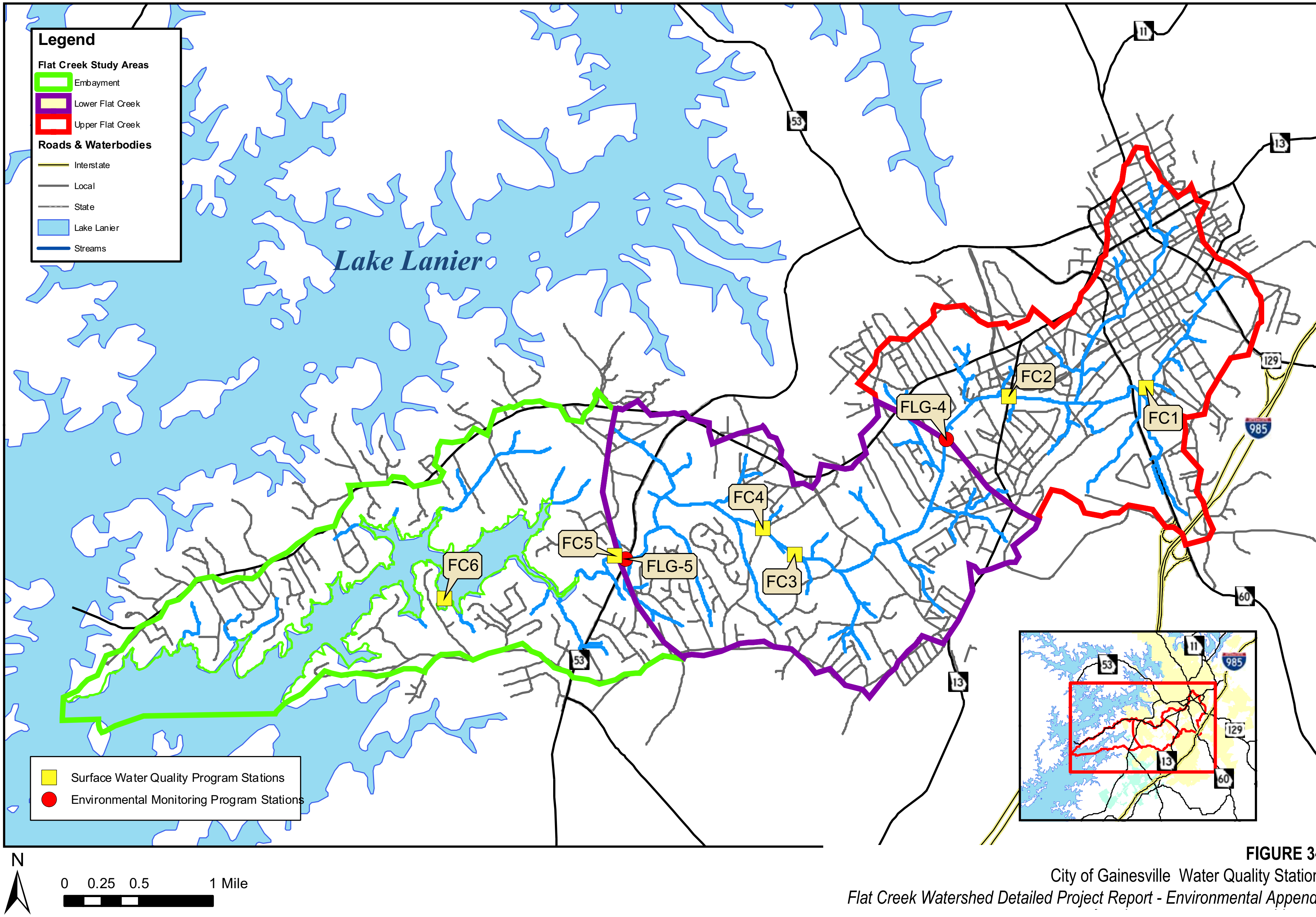

FIGURE 3-3

City of Gainesville Water Quality Stations

Flat Creek Watershed Detailed Project Report - Environmental Appendix

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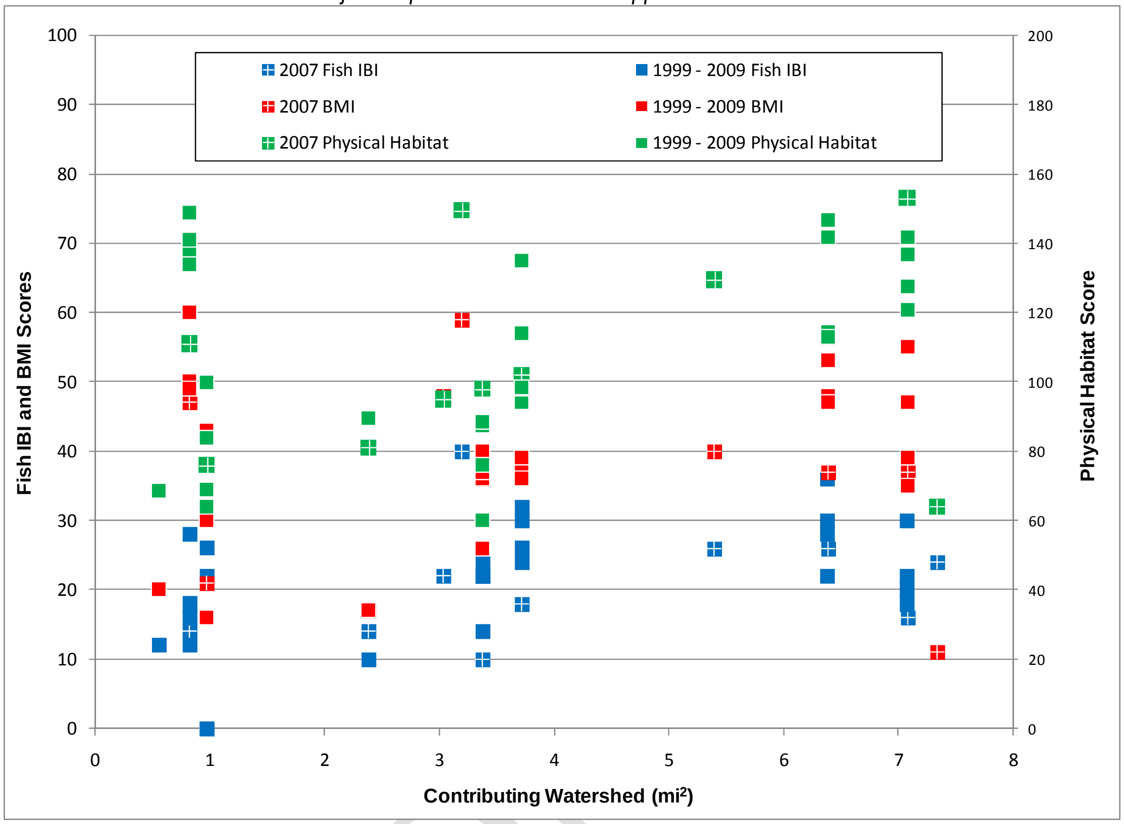
Figure 3-4 provides the results of biological monitoring at City of Gainesville and Hall County stations in 1999, 2003, 2005, 2007, and 2009 (2009 results were presented; though they do not form the basis of the existing conditions assessment which was begun prior to this sampling year). The data sets include samples collected at 6 locations in 1999, 2003, and 2005; 11 locations in 2007; and 8 locations in 2009. Data collected from 1999 to 2005 include the City of Gainesville long-term monitoring stations: FLG-4, FLG-5, Balus Creek at Old Flowery Branch Road, Cry Creek near Habersham Road, Longwood Park Creek at Pearl Nix Parkway, and Limestone Creek at Limestone Parkway. The 4 stations not located on Flat Creek were added to this analysis because they have similar drainage areas to the Flat Creek stations and were located in other areas of Hall County. The 2007 dataset included the addition of FLG-A and FLG-B, which were sample for use in the ERM analysis, as well as West Fork Little River at Homer White Road, West Fork Little River at Dahlonega Highway, and Bear Creek at Odum Smallwood Road, located in upper Hall County. The 2009 data include the City of Gainesville's long-term monitoring stations, FLG-A, and Flat Creek at Kenwood Drive, which was first sampled in 2009. For more information on this dataset and conditions at the time of sampling events, the series of Biannual Reports submitted to GAEPD is available beginning in 1999.

Results from 2007 do not suggest an anomalous sampling year and were therefore assumed to be applicable for the existing conditions analysis. Key observations based on Figure 3-4 include:

- A reduction in the stream base flow decreases the wetted perimeter of a stream channel, reducing available habitat for aquatic species. Physical habitat scores ranged from 60 to 153, and for most drainage area sizes, 2007 data were neither the highest nor the lowest value.
- Benthic macroinvertebrates exhibit little mobility within their aquatic habitats, making them susceptible to changes in physical habitat. In particular, species with preferences for riffle habitats were more likely to be affected as riffles may be shallower and reduced in width during drought. Benthic macroinvertebrate scores ranged from 11 to 60, and as with the physical habitat scores, 2007 data were neither the highest nor the lowest value.
- Fish species can take refuge in pools and move downstream and were less likely to be affected than macroinvertebrate species with much more limited mobility. As discussed in Biannual Reports, fish communities in these communities have exhibited very little species diversity and the most numerous species were ones more tolerant of disturbed habitat quality and pollution. As observed in Figured 3-4, fish communities exhibit generally low scores, with the majority below 30 and one score of 0 (or ranging from "poor" to "very poor"). In support of this pattern, fish scores in 2007 remained consistently low across the sampling area.

FIGURE 3-4
Historical Biological Data from City of Gainesville and Hall County Monitoring Stations
Flat Creek Watershed Detailed Project Report – Environmental Appendix



3.2.6 Fish Community Assessment Results

Fish community sampling in Flat Creek yielded a total of 11 species, including sunfishes (6 species), minnows (4 species), and catfishes (1 species). The most common species were golden shiners (*Notemigonus crysoleucas*), redbreast sunfish (*Lepomis auritus*), and green sunfish (*Lepomis cyanellus*). Table 3-3 presents the 2007 fish community metric values and final IBI scores for Flat Creek. The raw scores provided were related to a respective metric rating, which can be assigned a 1, 3 or 5, with 5 being the best possible score.

The August 2007 sampling event occurred during a severe drought in the area. Stream channel base flows were below average, which may have had a negative effect on fish sampling results. The fish community at station FLG-B received a Poor qualitative score, and the fish communities at the other three stations all rated as Very Poor. The higher score at station FLG-B was attributed to the relatively high percentage of insectivorous cyprinids and benthic fluvial specialists at the site. Except for these species, the fish assemblages were relatively uniform across the stations, although four species (warmouth, largemouth bass, blacktail shiner, and flat bullhead) were found at the downstream-most FLG-5 that were not found at the three other stations. These species most likely occurred at FLG-5 due to the close proximity of this station to Lake Lanier and the upstream movement of fish from the lake into the lower reaches of Flat Creek. A brief discussion of selected parameters is provided below.

Number of Benthic Invertivore Species. Streams with high biotic integrity often have several species of benthic invertivores inhabiting riffle areas. However, when siltation, flow modification, and low dissolved oxygen (DO) levels occur, the environment available for benthic feeding and reproduction becomes limited. No benthic invertivore species were found in Flat Creek, suggesting that the community of benthic invertivore species was affected, most likely by the high degree of sedimentation observed in Flat Creek. Also, the food source for these species may have been decreased during the drought conditions, influencing their presence.

TABLE 3-3
Fish Community IBI Metric Scores and Ratings for Flat Creek—2007
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Metric[a]	Raw Score (Metric Rating)[b]							
	FLG-A (Dorsey Street)		FLG-4 (Hilton Road)		FLG-B (Old Flowery Branch Road)		FLG-5 (McEver Road)	
1. Number of native species	2	(1)	4	(1)	2	(1)	8	(1)
2. Number of benthic invertivore species	0	(1)	0	(1)	0	(1)	0	(1)
3. Number of native sunfish species	1	(1)	2	(3)	1	(1)	3	(3)
4. Number of native insectivorous cyprinid species	0	(1)	0	(1)	1	(1)	2	(1)
5. Number of round-bodied sucker species	0	(1)	0	(1)	0	(1)	0	(1)
6. Number of sensitive species	0	(1)	0	(1)	0	(1)	0	(1)
7. Evenness	75.25	(5)	61.69	(1)	88.95	(1)	65.98	(3)
8. Percentage of individuals as *Lepomis* species	46.00	(3)	54.60	(1)	43.50	(3)	85.20	(1)
9. Percentage of individuals as insectivorous cyprinids	0.00	(1)	0.00	(1)	56.50	(5)	6.60	(1)
10. Percentage of individuals as generalist feeders and herbivore	54.00	(1)	45.40	(1)	0.00	(5)	5.60	(5)
11. Percentage of individuals as benthic fluvial specialists	0.00	(1)	0.00	(1)	56.50	(5)	1.00	(1)
12. Number of individuals per 200 meters	135.5	(1)	100.6	(1)	19.7	(1)	24.9	(1)
13. Correction factor: Percentage of individuals with external anomalies	1.61	(-4)	1.62	(-4)	0.00	0	1.53	(-4)
IBI Score (sum of 13 metric ratings)		**14**		**10**		**26**		**16**
Integrity Class	**Very Poor**		**Very Poor**		**Poor**		**Very Poor**	

[a] Metrics rated using the fixed criteria prescribed in the GADNR fish biomonitoring protocols (GADNR, 2005)
[b] The first number is the absolute metric value and the number in parentheses is the metric rating (1, 3, or 5).
[c] Four points were subtracted from the total score if the percentage of diseased fishes is greater than 1.2 percent (GADNR, 2005).

Proportion of Individuals as Insectivorous Cyprinid Species. Insectivorous cyprinids were expected to make up the dominant population in southeastern streams, often comprising more than 50 percent of the fish assemblage in healthy surface waters and comprising the dominant trophic guild (O'Neil and Shepard, 1998). However, historical sampling by the GADNR Wildlife Resources Division (WRD) has shown that human stressors to water quality reduce the occurrence of insectivorous cyprinids and that severely degraded sites may not contain any of these species. Low abundance or absence of minnows that feed upon insects often indicates poor variability in the aquatic insect food base observed in degraded streams. This can be caused by a variety of environmental impacts including sedimentation, habitat modification, and water quality degradation. No insectivorous cyprinids were collected at two of the Flat Creek stations, and relatively few were collected at one of the stations. Many insectivorous cyprinids use clean substrates in streams with a low percentage of embeddedness (covering of bottom substrate) for reproduction. The lack of insectivorous cyprinids indicates a lack of diversity in habitat types and a general lack of clean substrates.

Number of Sensitive Species. No sensitive species were collected in Flat Creek. This metric is a count of all collected species in a sample that have been designated as "sensitive" to environmental degradation. Designation of sensitive species is based on fish community analysis protocols (GADNR, 2005). The metric is an indicator of degradation of stream habitats, which included the effects of poor water quality, sedimentation, hydrologic modification, habitat alteration, and riparian zone disturbance. These types of disturbances were present throughout the Flat Creek watershed, leading to low overall ratings.

Percentage of Individuals as Lepomis Species. This metric is used as in indicator of habitat and water quality degradation and is determined by the number of *Lepomis* species (sunfishes) in a sample, including nonnative species and hybrids. An overabundance of *Lepomis* species often indicates that an area has undergone flow modification and habitat disturbance, as sunfishes tend to be habitat generalist species that were able to subsist in areas affected by these stressors. In addition, dominance by *Lepomis* species suggests a decrease in the diversity of the benthic macroinvertebrate community (GADNR, 2005). Stations FLG-4 and FLG-5 scored low for this metric, which suggests that degradation due to urbanization has affected these sites. It is also possible that point or nonpoint source pollution at these two stations may be affecting the downstream fish communities, as *Lepomis* species can dominate sites that are nutrient-rich (GADNR, 2005).

Percentage of Individuals with External Anomalies. In healthy stream systems, diseased or deformed fishes typically comprise less than 1.2 percent of the fish community (GADNR, 2005). This percentage was exceeded at three of the Flat Creek sites, resulting in a deduction from the overall metric sum. Degraded water quality conditions, extremely low flows, and high temperatures caused by severe drought or other environmental disturbances can cause fish to become stressed, and can often lead to disease or physical anomalies. The two forms of anomalies observed on sunfish in Flat Creek were milkeye and other lesions. Specific impacts that cause anomalies in fish are difficult to identify because they can be nonpoint pollution sources in the watershed or other conditions such as those discussed above. However, the presence of a relatively high number of anomalies was consistent with other 2007 Georgia fish assessments, suggesting that this is most likely due to the stresses of low flow during the severe drought conditions.

3.2.7 Benthic Macroinvertebrate Assessment Results

Table 3-4 presents the multimetric index scores and BMI scores for the four monitoring stations in the Flat Creek watershed. Although qualitative ratings were unavailable pending GAEPD's evaluation, a relative comparison between metrics and between stations can still be made.

Benthic macroinvertebrate sampling in Flat Creek yielded a total of 36 taxa, including mostly Chironomidae (midges) and caddisflies (Trichoptera order). No Plecoptera taxa (stoneflies) were found at any of the sampling stations. The farther upstream stations in the watershed were dominated by tolerant taxa, defined as those given a tolerance rating greater than or equal to 7 by GAEPD.

As noted above, Table 3-4 presents the BMI scores for the Flat Creek sampling stations. Corresponding qualitative ratings were currently unavailable, though they were expected to be provided by GAEPD in the near future. However, it should be noted that each metric was scored out of 100 points and that the Total Index Score was an average of the individual metric scores. This allows comparison between metrics and between sites. The macroinvertebrate index scores for Flat Creek ranged from 17 (FLG-A) to 40 (FLG-B) of a possible 100 points. The low percentages of the highest possible score suggest degradation of stream biotic integrity in the study area. A brief discussion of selected metrics is provided below.

TABLE 3-4
BMI Scores for Flat Creek—2007
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Metric	FLG-A		FLG-4		FLG-B		FLG-5	
	Raw Score	**Metric Score[a]**	**Raw Score**	**Metric Score[a]**	**Raw Score**	**Metric Score[a]**	**Raw Score**	**Metric Score[a]**
Plecoptera Taxa	0	0.0	0	0.0	0	0.0	0	0.0
Percent Trichoptera	1	3.4	20	63.2	32	100.0	52	100.0
Percent *Chironomus & Cricotopus*/Total Chironomidae	10	72.5	1	96.5	5	86.4	27	25.7
Tolerant Taxa	25	0.0	17	37.5	18	31.3	13	62.5
Percent Scraper	3	8.0	0.5	1.1	0	0.0	4	10.7
Clinger Taxa	3	15.2	4	20.2	4	20.2	4	20.2
Total Index Score[b]	**17**		**36**		**40**		**37**	

[a] Out of a possible 100 points
[b] Rounded average of Metric Scores

Number of Plecoptera Taxa. The Plecoptera taxa metric is the richness component of the index score and represents the diversity of relatively sensitive species in the stream. No Plecoptera taxa (stoneflies) were collected in Flat Creek, suggesting low species richness, poor habitat diversity, or negative water quality effects.

Percent of Trichoptera Individuals. The most upstream station on Flat Creek (FLG-A) scored much lower than the other Flat Creek stations, as only 1 percent of all individuals represented Trichoptera taxa (caddisflies). This low proportion is likely due to a decline in the variability of in-stream habitat, as this tends to result in an increase in habitat generalist species.

Number of Clinger Taxa. This metric is the habitat component of the macroinvertebrate index and is an evaluation of the number of taxa that inhabit, or cling to, the tops of rocks and other structures (i.e., members of the *Cheumatopsyche* and *Hydropsyche* genera in the Trichoptera order [caddisflies]). As stressors to water quality increase and the types of habitat become less variable, the number of clinger taxa is expected to decrease. All of the stations scored low for the number of clinger taxa, indicating that either riffle habitats or large woody debris habitats have been affected.

3.2.8 Physical Habitat Assessment Results

According to GAEPD, habitat assessment scores were no longer to be included with the benthic macroinvertebrate assessment calculation as they were in previous years. The main reason for this change is the subjective nature of the assessment and the extreme variation that may result from different assessors. Also, the scores were no longer compared to reference reach scores to develop a qualitative condition assessment, as was done in the past. However, the habitat assessment forms do provide qualitative categories for each metric that can be applied to overall habitat scores. Scores between 0 and 25 percent of the highest possible score can be considered "poor," between 26 and 50 percent were "marginal," between 51 and 75 percent were "suboptimal," and higher than 75 percent were "optimal." The raw scores and four qualitative categories were both useful for discussing location comparisons and trend analysis.

Table 3-5 summarizes the 2007 habitat assessment results. The highest possible habitat assessment score is 200 points. Stations FLG-A and FLG-4 both scored in the "marginal" category, station FLG-B in the "suboptimal" category, and station FLG-5 in the "optimal" category. Habitat scores increased approximately linearly between the most upstream station and the most downstream station. Relatively low scores at the upstream stations can be attributed to excessive sedimentation, embeddedness, low frequency of riffles, and reduced amount or absence of adequate shelter for fish and substrate for macroinvertebrates. Both stations have a large amount of sedimentation, which has caused an increase in embeddedness and a loss of riffles in the reaches. Sedimentation has also caused a decline in the in-stream cover available to fish and benthic macroinvertebrates. The upstream stations have smaller drainage areas and were expected to have less channel variability and in-stream cover.

TABLE 3-5
Physical Habitat Scores for Flat Creek—2007
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Parameter	FLG-A	FLG-4	FLG-B	FLG-5
Epifaunal Substrate/In-stream Cover	10.5	8	16	13
Embeddedness	4	10	14	15
Velocity/Depth Regimes	6.5	7	17	16
Sediment Deposition	7	12.5	9.5	15
Channel Flow Status	11.5	14.5	13.5	16
Channel Alteration	11.5	11	7.5	15
Frequency of Riffles	3	2	15	16
Bank Stability	8	11	11	16
Bank Vegetative Protection	14	11.5	14.5	15
Riparian Vegetative Zone	5	10.5	11.5	16
Total Physical Habitat Score	**81**	**98**	**129.5**	**153**

3.2.9 Summary and Comparison to Previous Data

Figures 3-5 through 3-7 compare data from all biological monitoring efforts to date with regard to physical habitat conditions, benthic macroinvertebrate communities, and fish communities (CH2M HILL, 2000; CH2M HILL, 2003; Brown and Caldwell, 2006; and CH2M HILL, 2007b). Results provide consistent evidence that aquatic integrity in Flat Creek was degraded, with Upper Flat Creek (FLG-A and FLG-4) being more impacted than Lower Flat Creek (FLG-B and FLG-5). During the 1999 and 2007 sampling events, drought conditions were present in north Georgia, and these weather conditions must be considered when analyzing biological results. Though drought conditions likely affected the two sampling events, total rainfall in 2007 (31.51 inches) was less than that in 1999 (41.45 inches) (National Oceanic and Atmospheric Administration [NOAA], 2008a).

For stations where data were collected in previous years (FLG-4 and FLG-5), fish and benthic macroinvertebrate communities have shown a declining or flat trend over time. By contrast, the physical habitats at these two stations have shown a general improvement over time; however, because of the subjective nature of the habitat assessments, these changes may be less attributable to in-stream habitat trends. For the two stations sampled for the purposes of the ERM, and for which historical data were not available, biological monitoring results at station FLG-A (in Upper Flat Creek) were more comparable to results at station FLG-4 (also in Upper Flat Creek), and results at station FLG-B (in Lower Flat Creek) were more comparable to results at station FLG-5 (also in Lower Flat Creek).

Historical fish scores in the Flat Creek watershed indicate significant degradation in the study area (CH2M HILL, 2000; CH2M HILL, 2003; Brown and Caldwell, 2006; and CH2M

HILL, 2007b). Fish monitoring results were compared to previous results from bi-annual monitoring performed by the City of Gainesville for the Watershed and Assessment Management Program. Fish scores have been rated as "poor" or "very poor" since sampling began in 1999, and declining trends were apparent at stations FLG-4 and FLG-5. In 2007, fish communities in Flat Creek were all evaluated as "poor" or "very poor," though results could be significantly affected by extreme drought conditions at the time of sampling. Rainfall in the City of Gainesville during the month of sampling in 2007 (August) was 1.81 inches, compared with greater than 4 inches for each of the two previous sampling events (NOAA, 2008b). Low flows resulting from the drought likely led to stress in the fish communities, and therefore to a greater number of external anomalies and a lower fish abundance. In 2007, no species that rely heavily on benthic habitat were observed, and no species that were sensitive to pollution were present. These results indicate that the stream conditions were affected due to both water quality and poor habitat conditions.

In 2007, marginal habitat scores in Upper Flat Creek were attributed to excessive sedimentation, embeddedness, low frequency of riffles, and reduced amount or absence of adequate shelter for fish and substrate for macroinvertebrates. Additionally, habitat at both stations was affected by altered substrate types due to activities in the watershed, including industrial development and historical and ongoing urban development. Physical habitat scores in Lower Flat Creek were "optimal" and "suboptimal," indicating that Lower Flat Creek has the ability to support more robust fish and benthic macroinvertebrate communities.

Benthic macroinvertebrate scores in the lower range of possible values indicate that the benthic macroinvertebrate habitat has been affected in Flat Creek. The score at the most upstream station (17 of a possible 100 points) suggests significantly degraded conditions and poor water quality. Similar to trends observed in fish communities, station FLG-4 has shown a flat trend over time, but scores at station FLG-5 have generally decreased over time.

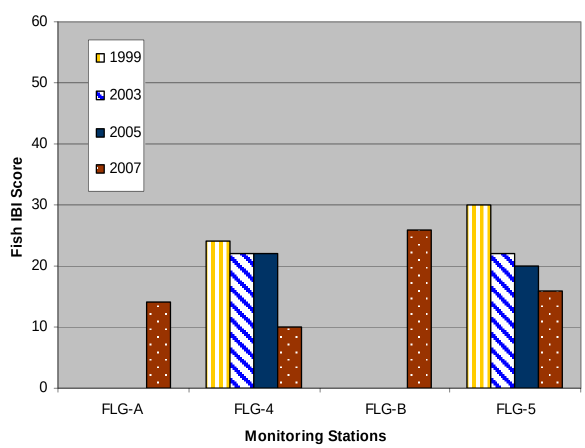

FIGURE 3-5
Historical Fish IBI Scores
Flat Creek Watershed Detailed Project Report – Environmental Appendix

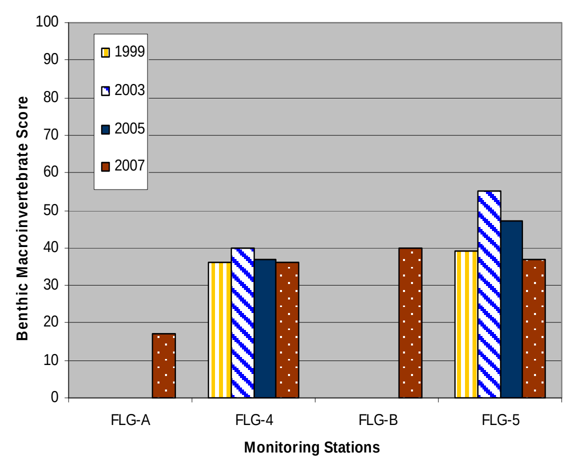

FIGURE 3-6
Historical Benthic Macroinvertebrate Scores
Flat Creek Watershed Detailed Project Report – Environmental Appendix

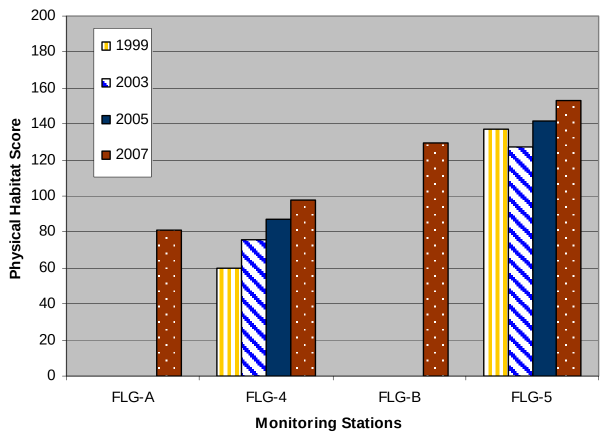

FIGURE 3-7
Historical Physical Habitat Scores
Flat Creek Watershed Detailed Project Report – Environmental Appendix

3.2.10 Water Quality Monitoring Findings

Dissolved Oxygen. DO levels were not consistently below State standards at any stations; however, during three events, DO levels below the Georgia water quality standard of 4.0 milligrams per liter (mg/L) were recorded at three stations in the Upper Flat Creek subwatershed (FC-1, FC-2, FLG-4). Low DO levels can have serious impacts on aquatic species, including a loss of species diversity and richness. Station FC-1 had a DO level of 2.85 mg/L in July 2005 after 0.7 inch of rain. In September 2006, stations FC-1 and FC-2 had DO levels of 3.96 and 3.90 mg/L, respectively, after 2.0 inch of rain. In August 2006, station FLG-4 had a DO level of 3.93 after 0.32 inch of rain. These stations were located in the Upper Flat Creek subwatershed, which has the largest percentage of impervious cover and the highest percentage of commercial/industrial land uses. It should be noted that Biochemical Oxygen Demand (BOD) levels during two of these events were not elevated (BOD not measured in August 2006), suggesting that organic waste (commonly associated with wastewater sources) was not likely a primary contributor to low DO levels. During warm weather, heated pavement and asphalt on parking lots and roadways can raise the temperature of stormwater, which could lead to the observed decreased DO levels.

Specific Conductance. At the time of analysis, there were no State standards for specific conductance; however, the USEPA has indicated that streams supporting good mixed fisheries have a range of 150 to 500 microSiemens per centimeter (µS/cm) (USEPA, 1997). Specific conductance values outside this range could indicate that the water was unsuitable for certain species of fish and macroinvertebrates. Specific conductance values in the Upper Flat Creek and Embayment subwatersheds were within the expected range. However, specific conductance levels at stations FC-4 and FC-5/FLG-5 (both located in the Lower Flat Creek subwatershed) had mean levels outside of the range during dry weather. Increased specific conductance values can be associated with a variety of sources, including nonpoint source pollution from urbanized watersheds, industrial and illicit discharges, and runoff from roadways and parking lots. Because mean specific conductance levels were higher during dry weather, point sources may be contributors. Specific conductance levels during wet weather varied widely (as evidenced by the standard deviation error bar in Figure 3-8), suggesting that nonpoint sources of pollution also influenced the values observed in the Lower Flat Creek subwatershed.

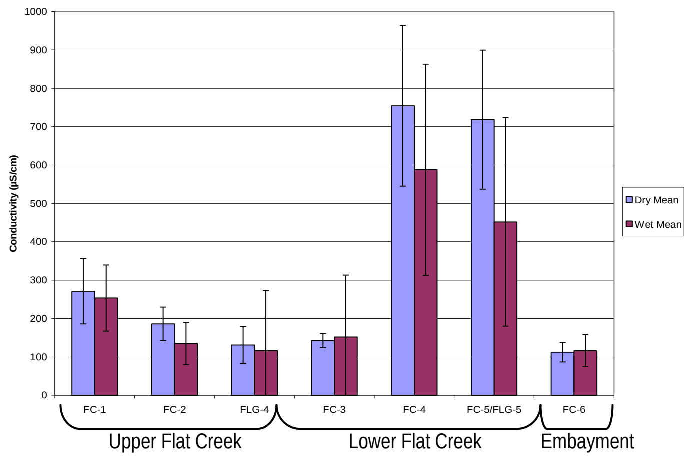

FIGURE 3-8
Mean Specific Conductance and Standard Deviation during Wet and Dry Weather (Jan. 2005—Jun. 2007)
Flat Creek Watershed Detailed Project Report – Environmental Appendix

pH. The State standard range for pH was between 6.00 and 8.50. None of the stations had a pH value below 6.0, and only 1 station (FC-6) had pH values that exceeded the upper limits in the past 2 years: 9.04 in August 2006 and 8.93 in July 2006, during dry weather. Station FC-6 was located in the Embayment subwatershed where waters were influenced by the backwaters of Lake Lanier, as well as runoff from surrounding residential land uses. Sources of elevated pH were difficult to determine but could include low flows, high temperatures, and/or a localized point source discharge. In July 2006, levels of BOD and TP were higher at every station than during any other sampling event. The pH levels could also be related to the high BOD and TP values measured during this same event. The highest TP level (4.57 mg/L) was measured at FC-4, just downstream of the Flat Creek WRF, though it should be noted that TP values were also somewhat elevated at stations upstream of the plant during this same event.

Nutrients (Total Phosphorus and Nitrate). While there were no State standards for nutrients, USEPA (2000) identified reference streams in the Level III Ecoregion IX (1 of 14 Ecoregions identified in the US). The document, titled Ambient Water Quality Criteria Recommendations—Rivers and Streams in Nutrient Ecoregion IX, includes the Flat Creek watershed as part of Ecoregion Level III Ecoregion IX Subecoregion 45. Data from this document were used to draw conclusions about the nutrient levels in Flat Creek. Aside from the previously mentioned elevated TP levels in July 2006, levels of TP at most Flat Creek stations were consistently observed to be within a normal range, compared to reference criteria provided by USEPA (2000). The mean value for TP samples collected in Ecoregion IX was approximately 0.002 mg/L, and the 25th percentile of samples collected in the Subecoregion 45 for TP was 0.03 mg/L. As shown in Figure 3-9, average levels of TP at all Flat Creek stations other than FLG-4 and FC-4 were below the USEPA reference value for Subecoregion 45. Nutrient levels were often higher during wet weather events at all Flat Creek stations except FLG-4 and FC-4, indicating potential nonpoint sources of nutrient pollutants in these areas. This is shown for TP in Figure 3-9.

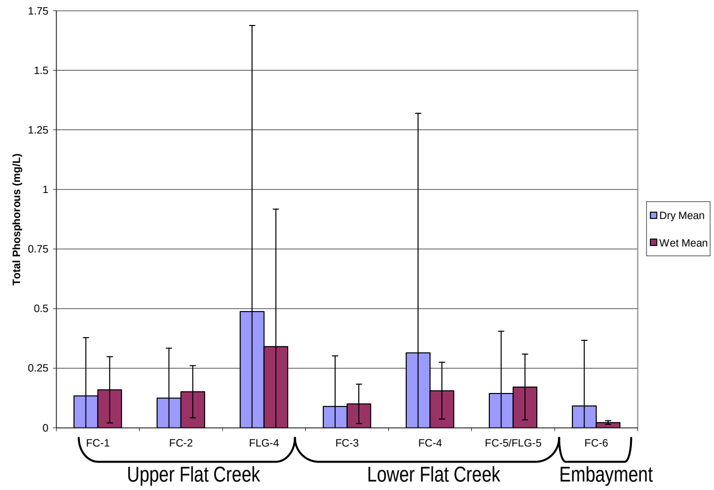

FIGURE 3-9
Mean Total Phosphorus and Standard Deviation during Wet and Dry Weather (Jan. 2005—Jun. 2007)
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Nitrate is an important water quality parameter because it represents the form of nitrogen that is readily available to plants. Nitrate values were generally higher than the USEPA (2000) reference criterion, where the mean value for nitrate-nitrite in Level III Ecoregion IX was approximately 0.75 mg/L, and the 25^{th} percentile of samples collected in Subecoregion 45 was 0.177 mg/L. Nitrate values at stations FC-4 and FC-6 were also noticeably higher during wet events, with a maximum value of 27.80 mg/L (Figure 3-10). High nitrate values (between 1.50 and 6.00 mg/L) were found at all stations; however, extremely high nitrate values (between 6.01 and 27.80 mg/L) were found mainly during both dry and wet weather events at the two stations in the Lower Flat Creek subwatershed that were downstream of the WRF (FC-4, FC-5/FLG-5). Thus, it is likely that nitrate concentrations in the Flat Creek watershed were influenced by both point and nonpoint source pollution.

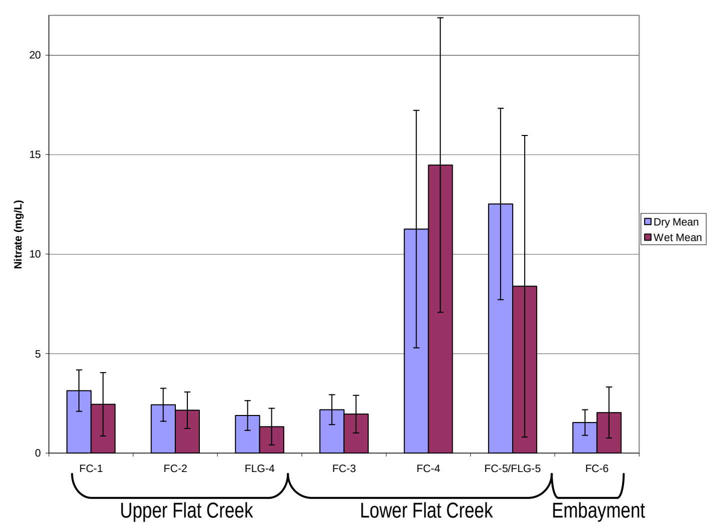

FIGURE 3-10
Mean Nitrate and Standard Deviation during Wet and Dry Weather (Jan. 2005—Jun. 2007)
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Total Suspended Solids. Total Suspended Solids (TSS) and turbidity levels indicate the sediment suspended in the water and often indicate upstream erosion problems associated with construction sites, unstable stream banks, and/or urban runoff. Thus, they were important parameters to monitor in highly urbanized areas with commercial activities and residential growth. In addition to impacting the physical stream channel habitat, elevated TSS and turbidity levels degrade water quality by decreasing light penetration, thus affecting the behavior and health of aquatic organisms. These elevated concentrations can inhibit fish gill functioning when fish were exposed to such conditions for extended periods of time.

Figure 3-11 shows the increase in TSS found during rain events, but the standard deviation error bars also show a wider range of concentrations recorded during rain events. This variability is commonly found in urban watersheds and should be noted when interpreting the results because it decreases the statistical confidence associated with conclusions. The highest levels of TSS were measured at stations FLG-4 (572 mg/L) and FC-5/FLG-5 (1,516 mg/L) during the same wet weather event in October 2005, during which approximately 0.6 inch of rainfall was recorded. Station FLG-4 has a drainage area that includes the entire Upper Flat Creek subwatershed, and station FLG-5 has a drainage area that includes the entire Lower Flat Creek subwatershed. During the October 2005 event, only EMP stations were sampled, so no data from the other stations were available on this date for comparison. During other sampling events, TSS values ranged between 5 and 154 mg/L, with higher values recorded during rain events. The lowest levels of TSS were consistently measured in the Embayment subwatershed at Station FC-6, the farthest downstream station. In this area, flows were diluted when they combine with the backwaters of Lake Lanier.

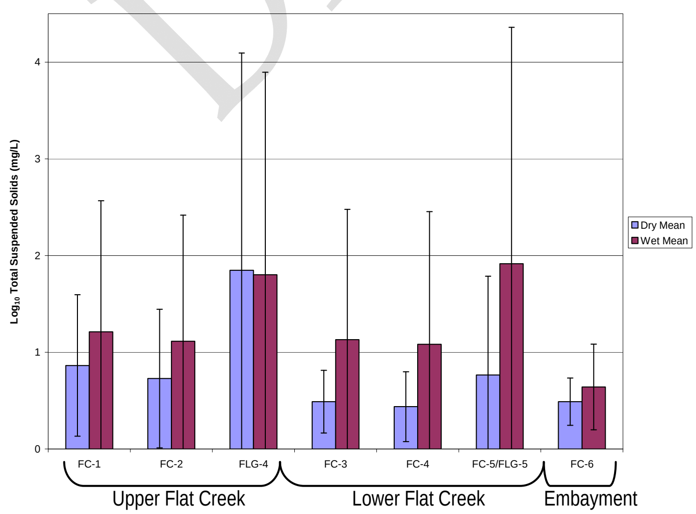

FIGURE 3-11
Log_{10} of Mean TSS and Standard Deviation during Wet and Dry Weather (Jan. 2005—Jun. 2007)
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Although the Upper Flat Creek subwatershed is currently the most developed subwatershed, the area is the most completely built out, limiting the amount of sediment that may come from construction sites that do not have proper erosion and sedimentation controls and other areas of loose soil. However, bank erosion due to flashy pulses of stormwater may also contribute to the higher TSS levels during rain events. The Lower Flat Creek subwatershed was also developed, but there were more construction sites and other areas of loose soil that could contribute sediment to the stream. In addition, the impervious areas in the watershed may lead to increased bank erosion, which can lead to increased TSS levels. Although the Lower Flat Creek subwatershed appears to have the highest sedimentation levels, both the Upper and Lower Flat Creek subwatersheds have high TSS levels, likely resulting from nonpoint sources.

Bacteriological Parameters (Fecal Coliform and *E. coli*). Fecal coliform and *E. coli* serve as pathogen indicators for other bacteria that have been proven to cause adverse human and animal health effects. These bacteria enter the stream from both anthropogenic and non-anthropogenic nonpoint sources, including sewer overflows, leaking sewer lines or failing septic systems, domestic animals, livestock, and local wildlife. GAEPD established a fecal coliform criterion of a geometric mean (4 samples collected over a 30-day period) of 1,000 colonies (col.)/100 milliliters (mL) for the months of November through April. During the months of May through October, when most recreational activities are expected to occur, the criterion is a geometric mean of 200 col./100 mL. For individual samples, the standard is 4,000 col./100 mL in any one sample. While Georgia does not have an established standard for *E. coli*, which is thought to be a more effective indicator of human pathogens than fecal coliform, a concentration of 576 col./100 mL for a single sample in a water body that is rarely used for full body contact recreation (USEPA, 2002) is an applicable standard.

Six of the seven stations had fecal coliform levels well above the State standards, with a maximum value exceeding 156,000 col./100 mL at Station FLG-5 in September 2005. An elevated *E. coli* concentration of 43,000 col./100 mL was also measured at FC-1 in June 2005, after a 0.7-inch rain event. Station FC-1, located in the Upper Flat Creek subwatershed in a highly industrialized and commercial downtown area, exhibited fecal coliform concentrations of 4,400 col./100 mL and *E. coli* concentrations of 4,300 col./100 mL in September 2006, following a 2-inch rain event. Furthermore, station FC-2, located in a commercial area of the Upper Flat Creek subwatershed, showed *E. coli* concentrations of 6,364 col./100 mL in February 2006, after 0.5 inch of rain, and 3,400 col./100 mL in May 2006, after 0.05 inch of rain. At station FC-5, in the Lower Flat Creek subwatershed, the *E. coli* maximum was only 450 col./100 mL in January 2006. This station was the furthest downstream before Flat Creek enters the backwaters of Lake Lanier; thus, the greatest amount of water was present, allowing bacteria concentrations originating from further upstream to be diluted.

Figures 3-12 and 3-13 present the logarithmically transformed mean concentrations of fecal coliform and *E. coli* data, respectively, at stations in the Flat Creek watershed and demonstrate trends similar to those of the TSS and turbidity values. Note that *E. coli* data were not collected at station FLG-4 during the reporting period. Compared to dry weather means, high (and variable) levels of fecal coliform and *E. coli* were seen during rain events. The likely sources were leaking or malfunctioning sewer or septic systems, illicit discharges, domestic animals, and/or wildlife such as ducks and geese.

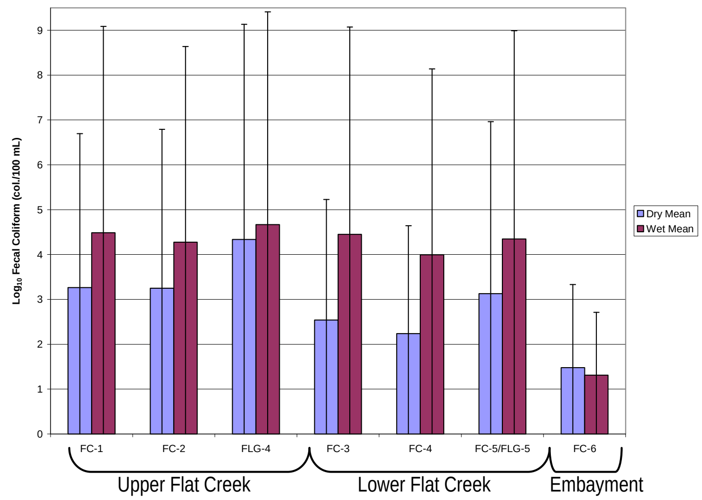

FIGURE 3-12
Log_{10} of Mean Fecal Coliform and Standard Deviation during Wet and Dry Weather (Jan. 2005—Jun. 2007)
Flat Creek Watershed Detailed Project Report – Environmental Appendix

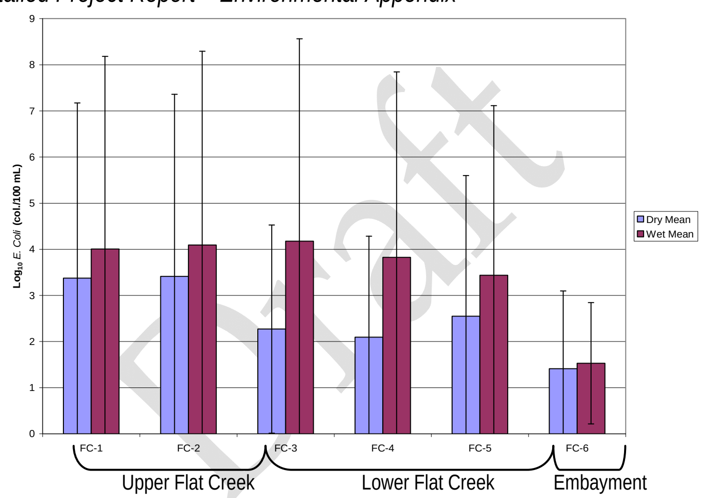

FIGURE 3-13
Log_{10} of Mean *E. Coli* and Standard Deviation during Wet and Dry Weather (Jan. 2005—Jun. 2007)
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3.2.11 Summary of Water Quality Monitoring

Water quality results in the Flat Creek watershed indicate that both point and nonpoint sources of pollution affect water quality. Nonpoint sources of pollution have the greatest effect in areas with the highest concentrations of impervious surfaces, as in the Upper Flat Creek subwatershed, and to a lesser extent the Lower Flat Creek subwatershed. However, results over the last two years indicate that water quality has not declined over that time period. Continued implementation of stormwater management practices on construction sites and commercial and industrial areas will be useful in preventing water quality from worsening in the Flat Creek watershed. In addition to stormwater controls already being implemented by the City and County, ecosystem restoration projects can be used to attenuate existing, ineffective stormwater controls in localized areas, particularly areas that were developed before site-specific stormwater controls were required as a part of new development.

To assess water quality data from the Flat Creek watershed and prioritize areas for ecosystem restoration based on the greatest degree of water quality degradation, each station was ranked based on several parameters, including fecal coliform, TSS, TP, and nitrate. These parameters were selected to provide a representation of nonpoint source pollution among all seven stations. Table 3-6 shows the wet weather mean, dry weather mean, and relative rankings (based on the wet weather mean) for each station. Based on the water quality data, the most impacted stations were FLG-5/FC-5, located immediately downstream of the Lower Flat Creek subwatershed, and FLG-4, located immediately downstream of the Upper Flat Creek subwatershed. It should be noted that these two stations were not sampled on the same dates as the other stations, so the means and standard deviations for each parameter reflect that difference. FLG-5/FC-5 includes samples from both the Surface Water Quality Program and the EMP, while FLG-4 only includes samples from the EMP. However, overall comparisons among all stations were still appropriate because samples were collected over the same 2-year period. Stations FLG-5/FC-5 has had relatively high levels of TSS, TP, and nitrate over the last 2 years, demonstrating the greatest potential impacts from nonpoint source pollution at these locations. At station FLG-4, levels of fecal coliform were relatively high; however, levels of nitrate were lower than at any other location in the watershed.

Overall, nonpoint source pollution was still ubiquitous in the Upper and Lower Flat Creek subwatersheds, although the specific pollutants may vary. When the summed ranks for each station (see Table 3-6) were averaged by subwatershed, water quality values indicate that Upper and Lower Flat Creek subwatersheds were similarly degraded, with Upper Flat Creek (rank = 13.7) being slightly more degraded than Lower Flat Creek (rank = 15). The Embayment subwatershed showed different water quality patterns than the other two subwatersheds. The Embayment Watershed has less impervious cover than the other two subwatersheds and was influenced by slower flows due to the presence of the Lake Lanier backwaters. Based on the only station in this subwatershed (FC-6), water quality conditions were less degraded in this area. Due to the presence of Lake Lanier (which limits the area available for projects) and the water quality results, the Embayment subwatershed was not as highly prioritized for ecosystem restoration projects.

TABLE 3-6
Means for Selected Water Quality Parameters and Corresponding Station Rankings
Flat Creek Watershed Detailed Project Report – Environmental Appendix

	Fecal Coliform (col./100 mL)			Total Suspended Solids (mg/L)			Total Phosphorus (mg/L)			Nitrate (mg/L)				
Station (Subwatershed)	Dry Mean	Wet Mean	Wet Mean Rank [a]	Dry Mean	Wet Mean	Wet Mean Rank [a]	Dry Mean	Wet Mean	Wet Mean Rank [a]	Dry Mean	Wet Mean	Wet Mean Rank [a]	Sum Rank	Total Rank [b]
FC-5/ FLG-5 (Lower Flat Creek)	1344	22378	4	6	82	1	0.144	0.171	2	12.52	8.34	2	9	1
FLG-4 (Upper Flat Creek)	21670	46468	1	70	63	2	0.488	0.340	1	1.89	1.33	7	11	2
FC-1 (Upper Flat Creek)	1845	30685	2	7	16	3	0.134	0.160	3	3.14	2.45	3	11	2
FC-4 (Lower Flat Creek)	173	9875	6	3	12	6	0.314	0.156	4	11.26	14.48	1	17	3
FC-3 (Lower Flat Creek)	347	28354	3	3	14	4	0.090	0.100	6	2.18	1.96	6	19	4
FC-2 (Upper Flat Creek)	1771	18862	5	5	13	5	0.125	0.152	5	2.43	2.16	4	19	4
FC-6 (Embayment)	30	21	7	3	4	7	0.092	0.022	7	1.54	2.04	5	26	5

[a] 1 = most degraded, 7 = least degraded
[b] 1 = most degraded, 6 = least degraded

3.3 Stream Assessment

Approximately 21 miles of streams were assessed for the Flat Creek WIP/ERR from late April through late May 2007. The assessment was conducted in accordance with methods described in the Field Data Collection Plan (CH2M HILL, 2007a) and the Quality Assurance Project Plan (CH2M HILL, 2007c). The stream inventory collection covered the three delineated subwatersheds within the Flat Creek watershed: Embayment, Lower Flat Creek, and Upper Flat Creek. The stream segments that were assessed were preliminarily identified in a desktop inventory, though slight changes were made in response to (1) recommendations from City staff and (2) actual field conditions. These unexpected field conditions included piped sections of stream, dry drainage swales, and stream segments where habitat assessments could not be conducted. Table 3-7 summarizes inventory data for each subwatershed and the extent of stream miles inventoried in each.

TABLE 3-7
Project Watershed Area, Stream Mile, and Inventory Data
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Subwatershed	Area (acres)	Area (mi^2)	Total Stream Miles	Stream Miles Assessed	Percent of Stream Miles Assessed	Number of Inventory Points
Embayment	2,110.2	3.30	6.53	4.95	75.76	75
Lower Flat Creek	2,364.3	3.69	14.51	11.35	78.25	215
Upper Flat Creek	2,163.9	3.38	12.97	5.36	41.32	99
Total	**6,638.4**	**10.37**	**34.01**	**21.66**	**63.69**	**389**

A total of 389 data points were collected in the Flat Creek watershed to complete the assessment (Figure 3-14). The data collected were used to characterize the condition of the watershed, prioritize stream projects, and identify the extent and location of potential stream restoration projects. A global positioning system (GPS) unit was used to note the locations of various channel alterations, including anthropogenic channel impacts, hydrologic alterations, bank erosion, inadequate buffers, water quality problems, and structural maintenance issues, as well as physical stream habitat score and channel types. A discussion of these degraded conditions is provided below.

Channel Alterations

Two types of channel alterations were inventoried in Flat Creek watershed: man-made and hydrologic. Man-made channel alterations included channelization (dredging or straightening), piped stream segments (culverts, road crossings, or piped sections under parking lots or other private property), and riprap rock or gabion rock baskets on stream banks. Hydrologic channel alterations included down-cutting channels, lateral drainage ditches causing headcuts and/or erosion, stable bedrock knickpoints limiting fish passage, and unstable headcuts actively contributing to bed erosion. Each type of channel alteration is discussed below.

Man-made Channel Alterations. There were 173 observed occurrences of man-made channel alterations in the Flat Creek watershed (Table 3-8 and Figure 3-15). The most frequently observed category, piped stream segments, is typical of urbanized watershed conditions, due to the need for road crossings and bypassing of development. Other observed categories included channelized reaches (straightened, often between developments, through pastures, or along rights-of-way [ROWs]), areas of floodplain buildup (areas where the floodplain has been constricted by backfill), concrete-lined channels, and riprapped or gabion-lined banks. The Lower Flat Creek subwatershed had the highest number of observed occurrences of man-made alterations, followed by the Upper Flat Creek subwatershed. However, when the number of man-made alterations was normalized by the miles of stream assessed per subwatershed (Table 3-8), the Upper Flat Creek subwatershed contained the highest occurrence of man-made channel alterations per stream mile. The Embayment subwatershed contained the fewest observances of man-made channel alterations per stream mile.

Of the three subwatersheds, Upper Flat Creek was the most impacted by man-made channel alterations, likely due to its highly urbanized character. Lower Flat Creek was also affected by man-made channel alterations. The low number of man-made channel alterations in the Embayment subwatershed was most likely due to the lower density of development and thus lower amount of impact from surrounding areas.

Hydrologic Channel Alterations. A total of 167 occurrences of hydrologic channel alterations were recorded in the Flat Creek watershed (Table 3-9 and Figure 3-16). The most frequently recorded hydrologic channel alterations included incising channels and widening channels. These conditions were prevalent throughout the watershed and were slightly underestimated in results due to restrictions in the number of hydrologic channel alterations which could be recorded per inventory point. Other hydrologic channel alterations included aggrading channels, incised and widening channels, lateral drainage ditches, stable knickpoints, and unstable headcuts.

The area most affected by hydrologic channel alterations was the Embayment subwatershed. There were approximately 9 occurrences of hydrologic channel alteration per mile assessed. This was also the case for Lower Flat Creek, with approximately 9 occurrences per assessed mile, and then Upper Flat Creek with approximately 4 occurrences per assessed mile. However, it is important to note that the only hydrologic alteration category frequently recorded in the Embayment subwatershed was "channel aggrading," which was due to the backwater effects of Lake Lanier in these streams. If this category were removed from the Embayment subwatershed assessment, the area would have the lowest number of detrimental hydrologic channel alterations per mile of assessed stream. Although the overall stream assessment analysis included discussion of channel alterations in areas experiencing backwater effects from Lake Lanier, no biological sampling was conducted in the backwater areas, and no stream restoration measures were recommended for the backwater areas.

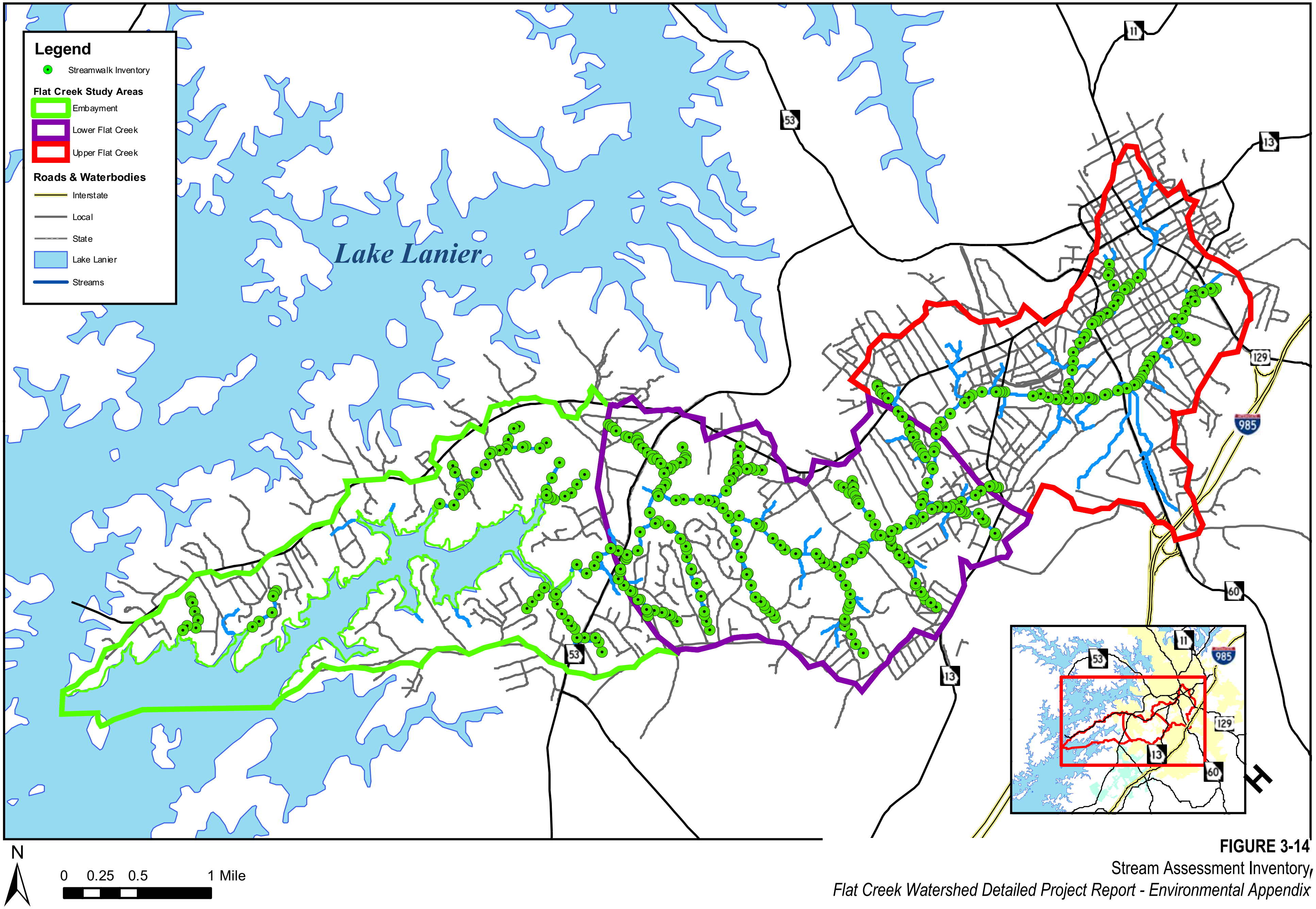

FIGURE 3-14
Stream Assessment Inventory
Flat Creek Watershed Detailed Project Report - Environmental Appendix

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\\PEACHTREE\PROJ\CITYOFGAINESVILLEGA\355665\GIS\355665_FLATCREEK\MAPDOCS\UPDATED\FIGURE3-8.MXD FIGURE3-8.PDF 7/20/2007; DDickman

TABLE 3-8
Man-made Channel Alterations (Occurrences)
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Concrete Channel	Channelized Reach	Floodplain Build-Up	Piped Reach	Riprap Channel	Total Occurrences	Stream Miles Assessed	Occurrences/ Stream Mile
Embayment	0	4	0	9	0	13	4.95	2.6
Lower Flat Creek	2	44	2	37	5	90	11.35	7.9
Upper Flat Creek	8	21	9	31	1	70	5.36	13.1
Total Occurrences	10	69	11	77	6	173	21.66	7.9

TABLE 3-9
Hydrologic Channel Alterations (Occurrences)
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Aggrading Channel	Incising Channel	Widening Channel	Lateral Drainage Ditch	Unstable Headcut	Channel Incised and Widening	Stable Knick-point	Total Occurrences	Stream Miles Assessed	Occurrences/ Stream Mile
Embayment	24	11	0	0	1	1	7	44	4.95	8.9
Lower Flat Creek	8	30	32	9	5	13	3	100	11.35	8.8
Upper Flat Creek	1	4	13	1	1	1	0	23	5.36	4.3
Total Occurrences	33	45	45	10	8	16	10	167	21.66	7.7

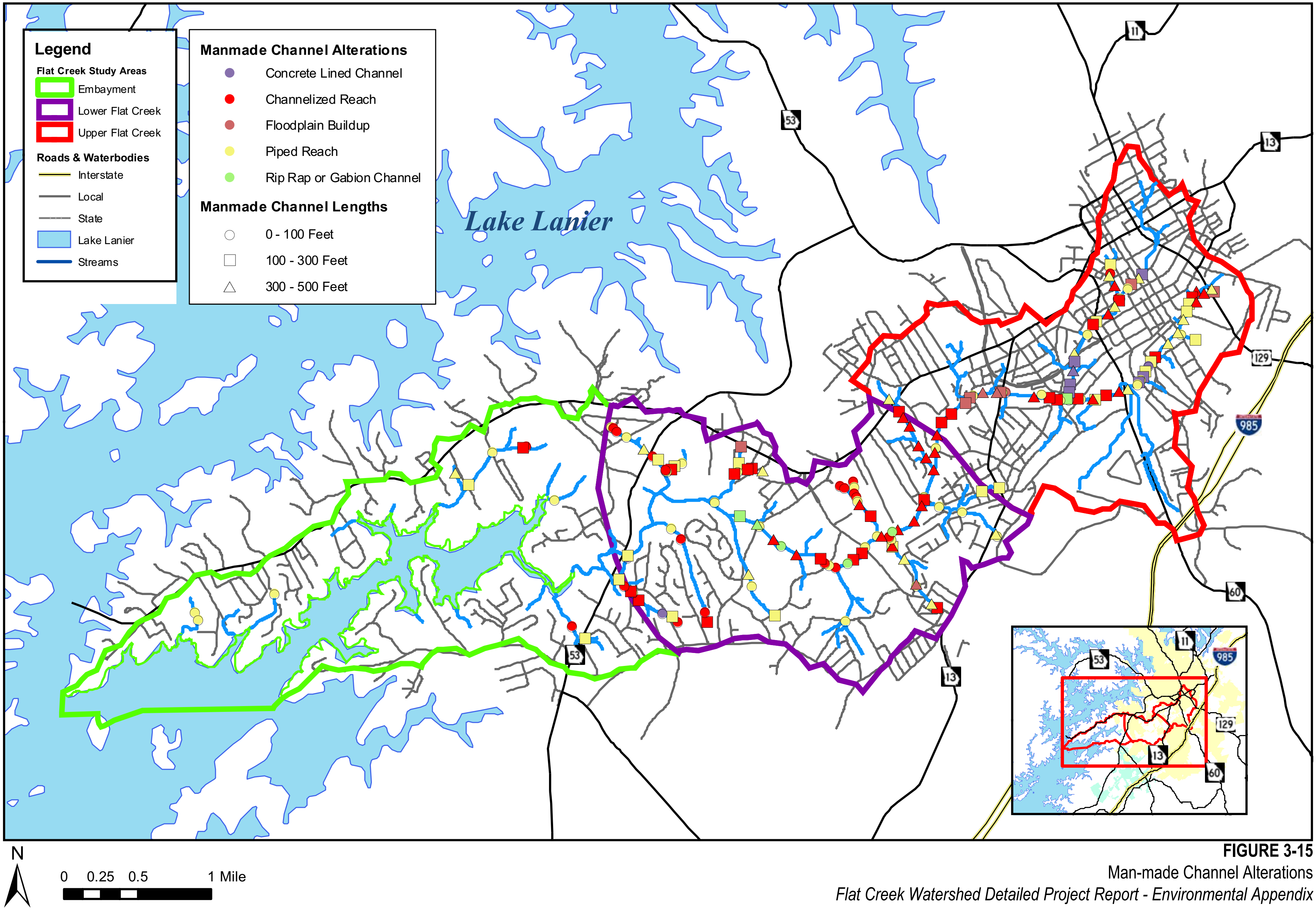

FIGURE 3-15
Man-made Channel Alterations
Flat Creek Watershed Detailed Project Report - Environmental Appendix
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\\PEACHTREE\PROJ\CITYOFGAINESVILLEGA\355665\GIS\355665_FLATCREEK\MAPDOCS\UPDATED\FIGURE3-9.MXD FIGURE3-9.PDF 7/20/2007; DDickman

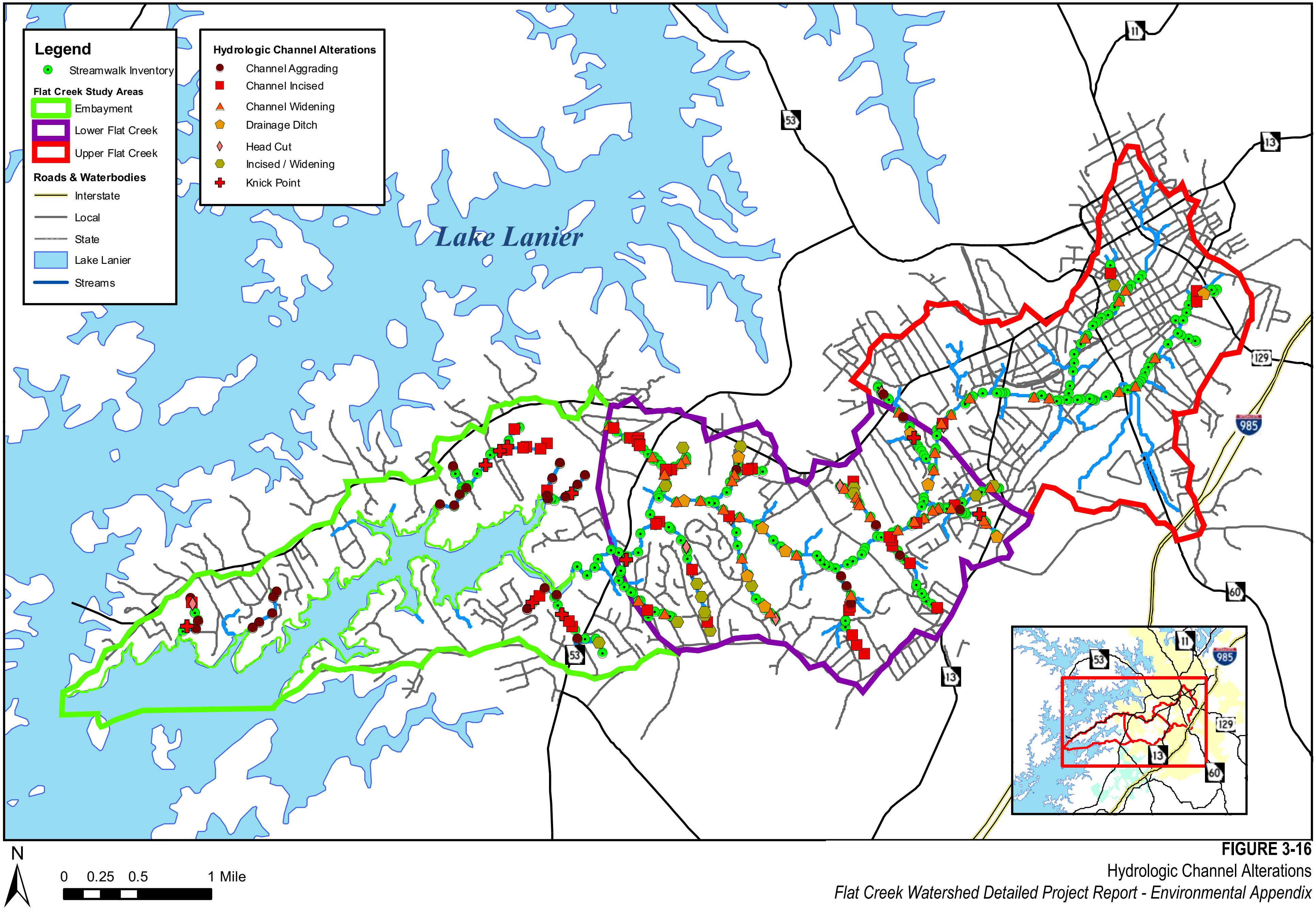

FIGURE 3-16
Hydrologic Channel Alterations
Flat Creek Watershed Detailed Project Report - Environmental Appendix

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\\PEACHTREE\PROJ\CITYOFGAINESVILLEGA\355665\GIS\355665_FLATCREEK\MAPDOCS\UPDATED\FIGURE3-10.MXD FIGURE3-10.PDF 7/20/2007; DDickman

Bank Erosion Scores

Bank erosion was present with varying degrees of severity throughout the entire Flat Creek watershed (Table 3-10, Figures 3-17 and 3-18). During the stream assessment, erosion was recorded for each bank in one of four categories (0 to 25 percent, 25 to 50 percent, 50 to 75 percent, or 75 to 100 percent), with an associated length. Figure 3-17 summarizes the percentage of all banks, for each subwatershed, that was assessed during the field survey as being included in each erosion category. As shown in the figure, the subwatersheds varied minimally in the amount of banks that were eroded between 50 and 75 percent eroded. The other erosion categories exhibited more differences across the subwatersheds, with the Embayment having by far the least bank area eroded (less than 25 percent) and Upper Flat Creek having the most significant bank area eroded (greater than 75 percent) (Figure 3-17).

Bank erosion scores shown on Figure 3-18 were calculated by multiplying the bank height by percent of bank eroded by the length of erosion extent, to arrive at an area eroded. Each subwatershed had an approximately equal distribution of bank erosion. The Upper and Lower Flat Creek subwatersheds had the highest percentage of severely eroded (75 to 100 percent) banks, while all three subwatersheds had an approximately equal extent of banks in the 50 to 75 percent erosion category. The Embayment and Lower Flat Creek subwatersheds had a higher percentage of 25 to 50 percent eroded banks than the Upper Flat Creek subwatershed. The Upper Flat Creek subwatershed had the highest percentage of bank erosion in the 0 to 25 percent category.

Apparent causes of the bank erosion in the Flat Creek watershed include degraded or non-existent riparian ecosystems (utility and road crossings, property owners clearing vegetation to the top of the bank), bank instability, active headcuts, high erosive storm flows from impervious surfaces, and otherwise altered hydrology. Table 3-11 provides a summary of bank erosion in the Flat Creek watershed, and the 3 subwatersheds were ranked (1 being the most severely eroded and 3 being the least eroded) according to the total eroded area per mile assessed.

Based on total area, the Embayment subwatershed had the least bank erosion, while Lower Flat Creek had the most (Table 3-11). This was expected, as the largest portion of the Flat Creek watershed assessed, and not piped, was in the Lower Flat Creek subwatershed. When normalized by the length of streams assessed, the Embayment subwatershed was still found to have the least amount of bank erosion (rank = 3). Upper Flat Creek (rank = 1) exhibited the highest percentage of eroded area, with Lower Flat Creek (rank = 2) also having a high percentage of erosion. Differences in bank erosion among subwatersheds occur in a pattern similar to patterns in more densely urbanized areas, indicating that the Upper and Lower Flat Creek subwatersheds have been negatively affected by urbanization and development.

Bank erosion extent per area of each subwatershed was also calculated. In this case, the Embayment subwatershed was found to have the lowest amount of bank erosion per square mile of subwatershed, and the Lower Flat Creek subwatershed showed the largest impact from bank erosion. This again reflects the impacts from urbanized land use in the Flat Creek watershed.

Inadequate Buffers

There were 383 occurrences (totaling 12.9 miles on either bank of 21.6 miles assessed) of inadequate buffers recorded in the Flat Creek watershed (Table 3-12 and Figure 3-19). The most frequently recorded inadequate buffer types include man-made structures within the 25-foot riparian buffer, impervious areas, cleared or maintained parallel ROWs, maintained lawns, old fields, and utility crossings or perpendicular ROWs. Of the riparian buffers assessed, the largest percentage of disrupted buffers was found in Upper Flat Creek, followed by Lower Flat Creek, and then the Embayment (Table 3-12). The vast majority of riparian interruptions in this subwatershed resulted from residential/commercial lawn areas and parallel ROWs existing within the 25-foot buffer. However, the Upper Flat Creek subwatershed was found to have the highest percentage of riparian interruptions in the Flat Creek watershed, where approximately 89 percent of the observed stream miles had at least one type of interruption.

TABLE 3-10
Bank Erosion Summary (Percent of Stream Miles Assessed)
Flat Creek Watershed Detailed Project Report – Environmental Appendix

	Percent of Bank Erosion			
Subwatershed	**Less than 25**	**25-50**	**50-75**	**75-100**
Embayment	10.9	36.7	48.4	3.9
Lower Flat Creek	5.2	36.8	48.3	9.7
Upper Flat Creek	21.7	17.9	50.9	9.4
Totals	10.0%	33.0%	48.9%	8.2%

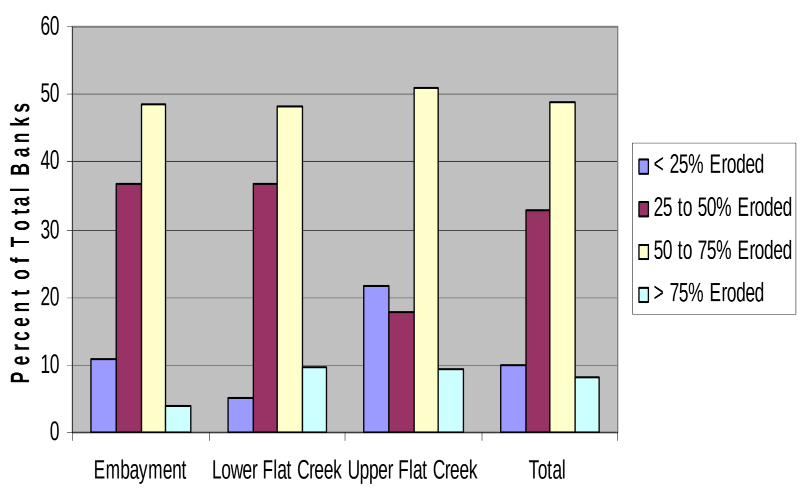

FIGURE 3-17
Percent of Bank Erosion
Flat Creek Watershed Detailed Project Report – Environmental Appendix

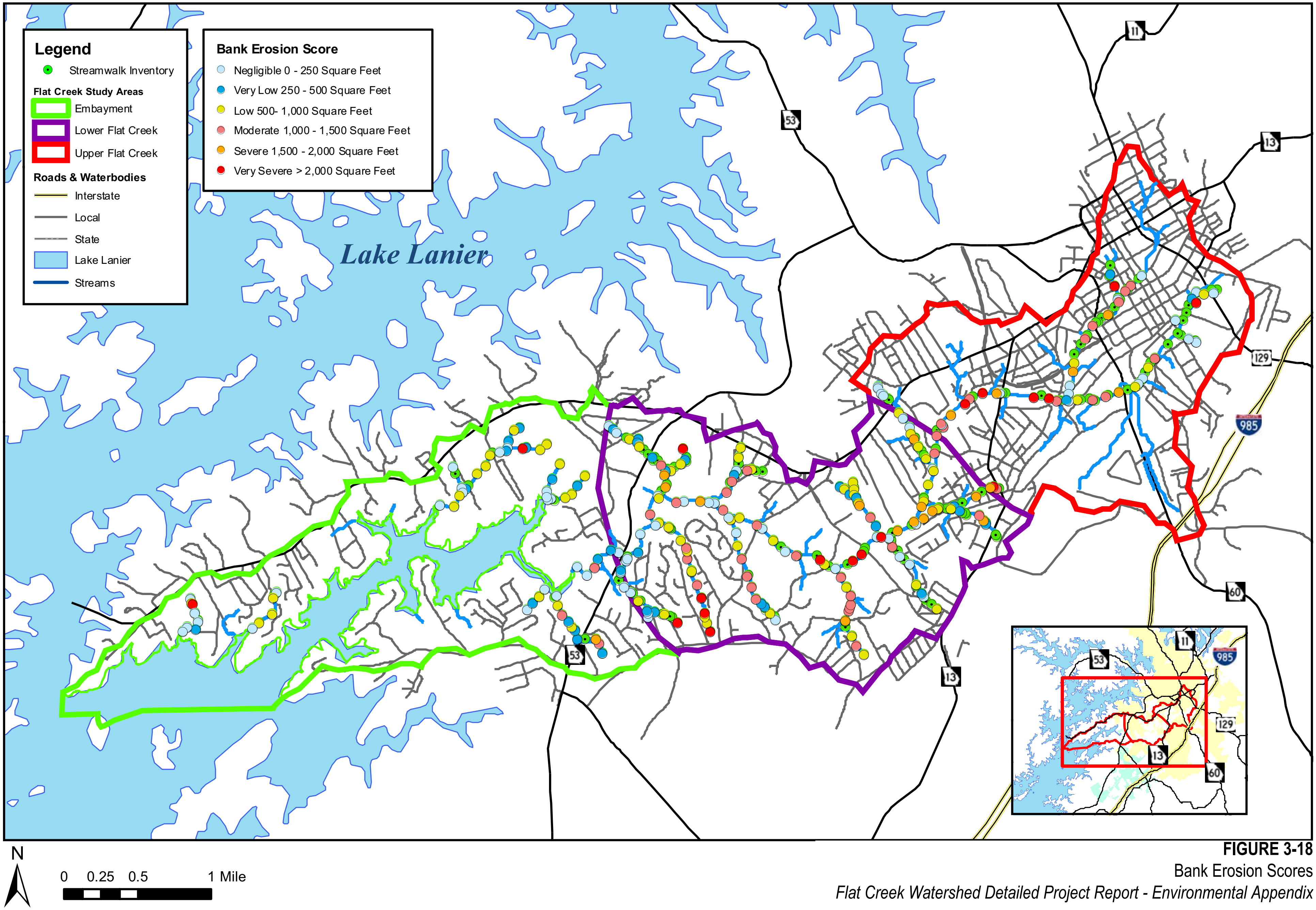

FIGURE 3-18

Bank Erosion Scores

Flat Creek Watershed Detailed Project Report - Environmental Appendix

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\\PEACHTREE\PROJ\CITYOFGAINESVILLEGA\355665\GIS\355665_FLATCREEK\MAPDOCS\UPDATED\FIGURE3-11.MXD FIGURE3-11.PDF 7/20/2007; DDickman

TABLE 3-11
Bank Erosion Summary (Erosion per Stream Miles Assessed and Watershed Drainage Area)
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Total Area Eroded (yd^2)	Total Stream Miles Assessed	Area Eroded per Assessed Mile (yd^2/mile)[a]	Area Eroded per Subwatershed (yd^2/mi^2)[b]	Rank[a]
Embayment	1,216	4.95	245.7	368.6	3
Lower Flat Creek	4,569	11.35	402.6	1,238.3	2
Upper Flat Creek	2,238	5.36	417.6	662.3	1
Totals	8,024	21.66	370.5	773.8	

[a] Based on area eroded per assessed mile (yd^2/mile); 1 = most eroded, 3 = least eroded

TABLE 3-12
Extent of Inadequate (less than 25 feet wide) Buffer
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Old Field/ Abandoned Land Use (ft)[a]	Lawn (ft)[a]	Impervious Surface/ Structure (ft)[a]	Cleared/ maintained Parallel Utility (ft)[a]	Maintained Perpendicular Utility (ft)[a]	Stream Miles Impacted	Stream Miles Assessed	Percent of Inadequate Buffer[b]
Embayment	1,475	475	2.025	0	1,800	1.09	4.95	22.1
Lower Flat Creek	4.975	10,150	7,250	1,750	13,000	7.03	11.35	61.9
Upper Flat Creek	1,550	3,250	16,475	975	2,950	4.77	5.36	89.4
Totals	15,950	4,525	25,750	13,875	8,000	12.9	21.66	59.6

[a] Total of right and left banks.
[b] Percent of buffers that were inadequate for assessed stream miles.

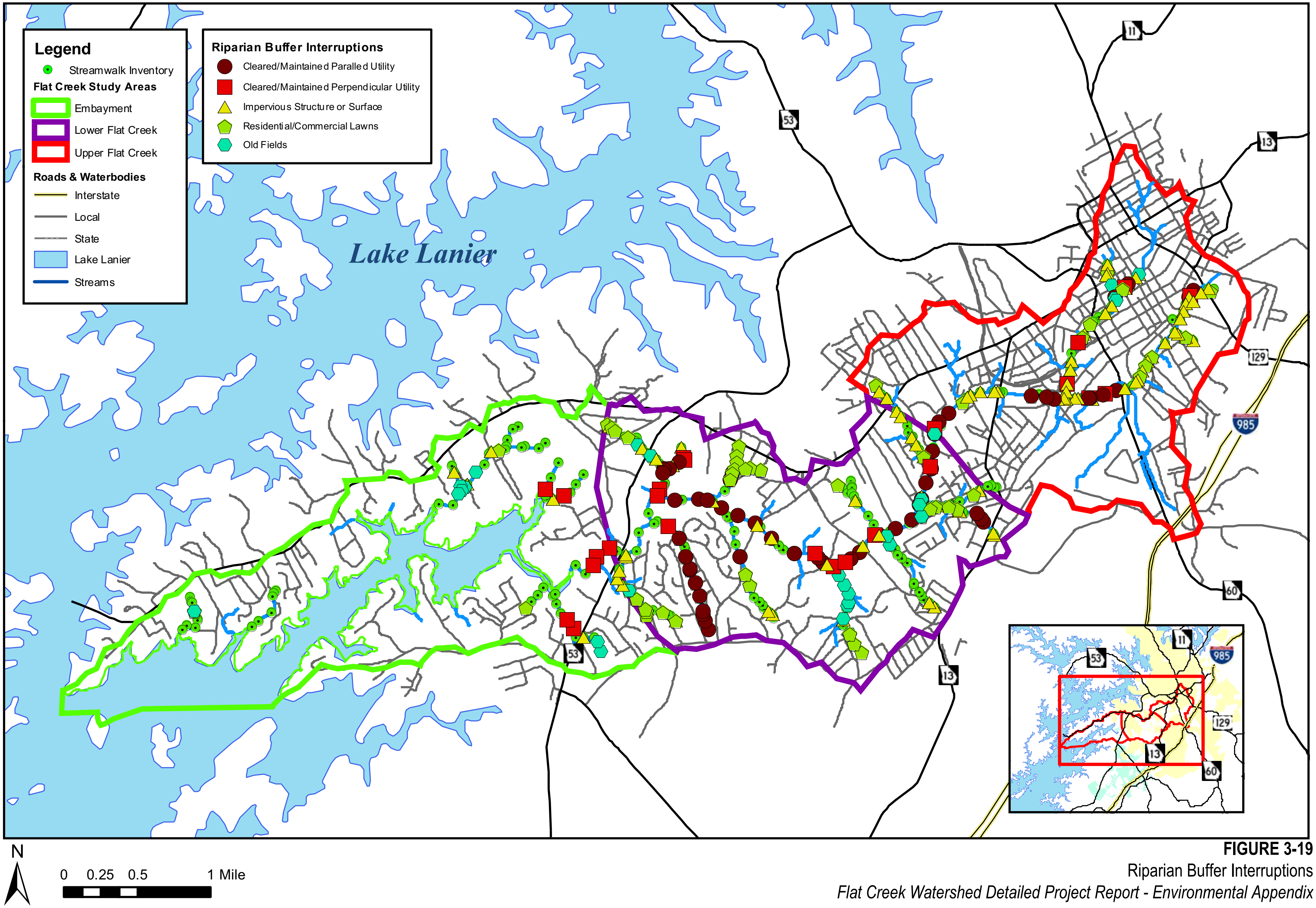

FIGURE 3-19

Riparian Buffer Interruptions

Flat Creek Watershed Detailed Project Report - Environmental Appendix

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The high percentage of riparian interruptions in the Upper and Lower Flat Creek subwatersheds may be attributed to the highly urbanized character of the land. The majority of the interruptions in these subwatersheds can be directly related to structures in the 25-foot riparian buffer, impervious areas, cleared maintained parallel ROWs, and residential/commercial lawns. These types of interruptions are typical in highly developed watersheds in urban areas. Conversely, the Embayment subwatershed contains fewer riparian interruptions because it was less developed and less impacted by urbanization. The majority of encroachments that do occur in the Embayment subwatershed were man-made structures in the 25-foot riparian buffer, impervious areas, or cleared/maintained perpendicular ROWs.

Water Quality Concerns

There were four occurrences of point source water pollution observed in the Flat Creek watershed and no observed instances of nonpoint source pollution. Three of the point source water quality problems were found in the Lower Flat Creek subwatershed, and one was located in the Upper Flat Creek subwatershed. Field teams identified two instances of septic tank failures and two occurrences of unknown illicit discharges. In each instance, City of Gainesville Public Utility Department (PUD) staff were present when these point source discharges were located. The discharge identified did not indicate significant water quality degradation, and issues were followed up by PUD staff.

Structural Maintenance Issues

A total of 98 occurrences of City/County structural maintenance issues were observed in the Flat Creek watershed (Table 3-13 and Figure 3-20). The most frequently observed maintenance issue was scour around either the headwall or the culvert of drainage structures. Additionally, many conveyance and drainage structures were found to be clogged with sediment or blocked with debris. Field teams also located headwall repair needs, pipe installation problems, septic tank issues, and other miscellaneous problems such as dumped trash, unknown discharges, and unsafe areas.

Typically, developed watersheds have many potential maintenance issues because much infrastructure exists to support higher-density development. This included road crossings and associated culverts, utility infrastructure such as water and sewer crossings, and storm sewer systems. Additionally, in many areas, infrastructure is becoming outdated and is no longer able to offer adequate water quality and channel protection.

The Embayment subwatershed was found to have the lowest number of potential maintenance issues in the Flat Creek watershed, most likely due to the low density of development in this area. The Upper Flat Creek subwatershed was found to have the highest number of potential maintenance issues, followed closely by the Lower Flat Creek subwatershed. The higher concentration of infrastructure in place to support the more densely developed watershed areas of Upper and Lower Flat Creek may be the reason a larger number of potential maintenance issues were located. Additionally, the more developed watersheds place a greater strain on the existing infrastructure, thereby increasing the need for maintenance.

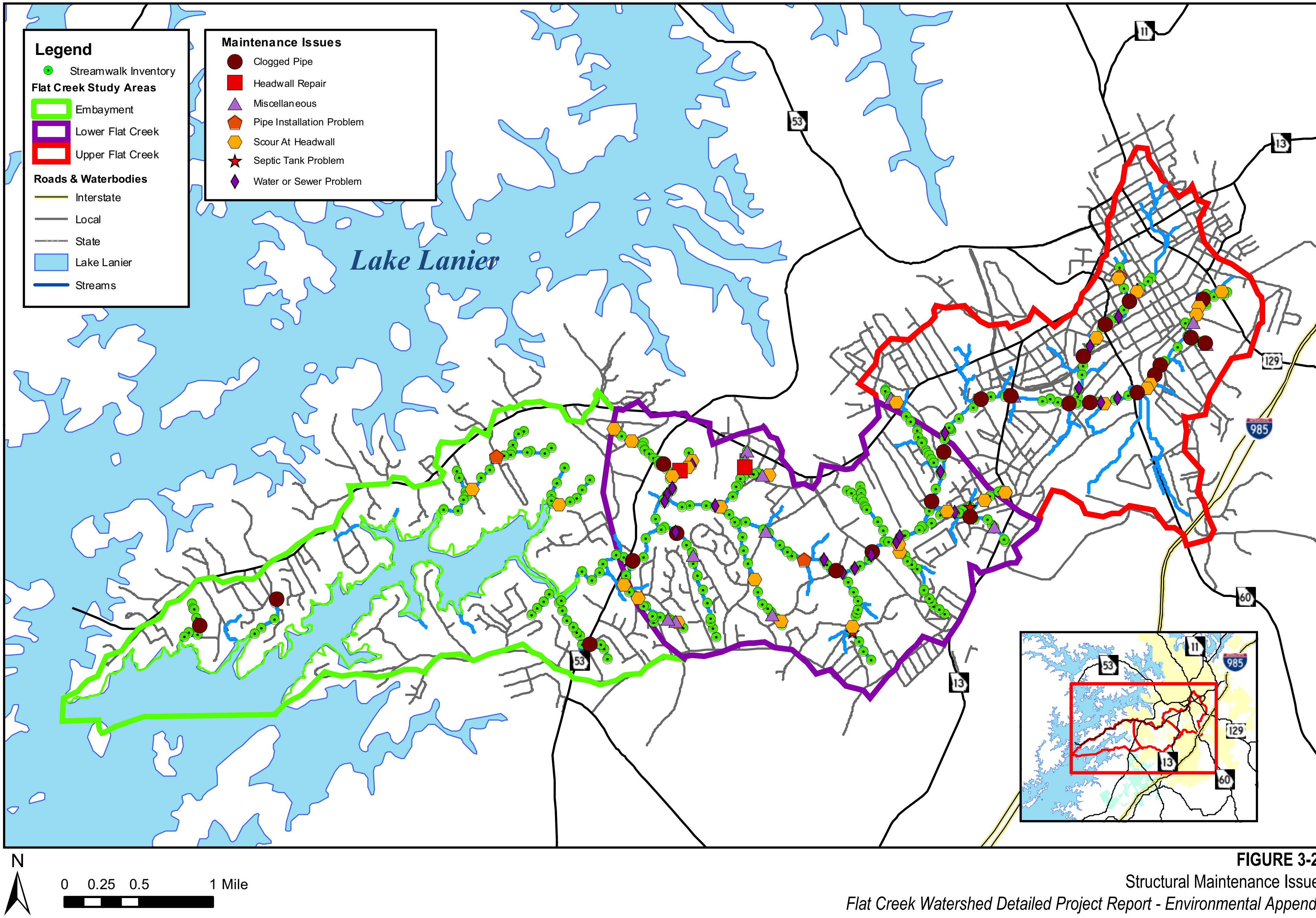

FIGURE 3-20
Structural Maintenance Issues
Flat Creek Watershed Detailed Project Report - Environmental Appendix
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\\PEACHTREE\PROJ\CITYOFGAINESVILLEGA\355665\GIS\355665_FLATCREEK\MAPDOCS\UPDATED\FIGURE3-11.MXD FIGURE3-13.PDF 7/20/2007; DDickman

TABLE 3-13
Structural Maintenance Issue Occurrences
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Blocked Culvert/Bridge	Headwall Maintenance	Pipe Installation Problem	Headwall Scour	Septic Tank Maintenance	Water/Sewer Maintenance	Occurrences / Stream Mile
Embayment	3	0	1	3	0	0	1.41
Lower Flat Creek	8	2	1	16	2	16	4.75
Upper Flat Creek	13	0	1	11	0	8	6.90
Total	24	2	3	30	2	24	4.52

Other Watershed Characteristics

A total of 101 occurrences of other watershed characteristics, that may either positively or negatively impact watershed conditions, were observed in Flat Creek and its tributaries (Table 3-14). Field teams inventoried up to eight watershed characteristics, both positive and negative, at each data collection point. The most frequently observed characteristics were the presence of invasive plant species, off-channel wetlands, in-stream debris dams, beaver dams, and water withdrawals.

The Embayment subwatershed had the most off-channel wetlands, followed by the Lower Flat Creek subwatershed. Much of the off-channel wetland area in the Embayment subwatershed was a result of the backwater effects from Lake Lanier. However, Lower Flat Creek wetlands were a result of low-lying areas along the mainstem of Flat Creek.

The Lower Flat Creek subwatershed had the greatest occurrences of invasive plant species along the surveyed stream reaches, followed by Upper Flat Creek. In many of the areas identified to contain invasive plant species, privet and kudzu dominated the vegetation. Other watershed characteristics were grouped as negative or positive characteristics; therefore, a total number of occurrences per mile assessed were not calculated.

Physical Habitat

Physical habitat scores were rated based on the USEPA RBP (Barbour et al., 1999) to determine qualitative conditions, ranging from “poor” (the worst conditions) to “optimal” (the best conditions) (Table 3-15). Scores in the subwatersheds ranged from 60 (“marginal”) to 161 (“optimal”), and the average habitat scores by subwatershed were between 94 and 133 (Table 3-15). The Upper Flat Creek subwatershed had the lowest average score, followed by increasing habitat scores in Lower Flat Creek and then the Embayment subwatershed. Physical habitat results suggest that the Embayment subwatershed has a greater diversity of available habitat than the other Flat Creek subwatersheds. The most common rating among physical habitat scores in Upper Flat Creek was “marginal-suboptimal,” and the most common rating among physical habitat scores in Lower Flat Creek was “suboptimal,” suggesting degraded conditions in the two subwatersheds.

TABLE 3-14
Miscellaneous Watershed Characteristics
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Invasive plant species	Debris Dam	Beaver Dam	Water Withdraw-al	Reference Reach	In-channel wetland	Off-channel wetland	Total
Embayment	8	1	1	0	0	0	7	17
Lower Flat Creek	40	4	4	2	0	0	5	63
Upper Flat Creek	19	0	0	0	0	0	0	21
Total	67	5	5	2	0	0	12	101

Stream Assessment Summary

Using data from the stream assessment, each stream reach was ranked to characterize the subwatersheds. The ranking was based on the severity of conditions observed in the field, with lowest-ranking stream reaches exhibiting the most degraded conditions. A total rank was then developed for the entire watershed by summing all of the ranking scores.

The following sections present an overview of the current conditions in each subwatershed, and Table 3-16 provides a summary of ranking scores. Many of the streams observed in the Flat Creek watershed have sustained historical channelization impacts and varying amounts of bank erosion. Rates of bank erosion were due primarily to high-density urbanization and impervious surfaces in the Upper and Lower Flat Creek subwatersheds. Many of the streams in the watershed were also incised and/or widened, especially in the more developed areas. Additionally, there were segments of mapped streams which were found to be piped, especially in the Upper Flat Creek subwatershed and several in the Lower Flat Creek subwatershed.

Embayment Subwatershed. The Embayment subwatershed was located furthest downstream where Flat Creek drains to Lake Lanier. Approximately 76 percent of streams with a drainage area of 25 acres or more were assessed in the Embayment subwatershed and, in general, this area was found to be the least impacted by existing hydrologic conditions. This subwatershed ranked highest (least degraded) in all of the channel characterization categories except hydrologic channel alterations.

The higher quality of existing conditions, compared to the other subwatersheds of Flat Creek, may be reflective of the lower impact from development in the Embayment subwatershed. This area contains lower percentages of impervious surfaces and areas of low-density residential land. Additionally, the Embayment subwatershed contains the USACE property boundary for Lake Lanier, within which development is restricted.

TABLE 3-15
Summary of Raw Habitat Scores
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Number of Reaches with Qualitative Category							Average Raw Score[a]	Total Rank
	Poor[b]	Poor-Marginal[2]	Marginal[b]	Marginal-Suboptimal[b]	Suboptimal[b]	Suboptimal-Optimal[b]	Optimal[b]		
Embayment	0	0	1 (8%)	0 (0%)	4 (33%)	3 (25%)	4 (33%)	133 (3)	12
Lower Flat Creek	0	0	4 (13%)	9 (30%)	13 (43%)	4 (13%)	0 (0%)	112 (2)	30
Upper Flat Creek	0	0	3 (27%)	7 (64%)	1 (9%)	0 (0%)	0 (0%)	94 (1)	11
Total	0	0	8 (15%)	16 (30%)	18 (34%)	7 (13%)	4 (0%)	53	53

[a] Average habitat score of assessed stream reaches for each subwatershed (rank in parenthesis).
[b] Reference stations were not established as a part of the project. Ranges were determined using the USEPA Rapid Bioassessment Protocol, (Barbour et al., 1999). optimal (151–200), suboptimal-optimal (135–150), suboptimal (113–134), marginal-suboptimal (90–112), marginal (60–89), poor-marginal (47–59), poor (0–47).

TABLE 3-16
Summary of Flat Creek Stream Inventory Data
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Man-made Channel Impacts		Hydrologic Channel Alterations		Bank Erosion (yd^2 per mile assessed)		Inadequate Buffers		Water Quality		Structural Maintenance Issues		Average Habitat Score	
	Total by Area	Rank[a]	Total by Area	Rank[b]	Total by Area	Rank[c]	Total by Area	Rank[d]	Total by Area	Rank[e]	Total by Area	Rank[f]	Total by Area	Rank[g]
Embayment	13	3	44	1	245.7	3	22.1%	3	0	3	1.41	3	133	3
Lower Flat Creek	90	2	100	2	402.6	2	61.9%	2	3	1	4.75	2	112	2
Upper Flat Creek	70	1	23	3	417.6	1	89.4%	1	1	2	6.90	1	94	1
Totals	**173**		**167**		**370.5**		**59.6%**		**4**		**4.52**		**113**	

[a] Number of manmade channel impact occurrences normalized by miles assessed, highest rank = 1, indicates most occurrences per assessed mile.
[b] Number of hydrologic channel impact occurrences normalized by miles assessed, highest rank = 1, indicates most occurrences per assessed mile.
[c] Square yards of erosion (total right and left banks) normalized by total miles of assessed streams, highest rank = 1, indicates most occurrences.
[d] Inadequate buffers (right and left banks) normalized by percent of total miles of assessed streams affected.
[e] Number of water quality impairments, highest rank = 1, indicates most occurrences observed.
[f] Number of maintenance issue occurrences normalized by miles assessed, highest rank = 1, indicates most occurrences per assessed mile.
[g] Average habitat score of assessed stream reaches. Highest rank = 1, indicates lower existing physical habitat conditions.

Lower Flat Creek Subwatershed. Approximately 78 percent of streams in the Lower Flat Creek subwatershed with a drainage area of 25 acres or more were assessed. In general, this area was found to be the most impacted by existing hydrologic conditions. This subwatershed ranked in the highest category (most impacted) for channel characteristics observed and reflected current and continuing problems from historical practices in the watershed.

Many portions of the mainstem and tributaries of the Lower Flat Creek subwatershed appear to have been previously channelized or altered in order to straighten the channel. Much of the channelization appears to have been implemented to help protect sewer lines along the mainstem and tributaries. In addition, the Lower Flat Creek area has a large amount of industrial and commercial areas, as well as a large proportion of residential areas. The heavy concentration of these types of land use may have a negative effect on the hydrology of the Lower Flat Creek area.

Upper Flat Creek Subwatershed. Due to the relatively large number of piped stream segments in Upper Flat Creek, only approximately 41 percent of streams which have a drainage area of 25 acres or more were assessed. This subwatershed was found to be in the median range for hydrologic impacts observed. Many of the streams assessed during field work in the Upper Flat Creek subwatershed appear to have been previously channelized or altered in order to straighten the channel. Additionally, from observations of degraded features surrounding developed areas, it appears that this subwatershed has been severely impacted by stormwater runoff from the highly impervious portions of the subwatershed, such as industrial and commercial areas, as well as high-density residential areas.

3.4 Stormwater Detention Structure Assessment

According to methods outlined in the Field Data Collection Plan (CH2M HILL, 2007a), a
According to methods outlined in the Field Data Collection Plan (CH2M HILL, 2007a), a
field investigation was conducted to confirm problems with and identify potential solutions for stormwater detention structures within the Flat Creek watershed. In the context of the stormwater detention structure assessment, stormwater detention structures include features designed for storage and treatment of stormwater. For this effort, all stormwater detention structures evaluated were stormwater storage sites (flow attenuation features), and stormwater storage sites were generically referred to as stormwater detention structures in this report. The major objective of this assessment was to identify and inventory existing stormwater detention structures for restoration opportunities and maintenance issues. This section outlines the results of the stormwater detention structure assessment, which was conducted in May 2007.

Prior to field investigations, stormwater detention structures were identified using GIS data provided by the City and the County, including stormwater inventory database, 2005 land use coverage, 2005 aerial photography, and GPS coordinates provided by the field team during the stream assessment phase of field data collection. During the desktop inventory, a total of 85 existing stormwater detention structures were identified as being located in the Flat Creek watershed or near the watershed with the potential to discharge into Flat Creek or its tributaries. The location of each of the stormwater detention structures is shown in Figure 3-21 and the number of stormwater detention structures in each subwatershed is shown in Table 3-17. As expected, the more densely populated areas of the Flat Creek watershed contain a greater number of stormwater detention structures per square mile.

TABLE 3-17
Identified Stormwater Detention Structures in Flat Creek watershed
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Area (mi^2)	Identified Stormwater Detention Structures	Identified Stormwater Detention Structures/mi^2
Embayment	3.30	10	3.0
Lower Flat Creek	3.69	**43**	11.7
Upper Flat Creek	3.38	**32**	9.5
Total	10.37	**85**	8.2

After the desktop inventory was completed, the 85 identified stormwater detention structures were then assessed to prioritize 30 for an additional field assessment. First, all stormwater detention structures that were constructed prior to 2000 were prioritized, based on the assumption that the design was not meeting current standards set forth in the Georgia Stormwater Management Manual (ARC et al., 2001). Next, the stormwater detention structures were prioritized if they were located on City- or County-owned land. Finally, they were prioritized if they had a relatively high ratio of stormwater drainage area to detention pond area (indicating improperly sized stormwater detention structures). Other factors that were considered but not included in the final prioritization included surrounding land use, outlet pipe size, and location relative to impacted areas. Information on most of the above-listed criteria was provided in the City and County's stormwater detention structure inventory, while other information, including drainage areas and detention pond areas, was approximated using aerial photography.

The number of identified stormwater detention structures surrounded by each land use type is summarized in Table 3-18, which included the following land uses:

- **Commercial** refers to areas used predominantly for the sale of products and services and can include highly developed areas such as shopping centers and central business districts.
- **Tax-exempt** includes schools, churches, and City- or County-owned property.
- **Industrial** refers to areas associated with manufacturing, processing, packaging, and/or assembly, which can often impact surrounding land and surface waters.
- **Residential** includes areas developed for residences.

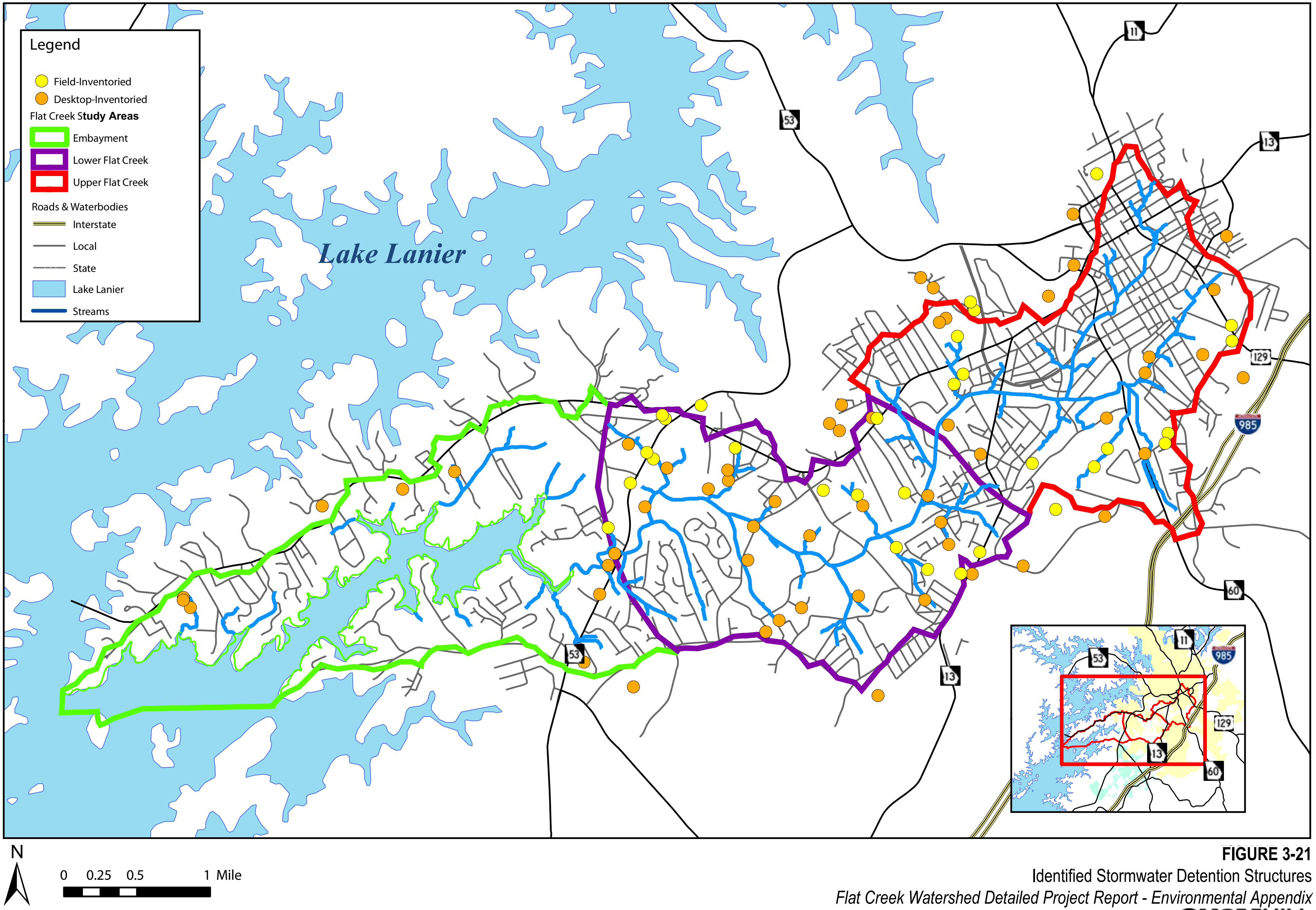

FIGURE 3-21

Identified Stormwater Detention Structures

Flat Creek Watershed Detailed Project Report - Environmental Appendix

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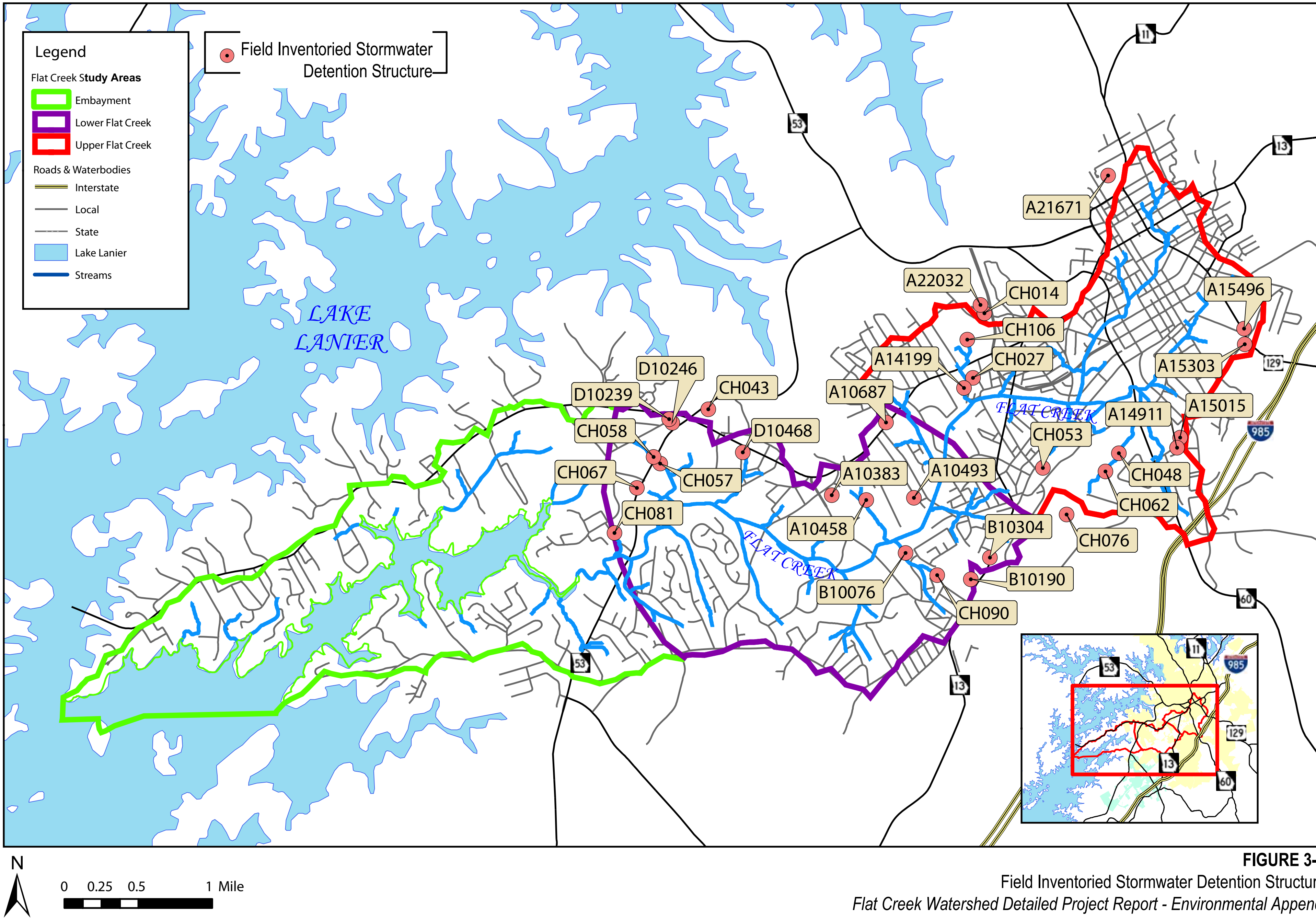

FIGURE 3-22

Field Inventoried Stormwater Detention Structures

Flat Creek Watershed Detailed Project Report - Environmental Appendix

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TABLE 3-18
Surrounding Land Use of Identified Stormwater Detention Structures
Flat Creek Watershed Detailed Project Report – Environmental Appendix

	Number of Identified Stormwater Detention Structures with Specified Surrounding Land Use					
Subwatershed	**Commercial**	**Tax-exempt**	**Industrial**	**Residential**	**Other[a]**	**Total**
Embayment	5	1	0	2	2	10
Lower Flat Creek	18	9	5	8	3	43
Upper Flat Creek	16	6	8	1	1	32
Total	39	16	13	11	6	85

[a] Agricultural (1), Conservation Space (1), Public Utility (1), Unidentified (3)

The purpose of the stormwater detention structure field assessment was to identify potential opportunities to improve functioning and attenuate peak flow. The field teams made an effort to assess the stormwater detention structures in order of decreasing priority, though some stormwater detention structures identified were not present in the location expected and were appropriately noted in the inventory. Stormwater detention structures in areas adjacent to the respective subwatersheds were also included, as the original stormwater detention structure evaluation effort included stormwater detention structures in the immediately surrounding areas as well. The locations of these stormwater detention structures, all within or directly adjacent to the Lower Flat Creek and Upper Flat Creek subwatersheds, and the stormwater detention structure identification number for each are shown on Figure 3-22. The number of field-assessed stormwater detention structures surrounded by each land use type is summarized in Table 3-19.

TABLE 3-19
Surrounding Land Use of Field-Assessed Stormwater Detention Structures
Flat Creek Watershed Detailed Project Report – Environmental Appendix

	Number of Field-Assessed Stormwater Detention Structures with Specified Surrounding Land Use				
Subwatershed	**Commercial**	**Exempt**	**Industrial**	**Residential**	**Total**
Lower Flat Creek	11	1	2	2	16
Upper Flat Creek	7	3	4	0	14
Total	18	4	6	2	30

Maps of stormwater detention structure locations were uploaded onto a handheld Personal Digital Assistant (PDA) prior to the field inventory. GIS software on the PDA, connected to a GPS unit, allowed the field team to locate all of the identified stormwater detention structures. In addition, various types of data were collected using the PDA. For quality assurance, data were also recorded on field sheets at each location. The types of data collected at each stormwater detention structure site included:

- Unique identifier, in conjunction with GPS coordinates, date and time of each evaluation

- Type of stormwater detention structure
- Condition of stormwater detention structure
- Maintenance issues
- Restoration/retrofit recommendations
- Plan view sketch of stormwater detention structure and outlet control structure
- Dimensions of any risers, standpipes, weirs, outlet pipes
- Photographs of stormwater detention structure
- Presence of vegetation
- Types and extent of erosion areas
- Additional relevant notes

Four types of stormwater detention structures were found in the Flat Creek watershed, including constructed wetlands, dry detention basins, and wet detention basins. Table 3-20 summarizes the types of stormwater detention structures that were found in each subwatershed in the Flat Creek subwatershed. Each stormwater detention structure type is discussed in the following paragraphs.

TABLE 3-20
Types of Stormwater Detention Structures in Field Inventory
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	Constructed Wetland	Dry Detention Basin	Wet Detention Basin	Other	Total
Lower Flat Creek	1	13	2	0	16
Upper Flat Creek	0	12	1	1	14
Total	1	25	3	1	30

Table 3-21 and Figure 3-23 provide the results of the stormwater detention structure assessment, including an evaluation of whether each stormwater detention structure was functioning to provide water quality and/or channel protection, as defined in the GSMM. As noted, a total of 30 stormwater detention structures were field-assessed. Of the 30 sites, 4 were inaccessible for a full evaluation (D10239, CH043, B10304, and B10076); 1 was identified as being a ditch, not a proper stormwater control (CH081); 1 was identified as meeting design criteria (B10190); and 24 stormwater detention structure problem sites were identified. Of the 24 stormwater detention structures identified as not providing adequate water quality or channel protection, 5 stormwater detention structures have outlet orifices that do not meet current design standards. Thus, the orifice size in these stormwater detention structures could be reduced to store water for longer periods. Also, proper outlet filtering devices could be installed to reduce flow velocities. At 17 of the 24 stormwater detention structures, the entire stormwater detention structure facility was built

TABLE 3-21
Summary of Stormwater Detention Structure Assessment
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Subwatershed	No Channel or Water Quality Protection	Water Quality Protection but No Channel Protection	Water Quality and Channel Protection
Lower Flat Creek	8	2	1
Upper Flat Creek	13	1	0
Total	21	3	0
Stormwater Detention Structure Inaccessible for Full Inventory			
Lower Flat Creek	4	1	0

prior to current design standard specifications. All 17 of these stormwater detention structures were dry detention basins that would require redesign, including earthwork, to meet current design standards.

Volume modification was recommended for 12 stormwater detention structures, 9 of which were in the Upper Flat Creek subwatershed. All but one of these stormwater detention structures require full redesign. In most cases, the best method for increasing the capacity of the stormwater detention structure would be to excavate the sides or bottom of the dry basin within its existing footprint. In one case, it was recommended that the pond be enlarged by building up the surrounding berms.

Stormwater Detention Structure Maintenance Issues

During the field inventory, stormwater detention structures were evaluated for maintenance issues. These maintenance issues were documented and should be addressed by the non-federal sponsor as part of on-going maintenance activities to improve the stormwater management capability of the stormwater detention structures. At eight of the detention ponds, the installation of a sediment filter and/or trash rack was needed. These devices prevent the outlet control structures from becoming clogged and inefficient. In addition, 15 detention ponds were overgrown with vegetation and/or were littered with debris and trash. These ponds should be cleared to maintain the stormwater detention structure. The locations of stormwater detention structures needing maintenance are shown on Figure 3-24. The locations and specific maintenance issues for each stormwater detention structure were communicated to the City of Gainesville and Hall County as a component of the Flat Creek Watershed Assessment Technical Memorandum (CH2M HILL, 2007b).

3.5 Ecosystem Response Model to Quantify Watershed Conditions

The first step in evaluating an ecosystem restoration project was the determination of baseline, or existing conditions of the watershed, for comparison to predicted future conditions with and without watershed improvement efforts. The ERM was used to evaluate existing conditions in Flat Creek, based on existing biological monitoring scores. The results are summarized in the following section.

3.5.1 Model Background

The ERM was used in multiple steps of the planning process, including: inventorying and forecasting conditions; evaluating the effects of alternative plans, comparing alternative plans, and selecting a recommended plan. The ERM was developed as a decision making tool to assist in the selection of ecosystem restoration projects by the comparing ecosystem benefits of various project alternatives, using existing and predicted future biological scores. The model was created by an interagency team led by the USACE, with members from the U.S. Fish and Wildlife Service (USFWS), USEPA, GADNR WRD, GAEPD, and local sponsors and stakeholders. According to USEPA, the health of an aquatic ecosystem can be determined by chemical water quality data and biological monitoring data (fish, benthic macroinvertebrate, and physical habitat) (USEPA, 1990). The interagency team that developed the ERM considered the biological conditions of a stream to be the strongest indicators of watershed conditions, as they provide a long-term measure of stream health;

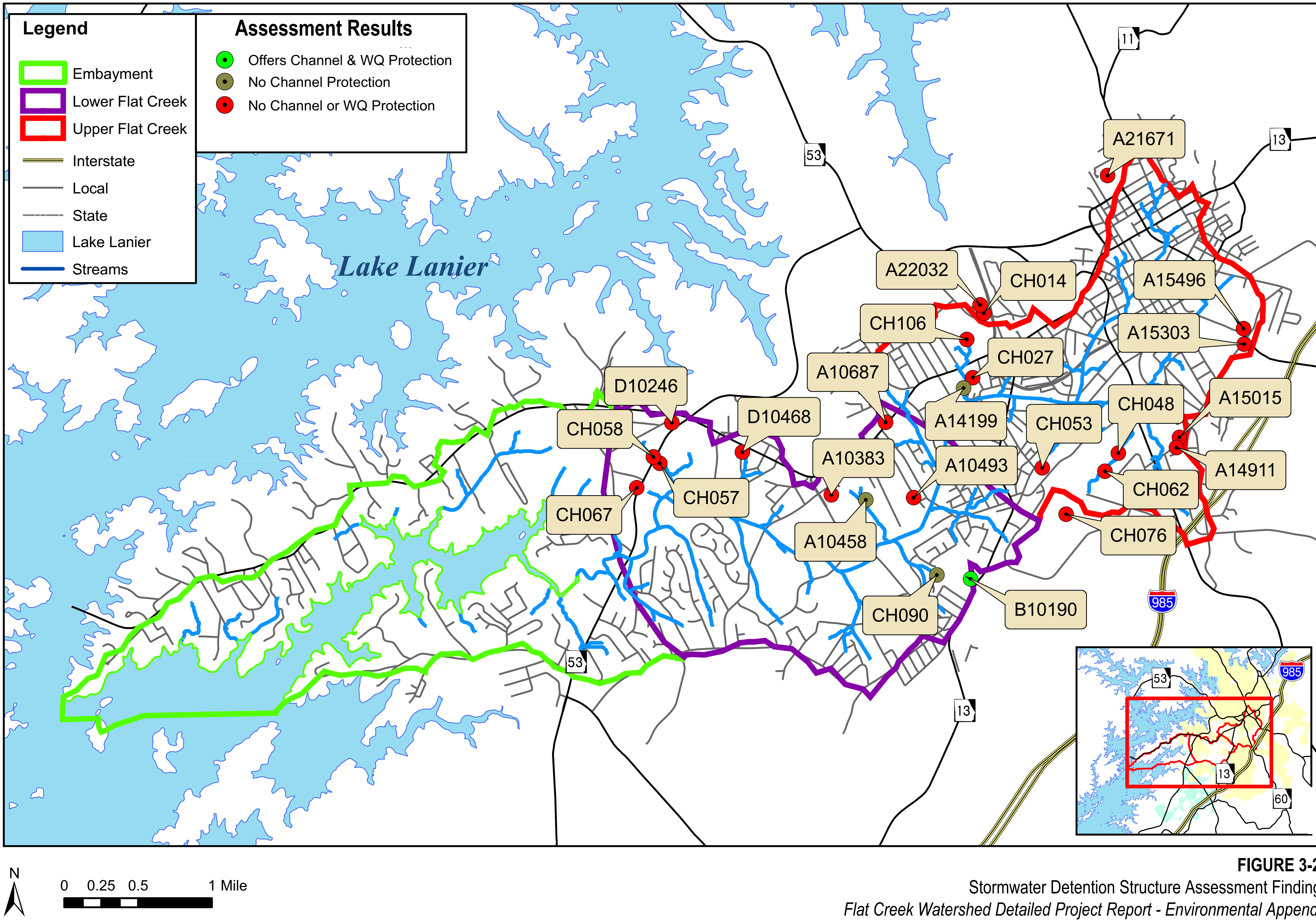

FIGURE 3-23

Stormwater Detention Structure Assessment Findings

Flat Creek Watershed Detailed Project Report - Environmental Appendix

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CH2MHILL

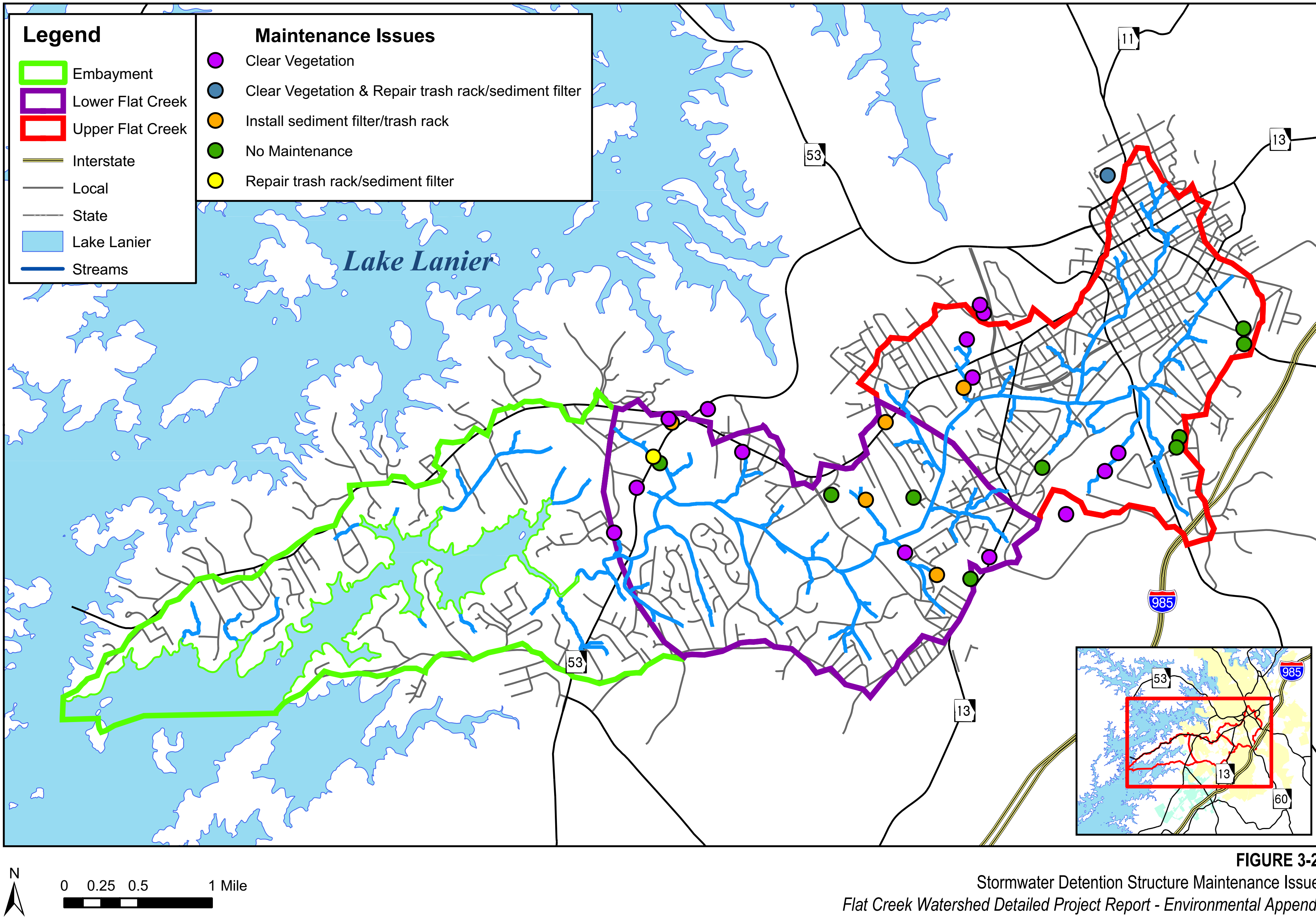

FIGURE 3-24

Stormwater Detention Structure Maintenance Issues

Flat Creek Watershed Detailed Project Report - Environmental Appendix

water quality data, on the other hand, provide a more instantaneous measure. Therefore, the ERM was developed to use physical habitat and biological monitoring data, collected using GADNR guidance (GADNR, 2005 and 2007), as an indicator of the overall stream ecosystem integrity. There was not yet a project completed to judge the success of the ERM, since this was a new tool. However, the model was reviewed over a 2-year period, first by IWR and USACE-HQ and recommended for certification to the USACE National Ecosystem Planning Center of Expertise (ECO-PCX). The ECO-PCX has approved the use of this model as a Plan Formulation Tool.

3.5.2 Description of Model

Inputs to the ERM include biological data from multiple locations throughout a watershed to calculate watershed- scale scores for (1) the fish community, (2) the benthic macroinvertebrate community, (3) the physical habitat (4) combined stream health score, based on fish, benthic macroinvertebrate, and fish scores, and (5) habitat units, based on the combined stream health score), all of which were representative of the watershed as a whole. Consideration of various watershed impacts was imperative to making sound predictions of future biological scores, as these scores provide valuable input for the ERM. The ERM can then be a powerful tool for estimating the potential benefits of ecosystem restoration projects.

Based on an algorithm that combines weighted averages for each biological score, the ERM outputs a combined stream health score, to represent the overall aquatic integrity of the watershed. The ERM also outputs habitat units, representative of the predicted improvement or decline across the watershed, which were used in subsequent Cost Effectiveness / Incremental Cost Analysis (CE/ICA) to identify restoration alternatives that were the least costly for providing the greatest benefit. The development of the ERM outputs for existing conditions, future without project conditions, and future with project conditions in Flat Creek are presented in subsequent sections.

3.5.3 ERM Step 1: Biological Monitoring Data Inputs

The 2007 biological monitoring data were input into the ERM to establish the existing conditions of the Flat Creek watershed. The results of the ERM are presented in the following section.

3.5.4 ERM Step 2: Existing Conditions Score Outputs

The ERM outputs a combined stream health score, based on an algorithm that combines weighted averages for each biological score, to represent the overall aquatic integrity of the watershed. The ERM also outputs habitat units representative of the predicted improvement or decline and used in subsequent CE/ICA to determine restoration alternatives that were the least costly for providing the greatest benefit. ERM outputs for Flat Creek are shown in Section 3.5.5 (Summary of Existing Conditions Analysis). The development of the ERM outputs for existing conditions in Flat Creek is presented below. The projection of future conditions using the ERM is discussed later in the Environmental Appendix.

Existing IBI Score

The existing Flat Creek fish IBI output was determined by calculating the average score of all Flat Creek stations and then expressing this score as a ratio of the total possible score:

- IBI Score = $\frac{14+10+26+16}{4}=16.5 \Rightarrow \frac{16.5}{60}=0.275 \Rightarrow 0.275*100=27.5$

Existing BMI Score

The existing Flat Creek BMI output was determined by calculating the average score of all Flat Creek stations and then expressing this score as a ratio of the total possible score:

- BMI Score = $\frac{17+36+40+37}{4}=32.5 \Rightarrow \frac{32.5}{100}=0.325 \Rightarrow 0.325*100=32.5$

Existing Physical Habitat Score

The existing Flat Creek physical habitat output was determined by calculating the average score of all Flat Creek stations and then expressing this score as a ratio of the total possible score:

- Physical Habitat Score = $\frac{81+98+129.5+153}{4}=115 \Rightarrow \frac{115}{200}=0.577 \Rightarrow 0.577*100=57.7$

Existing Combined Stream Health and Habitat Units

The combined stream health score was calculated by adding the weighted average (across the watershed) biological scores, where each average score is expressed as a ratio of the total possible score (60 points for fish IBI, 100 points for benthic macroinvertebrate, and 200 points for physical habitat). The two biological scores (fish and macroinvertebrates) each represent 40 percent of the combined stream health score, and the physical habitat score comprises the remaining 20 percent. The qualitative condition categories of existing biological scores, and the low percentage of the best possible combined stream health score, suggest degraded conditions in Flat Creek. The second model output, habitat units, was calculated by multiplying the combined stream health score by the number of stream miles in Flat Creek (6 miles). The importance of this value is its use in subsequent incremental cost analysis for project feasibility determinations. The calculation of both model outputs is presented below.

- Combined Stream Health Score = $(0.40*27.5)+(0.40*32.5)+(0.20*57.7)=35.6$
- Habitat Units = Combined Stream Health Score * Stream Miles = 35.6 * 6 = 213

3.5.5 Summary of Existing Conditions Analysis

Table 3-22 summarizes the biological scores, at each sampling station, from the 2007 biological monitoring effort, as well as the overall fish IBI, BMI, and physical habitat scores and the combined stream health score and habitat units for the Flat Creek watershed. These scores represent the existing conditions in Flat Creek watershed, and the steps taken to evaluate existing conditions are summarized below. Potential raw BMI scores range from 0 to 100, while potential raw physical habitat scores range from 0 to 200. For the Flat Creek watershed overall, the BMI score was 33 percent of the total overall possible score, while the physical habitat score was 58 percent of the total overall possible score.

TABLE 3-22
Summary of Flat Creek Watershed Existing Biological Scores
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Parameter	FLG-A	FLG-4	FLG-B	FLG-5	Flat Creek Watershed
Fish IBI score	14	10	26	16	28
BMI score	17	36	40	37	33
Physical habitat score	81	98	129.5	153	58
Combined stream health	--	--	--	--	35.6
Habitat Units	--	--	--	--	213

4. Analysis of Future without Project Conditions

4.1 Future Conditions Assessment

After the determination of existing conditions, the second step in quantifying the environmental benefits of various ecosystem restoration alternatives was to determine the future without project conditions of the stream. To make this determination, future environmental conditions were predicted based on land use changes estimated for 2030 and on the watershed model described below and detailed in Appendix E (Engineering Appendix) of the Detailed Project Report.

For the Flat Creek watershed project, a spreadsheet-based watershed model was used to quantify the following outputs under various scenarios (existing, future without project, and future with project) in the Flat Creek watershed: (1) percent imperviousness, (2) erosivity, and (3) total suspended solids (TSS) yield. Results of the modeling effort were important in the assessment of biological and physical habitat conditions and were used to compare the effects of various restoration alternatives, including the No Action Alternative, in the Flat Creek watershed. Additional details on the capabilities and development of the watershed model are presented in Appendix E (Engineering Appendix) of the Detailed Project Report. Projected land use changes considered during the referenced analysis were derived from the *City of Gainesville and Hall County Comprehensive Plan* (2004).

4.2 Approach to Predict Future without Project Conditions

By the year 2030, Flat Creek biological scores were expected to decrease if no ecosystem restoration alternatives were implemented. The following section details the analysis conducted to reach this conclusion. This section details the approach used to predict future Flat Creek biological scores for use in the ERM, leading to the overall ranking of potential restoration efforts in the watershed. To quantify the combined stream health score and habitat units under future conditions, both with and without alternative implementation, biological scores in the watershed must be predicted based on (1) the current condition of biological communities and habitats and (2) projected future watershed conditions. The methodology used to predict scores, described in the following section, included the following:

- **Future Biological Monitoring Score Ranges**—Analysis of current biological data from fish community, macroinvertebrate community, and physical habitat assessments to estimate the minimum and maximum amount of change expected in individual biological metrics assuming watershed degradation or improvement.
- **Watershed Model Analysis—**Analysis of existing and projected future flow, velocity, sediment delivery, and sediment budget based on hydrologic and hydraulic model output.

- **Future Score Prediction**—Use of the hydrologic and hydraulic model output to make a best professional judgment prediction of future biological scores for each sampling station based on the range of potential change expected from biological monitoring data analysis.
- **Future Conditions Determination—**Use of the predicted scores to determine combined stream health and habitat units for the entire Flat Creek watershed.

4.3 Future Biological Monitoring Score Ranges

Scores from the 2007 biological monitoring conducted in Flat Creek were analyzed to determine the minimum and maximum amount of expected decline under future conditions with no restoration implementation. For each biological parameter, individual metrics were examined with consideration to the environmental condition factor analysis. The results for fish IBI, BMI, and physical habitat future score prediction are summarized below.

4.3.1 Future Fish IBI Score Range

A prediction of future fish IBI scores, assuming the minimum amount of negative change expected and the maximum amount of negative change to the environmental condition factors expected is shown in Table 4-1. The metrics evaluated included four with 2007 scores greater than 1 for individual stations, and therefore, capable of negative change in the future, and the proportion of individuals with external anomalies. These metrics were chosen as those with the greatest likelihood for change, based on current results. The rationales for the expected declines in each of these metrics are provided below.

Evenness

This metric is a measure of the equity of proportion of species in a stream reach, and a higher score represents good water quality and habitat conditions. As Flat Creek becomes more degraded, the species that are more tolerant of pollution are expected to dominate the fish community. This metric score is expected to decrease from 5 to 3 or 1 at station FLG-A and from 3 to 1 at station FLG-5. The metric scores at the other two stations cannot decrease beyond their existing value.

Proportion of Individuals as Lepomis Species

According to data collected by GAWRD, stream locations that were highly impacted by anthropogenic sources tend to be dominated by *Lepomis* species (GAEPD, 2005). As Flat Creek becomes modified by increased development and urbanization, this metric is expected to decline from a 3 to a 1 at FLG-A and FLG-B. The other two stations' metric scores were the lowest possible value.

Proportion of Individuals as Insectivorous Cyprinids

Only station FLG-B scored higher than a 1 for this metric, which is used to represent the variability in aquatic insect food base. As sedimentation in Flat Creek increases and the benthic macroinvertebrate habitat is compromised, this metric is expected to decrease from a 5 to a 3 or 1.

TABLE 4-1
Fish Community Predicted Score Analysis—without Project
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Sampling Station	**FLG-A**		**FLG-4**		**FLG-B**		**FLG-5**	
Metric and Minimum & Maximum Potential Future Decline	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Number of Native Fish Species	0	0	0	0	0	0	0	0
Number of Benthic Invertivore Species	0	0	0	0	0	0	0	0
Number of Native Sunfish Species	0	0	0	0	0	0	0	0
Number of Native Insectivorous Cyprinid Species	0	0	0	0	0	0	0	0
Number of Native Round-bodied Sucker Species	0	0	0	0	0	0	0	0
Number of Sensitive Species	0	0	0	0	0	0	0	0
Evenness	-2	-4	0	0	0	0	-2	-2
Proportion of Individuals as *Lepomis* Species	-2	-2	0	0	-2	-2	0	0
Proportion of Individuals as Insectivorous Cyprinids	0	0	0	0	-2	-4	0	0
Proportion of Individuals as Generalist Feeders and Herbivores	0	0	0	0	-2	-4	-2	-4
Proportion of Individuals as Benthic Fluvial Specialists	0	0	0	0	0	0	0	0
Number of Individuals Collected per 200 Meters	0	0	0	0	0	0	0	0
Proportion of Individuals with External Anomalies	+4	0	+4	0	0	0	+4	0
Sum of potential change	0	-6	+4	0	-6	-10	0	-6
2007 IBI Score	14	14	10	10	26	26	16	16
Predicted Scores w/ Minimum Change and Maximum Change	**14**	**8**	**14**	**10**	**20**	**16**	**16**	**10**

Proportion of Individuals as Generalist Feeders and Herbivores

This metric is a measure of individuals which can utilize both plant and animal food types. As streams become more degraded, the variability in food resources declines and generalist feeders become more dominant. The percentage of generalist feeders were expected to out-compete the specialist feeders as the habitat in Flat Creek becomes more degraded. This metric is expected to decline at stations FLG-5 and FLG-B.

Proportion of Individuals with External Anomalies

It is expected that the relatively high percentage of individuals with external anomalies is likely due to the severe drought under which the 2007 sampling was conducted. Therefore, though stream degradation is expected to occur, higher water levels in the future may results in fewer external abnormalities. This could allow the potential for the fish IBI score to increase by 4 points at three of the sampling stations on Flat Creek.

4.3.2 Future BMI Score Range

A prediction of future BMI scores, assuming the minimum amount of change expected and the maximum amount of change expected is shown in Table 4-2. The metrics evaluated included five with 2007 scores greater than 0 for at least one, and therefore, capable of negative change in the future. The rationale for the expected declines in each sub-metric is provided below.

Percent Trichoptera Taxa

This metric is a composition component of the benthic macroinvertebrate score. As water quality decreases, the percent of Trichoptera taxa is expected to decrease. As the variation of habitat is reduced in Flat Creek by increased sedimentation, generalist macroinvertebrate species were expected to become more dominant. The percent of Trichoptera at station FLG-5 (52 percent) is so great that a substantial decrease is not expected to change the metric score of 100.0 (which is obtained for percentages greater than or equal to 32 percent). The metric score at FLG-A cannot decrease beyond its score of 0. However, the percent of Trichoptera at station FLG-B and FLG-4 were expected to decrease between 20 and 95 percent. The associated score changes are shown in Table 4-2.

Percent *Chironomus* and *Cricotopus*/Total Chironomidae

This metric is also a composition component of the benthic macroinvertebrate score, used to evaluate the proportions between species in a sample. As water quality decreases, the number of *Chironomus* and *Cricotopus* per the total amount of Chironomidae is expected to increase. The percentage measured at FLG-5 (52 percent) is already so high that this metric received the lowest possible score at this station. Therefore, it is not expected to change. The station with the next highest percentage of *Chironomus* and *Cricotopus* per total Chironomidae was FLG-A. It is expected that this metric will remain as low under the minimum change conditions or that the percentage will increase from 10 to 15 percent. Station FLG-B is expected to score the same as FLG-A or FLG -5 in the future. The resulting changes in score are shown in Table 4-2. The percentage of *Chironomus* and *Cricotopus* per total Chironomidae at station FLG-4 is expected to increase up to 10 times the current values.

TABLE 4-2
BMI Predicted Score Analysis—without Project
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Sampling Station	FLG-A		FLG-4		FLG-B		FLG-5	
Metric and Minimum & Maximum Potential Future Decline	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Plecoptera Taxa	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percent Trichoptera individuals	0.0	0.0	-16.0	-59.9	-16.0	-37.0	0.0	0.0
Percent *Chironomus* & *Cricotopus*/ Total Chironomidae	0.0	-14.0	-14.0	-24.0	-14.0	-61.0	0.0	0.0
Tolerant taxa	0.0	0.0	-6.0	-38.0	-6.0	-31.0	-6.0	-25.0
Percent Scraper	-1.0	-8.0	0.0	-1.0	0.0	0.0	-2.0	-10.0
Clinger taxa	-5.0	-10.0	-5.0	-10.0	-5.0	-10.0	-5.0	-10.0
Average of Potential Change	-1.0	-5.3	-6.8	-22.1	-6.8	-23.2	-2.2	-7.5
2007 Score	17.0	17.0	36.0	36.0	40.0	40.0	37.0	37.0
Predicted Scores w/ Minimum Change and Maximum Change	**16.0**	**11.7**	**29.2**	**13.9**	**33.2**	**16.8**	**34.8**	**29.5**

Tolerant taxa

As water quality decreases and habitat becomes degraded, the number of species which are tolerant to these stressors increases. Since nonpoint source pollution and sedimentation were expected to increase in Flat Creek, the number of tolerant taxa is expected to increase by at least 1 taxon at each station, and the maximum change for each station is an increase of between 4 and 6 taxa. The metric score at FLG-A, however, cannot decline beyond its current score of 0.

Percent Scraper

This metric evaluates the percentage of macroinvertebrates whose functional feeding guild is considered scraper. The percentage of these individuals is expected to decrease as water quality decreases. There were no scraper individuals found at station FLG-B during the 2007 biological monitoring, so this metric is not expected to change. The other stations all have low percentages of scraper, and these percentages were expected to decline further until this functional feeding guild is almost eliminated at the stations.

Clinger taxa

This metric is the habit component of the benthic macroinvertebrate score. Members of the clinger taxa prefer habitat to which they cling, including rocky riffle areas and large woody debris. Results of the watershed model and analysis of future land use suggest an increase in erodibility and a loss of riffle habitat and bank vegetation, which will result in a decline of clinger taxa. Three clinger taxa were found at FLG-A, and 4 were found at the other three stations. It is expected that the number of clinger taxa will decrease between 1 and 2 taxa at each station, further decreasing the benthic macroinvertebrate score.

4.3.3 Future Habitat Score Range

Based on existing physical habitat data, a prediction of future scores assuming the minimum amount of change expected and the maximum amount of change expected is shown in Table 4-3. The metrics evaluated include all physical habitat assessment parameters, with the exception of channel flow status and channel alteration, which were not expected to change under future conditions with no restoration implementation. The rationales for the expected declines in each parameter are provided below.

TABLE 4-3
Physical Habitat Predicted Score Analysis—without Project
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Sampling Station	**FLG-A**		**FLG-4**		**FLG-B**		**FLG-5**	
Metric and Minimum & Maximum Potential Future Decline	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Epifaunal substrate	-2.5	-7.5	-3	-5	-3	-13	-5	-10
Embeddedness	0	-2	-4	-7	-6	-11	-7	-12
Velocity/depth regime	-1.5	-4.5	-1	-4	-4	-14	-1	-6
Sediment deposition	-2	-3	-4.5	-9.5	-3.5	-6.5	-7	-12
Channel Flow Status	0	0	0	0	0	0	0	0
Channel Alteration	0	0	0	0	0	0	0	0
Frequency of riffles	0	0	0	0	0	0	0	0
Bank stability	-2	-6	-3	-6	-5	-9	-4	-8
Bank Vegetative protection	0	0	0	0	0	0	0	0
Riparian zone	0	0	0	-4	0	-5	0	-6
Sum of potential change	-8	-23	-15.5	-35.5	-21.5	-58.5	-24	-54
2007 Score	81	81	98	98	129.5	129.5	153	153
Predicted Scores w/ Minimum Change and Maximum Change	**73**	**58**	**82.5**	**62.5**	**108**	**71**	**129**	**99**

Epifaunal Substrate

Based on the degree of degradation predicted from the environmental condition categories, the maximum decrease in this metric at FLG-5 and FLG-B was expected to be greater than that at the downstream stations. All stations were expected to decline at least one habitat assessment condition category.

Embeddedness

Since TSS production was predicted to increase a greater percentage at the two upstream Flat Creek stations, the degree of embeddedness at these stations was predicted to increase more at these sites. Station FLG-A was already highly embedded, so this metric was not expected to change significantly under future without project conditions.

Velocity/Depth Regime

During the habitat assessment, stations FLG-B and FLG-5 scored in the optimal range for this metric. Relatively high increases in TSS production at these two stations were expected to cause substantial deposition of sediment in the area surrounding these stations, covering riffle substrate and causing a decrease in this metric between one and two habitat assessments categories. The two upstream stations currently score in the marginal range for this metric and were expected to score in the poor range under future without project conditions.

Sediment Deposition

Watershed model analysis indicates that TSS production and erosivity will increase in the future, which will lead to a greater amount of sediment deposition in Flat Creek. It was expected that the maximum change for all stations will result in each scoring in the poor category for this metric. Currently, sediment deposition was higher at FLG-A and FLG-B than at the other two stations.

Bank Stability

Watershed model analysis indicates that erosivity will increase in the future. If no restoration is implemented and storm pulses are not controlled, the moderately eroded banks seen throughout Flat Creek will continue to erode. The downstream stations were expected to have a greater decrease in bank stability, since the drainage area for these stations will undergo the most development and increase in percent imperviousness.

Riparian Zone

Analysis of current and future land use indicates further development in Flat Creek, especially in the downstream area. Riparian areas which have not been impacted in Flat Creek were expected to undergo disruptions under future urbanization. This will result in currently intact riparian areas declining by one habitat assessment category.

4.4 Watershed Model Analysis

4.4.1 Watershed Model

Baseline, or existing, conditions were first established to compare against projected future without project and future with project conditions. Future without project conditions reflect changes in the watershed expected to occur if no ecosystem restoration alternatives were implemented and the watershed continues to develop. To evaluate existing and future without project conditions, a watershed model was run (using current (2005) land use data for existing conditions and projected future (2030) land use data for future without project conditions), and results were scored based on condition category criteria

For the Flat Creek watershed feasibility study, a spreadsheet-based watershed model was developed to conduct H&H simulations and estimate existing and projected future environmental conditions related to aquatic habitat and ecosystems. The watershed model is detailed in Appendix E to the Detailed Project Report, including the development, uses, and results for this study. The watershed model uses data from multiple sources and accounts for key factors included in the ERM guidance document developed by the interagency team (NGWRA, 2007), including stream discharge, velocity, and sediment yield. ArcHydro tools, which enable Geographic Information Systems (GIS) modeling of hydrologic networks, were used to define drainage basins at various points in the Flat Creek watershed.

The watershed model was used to quantify the following outputs under various scenarios (existing, future without project, and future with project) in the Flat Creek watershed: (1) percent imperviousness, (2) erosivity, and (3) total suspended solids (TSS) yield. Percent imperviousness was an estimate of the proportion of a drainage area which was comprised of impervious structures that cannot be penetrated. Erosivity was a ratio of runoff rates and a measure of the ability of stream flow to erode and remove bank sediment. TSS yield was a measure of sediment transported to the stream from both upland and instream sources. Results of the modeling effort were important in the assessment of biological and physical habitat conditions and were used to compare the effects of various restoration alternatives, including the No Action Alternative, in the Flat Creek watershed.

4.4.2 Model Inputs

Table 4-4 summarizes the inputs that were used in the watershed model to estimate the three key outputs at locations throughout the watershed. A key data source for the modeling effort was the Flat Creek watershed field assessment conducted in 2007, which included assessments of approximately 21 miles of Flat Creek and its tributaries and 85 structural stormwater detention structures. Data collected during the field assessment was utilized to establish the hydrology, channel conditions, and stormwater detention structure controls throughout the watershed. The model inputs are detailed below, including current/future land use, erodibility, base erosion rate, stormwater detention structure efficiency, and upland TSS production.

Current (2005) Land Use

The analysis of land use data was a valuable tool for estimating the impacts of nonpoint source pollution on a watershed. Current land use in the Flat Creek watershed was depicted in the watershed model using the Atlanta Regional Commission's (ARC's) LandPro 2005 Geographic Information System (GIS) database for the 20-county Atlanta region, which was created using 2005 true color imagery provided by Aerials Express, Inc. The 2005 dataset was used to model the existing conditions of the Flat Creek watershed and to calculate percent imperviousness throughout the watershed.

TABLE 4-4
Summary of Flat Creek Watershed Model Inputs
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Input	Value(s)	Source(s)
Current (2005) land use	Varies across watershed	Atlanta Regional Commission's (ARC's) LandPro 2005 Geographic Information System (GIS) database
Projected future (2030) land use	Varies across watershed	*Gainesville/Hall County Comprehensive Plan* (CH2M HILL, 2004)
Erodibility (Percent)	12.5, 37.5, 62.5, or 87.5 (varies across approximately 300-foot stream segments)	2007 stream assessment data
Base erosion rate (lb/ft^2/year)	9.56	2007 stream assessment data; existing base erosion rate developed for a representative drainage basin
Stormwater detention structure efficiency, Eff_Q, (Percent)	80 - wet extended detention 50 - dry extended detention 50 - wet detention 30 - dry detention	2007 stormwater detention structure assessment and *Georgia Stormwater Management Manual* (ARC, 2001)
Upland TSS production (lb/acre/yr)	400– impervious (e.g., driveways, rooftops, parking lots) 65– disturbed pervious (e.g., lawns, gardens, porous pavement) 35– undisturbed pervious (e.g., woods, preserves) 15– undisturbed stream buffers	Hall County/City of Gainesville Stormwater Quality Performance Review (http://www.hallcounty.org/forms/watershed.asp)

Projected Future (2030) Land Use

Projected future land use was directly related to the model calculation of percent impervious in the year 2030. Changes to land use can substantially alter streamflow and increase the delivery of pollutants such as nutrients, pathogens, and sediment to nearby streams, causing adverse impacts to aquatic ecosystems. Projected future land use was incorporated in the watershed model for the year 2030. Future land use estimates were provided in the *Gainesville/Hall County Comprehensive Plan* (CH2M HILL, 2004). The 2030 projection was used to model the future without project conditions and future with project conditions of the Flat Creek watershed. Projected future land use was discussed in Section 2.2.2 (Projected Future Land Use).

Erodibility

Erodibility, as used in the model, was a measure of the percentage of a stream bank which has already eroded. Erosion on stream banks diminishes the benthic macroinvertebrate habitat by removing stream bank vegetation, and it also allows a larger volume and higher flow rate of stormwater runoff to enter the stream. This increases nonpoint pollution and sedimentation levels to the stream, both negatively impacting biological parameters. Sediment affects aquatic ecological processes and conditions, including nutrient cycling, carbon processing, substrate availability, and functioning of filter-feeding organisms. Sedimentation degrades biological conditions by covering crucial habitat and creating unstable environments to which certain species may be sensitive.

Existing erodibility was quantified in the watershed model based on the amount of bank erosion that was observed in the field during the Flat Creek stream assessment. Values of erodibility were determined at approximately 300-foot stream intervals. Categories for erodibility were included four overall categories: 0 to 25 percent (“optimal”), 25 to 50 percent (“suboptimal”), 50 to 75 percent (“marginal”), and 75 to 100 percent (“poor”). To quantify the erodibility of a specific stream segment, the median value was assigned (i.e., 12.5 for stream segments which were 0 to 25 percent eroded, 37.5 for stream segments which were 25 to 50 percent eroded, etc.). For modeling of future without project conditions, erodibility values remained unchanged. For future with project conditions, stream segments included in an ecosystem restoration alternative were assumed to have the lowest erodibility, 12.5 percent.

Base Erosion Rate

Erodibility and erosivity were used in the watershed model as modifying factors to calculate the base erosion rate. The base erosion rate specific to Flat Creek and applied in this model, 9.56 lb/ft^2/year, was derived using available monitoring data from other tributaries to the Chattahoochee River, erodibility data collected during the Flat Creek stream assessment, and erosivity values used to model other drainage areas representative of the Flat Creek watershed. The watershed model used the assumption that the Chattahoochee River tributaries in Gwinnett County and the Flat Creek watershed have similar TSS production rates, based on spatial proximity and comparable urban development. For the Chattahoochee River tributaries, monitoring data was collected from 50 stream sites selected in 2004, resulting in an estimated TSS production rate of 11.2 lb/ft^2/year (Brown and Caldwell, 2008). This value was used to derive the 9.56 lb/ft^2/year base erosion rate for Flat

Creek by dividing it by Flat Creek's average erodibility (0.514) and erosivity (2.28) values. This value was used to model both existing and future conditions.

Stormwater Detention Structure Efficiency

In the watershed model, stormwater detention structures were accounted for in the calculation of erosivity. Stormwater detention structure efficiencies were estimated based on field observation of conditions and using the *Georgia Stormwater Management Manual* estimates for TSS removal provided by stormwater detention structures. In accordance with the *Georgia Stormwater Management Manual*, TSS removal efficiencies for various types of stormwater detention structures were based on the stormwater detention structure's efficiency value, or Eff_Q as summarized in Table 4-5.

TABLE 4-5
Stormwater Detention Structure Efficiency Values by Stormwater Detention Structure Type
Flat Creek Watershed Detailed Project Report - Environmental Appendix

Stormwater Detention Structure Type	Stormwater Detention Structure Efficiency Value, Eff_Q (percent)
Extended Wet Detention	80
Extended Dry Detention	50
Wet Detention	50
Dry Detention	30
Constructed Wetland	80
Oil/Grit Separator	40
Grassed Swales (2 percent slope, dam)	15

Source: *Georgia Stormwater Management Manual, 2001*

For existing and future without project conditions, Eff_Q was based on the type of stormwater detention structure that was observed during the stormwater detention structure assessment. For future with project conditions, implementation of a restoration alternative including a stormwater detention structure was characterized by changing the stormwater detention structure's efficiency value. It was assumed that these alternatives included either: (1) retrofitting an existing dry detention pond (Eff_Q = 30 percent) to a extended dry detention pond (Eff_Q = 50 percent), (2) constructing a new extended dry detention pond (Eff_Q = 50 percent), (3) retrofitting an existing wet detention pond (Eff_Q = 50 percent) to a extended wet detention pond (Eff_Q = 80 percent), or (4) constructing a new extended wet detention pond (Eff_Q = 80 percent).

Upland TSS Production

Upland TSS production refers to sediment entering the stream from land in the stream's drainage area and was related to the degree of imperviousness of the surrounding land use. Existing and predicted future upland TSS production was calculated using land use data sets and assumed TSS production for each land use type. TSS yield values for impervious area (400 lb/acre/yr), disturbed pervious area (65 lb/acre/yr), and undisturbed pervious area (35 lb/acre/yr) were assigned based on the Hall County/City of Gainesville Stormwater Quality Performance Review (http://www.hallcounty.org/forms/watershed.asp).

4.4.3 Model Outputs

As previously mentioned, the watershed model was developed to quantify three key outputs: (1) percent imperviousness, (2) erosivity, and (3) TSS yield. A summary of the model outputs, and their importance, is provided below.

Percent Imperviousness

An increase in imperviousness decreases the infiltration and storage capacity of the watershed, thereby increasing both the volume and velocity of stormwater runoff. Due to the urbanized nature of the Flat Creek watershed, there were existing areas with inadequate stormwater controls to address this altered flow pattern. As land in the Flat Creek watershed continues to undergo development, altered flow patterns will lead to increased stream degradation, and the increase in impervious surfaces will intensify the frequency and strength of flood events. These impacts often result in the displacement of various native aquatic organisms that are sensitive to changes in the natural environment. The increase in runoff rates decreases the amount of sediment that is able to settle out of stormwater before it enters the stream. Additionally, an increase in stormwater velocity leads to an increase in bank erosion and thus instream sediment production. For new development, these effects will be offset by the current stormwater design regulations that are enforced by the City and County.

TABLE 4-6
Percent Imperviousness by Land Use Type
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Land Use Type	Percent Imperviousness
Agricultural	0
Commercial	80
Forest	0
Industrial	80
Institutional	65
Open space	0
High density residential	40
Medium density residential	20
Low density residential	10
Open water	0

The current (2005) and projected future (2030) percent imperviousness of the Flat Creek watershed were estimated using current and projected future land use data, based on a percent imperviousness associated with each land use type (Table 4-6). For each drainage basin defined in ArcHydro, the percent imperviousness was calculated based on a sum of the impervious cover, weighted by the acreage of each land type in the drainage area. This value provides a meaningful model output and was also used in the development of the additional model outputs, being a key factor in comparing existing conditions to future without project conditions.

Erosivity

In the watershed model, stream discharge was represented by erosivity. In the Flat Creek watershed, hydrologic channel impacts including a limited connection to the floodplain and more intense peak instream flow velocities have resulted in decreased habitat use for native, sensitive fish and benthic macroinvertebrate species. Erosivity was based on imperviousness of the drainage area and modified by stormwater detention structure efficiencies in the drainage area, both of which impact the velocity at which stormwater can enter a streams and erode streambanks. As runoff over impervious surfaces increases, the value of erosivity increases. Higher erosivity values were correlated with a higher degree of adverse impacts to aquatic ecosystems, as increased discharge rates can displace native aquatic organisms that are sensitive to changes in the natural environment and can lead to the embeddedness of substrates that are used as spawning and refuge habitats.

Erosivity is a nonlinear form of the urban to rural runoff ratio (Q_{URB}/Q_{RUR}) and was calculated as: $(Q_{URB}/Q_{RUR})^{1.5}$. An erosivity value of 1 characterizes a watershed having limited to no impact from urbanization, and this ratio increases as the percent of imperviousness in a drainage area increases. Erosivity values range from almost 0 (e.g., in a location immediately downstream from a stormwater control) to above 3 (e.g., in a highly urbanized watershed). In watersheds such as Flat Creek, erosivity values range from roughly 1.2 in the lower portion of the watershed to 3.8, in the highly urbanized headwaters.

To quantify the urban and rural runoff rates for erosivity, peak discharges were calculated using regional regression equations developed by the U.S. Geological Survey (USGS) for 2-year, 24-hour precipitation events (USGS, 1999). For rural areas, the following equation was used: $Q_{RUR} = 207A^{0.654}$, where Q_{RUR} is the rural 2-year peak discharge (ft^3/second), and A is the drainage area in mi^2. For urban areas the following equation was used: $Q_{URB} = 167A^{0.73}TIA^{0.31}$, where Q_{URB} is the urban 2-year peak discharge (ft^3/second), A is the drainage area (mi^2), and TIA is the total impervious drainage area in mi^2.

In drainage areas with stormwater detention structures, the erosivity value was modified to account for peak flow attenuation that the stormwater detention structure was estimated to provide.

The modified erosivity was calculated using the stormwater detention structure efficiency (Eff_Q) as:

$$\left(\text{Mod}\,\frac{Q_{URB}}{Q_{RUR}}\right)^{1.5} = \left(1+\left[\frac{100-Eff_Q}{100}\right]\times\left[\frac{Q_{URB}}{Q_{RUR}}-1\right]\right)^{1.5}$$

TSS Yield

Estimations of TSS yields to Flat Creek can project the degree of adverse impacts to aquatic ecosystems resulting from sediment deposition and habitat embeddedness. TSS can be introduced to a stream from the surrounding watershed or from the streambank itself. Levels from the surrounding watershed can increase due to natural sources (e.g., silt captured in runoff), and anthropogenic sources including construction sites and urban and agricultural land uses. Levels of TSS resulting from streambanks increase as banks continue to erode and allow stormwater runoff to carry bank sediment into the stream. In the Flat Creek watershed, a high degree of instream sedimentation and substrate embeddedness have reduced the availability and quality of instream habitat and created an unstable environment for aquatic organisms.

Overall TSS yield was comprised of sediment from both instream and upland sources. Instream TSS yield was a measure of the sediment being added to a stream from the stream channel itself and was related to the degree of bank erosion and to the streamflow erosivity. Upland TSS was a measure of sediment from the drainage area outside the stream channel. TSS yield was calculated using the following equations:

- TSS Yield (lb/acre/yr)
  $$= \frac{\text{Instream TSS Production (lb/yr)} + \text{Upland TSS Production (lb/yr)}}{\text{Drainage Area (acres)}}$$

- Instream TSS Production (lb/yr) = (Bank Erosion) × (Bank Height) × (Bank Length), where bank height and length were approximated using data collected during the stream assessment, at approximately 300-foot intervals
- Bank Erosion ($lb/ft^2/yr$) = (Erodibility) × (Erosivity) × (Base Erosion Rate)
- Upland TSS Production (lb/yr) = (Impervious acres × 400 lb/acre/yr) + (Disturbed pervious acres × 65 lb/acre/yr) + (Undisturbed pervious acres × 35 lb/acre/yr)

Table 4-7 summarizes the estimated TSS production for each land use type included in the watershed model. These values were based on the upland TSS production formula described previously in Section 4.4.2 (Model Inputs) and based on the Hall County/City of Gainesville Stormwater Quality Performance Review.

TABLE4-7
Estimated TSS Production by Land Use Type
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Land Use Type	Estimated TSS Production (lb/acre)
Industrial	249
Transportation	216
Commercial	233
High density residential	133
Medium density residential	114
High density residential	96
Agricultural	99
Parks	64
Forest	47
Open water	0

Source: Brown and Caldwell, 2008

4.4.4 Scoring Criteria for ERM Stations

Scoring criteria were developed for the Flat Creek watershed for eight environmental condition factors, including total suspended solids (TSS), erosivity, percent imperviousness, erodibility, riparian zone, frequency of riffles, embeddedness, and water quality. Existing environmental conditions were quantified to characterize existing conditions for the watershed, and future environmental conditions were estimated using projected future land use data for 2030 and the TSS model. For existing conditions and future conditions, each environmental condition category was assigned a score between 1 and 4 according to the ranges outlined in Table 4-8. Higher scores corresponded to more optimal environmental conditions. A description of each environmental condition factor was provided below. It should be noted that the scoring criteria for certain environmental condition factors were developed specific to the Flat Creek watershed and appropriate changes should be made for alternative watershed studies.

TABLE 4-8
Condition Category Scoring Criteria
Flat Creek Watershed Detailed Project Report – Environmental Appendix

	Environmental Condition Factor Score			
	1	2	3	4
Condition Category Based on Watershed Modeling				
Percent Imperviousness	>40	40 to 35	34 to 30	<30
Erosivity	>3.25	3.25 to 2.75	2.74 to 2.25	<2.25
TSS yield (lb/yr/ft)	>166	166 to 133	132 to 100	<100
Condition Category Based on Stream Assessments				
Erodibility (percent)	>60	60 to 30	29 to 5	<5
Riparian Zone	Poor	Marginal	Suboptimal	Optimal
Frequency of Riffles	Poor	Marginal	Suboptimal	Optimal
Embeddedness	Poor	Marginal	Suboptimal	Optimal
Water Quality[a]	--	--	--	--

[a] One point was subtracted from a station's cumulative score if water quality concerns were present

Percent Imperviousness

Based on a relative scale that was customized for the Flat Creek watershed, it was determined that a percent imperviousness greater than 40 represented the worst conditions in the Flat Creek watershed and that a percent imperviousness less than 30 represented the best conditions. These observations formed the basis of the scoring criteria for this environmental condition factor presented in Table 4-8.

Erosivity

The erosivity output provides a method to evaluate stream flow. Small changes in erosivity values can represent significant changes in the urban to rural runoff rate. Based on a relative scale that was customized for the Flat Creek watershed, it was determined that erosivity less than 2.25 represents the least urbanized areas of the watershed, and erosivity greater than 3.25 percent represents the most urbanized.

Total Suspended Solids (TSS) Yield

When TSS yield was analyzed across the watershed, as part of the future without project analysis, TSS greater than 166 pounds per year per linear foot (lb/yr/ft) was found in the most affected areas of the watershed, and levels less than 100 lb/yr/ft were seen in the least affected areas. Score rankings shown in Table 4-8 were based on these observations, and existing and future conditions at each station were scored accordingly.

Erodibility

From stream assessment data, average erodibility was determined for each station included in the ERM modeling process (Table 4-8). The scoring criteria for erodibility were based on GADNR guidance for physical habitat assessments (GADNR, 2007), and predicted future scores for each station were based on watershed modeling results for future erosivity and TSS production. GADNR qualifies bank erosion by the percent of eroded surface, and scores were based on these categories:

- “Poor” (> 60 percent) = 1
- “Marginal” (30 to 60 percent) = 2
- “Suboptimal” (5 to 30 percent) = 3
- “Optimal” (< 5 percent) = 4

Riparian Zone. The riparian zone consists of the area from the top of the stream bank to the edge of the floodplain. A vegetated riparian area can serve as a buffer to nonpoint source pollution, can control erosion, and can indirectly affect the type of habitat and food resources which will be available to aquatic organisms. Fish communities are sensitive to riparian zone disruption and associated flow modification. In addition, disruptions in vegetated buffer zones allow sediment to pass into the stream, potentially covering stream substrates and reducing aquatic habitat diversity. During biological monitoring in 2007, the condition of the riparian zone at each Flat Creek station was rated using GADNR guidance for physical habitat assessment. As described previously, the environmental condition category was scored based on the qualitative ranking from the physical habitat score. Future scores were predicted based on the potential for decline and the estimated amount of development expected from land use changes.

Frequency of Riffles. Riffles are a source of high-quality habitat for a variety of native aquatic species. A loss of riffles causes a decline in certain species of macroinvertebrates and fish that prefer riffle habitat and, therefore, reduces the diversity of the aquatic community. A low frequency of riffles also suggests that suitable riffle substrate has become embedded by sedimentation and that important sources of in-stream cover are generally lacking. Existing condition scores were based on physical habitat assessment results, and future scores were predicted based on TSS model results for future erosivity and TSS production, as sedimentation can cause a decrease in suitable riffle substrate.

Embeddedness. Embeddedness is the degree to which rocky substrates are surrounded by fine sediment. Stream reaches in which fine sediment and silt embed a majority of the living spaces between gravel, cobbles, and boulders do not support robust aquatic communities. Many benthic organisms depend on the interstitial areas between rocks for habitat and breeding, and many fish rely on clean rocky substrates for cover, spawning habitat, and invertebrate food sources. When substrates are unavailable for refuge, feeding, spawning and nursery function, the diversity of aquatic organisms diminishes. Existing embeddedness scores were based on physical habitat assessment results, and future scores were predicted based on TSS model results for future erosivity and TSS production.

Water Quality. Water quality data can provide a direct measure of the long-term health of an aquatic community. The interagency team involved in developing the ERM chose to base ecosystem health on biological monitoring data, which can provide long term insight into watershed conditions, since long-term water quality data was not generally available in areas for which watershed improvement projects were being developed. However, since historical monitoring data were available for Flat Creek, this environmental condition category was included to account for any water quality concerns that may impact biotic integrity (Table 4-8). One point was subtracted from a station’s cumulative score if water quality concerns were apparent based on historical information and long-term water quality data.

4.4.5 Results

Model output results, as well as data collected during the stream assessment were scored based on criteria developed for the Flat Creek watershed project to quantify existing conditions (Table 4-9). Condition categories were assigned a score at each ERM sampling station, according to the ranges outlined in Table 4-8. For existing conditions, these scores were based on watershed modeling and on data collected from stream assessments, physical habitat assessments, long-term water quality monitoring, and current land use maps. For future conditions, these scores were based on the results of watershed modeling and on best professional judgment.

Table 4-9 summarizes the condition category scores for existing and future without project conditions for each ERM sampling station based on the watershed model results. These scores were used to evaluate the projected change in environmental conditions if no restoration alternatives were implemented. A summary of the model results comparison is provided below, for each condition category. The existing and future scores for each station, as well as the projected extent of change assuming no projects were implemented, are presented in Table 4-9. The total changes in score for each station provides a relative degree of decline expected and were used as a determining factor in the prediction of future biological scores. In addition, the total existing score and total future score for each station provide an overall comparison of the current conditions of certain stations to the future conditions of other stations.

Percent Imperviousness

Current land use (2005) and projected future land use (2030) data provided by the City of Gainesville were analyzed to determine the percent imperviousness of each station's drainage area. The greatest percent imperviousness, hence the largest amount of development, was found in the drainage area of the upper Flat Creek stations (Table 4-9). However, as suggested in the TSS production results, these stations were expected to see the least amount of change under future conditions. Future scores, based on watershed model results, indicate a high percent of imperviousness throughout the entire watershed, which was expected to significantly impact the integrity of habitat in Flat Creek.

Erosivity

Erosivity results for Flat Creek were comparable to results from the percent imperviousness analysis, with the upstream stations having the worst conditions but expected to decline the least (Table 4-9). While erosivity at the most downstream station was expected to increase by 14 percent, erosivity at the most upstream station was only expected to increase by 3 percent, based on the watershed model results (Table 4-9). This environmental condition category accounts for surrounding land use and for stormwater detention structures in place to mitigate the impacts of development. As the upstream stations were already nearing complete development, the degree of erosivity was not expected to increase as much. However, erosivity at the downstream stations, which were currently less developed, was expected to increase, leading to an increase in nonpoint source runoff into Flat Creek.

Total Suspended Solid (TSS) Yield

Existing and future TSS yield at each Flat Creek station was calculated using the watershed model developed for the ERM. The largest amount of existing TSS yield, indicated by the model, was at station FLG-4 at Hilton Dr (Table 4-9). This may be attributed to bank erosion upstream of this station, surrounding land use, and/or lack of sufficient stormwater detention structures. The station with the lowest amount of existing TSS production was FLG-5, the station in close proximity to Lake Lanier (Table 4-9). This was most likely due to the relatively low development near this station. The expected percent increase in TSS production at each of the two downstream Flat Creek stations was higher than those at the upstream stations. This was most likely due to the fact that the drainage areas for the upstream stations were closer to being “built-out,” or fully developed.

Erodibility

Existing erodibility was determined based on stream assessment data collected in 2007. The average results varied between 35 and 43 percent eroded, resulting in comparable environmental condition scores for each station (Table 4-9). Erodibility was predicted to increase in the future with no project implemented, based on the expected increase in TSS production and percent imperviousness. Therefore, it was assumed that each station would decline by a score of one for this environmental condition category in the future (Table 4-9).

Riparian Zone

The riparian zone at each station was scored based on the physical habitat assessment conducted during the 2007 biological monitoring. Station FLG-A received the lowest score for this environmental condition factor, since both of its riparian buffers have been severely impacted by anthropogenic sources (Table 4-9). Stations FLG-4 and FLG-B each have a right-of-way near the stream bank on one side of the channel, and thus scored a 3 for this category. Station FLG-5 has minimally impacted and well-vegetated riparian buffers on both sides of the channel, and thus scored high for this category. It was assumed that currently intact riparian zones could slightly decline in the future, based on the expectation that development would continue to occur throughout the watershed. Therefore, each station’s predicted future decline was based on the current riparian conditions.

Frequency of Riffles

The two upstream stations on Flat Creek (FLG-A and FLG-4) both scored in the “poor” category for frequency of riffles during the physical habitat assessment, most likely due to the embedded nature of stream substrate. Conditions at these stations were not expected to change, since the score was already the lowest possible. The two downstream stations (FLG-B and FLG-5), however, were covered by riffles for at least 60 percent of the reach. These conditions have the potential to decline based on the increase in TSS production projected. Therefore, future conditions were expected to decline by 1 point each at these stations (Table 4-9).

Embeddedness

Embeddedness in Flat Creek increases with increasing drainage area, with FLG-A scoring a 1, and FLG-5 scoring a 4 (Table 4-9). The degree of embeddedness was expected to decrease at each station as TSS production increases. However, the embeddedness at the most downstream station was expected to increase by a larger percent, since TSS production was expected to increase the most at this location.

Water Quality

Historical water quality data were available for stations FLG-4 and FLG-5, the two long-term water quality monitoring stations. High levels of conductivity and nitrates have historically been measured at station FLG-5, the cause of which may be discharge from the

TABLE 4-9
Condition Category Rankings for Flat Creek
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Condition Category			FLG-A (Dorsey St)	FLG-4 (Hilton Dr)	FLG-B (Old Flowery Branch)	FLG-5 (McEver Rd)
Condition Category Based on Watershed Modeling						
Percent Imperviousness	Existing	Modeled Value	43.9	43.1	37.1	33.2
		Assigned Score	1	1	2	3
	Future	Modeled Value	46.9	43.5	40.1	37.8
		Assigned Score	1	1	1	2
	Modeled Extent of Change		*Increase 3%*	*Increase <1%*	*Increase 3%*	*Increase 4.6%*
Erosivity (-) (percent)	Existing	Modeled Value	3.5	3.6	3.1	2.2
		Assigned Score	1	1	2	4
	Future	Modeled Value	3.6	3.7	3.3	2.5
		Assigned Score	1	1	1	3
	Modeled Extent of Change		*Increase 3%*	*Increase 3%*	*Increase 6%*	*Increase 14%*
TSS Yield (percent)	Existing	Modeled Value	120	209	128	92
		Assigned Score	3	1	3	4
	Future	Modeled Value	122	217	137	104
		Assigned Score	3	1	2	3
	Modeled Extent of Change		*Increase 3%*	*Increase 3%*	*Increase 6%*	*Increase 14%*
Condition Category Based on Stream Assessment						
Erodibility (percent)	Existing	Observed Value	35	43	42	43
		Assigned Score	2	2	2	2
	Future	Projected Value	53	65	63	65
		Assigned Score	2	1	1	1
	Predicted Extent of Change		*Increase 2%*	*Increase 4%*	*Increase 7%*	*Increase 13%*
Riparian Buffer Zone Width	Existing	Observed Value	Poor	Suboptimal	Suboptimal	Optimal
		Assigned Score	1	3	3	4
	Future	Predicted Value	Poor	Marginal	Marginal	Marginal
		Assigned Score	1	2	2	2

TABLE 4-9
Condition Category Rankings for Flat Creek
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Condition Category			FLG-A (Dorsey St)	FLG-4 (Hilton Dr)	FLG-B (Old Flowery Branch)	FLG-5 (McEver Rd)
	Predicted Extent of Change		*Both sides substantially impacted by human sources; no potential for further degradation*	*LB minimally impacted; RB small riparian; potential for some decline*	*LB minimally impacted; RB small riparian; potential for some decline*	*Minimally impacted; expected to be affected by future development*
Frequency of Riffles	Existing	Observed Value	Poor	Poor	Suboptimal	Optimal
		Assigned Score	1	1	3	4
	Future	Predicted Value	Poor	Poor	Marginal	Suboptimal
		Assigned Score	1	1	2	3
	Predicted Extent of Change		*<25% covered by riffles; no potential for further decline*	*<25% covered by riffles; no potential for further decline*	*60-75% covered by riffles; may be affected by increased TSS production*	*>75% covered by riffles; may be affected by increased TSS production*
Embeddedness	Existing	Observed Value	Poor	Marginal	Suboptimal	Optimal
		Assigned Score	1	2	3	4
	Future	Predicted Value	Poor	Poor	Poor	Marginal
		Assigned Score	1	1	1	2
	Predicted Extent of Change		*>75% embedded; no potential for further degradation*	*50-75% embedded; potential impact from future TSS increase*	*25-40% embedded; possible substantial increase from TSS production*	*<25% embedded; possible increase from TSS production*
Water Quality	Existing	Observed Value	No concerns	No concerns	No concerns	Water quality concerns
		Assigned Score	0	0	0	-1
	Future	Projected Value	No concerns	No concerns	Water quality concerns	Water quality concerns
		Assigned Score	0	0	-1	-1
	Predicted Extent of Change		*No concerns from current data or expected future conditions*	*No concerns from current data or expected future conditions*	*Not currently monitored; expected impacts from Flat Creek WRF*	*Relatively high nitrate and conductivity levels; low DO levels; expected to continue to impact stream health*
Total Score	**Existing**		10	11	18	24
	Future		10	8	9	15
	Future - Existing		0	-3	-9	-9

Flat Creek WRF. This station received a score of -1 for this environmental condition category, as these water quality issues may impact biotic integrity. In addition, it was assumed that water quality conditions at station FLG-B, also downstream of the WRF, may also be affected in a similar manner. Because historical water quality data were not available for this station, the existing conditions were not scored a -1. However, the station received a score of -1 for predicted future conditions.

4.5 Future Score Prediction

Based on analysis of existing and projected future environmental conditions and on an evaluation of individual metrics for each biological monitoring component, future fish IBI, BMI, and physical habitat assessment scores were predicted for the Flat Creek stations.

4.5.1 Future Fish IBI Scores

The predicted future fish IBI scores for Flat Creek stations, as well as the existing scores, for comparison, are provided in Table 4-10 below. Conditions at FLG-A were expected to change the least among the stations (Table 4-9), and therefore the predicted score was chosen from the higher end of the ranges developed in Table 4-1. Because conditions at FLG-4 were not expected to improve, the predicted score was expected to stay the same, rather than to increase. Station FLG-B was predicted to undergo a relatively high degree of degradation, with future environmental conditions comparable to existing environmental conditions at FLG-A. Therefore, the score chosen reflects the existing score at FLG-A if no external anomalies were encountered (adds 4 points to the overall score), which was expected under normal conditions relative to the 2007 drought. Lastly, the score chosen for station FLG-5 was in the lower end of the range, since conditions here were expected to degrade by the highest percentage.

TABLE 4-10
Existing (2007) and Predicted Future (2030) Without Project Fish IBI Scores
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Sampling Station	FLG-A	FLG-4	FLG-B	FLG-5
Existing Score	14	10	26	16
Predicted Future without Project Score	12	10	18	12

4.5.2 Future BMI Scores

The predicted future benthic macroinvertebrate scores for Flat Creek stations, as well as the existing scores for comparison, are provided in Table 4-11 below. According the existing conditions analysis, the selected score for each station corresponds to the relative amount of degradation expected at the station (Table 4-9), i.e., the score for FLG-A was selected closer to the minimum amount of change expected, and the score for FLG-5 was selected closer to the maximum amount of change expected. Likewise, the scores for FLG-4 and FLG-B were chosen in the higher and middle, respectively, of the predicted score range from Table 4-2.

TABLE 4-11
Existing (2007) and Predicted Future (2030) Without Project BMI Scores
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Sampling Station	FLG-A	FLG-4	FLG-B	FLG-5
Existing Score	17	36	40	37
Predicted Future without Project Score	16	22	25	30

4.5.3 Future Physical Habitat Scores

The predicted future physical habitat scores for Flat Creek stations, as well as the existing scores for comparison, are provided in Table 4-12. The existing habitat score at FLG-A was the lowest of the Flat Creek stations; however, since environmental conditions there were expected to change minimally (Table 4-9), the predicted score with the least amount of change was selected from Table 4-3. Because of the subjective nature of the physical habitat assessment, scores for the remaining three stations were selected from the middle of the predicted score range in Table 4-3. This provides a conservative future score prediction for physical habitat in Flat Creek.

TABLE 4-12
Existing (2007) and Predicted Future (2030) Without Project Physical Habitat Scores
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Sampling Station	FLG-A	FLG-4	FLG-B	FLG-5
Existing Score	81	98	129.5	153
Predicted Future without Project Score	73	73	90	114

4.5.4 Future Conditions ERM Outputs

For future conditions analysis, inputs to the ERM include predicted IBI, BMI, and physical habitat scores at various locations in the stream reach being analyzed. The ERM then outputs future IBI, BMI, and physical habitat scores that were representative of the entire stream reach. To calculate these outputs, predicted future biological scores were averaged and represented as a fraction of the total possible score. Using these outputs, the ERM also outputs a predicted future combined stream health score. Development of outputs is presented below.

Future IBI Score

The future Flat Creek fish IBI output was determined by calculating the average predicted score of all Flat Creek stations (Table 4-10) and then expressing this score as a ratio of the total possible score:

- IBI score = $\frac{12+10+18+12}{4} = 13 \Rightarrow \frac{13}{60} = 0.22 \Rightarrow 0.22 * 100 = 22$

Future BMI Score

The future Flat Creek BMI output was determined by calculating the average predicted score of all Flat Creek stations (Table 4-11) and then expressing this score as a ratio of the total possible score:

- BMI Score = $\frac{16+22+25+30}{4}=23.3 \Rightarrow \frac{23.3}{100}=0.23 \Rightarrow 0.23*100=23$

Future Physical Habitat Score

The future Flat Creek physical habitat output was determined by calculating the average predicted score of all Flat Creek stations (Table 4-12) and then expressing this score as a ratio of the total possible score:

- Physical Habitat Score = $\frac{73+73+90+114}{4}=87.5 \Rightarrow \frac{87.5}{200}=0.44 \Rightarrow 0.44*100=44$

Future Combined Stream Health Score

The future combined stream health score from the ERM was a weighted average of the predicted future representative IBI, BMI, and physical habitat scores, shown below. The predicted future combined stream health score for Flat Creek was 27 out of 100 possible points, 9 points lower than the existing conditions combined stream health score. These numbers will be compared to predicted future with project conditions, for various alternatives, but initial analysis demonstrates the degradation which was expected in Flat Creek.

- Combined Stream Health Score = $(0.40*22)+(0.40*23)+(0.20*44)=26.7$
- Habitat Units = Combined Stream Health Score * Stream Miles = 26.7 * 6 = 160

4.6 Future without Project Conditions Summary

By analyzing environmental condition factors and current biological monitoring data, a prediction was made of future biological scores at four sampling locations in Flat Creek, assuming no stream restoration projects were implemented. The ERM provides a method for using the predicted scores to indicate the degree of overall degradation expected in a watershed. Using the ERM, existing and future Flat Creek combined stream health scores were calculated. The existing score for Flat Creek was 36, and the predicted future score was 27, of a possible 100 points, indicating a decline in stream health of 9 percent if no ecosystem restoration alternatives were implemented. Table 4-13 summarizes the change in score expected at each station and the average score for all Flat Creek stations expressed as a ratio of the total possible score. Initial analysis demonstrates the need for stream restoration measures in Flat Creek, as current conditions were severely degraded and were expected to decline further. The two upstream stations were currently the most severely impacted in the stream, although predicted degradation at the downstream stations was expected to contribute to a larger percentage in the decline of the combined stream health score.

TABLE 4-13
Flat Creek Existing and Predicted Future Without Project Biological Scores
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Location	**FLG-A**	**FLG-4**	**FLG-B**	**FLG-5**	**Flat Creek Watershed**
Existing IBI	14	10	26	16	28
Future IBI	12	10	18	12	22
Existing BMI	17	36	40	37	33
Future BMI	16	22	25	30	23
Existing Habitat	81	98	129.5	153	58
Future Habitat	73	73	90	114	44
Existing Combined Stream Health	--	--	--	--	35.6
Future Combined Stream Health	--	--	--	--	26.7
Existing Habitat Units	--	--	--	--	213
Future Habitat Units	--	--	--	--	160

5. Formulating Alternative Plans

Plan formulation is the process of developing an array of plans that meet the planning objectives and avoid planning constraints. Plan formulation should involve input from agencies, stakeholders, citizens, the USACE, and the nonfederal sponsor. Alternative plans were comprised of structural and nonstructural components, called restoration measures, and are developed to the extent that they could be realistically evaluated and compared in terms of meeting planning objectives (Planning Manual, 1996). Alternative plans were formulated to meet the planning objectives and avoid planning constraints specified in Section 2 of the Detailed Project Report (Identifying Problems and Opportunities). The formulation of alternative plans involved: (1) identifying restoration measures that could meet the planning objectives and avoid planning constraints; (2) identifying problem sites in the watershed that would benefit from restoration; and (3) formulating alternatives using the restoration measures to address problem sites. Using these steps, 73 single-site restoration alternatives for the Flat Creek watershed were identified. Section 5 of the Detailed Project Report (Evaluating Alternative Plans) evaluates combinations of these alternatives, and the No Action Alternative.

5.1 Identification of Restoration Measures

Before formulating alternative plans, a full array of restoration measures was identified to facilitate a sustainable and holistic approach to addressing watershed problems. Thirty-nine potential restoration measures were identified to address problems in freshwater, riverine ecosystems and to formulate alternatives (Table 5-1). These measures established a list of options that could be included in ecosystem restoration alternatives, and include both structural and nonstructural elements as defined below The measures were divided into 3 structural categories (instream, streambanks, riparian, and flow attenuation) and 1 nonstructural category, as shown in Table 5-1 and described in subsequent sections.

- Structural restoration measures required onsite construction, and may involve installation of features within the streambed (instream), along the streambanks, or within the stream riparian ecosystem. Riparian ecosystem measures may involve vegetative restoration or flow attenuation features designed to reduce peak stormwater discharges to the stream. Each potential structural measure considered for the watershed is described in detail below.
- Nonstructural measures included activities, programs, ordinances, or policies aimed at protecting watersheds and streams from activities that may cause adverse impacts. These measures did not involve construction-related activities, but rather established programs or policies that promote protection and preservation of the physical stream conditions and overall ecosystem integrity. Nonstructural measures may involve removal of litter and invasive plant species, public education programs, and scheduled stream inspections or monitoring programs.

Table 5-1 summarizes structural and nonstructural restoration measures considered in the alternative formulation process. The 39 potential restoration measures are detailed below.

TABLE 5-1
Potential Restoration Measures for Alternative Plans
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Structural				
Instream	**Streambanks**	**Riparian**	**Flow Attenuation**	**Nonstructural**
Engineered riffle	Adjust stream meanders (add bends)	Cattle exclusion fencing [a]	Extended wet detention basin	Adoption of protective stormwater ordinances [a]
J-hook	Create bankfull bench	Invasive plant species removal	Extended dry detention basin	Enforcement of protective ordinances [a]
Cross vane	Bank grading	Riparian planting (native hardwoods)	Outlet control structure	Litter cleanup in stream corridors [a]
Debris jam removal	Bank stabilization matting	Riparian planting (seeding and mulching)	Outlet control structure retrofit	Public educational components: interpretive signage, trails, boardwalks, benches [a]
Culvert replacement	Streambank planting		Detention basin expansion	Ongoing invasive plant species removal [a]
Stone toe protection	Riprap		Created wetlands	Post-construction stormwater management [a]
Boulders	Rootwad		Aquatic vegetation planting	Construction site inspection program [a]
Pool/Step pool			Micropool	Preservation of greenspace [a]
Log sill			Sediment forebay	Long-term stream monitoring [a]
			Pilot channel	

[a] Note that all applicable measures were considered, including these that are being implemented by the City of Gainesville as part of ongoing watershed management efforts that were separate from this project (Section 2.1.2).

5.1.1 Structural Restoration Measures

Instream Measures

Instream restoration measures would be installed along the streambed (below bankfull elevation) to adjust or stabilize the stream profile, provide improved habitat conditions, or establish flow regimes to better support aquatic ecosystem communities. These measures included various structures that provide refuge and spawning habitats for aquatic species. The placement of instream restoration measures, especially in areas with a homogeneous habitat structure, would provide a greater habitat diversity, which, in turn, promotes ecosystem resiliency and species diversity. Instream restoration measures implemented within or upstream of an area of concern would provide benefits at the associated area of concern.

Engineered Riffles

Riffles are important stream features for several reasons. They provide streambed stability, provide suitable habitat for aquatic and macroinvertebrate communities, and provide grade control for creating or maintaining a stable channel gradient. Considering riffles as an instream restoration measure, there are several varieties of riffle types to choose from. Low-gradient linear riffles are suitable to maintain a gentle stream profile, while also establishing habitat enhancement. For steeper stream reaches, Newberry riffles or rock ramps are better suited. These structures can effectively provide grade control within moderate to steep gradient streams, while also providing adequate fish passage and habitat features. In the Flat Creek watershed, the stream channel has been degraded due to sedimentation, resulting in decreased frequency and diversity of riffles. As a result, engineered riffles were a valid restoration measure in the Flat Creek watershed.

J-hooks

J-hooks are named for their J-shape and typically consist of stone or logs. They are usually placed along channel meanders (up to the bankfull elevation), and are intended to keep erosive flows away from streambanks. Together with cross vanes, J-hooks can be used to establish channel grade control and to help form riffle/pool sequences that promote instream habitats critical for maintaining species diversity. Aquatic habitat diversity provided by riffle/pool sequences was scarce and peak instream flow velocities have increased in the Flat Creek watershed. J-hooks were a valid restoration measure in this watershed to carry forward in the planning process.

Cross Vanes

Similar to J-hooks, cross vanes typically consist of stone or logs. They are U-shaped structures that can be placed in the channel (up to the bankfull elevation) to keep erosive flows off stream banks, establish grade control, and form riffle/pool sequences. Cross vanes typically are placed along straight channel reaches and can be used to effectively create and maintain a stable channel gradient. By helping to form riffle/pool sequences, this measure creates a diversity of instream habitats critical for maintaining species diversity and to create and maintain a stable channel gradient. While cross vanes would serve the same purpose as engineered riffles and log sills, each of these measures were selected for further evaluation since the stream type, hydrology, soils, and surrounding land use may dictate which measure would be more effective in a single location.

Debris Jam Removal

Streams with altered hydrology and having altered sediment transport regimes often experience excessive erosion and carry large material or debris downstream. Debris jams are created when fallen trees and other debris accumulate and obstruct flow. This situation adversely affects natural channel conditions, not only resulting in local degradation of habitat conditions, but also causing sedimentation/embeddedness of the upstream channel, obstruction to fish passage, and downstream channel scour and erosion. Debris jam removal was a valid restoration measure and was considered where these conditions persist.

Culvert Replacement

Culverts are constructed at set elevations, but stream channels over time evolve and often change elevation, especially in degraded streams. Replacing a culvert at a different elevation can reconnect upstream and downstream stream reaches during base flow conditions, removing a fish passage barrier especially for smaller species. Culvert type and installation method are important considerations for this measure. Bottomless or buried culverts maintain connectivity of stream substrate, further improving fish mobility. During the Flat Creek stream assessments, many culvert maintenance issues were identified, including culverts needing replacement. For this reason, culvert replacement is an appropriate restoration measure to move forward in the planning process.

Stone Toe Protection

Streambank erosion often is due to excessive flow and stress at the toe of slope. Erosion and undercutting at the toe of slope can lead to sloughing of the streambanks and ultimately sedimentation of habitats. Stone toe protection measures may be installed to alleviate stresses and stabilize this critical point of the channel section. Stone toe protection techniques range from simply placing riprap along the toe of slope, to more elaborate measures such as longitudinal peaked stone toe protection. These measures include planting woody vegetation such as willows within the interstitial spaces between the stones. This reduces the introduction of sediment from eroded stream banks to stream habitat. This measure would be suitable for spot repairs of eroded stream bank or for longer reaches of eroded channel such as runs and outer bends. In the Flat Creek watershed, eroded streambanks are contributing sediment load to the channel and affecting aquatic habitats.

Boulders

Boulders may be placed within the stream channel for multiple purposes. They may serve to provide streambank stability by deflecting erosive flow, but they might also provide cover and spawning areas for fish and benthic macroinvertebrate species. Boulders typically are placed along the outer bend toe of slope for bank stability purposes, but they might also be placed along inside bends or within pools to provide habitat enhancement and cover. In the Flat Creek watershed, the diversity of aquatic habitats has been degraded by changes in hydrology. For this reason, the placement of boulders was carried forward as an appropriate restoration measure for consideration in this watershed.

Pool / Step Pool

Pools are instream features that promote diversity of flow regimes by establishing deep, slow flow conditions (suitable habitat for various aquatic species). Depending upon the depth, pools can also provide shade and cooler conditions that further support aquatic diversity. Steps pools are instream restoration measures that can be used to create or maintain stable channel profile, especially in high gradient reaches where other low-gradient grade control features (such as cross vanes or engineered riffles) may not be applicable. Step pools enhance instream habitat by providing cover and spawning areas for fish and benthic macroinvertebrate species. With degradation in the Flat Creek watershed limiting aquatic habitat and species diversity, the use of step pools as a restoration measure was valid.

Log Sill

Log sills may be used as grade control structures (in similar fashion as engineered riffles and cross vanes), but their use is more applicable to low-gradient reaches where the required vertical drop across the structure is at or below 6 inches. Similar to the other grade control structures, log sills may be used to create or maintain a stable channel profile. Instream logs also provide suitable habitat for several aquatic and macroinvertebrate species. Log sills, as well as other grade control restoration measures, were appropriate for consideration in the Flat Creek watershed to address channel stability and affected aquatic habitat.

Streambank Restoration Measures

Streambank restoration measures included features that can be constructed along the streambank (between bankfull elevation and top of bank), stabilizing the banks by placement of structural or vegetative reinforcement. Selecting the appropriate streambank restoration measure is dependent upon the severity of the erosion, flow velocities, soil types, bank height and steepness, and stream alignment (degree of meandering). The various streambank restoration measures available for consideration are described below.

Adjust Stream Meander (Add Bends)

Adding meanders to a straightened stream segment can reduce instream velocity and return the flow regime to a more natural pattern. This measure is applicable to longer reaches of straightened stream segments and is one of the more intensive restoration measures from a construction standpoint. Increasing the sinuosity of a channel improves the diversity of riffle/pool habitat for aquatic ecosystems and reduces instream channel velocities by decreasing channel slope and promoting attenuation of peak flows. Both a reduction in riffle/pool habitat and increases in instream flow velocities are present in the Flat Creek watershed. For these reasons, the adjustment of stream meanders is deemed a suitable restoration measure.

Create Bankfull Bench

Construction of channel bankfull bench (or floodplain bench) increases the capacity of a stream to carry larger flow events and reduces erosive forces that affect instream habitats. This restoration measure is suitable for incised channel reaches with little or no connection to the floodplain. Channel benching includes excavation of benches without disturbing the streambed, and results include improved streambank stability, improved sediment transport, and return of the stream hydrograph to a more natural condition. This measure promotes enhancement and maintenance of instream habitats by reducing erosive forces and sediment sources. Because the Flat Creek watershed exhibits a flashy hydrograph, an altered stream hydrology, and streambank instability, the creation of bankfull benches is a valid restoration measure for consideration within the watershed.

Bank Grading

Bank grading is an applicable restoration measures in areas experiencing bank erosion and instability. Laying back steep banks can aid in the return of streamflow patterns to a natural state and minimize impacts associated with flashy streamflow. Grading and stabilizing of eroded banks reduces instream sedimentation sources and supports the return of streamflow patterns to a more natural state. This restoration measure is being carried forward to consider in areas of the Flat Creek watershed exhibiting extensive stream bank erosion and instability, which contribute sediment loading to the stream channel and affect aquatic habitats. This restoration measure is valid in light of the flashy hydrograph of the watershed.

Bank Stabilization Matting

Bank stabilization reduces soil loss, which leads to instream sedimentation and substrate embeddedness. This measure includes implementing practices structural in nature where banks threaten private property or public infrastructure and may be employed when available space or highly erosive flows are a constraint. A common factor along most degrading streams is the erosion of streambanks especially along outer bends and the introduction of sediment to stream habitat from this erosion. This approach typically reduces the bank slope so that it is less susceptible to the erosive force of storms.

To enhance bank stabilization efforts, several types of matting or geotextile protection can be considered. Available options range for simple jute matting, to more structural geotextile/geo-grid products. Selection of the appropriate stabilization product is based upon the severity of the condition and erosive forces that are encountered. In the Flat Creek watershed, increased stream velocities have contributed to bank instability. This restoration measure, the use of bank stabilization matting, is appropriate for use in this watershed.

Streambank Planting

Vegetative planting of streambanks is important to enhance stability and to provide cover, refuge, and food supply to aquatic communities. This measure may be used in combination with bank grading or bank stabilization matting to improves the overall effectiveness of these stabilization measures. Through vegetative planting, a root matrix is established within the upper soil layer which helps bind soils and protect against soil loss/erosion. Streambank instability and lack of vegetation are identified problems in the Flat Creek watershed. The use of vegetative planting on streambanks is a valid approach to carry forward in the planning process.

Riprap

Riprap is one of the most common measures used to stabilize streambanks. This measure involves bank grading and reshaping before placing riprap boulders to stabilize the streambank. Filter fabric typically (although not always) is placed along the graded bank before placing riprap. The voids between riprap boulders sometimes are planted with woody vegetation, or sometimes grouted to prevent movement of the stones and further enhance stability. Riprap stabilization protects the banks against erosive flows and provides some refuge for aquatic communities but does not provide effective shading or food supply compared to more natural techniques that incorporate streambank vegetation. In the Flat Creek watershed, streambank instability is contributing to the degradation of aquatic habitats. For this reason, riprap is a valid restoration measure, but with limitations.

Root Wad

Root wads are a streambank protection technique that provides immediate streambank stabilization, protects the toe-of-slope, and provides excellent fish habitat, especially for juveniles. They provide toe support for bank revegetation techniques and collect sediment and debris that will enhance bank stability over time. Root wads are installed by excavating into the streambank deep enough to accommodate an 8- to 10-foot tree bole (tree tops should be removed, leaving the trunks at least 10 feet long with root fans attached). Optional header and footer logs may be installed and pinned in place using rebar to help stabilize root wads into the bank. With instream habitat degraded in the Flat Creek watershed, root wads can improve bank stability and create aquatic habitat. For these reasons, root wad is considered a valid restoration measure.

Riparian Restoration Measures

Riparian restoration measures include features that can be constructed immediately outside the channel section but within the stream's riparian ecosystem. These measures are related primarily to establishment of effective native riparian vegetation (including hardwoods, shrubs, and seeding), but also include invasive plant species removal measures.

Cattle Exclusion Fencing

Cattle use streams as a water source and for refuge during hot weather, and they often trample streambanks in the process, degrading streambank stability and establishment of natural woody vegetation. This measure removes that impact, allowing streambanks to stabilize and woody vegetation to grow. Another benefit of cattle fencing is the reduction of bacteriological loading to the stream. Many areas in North Georgia, which are or have been predominantly agricultural and undeveloped, have been affected by livestock entering the stream. The measure is applicable to the problems and opportunities identified for this feasibility study and would contribute to the federal objective of ecosystem restoration by improving and protecting instream and riparian habitat

Invasive Plant Species Removal

Wetlands and stream buffers can be enhanced with the removal of exotic and invasive plant species, and replacement with native vegetation. Removal of invasive plant species improves riparian aquatic ecosystem conditions and increases bank stability by (1) allowing native species to populate, (2) providing improved woody vegetation for bank stability, (3) establishing diversity of vegetative cover, (4) increasing available food sources for aquatic and riparian communities, and (5) providing improved stream buffer shading and refuge.

Selective removal of vegetation most often is used to control invasive plant species that dominate the stream channel and stream terraces. Mechanical removal is another method, but it is not often recommended for streambanks unless used in conjunction with grading or other stabilization methods. Methods using regulated chemicals approved for invasive plant species management, including broadcast and spot treatments, must be carefully considered when working near streams. Buffer areas disturbed during other enhancement and alteration activities associated with restoration should be replanted with native vegetation. In the Flat Creek watershed, streams would benefit from an increase in available food sources, shading, and other benefits of a native riparian area. Removal of invasive plant species would improve the riparian area, making this restoration measure appropriate to carry forward in the planning process.

Riparian Planting (Native Hardwoods)

Planting native trees or other woody vegetation in riparian zones (especially those that have been impacted or cleared) is intended to improve riparian aquatic ecosystems. The benefits of this measure include shading the stream, providing habitat and shelter with root masses and woody debris, leaf litter as a food source to organisms, and reduction of bank erosion and sediment loading to the stream. Riparian planting can be used alone in areas identified during stream walks or used following other land-disturbing measures such grading or benching streambanks. This measure may not be very effective in the short term (while woody vegetation is being established), but it is effective over the long term by adding stability and protection to a stream channel and its aquatic habitats. This measure should be considered along stream reaches affected by disturbance of the riparian corridor. Such reaches have been identified in the Flat Creek watershed. For this reason, riparian planting is considered a valid, long-term restoration measure.

Riparian Planting (Seeding and Mulching)

In addition to planting native trees and hardwoods within riparian zones, seeding and mulching are also important to provide immediate protection. Shrubs, grasses, and other plantings typically establish more quickly than the larger woody vegetation, and help establish an immediate source of cover and protection within the buffer. Riparian planting with seeding and mulching results in many of the same benefits listed above related to native hardwoods, and so is carried forward for the same reasons.

Flow Attenuation Restoration Measures

Flow attenuation restoration measures include features that can be constructed adjacent to the stream, but within the riparian ecosystem. They are intended to mitigate hydrologic impacts to the stream by attenuating peak stormwater discharges. These measures are strategically placed to capture runoff, provide stormwater storage (through pond or basin excavation), and regulate/reduce peak discharge releases to the stream. When designed properly, these measures can effectively improve both stream and riparian habitat communities in a number of ways. In accordance with the Section 206 authority, flow attenuation measures for ecosystem restoration should primarily address instream flows, as opposed to stormwater runoff. A brief description of potential flow attenuation restoration measures, with a focus on reducing instream peak flows, is provided below.

Extended Wet Detention Basin

An extended dry detention basin is an excavated surface storage facility designed to collect and temporarily store stormwater runoff, and release it at a reduced rate. An extended wet detention basin is generally deeper than either extended dry detention basins or created wetlands, and is designed to maintain a permanent pool. This measure helps restore natural flow regimes by attenuating peak flows through stormwater capture, storage, and regulated release. Similar to both extended dry detention basins and created wetlands, extended wet detention basins can help protection downstream channel integrity, stability, and habitat through peak flow attenuation. In the Flat Creek watershed, the natural flow regime has been altered and frequent, high-intensity peak flows were common. An extended wet detention basin would address this identified problem and was a valid restoration measure.

Extended Dry Detention Basin

Similar to the extended wet detention basin described above, an extended dry detention basin is an excavated surface storage facility designed to collect and temporarily store stormwater runoff, and release it at a reduced rate. An extended dry detention basin is designed to drain completely following a storm. Its primary purpose typically is flood control, but basins can effectively attenuate peak flows from any size storm and protect downstream channels and habitats. The attenuation of peak flows is necessary to restore natural flow regimes that have been modified by changes to surrounding land use. Extended dry detention basins serve a purpose similar to other flow attenuation structures (extended wet detention basins and created wetlands), but each is selected for further evaluation in the Flat Creek watershed since the hydrology, soils, and surrounding land use may dictate which measure would be more effective in a single location.

Outlet Control Structure

Outlet control structures (OCSs) are stormwater devices used to regulate flow (discharge) from a stormwater storage basin, including extended dry/wet detention basins and created wetlands. OCSs typically are concrete structures (round or rectangular riser structures having formed notches and weirs) but might include stone structures such as stone spillways. OCSs often incorporate multiple stage openings to regulate discharge for various recurring storms. These structures also often incorporate the use of trash racks, debris screens, or sediment filters to enhance operational performance. An OCS was considered a valid restoration measure to address the altered hydrology and specifically, the increases in peak events in the Flat Creek watershed.

Outlet Control Structure Retrofit

This measure includes retrofitting or modifying an OCS to adjust/enhance operational performance. Typical OCS retrofits might include reduction in weir or orifice openings, adjustments to control elevations, modifications to the OCS discharge pipe, and installation of a trash rack, debris shield, or sediment filter. Minor retrofitting of an OCS might significantly improve its performance by reducing flow released to the receiving stream. This restoration measure was appropriate for carrying forward in the planning process, as it addresses altered hydrology in the watershed, similar to installation of a new OCS.

Detention Basin Expansion

Expansion of a detention basin may also be a feasible flow attenuation measure. Basin expansion might be accomplished vertically by increasing depth, laterally by expanding the footprint, or by adjusting the side slope angle to allow for increased storage capacity. Expansion of a detention basin directly improves its efficiency through increase storage volumes and reduced discharge to the receiving stream. Reduction in peak flow releases to the stream helps to minimize hydrologic alterations within the watershed and restore natural flow regimes. In the Flat Creek watershed, altered hydrology and increased peak flows limit aquatic habitat diversity. Detention basin expansion is an appropriate restoration measure for these reasons.

Created Wetlands

The creation of riparian wetlands can attenuate peak stormwater discharges to the stream by providing capture and storage of stormwater runoff, and regulating its release back to the stream. Wetland construction within the riparian corridor helps to restore natural flow regimes by decreasing the velocity and volume of stormwater runoff and providing protection of downstream channels and habitat. Other beneficial functions of riparian wetlands include (1) providing habitat for aquatic organisms by establishment of necessary depths and vegetative cover, (2) removing pollutants through vegetative filtering, and (3) improving water quality through sediment removal (see also "sediment forebay" below). These functions provide associated benefits to aquatic ecosystems. Created wetlands are carried forward in the planning process to address altered instream hydrology for the same reasons as detention ponds and OCS and their retrofits.

Aquatic Vegetation Planting

Aquatic vegetation planted within wetland areas or extended wet detention basins help to stabilize these features and minimize impacts related to peak flows, such as the potential for channelization. Establishing aquatic vegetation will also reduce the potential for erosion and sedimentation throughout the facility. As an associated benefit, aquatic vegetation provides both a food source and habitat for riparian organisms that inhabit the riparian wetland or extended wet detention basin. Vegetation also promotes nutrient uptake and overall water quality improvement. All these functions benefit the receiving stream in term of water quality improvement. In conjunction with flow attenuation measures, aquatic vegetation planting is an appropriate measure to carry forward to address the altered hydrology in the Flat Creek watershed.

Micropool

A micropool is a measure that can be incorporated into the design of a created wetland or an extended wet or dry detention basin. The micropool typically is shallow and permanently inundated. Its function is to reduce resuspension of sediment and to guard against vegetation encroachments toward the OCS. The micropool can be planted with wetland vegetation, but it should be deep enough at the OCS pipe to discourage vegetative encroachments that could cause clogging. In the Flat Creek watershed, altered hydrology and peak volumes are identified problems. A micropool used in conjunction with other flow attenuation devices is a valid restoration measure.

Sediment Forebay

The sediment forebay is a measure associated with created wetland and extended wet or dry detention basins. When used, this measure can enhance sediment reduction by trapping larger particles near the inlet of the pond. If possible, the forebay should include a permanent pool to minimize the potential for scour and resuspension of sediment. Sediment forebays should be designed with ease of maintenance, facilitating periodic scheduled sediment removal. A sediment forebay, in conjunction with a flow attenuation device, is a feasible restoration measure for the same reasons given for other detention enhancements.

Pilot Channel

A pilot channel is a surface conveyance used within created wetlands and extended wet or dry detention basins to convey low flows through those facilities. Because flows are concentrated under low-flow conditions, flow traveling through such facilities can be erosive and cause erosion and sedimentation within the basin. By concentrating low flows through a pilot channel, the channel can be designed and stabilized to withstand the flow with causing adverse erosion and sedimentation. A pilot channel is a valid restoration measure, when used to enhance the functionality of other flow attenuation measures, for consideration in the Flat Creek watershed. The watershed exhibits altered hydrology and increases in peak volumes.

5.1.2 Nonstructural Restoration Measures

Nonstructural restoration measures include activities, programs, ordinances, or policies aimed at protecting streams and riparian ecosystems from activities that might cause adverse impacts. These measures do not involve construction-related activities, but rather establish programs or policies that promote protection and preservation of the physical stream conditions and overall ecosystem integrity. Each nonstructural measures identified would promote the sustainability of ecosystem restoration in the Flat Creek watershed; however the City of Gainesville would implement all the measures as part of its ongoing watershed management program (Section 2.1.2, Ongoing Local Programs). Note that the City of Gainesville and Hall County have all these measures in place, except for public educational components associated with a restoration implementation and invasive plant species removal.

Adoption of Protective Stormwater Ordinances

Adoption of stormwater ordinances, such as those developed by the Metropolitan North Georgia Water Planning District, promotes stream restoration through establishment of stormwater management regulations. Adoption, implementation, and enforcement responsibilities fall onto municipalities and local jurisdictions. Federal- and state-mandated programs, such as NPDES permitting, now apply to construction activities as well as communities that fall under Phase 1 and Phase 2 regulations. Such programs are effective in terms of establishing standards for land use and development, as well as establishing programs to monitor streams and stormwater discharges. Municipalities can also adopt development standards related to stormwater management, such as those provided in the *Georgia Stormwater Management Manual*.

Enforcement of Protective Ordinances

Protective ordinances may be related to stream buffer protection, greenway preservation, development standards, construction standards, and other activities. Ongoing enforcement of these ordinances can ultimately protect streams, stream buffers, and the benefits they provide to aquatic ecosystems. Enforcement of protective ordinances and public education concerning the benefits of stream buffers work together to preserve continuous reaches of stream buffers, which are critical to stream stability and the avoidance of degradation from impacts related to development. Enforcement is the responsibility of local governments, which must plan and dedicate resources for this effort to be effective.

Litter Cleanup in Stream Corridors

Another nonstructural measure that can be used to promote environmental awareness, ecosystem protection, and stream restoration are scheduled stream walks and cleanup activities. These programs would be sponsored by municipalities or various civic organizations, and are usually focused on a specific segment of stream known to be affected by excessive litter and debris. Such events require planning and promotion, but if well-organized can very effectively improve affected streams.

Public Educational Components: Interpretive Signage, Trails, Boardwalks, Benches

Public educational components can be implemented with other structural restoration measures to convey and demonstrate environmental stewardship principals related to stormwater management and protection of streams and rivers. Interpretive signage, mulch trails, boardwalks, or benches may be incorporated, where appropriate, into a restoration design. Educational programs can target a variety of citizen groups (including schools and civic organizations) and may use a vast array of resources to deliver pertinent information. Available sources that can be used to disseminate of information include newspapers and publications, media broadcasts, mailing of brochures, and various other sources.

Ongoing Invasive Plant Species Removal

Some municipalities have implemented removal programs to control the propagation of invasive plant species present within stream corridors. This nonstructural measure requires either dedication of in-house resources or an annual contract/budget to programmatically target and remove invasive plant species on a regular schedule.

Post-construction Stormwater Management

Post-construction stormwater management includes implementation of a program to review design plans and inspect completed construction sites and developments to observe functionality of the constructed stormwater management facilities. This activity would help identify any necessary modifications to the operation or maintenance of features, such as outlet structures, detention ponds, and other stormwater infrastructure. This nonstructural measure may serve as an early warning/preventative maintenance system to identify and address potential adverse conditions before they develop further or worsen.

Construction Site Inspection Program

Stormwater runoff from improperly managed and controlled construction sites can be detrimental to the overall health of the receiving streams. Insufficient sediment and erosion control measures at construction sites can result in high concentrations of TSS in stormwater runoff and downstream sedimentation. A construction site inspection program, in conjunction with erosion and sedimentation control ordinances, can be an effective nonstructural measure to prevent such occurrences.

Preservation of Greenspace

In addition to enforcement of stream buffers, designating and preserving greenway corridors can further protect streams by extending setbacks and limiting disturbance within an established distance from the stream. Preservation of greenspace further protects the stream corridor from impacts related to clearing, encroachments, or unauthorized activities.

Long-Term Stream Monitoring

Monitoring programs can help to identify conditions that may be adversely affecting streams, or have potential to cause adverse impacts. Identification of debris jams, severe bank erosion or worsening conditions, changes in stream alignment and stability, unauthorized clearing or encroachments, and other developing situations might be detected through scheduled monitoring. In this way, monitoring can be a means of early detection of developing problems, which might be quickly addressed or prevented before conditions worsen.

5.2 Evaluation and Screening of Restoration Measures

The restoration measures identified in Table 5-1 were evaluated and screened based on the following factors:

- Potential to meet the Flat Creek watershed planning objectives
- Necessary groupings of restoration measures
- Estimated costs of mutually exclusive measures

Based on this screening and evaluation, detailed below, all potential restoration measures to improve aquatic ecosystems in the Flat Creek watershed (Table 5-1) were selected to be included in the formulation of alternative plans. No restoration measures were screened out based on this process.

5.2.1 Screening of Restoration Measures Based on Plan Objectives

Restoration measures were evaluated based on their applicability to the Flat Creek watershed objectives and opportunities. These restoration measures that could address each identified opportunity are summarized in Table 5-2 and organized based on the ecosystem restoration opportunities identified for the Flat Creek watershed. Comparing ecosystem restoration opportunities with the potential restoration measures listed in Table 5-1, each of the potential structural restoration measures identified remains viable for consideration in formulation of alternative plans. Further, although the nonstructural programs and activities listed in Table 5-1 do not directly address specific ecosystem restoration opportunities for the Flat Creek watershed, these programs could directly enhance these opportunities for ecosystem restoration.

TABLE 5-2
Ecosystem Opportunities and Potential Restoration Measures
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Ecosystem Restoration Opportunity	Potential Restoration Measures	
To restore native, intolerant aquatic species and increase species richness/evenness in the watershed.	• Engineered riffle • J-hook • Cross vane • Pool/step pool	• Log sill • Root wad • Boulders • All nonstructural measures
To restore natural flow regimes to a practicable extent and reconnect the stream to the floodplain to dissipate peak flow velocities, which increases the quality of instream and riparian habitats.	• Debris jam removal • Culvert replacement • Adjust stream meanders • Create bankfull bench • Bank grading • Extended wet detention basin • Extended dry detention basin • Outlet control structure	• OCS retrofit • Existing detention basin expansion • Created wetland • Aquatic vegetation planting • Micropool • Sediment forebay • Pilot channel • All nonstructural measures
To restore and protect native, sensitive fish and macroinvertebrate species by increasing the frequency and quality of riffle/pool habitats in the watershed.	• Engineered riffle • J-hook • Cross vane	• Pool/step pool • Log sill • All nonstructural measures
To increase in-stream food availability, refuge, and stream shading by adding woody, native vegetation in disturbed riparian areas.	• Streambank planting • Rootwad • Invasive plant species removal	• Riparian planting (native hardwoods) • Riparian planting (seeding and mulching) • Cattle exclusion fencing • All nonstructural measures
To reduce sedimentation and prevent further habitat embeddedness by improving bank stability and enhancing vegetated riparian ecosystems.	• Bank stabilization using geotextile mattress • Stone toe protection • Bank grading	• Streambank planting • Riprap • Cattle exclusion fencing • All nonstructural measures

5.2.2 Evaluation of Restoration Measure Combinations

After potential restoration measures were screened to identify those that can address problems in the watershed (all measures included in Table 5-1), the dependence and compatibility of different restoration measures were evaluated. Combining some restoration measures may be necessary for a sustainable result (**Measures that Must be Combined**). Other measures cannot be effectively combined (**Measures that are Mutually Exclusive**), and still others have a sustainable result when implemented in combination or independently (**Measures that Can be Combined**). To formulate alternatives that were logical and focused, combinations of potential restoration measures were categorized into one of these three potential categories (summarized in Tables 5-3 through 5-7 and detailed below). This information was used in the alternative formulation process.

Measures That Must Be Combined

Restoration measures that must be combined included those that, without use in combination with one or more other measures, were not considered to be sustainable. Table 5-3 summarizes measures that must be combined with one or more other measures to obtain benefit and provides an explanation for the measure combinations.

Measures That Are Mutually Exclusive

Mutually exclusive measures included those that serve the same purpose, as well as those that could not be combined in a single location. Table 5-4 lists restoration measures that would be included in the Flat Creek alternatives analysis and that are mutually exclusive. Measures that were mutually exclusive would be independently evaluated for a single location, but based on materials and requirements, they can be combined into a restoration alternative.

Measures That Can Be Combined

Combining measures was an important consideration during alternative plan formulation, since many measures are more effective when used in series with other measures. As an example, use of multiple instream measures such as cross vanes, pools, J-hooks and engineered riffle help to maximize restoration efforts by establishing desired riffle/pool sequences. Categories of restoration measures (instream, streambank, riparian, and flow attenuation) also provide benefits that enhance and sustain each other. The previous sections identified restoration measures that must be combined or are mutually exclusive. Any remaining combinations contained individual measures that were identified as applicable to the Flat Creek watershed project, and therefore can be combined in a single alternative. Tables 5-5 through 5-7 summarize the compatibility of the restoration measures identified in Section 5.1. Combinations of these measures will be included in the formulation of alternative plans and were further evaluated in the economics analysis of the final array of alternatives.

5.2.3 Screening of Mutually Exclusive Measures Based on Cost

After potential restoration measures were screened to identify those that can address problems and opportunities in the watershed, and evaluated based on dependence and compatibility, restoration measures were screened based on estimated cost. With regards to cost considerations, only a discussion of mutually exclusive measures is applicable. Mutually exclusive measures include those that serve the same purpose, as well as those that could not be combined in a single location. For mutually exclusive measures, the least costly measure should be selected where applicable. Table 5-4, above, summarizes restoration measures identified as mutually exclusive. While the flow attenuation measures in Table 5-4 would not be implemented in combination, the selection of the measure is dependent on hydrology, the water table, and surrounding land use, as opposed to the instream restoration measures which could be implemented at a variety of locations. Therefore, preliminary economic analysis of individual measures was conducted on the mutually exclusive instream restoration measures only.

Unit costs for cross vanes, log sills, and engineered riffles were developed based on 2007 unit costs for construction elements (see Table 5-8). The costs were examined to determine the least costly method of obtaining grade control and placement of riffle/pool sequences. Table 5-8 shows the estimated unit costs of individual components associated with each instream restoration measure from Table 5-4. Where applicable, the lowest cost restoration measure was used in development of alternatives. Combinations of measures were included in the formulation of alternative plans, outlined in the next section, and were further evaluated in the economics analyses of the final array of alternatives.

TABLE 5-3
Restoration Measures that Must be Combined
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Primary Measure	Complementary Measures	Explanation
Streambank Restoration Measures		
Stream meander (add bends)	Bank grading, bank stabilization matting or riprap, and streambank planting	Stream meandering requires bank grading to reshape the stream; this measure would not be implemented without the subsequent stabilization and planting of the streambanks (that are created from the stream meander measure) to mitigate the bank grading and assure sustainability of the meanders.
Create bankfull bench	Bank grading, bank stabilization matting or riprap, and streambank planting	Creating a bankfull bench requires bank grading to reshape the banks. This measure would not be implemented without the subsequent stabilization and planting of the streambanks to mitigate bank grading and ensure sustainability of the bankfull bench.
Bank grading	Bank stabilization matting or riprap, and streambank planting	Bank grading would be implemented either to create a bankfull bench or to meander the stream. This measure would not be implemented without the subsequent stabilization and planting of the streambanks to mitigate the bank grading.
Bank stabilization matting	Streambank planting	Bank stabilization matting requires streambank planting to maintain streambank stability after the stabilization materials have biodegraded.
Riparian Restoration Measures		
Invasive plant species removal	Riparian planting (native hardwoods and seeding and mulching)	Invasive plant species removal would require the subsequent planting of cleared areas to allow for benefits of riparian restoration measures.
Flow Attenuation Restoration Measures		
Extended wet detention basin	Outlet control structure and aquatic vegetation planting	Extended wet detention basins must include an outlet control structure and aquatic vegetation to function as a flow attenuation measure.
Extended dry detention basin	Outlet control structure	Extended dry detention basins must include an outlet control structure to function as a flow attenuation measure.
Created wetlands	Outlet control structure and aquatic vegetation planting	Created wetlands must include an outlet control structure and aquatic vegetation to function as a flow attenuation measure.
Outlet control structure	Extended wet detention basin, created wetlands, extended dry detention basin, or detention basin expansion	Outlet control structures must be constructed within a detention basin (new or existing) to function as a flow attenuation measure.
Aquatic vegetation planting	Extended wet detention basin or created wetlands	Aquatic vegetation could be planted only in an area that is intended to remain wet (wet detention basin or created wetlands) in order to be maintained.
Micropool	Extended wet detention basin, created wetlands, extended dry detention basin, or detention basin expansion	A micropool can enhance the benefits of a flow attenuation measure but can be constructed only within a detention basin (new or existing) or created wetlands.

TABLE 5-3
Restoration Measures that Must be Combined
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Primary Measure	Complementary Measures	Explanation
Sediment forebay	Extended wet detention basin, created wetlands, extended dry detention basin, or detention basin expansion	A sediment forebay can enhance the benefits of a flow attenuation measure but can be constructed only within a detention basin (new or existing) or created wetlands.
Pilot channel	Extended wet detention basin, created wetlands, extended dry detention basin, or detention basin expansion	A pilot channel can enhance the benefits of a flow attenuation measure, but it can be constructed only within a detention basin (new or existing) or created wetlands.

TABLE 5-4
Restoration Measures that are Mutually Exclusive
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Mutually Exclusive Measures	Explanation
Instream Restoration Measures	
Cross vane Log sill Engineered riffle	These measures are all implemented to achieve grade control and to construct riffle/pool sequences. Only one would be required at a single location.
Flow Attenuation Restoration Measures	
Extended wet detention basin Extended dry detention basin Created wetland Detention basin expansion	Only one of these measures could be constructed/implemented in a single location, although the measures could be combined into an alternative.
Outlet control structure retrofit Outlet control structure	Only one of these measures would be implemented, based on whether a detention basin is being constructed or an existing basin is being retrofitted.
Outlet control structure retrofit Extended dry detention basin Extended wet detention basin Created wetlands	An outlet control structure retrofit would not be included with the construction of new detention basins or created wetlands, since there would be no existing outlet control structure.
Aquatic vegetation planting Extended dry detention basin	Aquatic vegetation would not be planted in an extended dry detention pond, since the pond will not sustain this type of vegetation.

TABLE 5-5
Combinations of Instream Restoration Measures
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Complementary Measures / Primary Measure	Log sill	Engineered riffle	Cross vane	J-hook	Debris jam removal	Culvert replacement	Pool/Step pool	Boulders	Stone toe protection
Log sill		M/E	M/E	C	C	C	C	C	C
Engineered riffle	M/E		M/E	C	C	C	C	C	C
Cross vane	M/E	M/E		C	C	C	C	C	C
J-hook	C	C	C		C	C	C	C	C
Debris jam removal	C	C	C	C		C	C	C	C
Culvert replacement	C	C	C	C	C		C	C	C
Pool/Step pool	C	C	C	C	C	C		C	C
Boulders	C	C	C	C	C	C	C		C
Stone toe protection	C	C	C	C	C	C	C	C	

C – can be combined
M/C – must be combined
M/E – mutually exclusive

TABLE 5-6
Combinations of Streambank and Riparian Restoration Measures
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Primary Measure \ Complementary Measures	Adjust stream meander (add bends)	Creation of bankfull bench	Bank grading	Bank stabilization matting	Riprap	Streambank planting	Rootwad	Invasive plant species removal	Riparian planting (native hardwoods)	Riparian planting (seeding/ mulching)
Adjust stream meander (add bends)		C	M/C	M/C (with at least one)		M/C	C	C	C	C
Creation of bankfull bench	C		M/C	M/C (with at least one)		M/C	C	C	C	C
Bank grading	C	C		M/C (with at least one)		M/C	C	C	C	C
Bank stabilization matting	C	C	C		C	M/C	C	C	C	C
Riprap	C	C	C	C		C	C	C	C	C
Streambank planting	C	C	C	C	C		C	C	C	C
Rootwad	C	C	C	C	C	C		C	C	C
Invasive species removal	C	C	C	C	C	C	C		M/C	M/C
Riparian planting (native hardwoods)	C	C	C	C	C	C	C	C		C
Riparian planting (seeding/mulching)	C	C	C	C	C	C	C	C	C	

C – can be combined
M/C – must be combined
M/E – mutually exclusive

TABLE 5-7
Combinations of Flow Attenuation Restoration Measures
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Primary Measure \ Complementary Measures	*Extended wet detention basin*	*Created wetlands*	*Extended dry detention basin*	*Detention basin expansion*	*Outlet control structure*	*Outlet control structure retrofit*	*Aquatic vegetation planting*	*Micropool*	*Sediment forebay*	*Pilot channel*
Extended wet detention basin		M/E	M/E	M/E	M/C	M/E	M/C	C	C	C
Created wetlands	M/E		M/E	M/E	M/C	M/E	M/C	C	C	C
Extended dry detention basin	M/E	M/E		M/E	M/C	M/E	M/E	C	C	C
Detention basin expansion	M/E	M/E	M/E		C	C	C	C	C	C
Outlet control structure	M/C (with at least one)					M/E	C	C	C	C
Outlet control structure retrofit	M/E	M/E	M/E	C	M/E		C	C	C	C
Aquatic vegetation planting	M/C (with at least one)		M/E	C	C	C		C	C	C
Micropool	M/C (with at least one)				C	C	C		C	C
Sediment forebay	M/C (with at least one)				C	C	C	C		C
Pilot channel	M/C (with at least one)				C	C	C	C	C	

C – can be combined
M/C – must be combined
M/E – mutually exclusive

TABLE 5-8
Unit Costs for Mutually Exclusive Instream Restoration Measures
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Description	Unit Cost	Unit Price
Cross Vane		
Structure	Each	$10,600
3' to 3.5' diameter boulders for footers and cross vanes	Square yard	$250
Geotextile Fabric	Square yard	$3.50
Log Sill		
Structure	Each	$3,500
Engineered Riffle		
Rip Rap	Cubic yard	$58.80
3’ to 3.5’ boulders	Each	$250

5.3 Developing Alternative Plans

The first step in formulating alternative plans was to identify locations in the watershed with the greatest potential to provide habitat improvement, with the implementation of restoration measures. Alternative formulation included applying measures to these problem areas to develop plans, combining plans into additional alternatives, and screening alternatives to keep those most likely to solve the problems. This process involved further reviews of: (1) the restoration measures identified as having the potential to meet the planning objectives; (2) site-specific problems and opportunities in the Flat Creek watershed; and (3) restoration measures appropriate for each problem site. The alternative formulation process resulted in 73 single-site restoration alternatives, all possible combinations of the 73 alternatives, and the No Action Alternative. Steps followed to formulate alternatives are outlined below.

Restoration alternatives for the Flat Creek watershed were developed by applying the restoration measures at 73 problem sites that were identified during the 2007 field assessment. The problem sites identified during the field assessment are shown on Figures 5-1 (stream problem sites) and 5-2 (stormwater detention structure problem sites). Restoration measures were applied to each of the 73 problem sites to develop 73 single-site alternatives. Table 5-9 summarizes the 73 single-site alternatives, and describes the location, extent, and nature of the problems, as well as the appropriate restoration measures to address them.

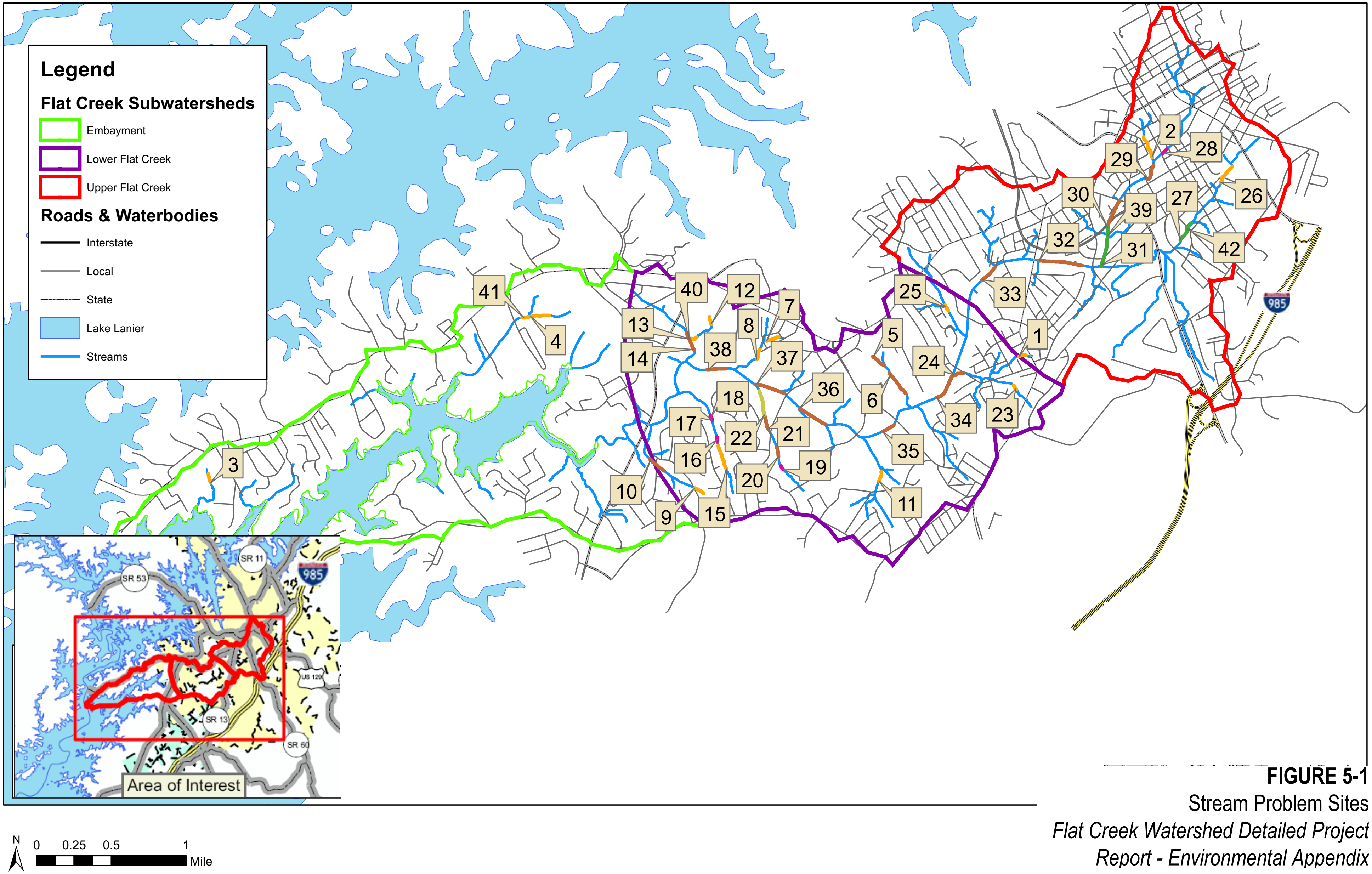

FIGURE 5-1
Stream Problem Sites
Flat Creek Watershed Detailed Project
Report - Environmental Appendix

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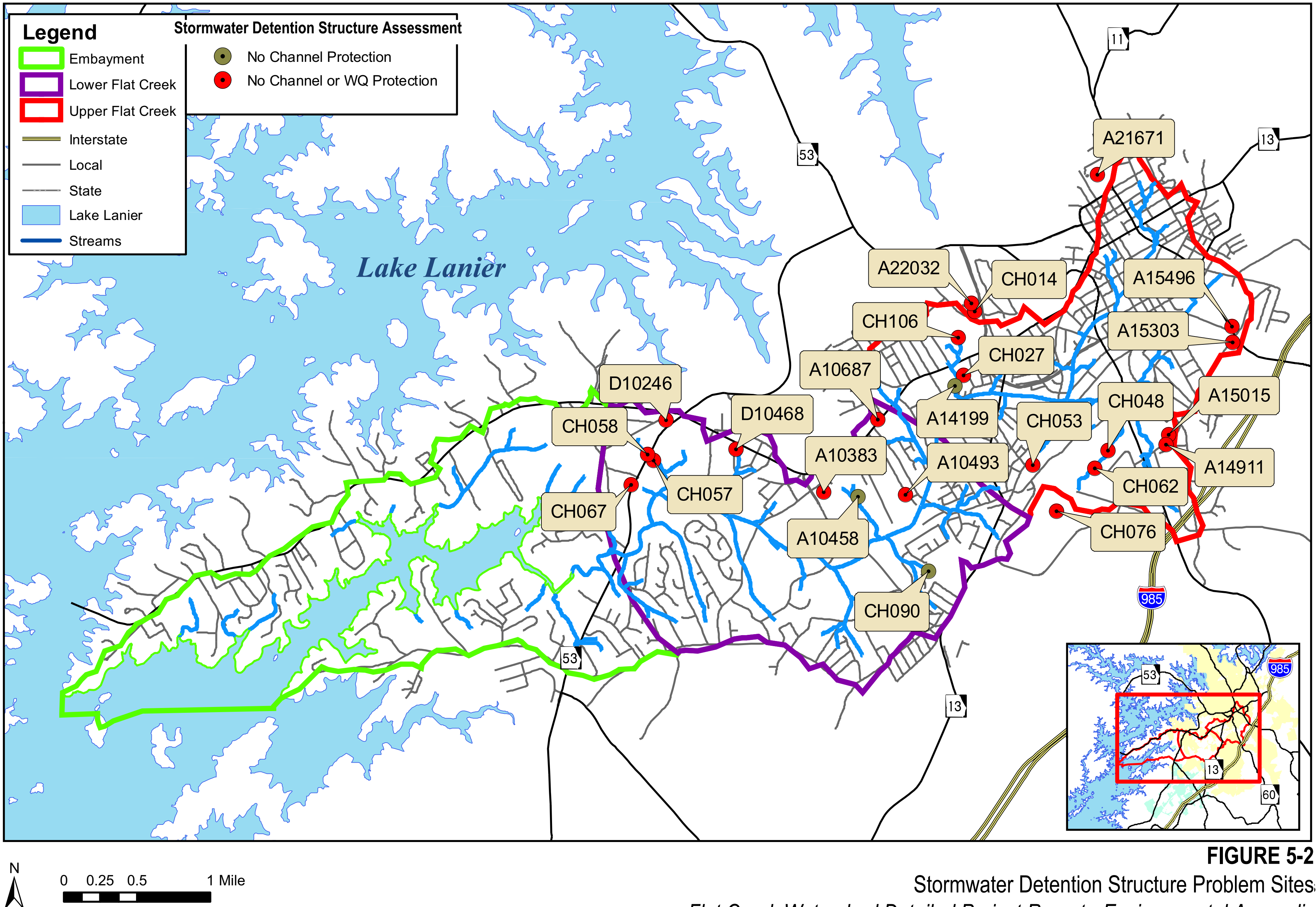

FIGURE 5-2

Stormwater Detention Structure Problem Sites

Flat Creek Watershed Detailed Project Report - Environmental Appendix

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TABLE 5-9
Potential Restoration Alternatives for the Flat Creek Watershed
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Alter-native ID	Type/Location	Problems	Extent (ft)	Applied Restoration Measures	
1	Stream/ Upper Flat Creek	Channel incising and widening	300	• Engineered riffle • J-hook • Cross vane • Boulders	• Creation of a bankfull bench • Bank grading • Bank stabilization matting • Streambank planting
2	Stream/ Upper Flat Creek	Channelized stream; channel incising; impervious area/ structure in floodplain	900	• Engineered riffle • Culvert replacement • J-hook • Cross vane • Boulders • Create bankfull bench	• Bank grading • Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
3	Stream/ Embayment	Channel incising	300–500	• Engineered riffle • J-hook • Boulders • Stone toe protection • Bank grading	• Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
4	Stream/ Embayment	Channelized stream; channel incising	500–1,000	• Engineered riffle • J-hook • Boulders • Stone toe protection • Create bankfull bench • Bank grading	• Bank stabilization matting • Riprap • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
5	Stream/ Lower Flat Creek	Channelized stream; channel widening; invasive plant species present	300–500	• Engineered riffle • J-hook • Cross vane • Boulders • Create bankfull bench • Bank grading	• Bank stabilization matting • Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
6	Stream/ Lower Flat Creek	Channelized stream; channel widening; invasive plant species present	1,000–1,500	• Engineered riffle • J-hook • Pool/Step pool • Boulders • Creation of a bankfull bench	• Bank grading • Bank stabilization matting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)

TABLE 5-9
Potential Restoration Alternatives for the Flat Creek Watershed
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Alter-native ID	Type/Location	Problems	Extent (ft)	Applied Restoration Measures	
7	Stream/ Lower Flat Creek	Channelized stream; channel incising; lawn in floodplain; invasive plant species present	300–500	• Log sill • Cross vane • Rootwad • Bank stabilization matting	• Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
8	Stream/ Lower Flat Creek	Channel widening; lawn in floodplain; invasive plant species present	300–500	• Log sill • Engineered riffle • Cross vane • Pool/Step pool • Rootwad	• Bank stabilization matting • Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
9	Stream/ Lower Flat Creek	Channelized stream; channel incising and widening, lawn in floodplain	100–300	• Log sill • J-hook • Cross vane	• Rootwad • Bank stabilization matting • Streambank planting
10	Stream/ Embayment	Channelized stream; channel widening; lawn in floodplain	500–1,000	• Log sill • J-hook • Cross vane	• Rootwad • Bank stabilization matting • Streambank planting
11	Stream/ Lower Flat Creek	Channel incising; invasive plant species present	300–500	• Engineered riffle • J-hook • Boulders • Stone toe protection • Create bankfull bench • Bank grading	• Bank stabilization matting • Riprap • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
12	Stream/ Lower Flat Creek	Channel incising and widening	100–300	• Engineered riffle • J-hook • Boulders • Stone toe protection • Bank grading	• Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
13	Stream/ Lower Flat Creek	Channelized stream; channel incising; cleared/maintained parallel utility in floodplain	300–500	• Log sill • J-hook • Cross vane	• Rootwad • Bank stabilization matting • Streambank planting
14	Stream/ Lower Flat Creek	Channelized stream; channel incising; severe bank erosion	500–1,000	• Log sill • J-hook • Cross vane • Rootwad	• Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)

TABLE 5-9
Potential Restoration Alternatives for the Flat Creek Watershed
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Alter-native ID	Type/Location	Problems	Extent (ft)	Applied Restoration Measures	
15	Stream/ Lower Flat Creek	Channel incising and widening; cleared/maintained parallel utility in floodplain; invasive plant species present	1,000–1,500	• Log sill • J-hook • Cross vane • Rootwad	• Bank stabilization matting • Streambank planting • Invasive plant species removal
16	Stream/ Lower Flat Creek	Unstable head cut; cleared/maintained parallel utility in floodplain	50–100	• Log sill • Pool/Step pool • Create bankfull bench	• Bank grading • Bank stabilization matting • Streambank planting
17	Stream/ Lower Flat Creek	Severe bank erosion	100–300	• J-hook • Cross vane • Stone toe protection • Bank grading	• Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
18	Stream/ Lower Flat Creek	Unstable head cut	150	• Engineered riffle • J-hook • Cross vane • Boulders • Create bankfull bench	• Bank grading • Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
19	Stream/ Lower Flat Creek	Severe bank erosion	100–300	• J-hook • Cross vane • Stone toe protection • Bank grading	• Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
20	Stream/ Lower Flat Creek	Stream piped; channel incising and widening; lawn in floodplain; invasive plant species present	300–500	• Log sill • J-hook • Culvert replacement	• Stone toe protection • Riprap • Invasive plant species removal
21	Stream/ Lower Flat Creek	Channel widening; cleared/maintained parallel utility in floodplain; invasive plant species present	300–500	• Log sill • J-hook • Cross vane • Rootwad	• Bank stabilization matting • Streambank planting • Invasive plant species removal
22	Stream/ Lower Flat Creek	Evidence of high velocity flow	500–1,000	• Created wetland • Log sill • J-hook • Cross vane • Rootwad	• Bank stabilization matting • Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)

TABLE 5-9
Potential Restoration Alternatives for the Flat Creek Watershed
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Alternative ID	Type/Location	Problems	Extent (ft)	Applied Restoration Measures	
23	Stream/ Lower Flat Creek	Channel widening; cleared/maintained parallel utility in floodplain; invasive plant species present	200	• Engineered riffle • J-hook • Cross vane • Boulders • Bank stabilization matting	• Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
24	Stream/ Lower Flat Creek	Channel widening; lawn in floodplain; invasive plant species present	500–1,000	• Log sill • Engineered riffle • Cross vane • Pool/Step pool • Rootwad	• Bank stabilization matting • Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
25	Stream/ Lower Flat Creek	Stable knick point; impervious area/structure in floodplain	250	• Engineered riffle • J-hook • Cross vane • Debris jam removal • Boulders	• Creation of a bankfull bench • Bank grading • Bank stabilization matting • Streambank planting
26	Stream/ Upper Flat Creek	Channelized stream; channel incising; impervious area/ structure in floodplain; invasive plant species present	900	• Engineered riffle • J-hook • Cross vane • Boulders • Bank stabilization matting	• Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
27	Stream/ Upper Flat Creek	Concrete-lined channel; lawn in floodplain; invasive plant species	900	• Pool/Step pool • Stone toe protection • Rootwad • Create bankfull bench • Bank grading	• Bank stabilization matting • Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
28	Stream/ Upper Flat Creek	Buildup in floodplain; cleared/ maintained parallel utility in floodplain	200	• J-hook • Create bankfull bench • Bank grading	• Bank stabilization matting • Streambank planting

TABLE 5-9
Potential Restoration Alternatives for the Flat Creek Watershed
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Alter-native ID	Type/Location	Problems	Extent (ft)	Applied Restoration Measures	
29	Stream/ Upper Flat Creek	Channelized stream; channel widening; old field in floodplain; invasive plant species removal	600	• J-hook • Debris jam removal • Bank stabilization matting • Streambank planting	• Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
30	Stream/ Upper Flat Creek	Channel widening; lawn in floodplain	300–500	• Log sill • Engineered riffle • Cross vane • Pool/Step pool	• Rootwad • Bank stabilization matting • Streambank planting
31	Stream/ Upper Flat Creek	Concrete-lined channel; impervious area/structure in floodplain	1,800	• Pool/Step pool • Stone toe protection • Rootwad • Create bankfull bench	• Bank grading • Bank stabilization matting • Streambank planting
32	Stream/ Upper Flat Creek	Channelized stream; channel widening; cleared/maintained utility in floodplain	1,800	• Engineered riffle • Boulders • Stone toe protection • Rootwad • Create bankfull bench	• Bank grading • Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
33	Stream/ Upper Flat Creek	Buildup in floodplain	700	• Engineered riffle • Stone toe protection • Create bankfull bench • Bank grading	• Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
34	Stream/ Lower Flat Creek	Channelized stream; old field in floodplain	1,000–1,500	• Log sill • Adjust stream meander (add bends) • Create bankfull bench	• Bank grading • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
35	Stream/ Lower Flat Creek	Channelized stream	300–500	• Log sill • Adjust stream meander • Create bankfull bench	• Bank grading • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)

TABLE 5-9
Potential Restoration Alternatives for the Flat Creek Watershed
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Alter-native ID	Type/Location	Problems	Extent (ft)	Applied Restoration Measures	
36	Stream/ Lower Flat Creek	Channelized stream; channel widening; cleared/maintained utility in floodplain	1,000–1,500	• Log sill • J-hook • Cross vane • Pool/Step pool	• Rootwad • Bank stabilization matting • Streambank planting
37	Stream/ Lower Flat Creek	Rip rap or gabions along channel	1,000–1,500	• Engineered riffle • Debris jam removal • Pool/Step pool	• Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
38	Stream/ Lower Flat Creek	Channel widening	500–1,000	• Log sill • J-hook • Cross vane • Pool/Step pool • Rootwad	• Bank stabilization matting • Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
39	Stream/ Upper Flat Creek	Concrete-lined channel; impervious area/structure in floodplain	750	• J-hook • Adjust stream meander • Bank stabilization matting	• Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
40	Stream/ Lower Flat Creek	Channel incising and widening	100–300	• Engineered riffle • J-hook • Boulders • Stone toe protection • Bank grading	• Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
41	Stream/ Embayment	Channel incising	250–500	• Engineered riffle • J-hook • Boulders • Stone toe protection • Bank grading	• Bank stabilization matting • Streambank planting • Invasive plant species removal • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
42	Stream/ Upper Flat Creek	Channelized stream; channel widening; lawn in floodplain; invasive plant species present	800	• J-hook • Adjust stream meander • Create bankfull bench • Bank grading	• Bank stabilization matting • Streambank planting • Riparian planting (native hardwoods) • Riparian planting (seeding/mulching)
A10383	Dry Detention Pond/ Lower Flat Creek	No water quality or channel protection; shallow	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (build up berms to increase capacity)	
A10458	Dry Detention Pond/ Lower Flat Creek	No channel protection; channelization in pond	N/A	• Outlet control structure retrofit (reduce lower orifice and install proper outlet filtering)	

TABLE 5-9
Potential Restoration Alternatives for the Flat Creek Watershed
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Alter-native ID	Type/Location	Problems	Extent (ft)	Applied Restoration Measures
A10493	Dry Detention Pond/ Lower Flat Creek	No water quality or channel protection; potential for large runoff amounts	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation)
A10687	Dry Detention Pond/ Lower Flat Creek	No water quality or channel protection; eroding berm	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation)
A14199	Wet Detention Pond/ Upper Flat Creek	No channel protection	N/A	• Outlet control structure retrofit (reduce lower orifice and install proper outlet filtering) • Aquatic vegetation planting
A14911	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit (significantly redesign)
A15015	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection; shallow	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation)
A15094	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit • Existing detention basin expansion (excavation)
A15303	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation)
A15496	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit (reduce lower orifice and install proper outlet filtering) • Existing detention basin expansion (excavation)
A21671	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection; berm erosion; channelization; overgrown	N/A	• Outlet control structure retrofit (reduce lower orifice and install proper outlet filtering) • Debris removal
A22032	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Existing detention basin expansion (excavation) • Debris removal
CH014	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection; no outlet control structure; very overgrown	N/A	• Outlet control structure retrofit (significantly redesign)
CH015	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit • Existing detention basin expansion (excavation)
CH016	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit • Existing detention basin expansion (excavation)
CH022	Wet Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit • Existing detention basin expansion (excavation)

TABLE 5-9
Potential Restoration Alternatives for the Flat Creek Watershed
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Alter-native ID	Type/Location	Problems	Extent (ft)	Applied Restoration Measures
CH025	Wet Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit • Existing detention basin expansion (excavation)
CH027	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection; eroding berm	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation) Debris removal
CH033	Dry Detention Pond/ Lower Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit • Existing detention basin expansion (excavation)
CH036	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit • Existing detention basin expansion (excavation)
CH048	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit (significantly redesign)
CH053	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation)
CH057	Dry Detention Pond/ Lower Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit (significantly redesign)
CH058	Dry Detention Pond/ Lower Flat Creek	No water quality or channel protection; catch basin erosion; overgrown	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation)
CH062	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection; inlet erosion; overgrown	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation)
CH067	Dry Detention Pond/ Lower Flat Creek	No water quality or channel protection; overgrown	N/A	• Outlet control structure retrofit (significantly redesign)
CH076	Swale/ Upper Flat Creek	No water quality or channel protection; overgrown	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation)
CH090	Wet Detention Pond/ Lower Flat Creek	No channel protection	N/A	• Outlet control structure retrofit (reduce upper orifice size)
CH106	Dry Detention Pond/ Upper Flat Creek	No water quality or channel protection; channelization; sedimentation	N/A	• Outlet control structure retrofit (significantly redesign) • Existing detention basin expansion (excavation)
D10246	Dry Detention Pond/ Lower Flat Creek	No channel protection	N/A	• Outlet control structure retrofit (reduce lower orifice and install proper outlet filtering)
D10468	Dry Detention Pond/ Lower Flat Creek	No water quality or channel protection	N/A	• Outlet control structure retrofit (significantly redesign)

The problems in Flat Creek varied by severity (such as amount of sedimentation in a given area) and extent (distance along the stream). However, they were similar in type, where most stream reaches were channelized with degraded habitat because of sedimentation and a limited riparian ecosystem. As a result, the PDT formulated one alternative plan to address each individual problem site. Measures were selected and combined to address the specific problems observed. Other measures were eliminated if they did not specifically address the problem, were less effective than the selected measures, did not meet the planning objectives, or could not be implemented because of site constraints. During formulation, the PDT considered many combinations of measures to address problems, avoid constraints, and meet the planning objectives. However, only one set of measures was ultimately selected to address the problems at each site.

For instream measures, the PDT evaluated each problem site to determine which method(s) of grade control would be most applicable, if any. For example, log sills are well-suited for smaller stream systems experiencing some degree of incising. Other methods of grade control (such as engineered riffles or cross vanes) would be more appropriate for stream profile stabilization and to address the more severe incising conditions observed at other problem sites. Bank stabilization measures were selected based on observed conditions, with measures including bank grading, matting, or planting used instead of riprap (or other bank hardening approaches) where possible. Riparian measures (if selected) were selected as appropriate to enhance disturbed riparian ecosystem conditions.

Flow attenuation measures applied to alternatives generally included outlet control structure retrofits or expansion of existing detention structures. Because of the developed conditions of the Flat Creek watershed and limited available undeveloped land, the PDT focused mainly on opportunities to modify existing basins rather than on construction of new basins. Since most of the existing detention basins observed did not provide adequate channel protection or extended detention capabilities, measures such as adding sediment forebays, micropools, or pilot channels were not used because of their limited potential impact in terms of significantly increasing storage capacity or attenuating peak stormwater discharges. Outlet control structure retrofits were selected when channel protection volume could not be achieved with the current outlet control structure configuration. Basin expansion was selected as a measure when the pond could be expanded (deepened or expanded laterally) given current site use, conditions, and constraints.

The alternative plans developed for the Flat Creek watershed included the No Action Alternative, the 73 single-site alternatives in Table 5-9, and any combination of the 73 single-site alternatives. Alternative screening and reformulation are detailed in Section 5 of the Detailed Project Report (Evaluating Alternative Plans).

6. Screening and Reformulation of Alternative Plans

Step 4 of the planning process is evaluating alternative plans. It involves quantifying the expected contribution of individual plans and using this information to screen out or reformulate alternative plans. The purpose of step 4 of the planning process is to “determine whether or not the plan qualifies to advance and be compared against other plans that have independently qualified” (Planning Manual, 1996). This section outlines the methods used to evaluate alternatives and determine a final array of alternative plans for final selection of a recommended plan. In Step 5 of the planning process, “the specific criteria that will be used to compare those plans that do qualify and advance to the comparison step” (Planning Manual, 1996).

6.1 Screening Alternative Plans

Before conducting detailed evaluations of environmental benefits and costs for each alternative plan, the 73 single-site alternative plans (excluding the No Action Alternative) were screened to identify only those that would sustainably meet the planning study objectives by addressing the most severe areas of habitat loss in the watershed with the greatest potential for future habitat improvement. The alternative plans were also screened for those that would avoid the planning constraints, such as those constrained by the presence of infrastructure and other structures. Alternative plans with unavoidable constraints were dropped from further analysis. After the 73 single-site alternative plans were screened, 45 alternative plans were dropped either because they did not meet the planning objectives or they had unavoidable constraints. Thus, 28 single-site alternative plans were retained for further evaluation, including 12 stream restoration alternatives and 16 stormwater detention structure alternatives.

6.1.1 Screening Criteria

The 73 alternatives were screened based on four factors to ensure that they addressed aquatic habitat problems (bank erosion, erosivity, instream sediment production, and existing biological conditions) at a level that would meet planning objectives, as well as on the ability of the alternative to avoid planning constraints. The screening criteria include:

Factor:	**Measured by:**
• Existing bank erosion	• Bank erodibility (percent bare soil on banks)
• Modeled change in erosivity	• Impervious cover, land use, and stormwater infrastructure data
• Modeled change in instream sediment production	• Modeled total suspended solids (TSS) production
• Existing biological conditions	• ERM-based score using fish, macroinvertebrates, and habitat at nearest downstream sampling station
• Constraints	• Identification of nearby infrastructure and structures

For the first four factors, each of the 73 alternatives was given a score from 1 to 4, with 1 being the least optimal restoration conditions and 4 being the most optimal restoration conditions with the greatest potential for improvement. The final (cumulative) score for each alternative was then calculated to screen out alternatives below a certain threshold. Alternative plans were also screened to ensure that they avoided the planning constraints before they were carried forward.

While bank erosion and biological condition values were based on field data, future hydrological changes and TSS production values were determined using the previously watershed model (detailed in Appendix E [Engineering Appendix] to the Detailed Project Report). Each of these four categories was deemed to represent separate but important factors by the PDT to identify alternatives that would meet the planning objectives. The scoring factors used for alternative plan screening is described below. Note, alternatives were not screened out based on any single factor. These scores were used to develop the cumulative score, as detailed in Section 6.1.2, to screen out alternatives.

Existing Bank Erosion

Existing bank erosion was field-assessed in 2007, throughout the entire Flat Creek watershed. Erodibility is a measure of the percentage of a stream bank that has already eroded. It was quantified based on the amount of bare soil on banks that was observed in the field during the stream assessment. For stormwater detention structure alternatives, it was assumed that the erodibility at the nearest stream alternative would be a representative value. Bank erodibility is the percentage of bare soil over a representative reach, classified into one of four categories based on those provided in the Georgia SOP (GADNR, 2007).

Erodibility scores were based on GADNR SOPs for physical habitat assessments (2007); however, GADNR qualitative categories were considered with relation to average Flat Creek erodibility factors to determine the scoring criteria. The PDT reviewed the alternatives on a case-by-case basis, and determined that if an alternative plan had an average erodibility value of optimal or suboptimal (that is, $\leq$ 37.5 percent bare soil), then the alternative plan had limited potential to meet the planning objectives and restore habitat quality and quantity by reducing bank erosion, and deflecting flows. Scores assigned to represent potential habitat improvement based on bank erodibility:

Better existing conditions	$\leq$ 37.5%	=1
↓	37.5% to 50.0%	=2
	50.0% to 60.0%	=3
Worse existing conditions	$\geq$ 60.0%	=4

Modeled Change in Erosivity

While erodibility is a measure of the percentage of a stream bank that has already eroded, erosivity is a measure of the ability of a streambank to further erode. In the watershed model used for Flat Creek, stream discharge was represented by erosivity, which is an urban to rural discharge ratio. The PDT assumed that restoration measures may not be as predictable or successful in restoring habitat if future hydrological conditions were modeled to be worse than existing conditions. This would decrease the potential to meet the planning objectives, particularly for establishing instream structures and stabilizing bank conditions. Alternatives were screened based on their modeled change in erosivity, representing the likelihood that future hydrological conditions would change. For stormwater detention structure alternatives, it was assumed that the erosivity at the nearest stream alternative would be a representative value.

In the Flat Creek watershed, hydrologic channel impacts including a limited connection to the floodplain and more intense peak instream flow velocities have resulted in decreased habitat use for native, sensitive fish and benthic macroinvertebrate species. Erosivity was based on imperviousness of the drainage area and modified by stormwater detention structure efficiencies in the drainage area, both of which affect the velocity at which stormwater can enter a streams and erode streambanks. As runoff over impervious surfaces increases, the value of erosivity increases. Higher erosivity values were correlated with a higher degree of adverse impacts to aquatic ecosystems, as increased discharge rates displace native aquatic organisms that are sensitive to changes in the natural environment and can lead to the embeddedness of substrates used as spawning and refuge habitats.

In general, erosivity values can range from almost zero (as in a location immediately downstream from a functioning stormwater control) to more than 3 (as in a highly urbanized watershed with no stormwater controls). To represent potential habitat improvement based on hydrologic erosivity, the predicted change from existing to future erosivity (based on existing and future land use data) were score based on percentiles of the overall dataset:

Greater change in hydrologic conditions	≥ 0.289 (unitless ratio)	=1
↓	.163 to 0.289	=2
	0.148 to 0.162	=3
More stable hydrologic conditions	≤ 0.148	=4

Modeled Change in Instream Sediment Production

Estimations of total suspended solids (TSS) yields to Flat Creek can indicate the degree of adverse impacts to aquatic ecosystems resulting from sediment deposition and habitat embeddedness. TSS can be introduced to a stream from the surrounding watershed or from the streambank itself. Levels from the surrounding watershed can increase because of natural sources (such as silt captured in runoff), and anthropogenic sources including construction sites and urban and agricultural land uses. Levels of TSS resulting from streambanks increase as banks continue to erode and allow stormwater runoff to carry bank sediment into the stream. In the Flat Creek watershed, a high degree of instream sedimentation and substrate embeddedness have reduced the availability and quality of instream habitat and created an unstable environment for aquatic organisms. An analysis of existing in-stream and upland TSS production (referred to cumulatively as *TSS yield*) was conducted using the watershed model.

Results provided insight into potential habitat improvement by reducing sediment deposition in Flat Creek. For stormwater detention structure alternatives, it was assumed that the TSS production at the nearest stream alternative would be a representative value. Scores assigned to represent potential habitat improvement based on the potential to reduce future sediment production were based on percentiles of the overall dataset:

Smaller potential to reduce sediment	$\leq$ 99.008 lb/yr/ ft	=1
↓	99.008 to 156.682 lb/yr/ ft	=2
	156.682 to 173.251 lb/yr/ ft	=3
Greater potential to reduce sediment	$\geq$ 173.251 lb/yr/ ft	=4

Existing Biological Conditions

The biological health at the sampling station immediately downstream of each problem site reach was determined in order to approximate the stream problem sites with the most affected biological health. The score for each station was calculated in accordance with the ERM algorithm determined by the interagency team to be most representative of overall biological health. Therefore, the biological health for each station was approximated using the 2007 fish IBI score, benthic macroinvertebrate score, and physical habitat score, each as a ratio of the total possible score. A weighted average of these ratios was then calculated, using 40 percent for the IBI score, 40 percent for the BMI score, and 20 percent for the physical habitat score, based on the algorithm used in the ERM tool. The stations were then scored according to the biological condition of each:

Better existing conditions	FLG-B (48 of 100 points)	=1
↓	FLG-5 (42 of 100 points)	=2
	FLG-4 (32 of 100 points)	=3
Worse existing conditions	FLG-A (26 of 100 points)	=4

Planning Constraints

The planning study constraints discussed in Section 2 of the Detailed Project Report (Identifying Problems and Opportunities) included (1) protection of infrastructure and structures, (2) no loss of downstream flood protection, and (3) GAEPD mitigation requirements for stream buffer impacts. Alternatives were screened based on the planning constraints and removed if a constraint made the alternative less feasible.

6.1.2 Screening out Alternatives Plans

In this section, 45 single-site alternatives are screened out from further consideration. Of these, 39 were removed due to having relatively low potential for providing aquatic habitat improvement (see shaded alternatives in Table 6-1), and 6 were screened out based on constraints (see bolded alternatives in Table 6-1).

Table 6-1 provides the individual and combined scores for the 73 alternative plans for the four criteria related to planning objectives. The 42 alternative plans with the lowest cumulative score (less than 11) were considered limited in potential of the alternative to improve habitat and meet the planning objectives for the watershed. However, based on meetings with the PDT and nonfederal sponsor, three of these alternatives were selected to be carried forward based on acceptability: A10687, CH033, and CH025. Therefore, 39 alternatives were screened out during this process.

The remaining 34 alternatives were screened to ensure that they not only would meet the planning objectives, but also would avoid planning constraints. Based on this analysis, an additional 6 alternatives were removed from further consideration.

Existing Bank Erosion

In Flat Creek, erodibility values ranged from 19.9 to 87.5 percent eroded. Of the 73 alternatives, 15 had an erodibility less than or equal to 37.5 percent (considered optimal or suboptimal, based on GADNR SOPs for physical habitat [2007]). These alternatives were given an erodibility score of 1 to indicate their ineffectiveness at meeting planning objectives from the perspective of bank erosion. Thirty-seven additional alternatives had an erodibility of 50.0 percent or less. These alternatives were given a bank erodibility score of 2, because they had a moderate potential for improved habitat due to bank erosion status, but the PDT considered that these alternatives may still have a limited ability to meet the planning objectives. Nine additional alternatives had a streambank erodibility value less than 60 percent. These alternatives were assigned a score of 3 because of their favorable potential to improve with implementation of restoration measures. The remaining 12 alternatives, with bank erodibility greater than or equal to 60.0 percent, had the most bare, eroded banks with the greatest potential for future habitat improvement. As a result, they were assigned the highest score of 4.

Modeled Change in Erosivity

In Flat Creek, erosivity values ranged from roughly 1.2 in the lower part of the watershed to 3.8 in the highly urbanized headwaters. The score ranges shown below were based on an evaluation of the dataset and relative erosivity across the problem sites identified. Erosivity scores less than 0.148 were considered to be the most favorable for meeting the planning objectives and avoiding areas with changing, unpredictable hydrologic conditions. Eighteen alternatives received a score of 4 (relatively favorable conditions) for this factor. An additional 17 alternatives had modeled future erosivity of 0.148 to 0.162 were assigned a score of 3 to reflect their favorable conditions for improving future habitat. Nineteen alternatives had a modeled future change in erosivity of less than 0.162 to 0.289. This future change could influence habitat conditions and channel stability. As a result, these alternatives were assigned a score of 2. The remaining 19 alternatives had the largest future increase in erosivity of greater than 0.289. This change could substantially influence the hydrologic conditions at a stream restoration site, leading to a decreased likelihood of successfully improving habitat.

Modeled Change in Instream Sediment Production

Of the 73 alternatives, 18 had TSS production (lb/yr per linear ft) less than 99.008, which the PDT considered to be a relatively sustainable level of TSS production; therefore the future habitat improvement was limited and these alternatives were assigned the lowest score of 1. Fifteen alternatives had future TSS production less than 156.682, which was assigned a score of

2 and considered to be a low to moderate level that may lead to limited potential for habitat improvement and meeting the planning objectives. Twenty alternatives had future TSS production less than 173.251, which was considered to be favorable locations to improve habitat and meet planning objectives. The remaining 20 alternatives had future TSS production of 311.361 or less. They considered to be the most likely to reduce sedimentation and to improve habitat conditions in Flat Creek, and so they were assigned the highest score of 4.

Existing Biological Conditions

Existing biological conditions were based on 2007 biological monitoring and the ERM algorithm for calculating habitat units. As detailed above, the biological health at the sampling station immediately downstream of each problem site reach was determined in order to approximate the stream problem sites with the most affected biological health. For this factor, 13 alternatives received a score of 4 (most degraded existing conditions and most optimal restoration conditions), 15 alternatives received a score of 3, 26 alternatives received a score of 2, and 19 alternatives received a score of 1 (Table 6-1).

Planning Constraints

The alternatives removed due to planning constraints are shown in bold in Table 6-1. As previously mentioned, the 42 alternative plans with the lowest cumulative score (less than 11) were considered limited in potential of the alternative to improve habitat and meet the planning objectives for the watershed. However, based on meetings with the PDT and nonfederal sponsor, three of these alternatives were selected to be carried forward based on acceptability: A10687, CH033, and CH025. Therefore, 39 alternatives were screened out during the process outlined above.

The remaining 34 alternatives were screened to ensure that they not only would meet the planning objectives, but also would avoid planning constraints. Most of the alternatives remaining would avoid the planning constraints. Alternatives CH014, A22032, 9, 11, 12, and 27 would not, so they were dropped from further evaluation. These six alternatives were determined to have a construction footprint that would affect commercial buildings, parking lots, homes, sewer lines, or roadways. If designed to avoid impacts to the nearby constraints, they would be ineffective at meeting the planning objectives and thus unacceptable. For example, Alternative 12 could be accessed only from a small utility road and only with extensive tree removal. This would reduce the effectiveness of the project and also the functioning of the riparian ecosystem. Alternatives 9 and 11 are adjacent to residential areas that would constrain the design footprint. Alternatives CH014 and A22032 are adjacent to commercial buildings and parking lots with limited potential to avoid structures and still meet planning objectives.

TABLE 6-1
Preliminary Screening of 73 Alternatives
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Alternative	Average Erodibility (percentage)	Erodibility Score	Future Change in Erosivity (unitless ratio)	Erosivity Change Score	Future Stream TSS Production (lb/yr per linear ft)	TSS Score	Biological Monitoring Index (out of 100)	Biological Score	Combined Score
28	0.499	2	0.027	4	228.489	4	26	4	14
42	0.527	3	0.019	4	173.251	3	26	4	14
CH022	0.527	3	0.019	4	173.251	3	26	4	14
A15015	0.527	3	0.019	4	173.251	3	26	4	14
A14911	0.527	3	0.019	4	173.251	3	26	4	14
A15094	0.527	3	0.019	4	173.251	3	26	4	14
1	0.750	4	0.049	4	311.361	4	48	1	13
2	0.430	2	0.112	4	172.498	3	26	4	13
23	0.875	4	0.103	4	291.745	4	48	1	13
25	0.875	4	0.121	4	274.622	4	48	1	13
A10687	0.448	2	0.149	3	149.762	3	48	1	9
CH033	0.448	2	0.149	3	149.762	3	48	1	9
29	0.414	2	0.042	4	142.234	3	26	4	13
9	**0.587**	**3**	**0.158**	**3**	**188.976**	**4**	**42**	**2**	**12**
26	0.375	1	0.000	4	170.375	3	26	4	12
27	**0.383**	**2**	**0.088**	**4**	**139.750**	**2**	**26**	**4**	**12**
39	0.460	2	0.097	4	99.009	2	26	4	12
11	**0.624**	**4**	**0.409**	**1**	**190.869**	**4**	**42**	**2**	**11**
12	**0.551**	**3**	**0.272**	**2**	**327.733**	**4**	**42**	**2**	**11**
18	0.610	3	0.162	2	285.599	4	42	2	11

TABLE 6-1
Preliminary Screening of 73 Alternatives
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Alternative	Average Erodibility (percentage)	Erodibility Score	Future Change in Erosivity (unitless ratio)	Erosivity Change Score	Future Stream TSS Production (lb/yr per linear ft)	TSS Score	Biological Monitoring Index (out of 100)	Biological Score	Combined Score
32	0.422	2	0.162	2	238.159	4	32	3	11
CH053	0.422	2	0.162	2	238.159	4	32	3	11
CH048	0.422	2	0.162	2	238.159	4	32	3	11
CH062	0.422	2	0.162	2	238.159	4	32	3	11
CH036	0.422	2	0.162	2	238.159	4	32	3	11
33	0.452	2	0.149	3	169.616	3	32	3	11
A22032	**0.452**	**2**	**0.149**	**3**	**169.616**	**3**	**32**	**3**	**11**
CH014	**0.452**	**2**	**0.149**	**3**	**169.616**	**3**	**32**	**3**	**11**
CH016	0.452	2	0.149	3	169.616	3	32	3	11
CH015	0.452	2	0.149	3	169.616	3	32	3	11
CH106	0.452	2	0.149	3	169.616	3	32	3	11
A14199	0.452	2	0.149	3	169.616	3	32	3	11
CH027	0.452	2	0.149	3	169.616	3	32	3	11
CH025	0.338	1	0.172	4	201.152	1	32	3	9
13	0.631	4	0.735	1	156.683	3	42	2	10
D10246	0.631	4	0.735	1	156.683	3	42	2	10
CH058	0.631	4	0.735	1	156.683	3	42	2	10
CH057	0.631	4	0.735	1	156.683	3	42	2	10
24	0.560	3	0.139	3	155.488	3	48	1	10
30	0.298	1	0.071	4	69.137	1	26	4	10

TABLE 6-1
Preliminary Screening of 73 Alternatives
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Alternative	Average Erodibility (percentage)	Erodibility Score	Future Change in Erosivity (unitless ratio)	Erosivity Change Score	Future Stream TSS Production (lb/yr per linear ft)	TSS Score	Biological Monitoring Index (out of 100)	Biological Score	Combined Score
31	0.199	1	0.087	4	80.898	1	26	4	10
3	0.551	3	0.128	3	132.006	2	48	1	9
17	0.338	1	0.172	2	201.152	4	42	2	9
CH076	0.338	1	0.172	4	201.152	1	32	3	9
34	0.448	2	0.149	3	149.762	3	48	1	9
A10493	0.448	2	0.149	3	149.762	3	48	1	9
40	0.625	4	0.421	1	81.907	2	42	2	9
7	0.414	2	0.222	2	110.086	2	42	2	8
8	0.407	2	0.283	2	108.473	2	42	2	8
D10468	0.407	2	0.283	2	108.473	2	42	2	8
15	0.395	2	0.193	2	97.740	2	42	2	8
16	0.452	2	0.185	2	134.468	2	42	2	8
19	0.375	1	0.367	1	244.595	4	42	2	8
35	0.376	1	0.165	3	196.865	3	48	1	8
CH090	0.376	1	0.165	3	196.865	3	48	1	8
14	0.472	2	0.436	1	119.619	2	42	2	7
CH067	0.472	2	0.436	1	119.619	2	42	2	7
20	0.427	2	0.394	1	115.816	2	42	2	7
37	0.207	1	0.261	2	85.868	2	42	2	7
6	0.488	2	0.361	1	108.874	2	48	1	6

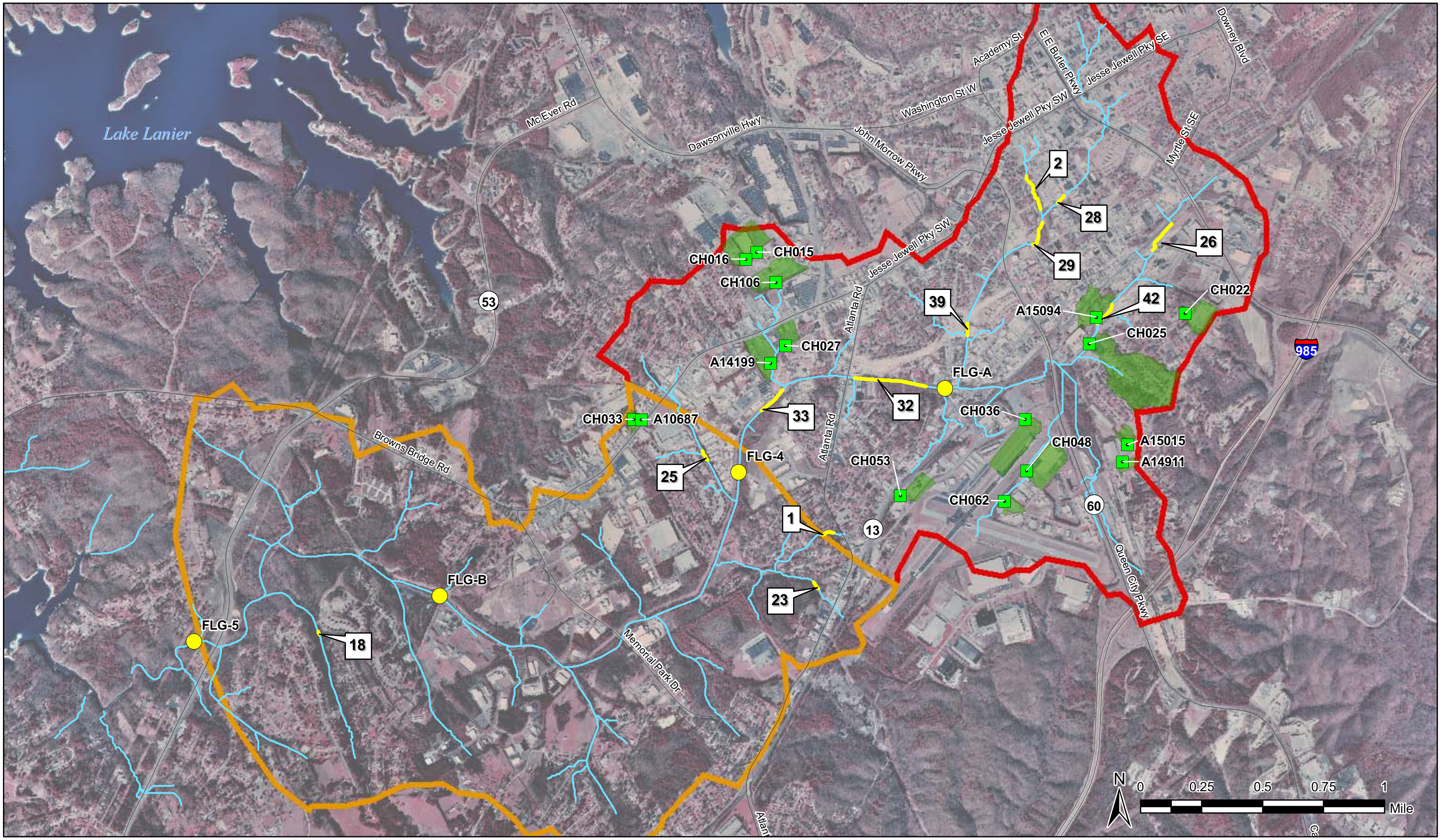
TABLE 6-1
Preliminary Screening of 73 Alternatives
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Alternative	Average Erodibility (percentage)	Erodibility Score	Future Change in Erosivity (unitless ratio)	Erosivity Change Score	Future Stream TSS Production (lb/yr per linear ft)	TSS Score	Biological Monitoring Index (out of 100)	Biological Score	Combined Score
10	0.315	1	0.171	2	38.645	1	42	2	6
21	0.384	2	0.296	1	69.062	1	42	2	6
38	0.396	1	0.290	2	66.674	1	42	2	6
A15303	0.396	1	0.290	2	66.674	1	42	2	6
A15496	0.396	1	0.290	2	66.674	1	42	2	6
4	0.395	2	0.990	1	49.341	1	48	1	5
22	0.372	1	0.366	1	25.919	1	42	2	5
36	0.260	1	0.232	2	78.096	1	48	1	5
A21671	0.260	1	0.232	2	78.096	1	48	1	5
41	0.430	2	1.070	1	30.849	1	48	1	5
5	0.316	1	0.289	1	72.492	1	48	1	4
A10383	0.316	1	0.289	1	72.492	1	48	1	4
A10458	0.316	1	0.289	1	72.492	1	48	1	4

6.2 Reformulation of Alternative Plans

The 12 stream problem sites and 16 stormwater detention structure problem sites carried forward for further analysis are shown in Figure 6-1. As part of an additional evaluation after the screening, the PDT recognized that the single-site alternatives should be limited to the 12 single-site stream restorations, and that the stormwater detention structure single-site alternatives would not provide self-sustaining aquatic habitat improvement. The PDT determined that other alternatives should include combinations of the 28 single-site alternatives to provide benefits by improving a greater extent of habitat in the watershed. Combination alternatives were assumed to have cumulative benefits when compared to single-site alternatives with the same locations. Following screening, the PDT recognized that some alternative plans to retrofit stormwater detention structures were still important to evaluate in specific combinations, even though they did not meet planning objectives (specifically, reduced flows throughout Flat Creek) when evaluated individually. Because of the relatively small drainage area of some stormwater detention structures, they did not individually reduce flows in Flat Creek, and thus did not meet planning objectives. However, model results suggested that some stormwater detention structures could be important components of a plan under two scenarios: in combination with immediately downstream stream restoration alternatives, or in combination with other stormwater detention structures in the same part of the watershed.

As a result of the reformulation, the PDT developed 12 combination alternative plans. Twenty-four restoration alternatives were developed for the Flat Creek watershed from the 12 stream problem sites and 16 stormwater detention structure problem sites (Table 6-2). The 12 single-site alternatives (stream restorations) and the 12 combination alternatives (24 alternatives total, plus the No Action Alternative) were carried forward. All other alternative plans were dropped. The measures listed below under each formulated alternative were selected to address the specific problems observed at the site during field assessments. During formulation, the PDT considered many combinations of measures to address problems, avoid constraints, and meet the planning objectives. The problems in Flat Creek varied by severity (such as amount of sedimentation in a given area) and extent (distance along the stream). However, they were similar in type, where most stream reaches were channelized with degraded habitat because of sedimentation and a limited riparian ecosystem. As a result, the PDT formulated one alternative plan to address each individual problem site. Measures were selected and combined to address the specific problems observed. Other measures were eliminated if they did not specifically address the problem, were less effective than the selected measures, did not meet the planning objectives, or could not be implemented because of site constraints. For instream measures, log sills were not used for grade control in any alternative plans, because other instream measures were deemed more appropriate for channel conditions and to redirect flow to the center of the stream. Although log sills are well-suited for smaller stream systems experiencing some degree of incising, the PDT determined that a more robust method of grade control (such as engineered riffles or cross vanes) would be more appropriate for stream profile stabilization and to address the more severe incising conditions observed at problem sites. Bank stabilization measures were selected based on observed conditions, with measures including bank grading, matting, or planting used instead of riprap (or other bank hardening



- ERM Sampling Station
- Stormwater Detention Problem Site
- Streams
- Stream Problem Areas
- Stormwater Detention Drainage Area
- Lower Flat Creek Subwatershed
- Upper Flat Creek Subwatershed

FIGURE 6-1
Problem Sites Included in Final Array of Alternative Plans
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approaches) where possible. Riparian measures (if selected) were selected as appropriate to enhance disturbed riparian ecosystem conditions.

Each alternative is described below, along with a discussion of how the PDT applied measures to address problems.

No Action Alternative

The No Action Alternative represents the option of not implementing any restoration measures in the watershed. It provided a baseline for comparison of the potential impacts of the proposed action. If no action was to be taken, it was expected that the Flat Creek watershed would continue to degrade as additional development occurred, and it was likely that water quality, fish communities, and benthic macroinvertebrate communities would continue to decline.

Alternative A (Stream Problem Site 1)

Alternative A is in a residential subdivision in the upper reaches of a tributary to Flat Creek, between sampling stations FLG-4 and FLG-5 (near Atlanta Highway and Cronic Street). The site is characterized by a widening and incising stream channel, displaying a lack of adequate velocity/depth regimes and riffle substrate. The stream reach includes about 300 feet of moderate bank erosion (50 to 75 percent bare soil) and 150 feet of severely eroded (> 75 percent bare soil) banks. Banks range in height from 4 to 12 feet. To address channel widening and incising, the instream measures listed below were selected for grade control and to deflect flow from eroding banks. The bank stabilization measures listed below were selected to restore the eroded banks and to protect the streambanks from continued degradation.

Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures are not necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. No riparian measures were selected for Alternative A because the riparian ecosystem is intact, with mature woody vegetation along both sides of the stream. If Alternative A were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles	Create bankfull bench	None selected	None selected
J-hooks	Bank grading		
Cross vanes	Bank stabilization matting		
Boulders	Streambank planting		

Alternative B (Stream Problem Site 2)

Alternative B is located within a business district near Banks Street and in the headwaters of Flat Creek. The site includes a 900-foot stream reach characterized by a widening and incising channel section. Riparian ecosystems include lawns, open fields, impervious structures, and areas dominated by kudzu. A collapsing section of box culvert was observed within the problem site. The downstream part of the site includes a 400-foot reach consisting of severe erosion on both banks (10-foot bank height) and a sewer pipe impeding flow. The middle section of the project site includes a 350-foot piped section, whereas the upstream 150-foot reach consists of lower (4-foot) banks having moderate erosion.

To address channel widening and incising, the instream measures listed below were selected for grade control and to deflect flow from eroding banks. The bank stabilization and riparian ecosystem enhancement measures listed below were selected to restore the eroded banks and to protect the streambanks and riparian ecosystem from continued degradation. Maintenance of the collapsing box culvert is included as a selected restoration measure. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures would not be necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles J-hooks Cross vanes Boulders Culvert replacement	Create bankfull bench Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	None selected

Alternative C (Stream Problem Site 18)

Alternative C is located in a residential subdivision on a tributary to the mainstem of Flat Creek, upstream of sampling station FLG-5, in the Lower Flat Creek subwatershed. The total stream length is roughly 150 feet, including a 50-foot segment exhibiting severe erosion (> 75 percent bare soil) and a 12-foot headcut that is actively eroding. In the stream segment immediately upstream of Alternative C, drain pipes from surrounding residential areas are present, trash has been dumped in the stream, and severe erosion is present. To address headcutting, the instream measures listed below were selected for grade control and to deflect flow from eroded banks. The bank stabilization measures listed below also were selected to restore the eroded banks and to protect the streambanks from continued degradation.

Based on watershed model results for erosivity and sediment production, which account for changing flow conditions, flow attenuation measures would not be necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. No riparian measures were selected for this alternative, because the riparian ecosystem is intact with mature woody vegetation along both sides of the stream. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles J-hooks	Create bankfull bench Bank grading	None selected	None selected

Cross vanes	Bank stabilization matting
Boulders	Streambank planting

Alternative D (Stream Problem Site 23)

Alternative D is located in a residential subdivision (near Wood Avenue and west of Atlanta Highway) on a tributary to the mainstem of Flat Creek, in the Lower Flat Creek subwatershed. The site is characterized by an actively widening channel with severe erosion (75 to 100 percent bare soil) for roughly 200 feet. The left bank riparian corridor was cleared for a parallel utility, and the riparian areas are dominated by invasive species, including Chinese privet. The site has limited velocity/depth regimes and a lack of adequate riffles.

To address channel widening and incising, the instream measures listed below were selected for grade control and to deflect flow from eroded banks. In addition, the bank stabilization and riparian ecosystem enhancement measures (including invasive species management) listed below were selected to restore the eroded banks and to protect the existing streambanks and riparian ecosystem from continued degradation. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures are not necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles	Create bankfull bench	Planting of native hardwoods	None selected
J-hooks	Bank grading	Seeding and mulching	
Cross vanes	Bank stabilization matting		
Boulders	Streambank planting		

Alternative E (Stream Problem Site 25)

Alternative E is located in a residential subdivision (near Hilton Drive) on a tributary to the mainstem of Flat Creek, in the Upper Flat Creek subwatershed. The tributary's confluence with the mainstem is just downstream of sampling station FLG-4. The problem site extends roughly 250 feet in length, and consisted of banks 5 feet tall and severely eroded (75 to 100 percent bare soil). There was also a steep drop in streambed elevation (known as a knick point) that was causing the stream to incise and erode. The knick point will move upstream if left unchecked.

To address the eroded banks and to protect the streambanks from continued degradation (particularly upstream of the knick point), the instream and bank stabilization measures listed below were selected for grade control, bank stabilization, and flow deflection. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures are not necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. No riparian measures were selected for this alternative because the riparian ecosystem is intact with mature woody vegetation along both sides of the stream. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles J-hooks Cross vanes Debris jam removal Boulders	Create bankfull bench Bank grading Bank stabilization matting Streambank planting	None selected	None selected

Alternative F (Stream Problem Site 26)

Alternative F is located in an industrial/commercial area in the Upper Flat Creek subwatershed (near E. E. Butler Parkway and Chestnut Street). The site is characterized by a widening and incising stream channel, displaying a lack of adequate velocity/depth regimes and riffle substrate. The total stream reach is roughly 900 feet, with 250 feet having moderate bank erosion (50 to 75 percent bare soil). The riparian ecosystems consisted of some buildings/structures on both sides of the stream, primarily near the southern extent of the problem site. These structures pose a minor constraint in implementing riparian ecosystem enhancement for a small part of the reach. Invasive species, including Chinese privet, dominate the riparian corridor.

To address channel widening and incising, the instream measures listed below were selected for grade control and to deflect flow from eroded banks. The bank stabilization and riparian measures (including invasive species management) listed below were selected to restore the eroded banks, protect the streambanks and riparian ecosystems from continued degradation. Based on watershed model results for erosivity and sediment production, which account for changing flow conditions, flow attenuation measures are not necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles J-hooks Cross vanes Boulders	Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	None selected

Alternative G (Stream Problem Site 28)

Alternative G is located in a residential/commercial area in the Upper Flat Creek subwatershed, between Grove Street and Maple Street. Within this 200-foot reach, most of the right bank riparian corridor consists of buildings and paved parking areas, with one business significantly losing property because of severe streambank erosion. The right bank is roughly 8 feet high and severely eroded (75 to 100 percent bare soil) for a distance of about 100 feet, whereas the left bank is roughly 5 feet high and moderately eroded (50-75 percent bare soil) for a distance of about 150 feet. The left bank riparian corridor had been cleared for the maintenance of a parallel utility.

To address channel widening and bank erosion, the instream and bank stabilization measures listed below were selected to deflect flow from eroded banks, restore the eroded banks, and protect the streambanks from continued degradation. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures would not be necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. No riparian measures were selected for this alternative because of constraints associated with floodplain buildup (including paved surfaces, buildings, and an existing utility easement). If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
J-hooks	Create bankfull bench Bank grading Bank stabilization matting Streambank planting	None selected	None selected

Alternative H (Stream Problem Site 29)

Alternative H is located in the Upper Flat Creek subwatershed on city-owned property near Pine Street and High Street. The total stream reach is roughly 600 feet, with about 200 feet having moderate bank erosion (50 to 75 percent bare soil). The remaining 400 feet of the reach had been piped. The segment of stream not channelized by piping has eroded banks resulting in an overwidened, unstable stream channel. The riparian ecosystems consisted mainly of open space, but invasive species, including Chinese privet and kudzu, occur along both banks of the open channel section.

To address channel widening, the instream measures and bank stabilization measures listed below were selected to deflect flow from eroded banks, restore the eroded banks, and protect the existing streambanks from continued degradation. Restoring 250 feet of the channelized/piped segment of stream was selected to reestablish a natural stream section and restore ecosystem habitat. Finally, riparian measures (including invasive species management) listed below were selected to restore and enhance the riparian ecosystem. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures are not necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
J-hooks Debris jam removal	Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	None selected

Alternative I (Stream Problem Site 32)

Alternative I is located along the mainstem of Flat Creek in a residential/commercial area just downstream of sampling station FLG-A (between Atlanta Highway and Dorsey Street). The site includes a channelized and actively widened 1,800-foot stream. Banks are roughly 9 feet high and moderately eroded (50 to 75 percent bare soil) over at least 700 feet of the reach. The right bank riparian corridor has lawns throughout most of the reach, and the left bank riparian corridor was cleared for a parallel utility.

To address channel widening and bank erosion, the instream and bank stabilization measures listed below were selected to deflect flow from eroded banks, restore the eroded banks, and protect the streambanks from continued degradation. The riparian measures listed below were selected to enhance vegetative protection along segments of the ecosystem affected by clearing and development. Based on watershed model results for erosivity and sediment production, which account for changing flow conditions, flow attenuation measures would not be necessary to sustainably address problems, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles	Rootwads	Planting of native hardwoods	None selected
Boulders	Bank grading	Seeding and mulching	
Stone toe protection	Bank stabilization matting		
	Streambank planting		

Alternative J (Stream Problem Site 33)

Alternative J is located along the mainstem of Flat Creek in a commercial/industrial area just upstream of sampling station FLG-4 and downstream of Highland Terrace. The site includes a channelized and actively widened 700-foot stream reach. Banks are roughly 8 feet high, steep, and moderately to severely eroded throughout the site. The riparian corridor on the right bank includes lawns throughout most of the reach. The riparian corridor on the left bank was cleared for a parallel utility.

To address channel widening and bank erosion, the instream and bank stabilization measures listed below were selected to deflect flow from eroded banks, restore the eroded banks, and protect the existing streambanks from continued degradation. The riparian measures listed below were selected to enhance vegetative protection along segments of the ecosystem that had been affected by clearing and development. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures would not be necessary to sustainably address problems, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*

Engineered riffles Stone toe protection	Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	None selected

Alternative K (Stream Problem Site 39)

Alternative K is located along the mainstem of Flat Creek in a commercial/industrial area just upstream of sampling station FLG-A, near Pearl Nix Parkway and Dorsey Street. The total site reach extends roughly 750 feet and includes a 200-foot segment of severe erosion on the right bank. The riparian ecosystems had been significantly affected, with buildings and paved parking surfaces situated on both sides of the channel. The channel is partially lined with concrete for roughly 200 feet, which would be removed and replaced with a natural stream section if this alternative were selected. The physical habitat at the site scored very low, primarily because of significant channel alteration, poor bank stability and vegetation, disrupted riparian ecosystems, and an inadequate amount of substrate and cover.

To address bank erosion, the instream and bank stabilization measures listed below were selected to deflect flow from eroded banks, restore the eroded banks, and protect the streambanks from continued degradation. The riparian measures listed below were selected to enhance vegetative protection along segments of the ecosystem that had been affected by clearing and development. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures would not be necessary to sustainably address problems, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
J-hooks	Adjust stream meander Bank grading Create bankfull bench Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	None selected

Alternative L (Stream Problem Site 42)

Alternative L is located near Lee Gilmer Airport, in the headwaters of Flat Creek. The site is characterized by a widening and incising stream channel, displaying a lack of adequate velocity/depth regimes and riffle substrate. The overall reach extends 800 feet and includes a 200-foot segment of severe erosion on both banks. The riparian ecosystems are severely affected, with buildings and paved parking surfaces on the right bank and residential lawns on the left. The physical habitat at the site scored low, primarily because of poor bank stability and vegetation, disrupted riparian ecosystems, a low frequency of riffles, and an inadequate amount of substrate suitable for aquatic organisms.

To address channel widening and incising, the instream measures listed below were selected for grade control and to deflect flow from eroded banks. In addition, the bank stabilization and riparian ecosystem enhancement measures listed below were selected to restore the eroded banks and to protect the streambanks and riparian ecosystem from continued degradation. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures would not be necessary to sustainably address problems, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
J-hooks	Adjust stream meander Create bankfull bench Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	None selected

Alternative M (Stream Problem Sites 1 and 23)

Alternative M addresses the degraded ecosystem conditions observed at problem sites 1 and 23. Existing conditions at those sites are discussed under Alternatives A and D. A combined list of selected measures is listed below. Recognizing that the amount and success of habitat improvements may benefit from restoring multiple stream reaches in a similar segment of the watershed, Alternative M combines Alternatives A and D. Combining the stream problem sites into a stand-alone alternative was done primarily because of proximity of location (each site is located along a tributary to mainstem Flat Creek, within about a quarter mile of each other), and also similarities in degraded ecosystem conditions and selected measures necessary to address problems.

Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures are not necessary to sustainably address problems, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
J-hooks Cross vanes Boulders	Create bankfull bench Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	None selected

Alternative N (Stream Problem Site 25 and Stormwater Detention Structure Problem Sites A10687 and CH033)

Alternative N addresses degraded ecosystem conditions observed at stream problem site 25, combined with flow attenuation/peak discharge reduction opportunities identified for Stormwater Detention Structure Problem Sites A10687 and CH033. It was formulated to evaluate benefits of peak flow attenuation in conjunction with physical stream restoration. Existing conditions at stream problem site 25 are discussed under Alternative E. In Alternative N, stormwater detention structure problem sites A10687 and CH033 are combined with this stream problem site because of proximity to the stream segment (within one-half mile), relative location immediately upstream of the stream site, and potential to reduce peak flows released to the stream.

Stormwater detention structure problem site A10687 is a dry detention basin in Lower Flat Creek near Browns Bridge Road. Based on design standards in the GSMM, the site does not provide adequate water quality or channel protection volume. The selected measures include increasing the storage volume by excavating the sides and bottom of the basin, modifying the outlet control structure, and adding a trash rack. The outlet control structure half-round also needs perforations and reinstallation.

Stormwater detention structure problem site CH033 is a dry detention pond in Lower Flat Creek near Browns Bridge Road, and also near stormwater detention structure problem site A10687. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of the basin to increase capacity. The combined stream restoration and flow attenuation measures selected for Alternative N are listed below. No riparian measures are selected for this alternative because the riparian ecosystem is intact with mature woody vegetation along both sides of the stream. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles	Create bankfull bench	None selected	Retrofit of outlet control structure
J-hooks	Bank grading		Expansion of existing detention basin
Cross vanes	Bank stabilization matting		
Debris jam removal	Streambank planting		
Boulders			

Alternative O (Stream Problem Site 33 and Stormwater Detention Structure Problem Sites A14199, CH015, CH016, CH027 and CH106)

Alternative O addresses degraded ecosystem conditions observed at stream problem site 33, combined with flow attenuation/peak discharge reduction opportunities identified for Stormwater Detention Structure Problem Sites A14199, CH015, CH016, CH027 and CH106. It was formulated to evaluate benefits of peak flow attenuation in conjunction with physical stream restoration. Existing conditions at stream problem site 33 are discussed under Alternative J. Stormwater Detention Structure Problem Sites A14199, CH015, CH016, CH027 and CH106 are combined with the stream problem site because of their proximity to the stream segment (within one-half mile), their relative location immediately upstream of the stream site, and their potential to reduce peak flows released to the stream.

Stormwater detention structure problem site A14199 is a wet detention basin in Upper Flat Creek near Delta Drive. It does not provide adequate channel protection volume. Selected measures included retrofitting the site to an extended wet detention basin by retrofitting the outlet control structure orifice to reduce peak flow discharge rates.

Stormwater detention structure problem site CH015 is a dry detention pond in Upper Flat Creek near Shallowford Road and also near stormwater detention structure problem site CH016. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH016 is a dry detention pond in Upper Flat Creek near Skelton Road and also near stormwater detention structure problem site CH015. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH027 is a dry detention basin in Upper Flat Creek near Lyman Street. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity. The outlet control structure also requires maintenance to remove debris.

Stormwater detention structure problem site CH106 is a dry detention basin in Upper Flat Creek near Browns Bridge Road and Pearl Nix Parkway. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity. The basin requires maintenance to remove sediment buildup from the bottom of the pond. The combined stream restoration and flow attenuation measures selected for Alternative O are listed below.

If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles Stone toe protection	Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	Retrofit of outlet control structure Expansion o existing detention basin

Alternative P (Stream Problem Site 32 and Stormwater Detention Structure Problem Site CH048)

Alternative P addresses degraded ecosystem conditions observed at stream problem site 32, combined with flow attenuation/peak discharge reduction opportunities identified for

Stormwater Detention Structure Problem Site CH048. Existing conditions at stream problem site 32 are discussed for Alternative I. Stormwater detention structure problem site CH048 was combined with the stream problem site because of its proximity to the stream segment (about one-half mile), its relative location upstream of the stream site, and its potential to reduce peak flows released to the stream. CH048 is a dry detention basin in Upper Flat Creek near Airport Parkway. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity. The combined stream restoration and flow attenuation measures selected for Alternative P are listed below. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles	Rootwads	Planting if native hardwoods	Retrofit of outlet control structure
Boulders	Bank grading	Seeding and mulching	Expansion of existing detention basin
Stone toe protection	Bank stabilization matting		
	Streambank planting		

Alternative Q (Stormwater Detention Structure Problem Sites A14911, A15015, CH036, CH048 and CH062)

Alternative Q includes flow attenuation/peak discharge reduction at multiple stormwater detention structure problem sites in the same headwaters part of Flat Creek, where flow attenuation might have the greatest downstream benefit (A14911, A15015, CH036, CH048 and CH062). The PDT formulated this alternative isolates the potential aquatic ecosystem benefits that could occur with flow attenuation but without instream ecosystem restoration. The alternative covers multiple locations to maximize the potential of the alternative to have a significant benefit. If these 5 locations were formulated in other combinations (that is 2 locations only, or 4 locations only), watershed model results indicate that they would not have a significant effect on downstream flows in Flat Creek.

Stormwater detention structure problem site A14911 is a dry detention basin in Upper Flat Creek near West Ridge Road and also near stormwater detention structure problem site A15015. The site does not have adequate water quality or channel protection volume. Selected measures include retrofitting the site to a dry extended detention basin by retrofitting the outlet control structure and decreasing the size of the 18-inch outlet control pipe.

Stormwater detention structure problem site A15015 was a dry detention basin in Upper Flat Creek near West Ridge Road and also near stormwater detention structure problem site A14911. The site does not provide adequate water quality or channel protection volume. Selected measures include retrofitting the site to an extended dry detention basin by replacing the outlet control structure and excavating the sides or bottom of the basin to increase capacity.

Stormwater detention structure problem site CH036 is a dry detention pond in Upper Flat Creek near Aviation Boulevard. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH048 is a dry detention basin in Upper Flat Creek near Airport Parkway. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH062 is a dry detention basin in Upper Flat Creek near Airport Parkway. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by replacing the outlet control structure and excavating the sides or bottom of basin to increase capacity.

The stream restoration and flow attenuation measures selected for Alternative Q are listed below.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
None selected	None selected	None selected	Retrofit of outlet control structure Expansion of existing detention basin

Alternative R (Stream Problem Site 42 and Stormwater Detention Structure Problem Sites A15094 and CH025)

Alternative R addresses degraded ecosystem conditions observed at stream problem site 42, combined with flow attenuation/peak discharge reduction opportunities identified for stormwater detention structure problem sites A15094 and CH025. Conditions at stream problem site 42 are discussed under Alternative L. Stormwater detention structure problem sites A15094 and CH025 were combined with the stream problem site because of their proximity to the stream segment (within one-quarter mile), their relative location near the stream site, and their potential to reduce peak flows released to the stream.

Stormwater detention structure problem site A15094 is a dry detention pond in Upper Flat Creek near Dean Street. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH025 is a wet detention pond in Upper Flat Creek near Marler Street. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended wet detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

The combined stream restoration and flow attenuation measures selected for Alternative R are listed below. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
J-hooks	Adjust stream meander Create bankfull bench Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	Expansion of existing detention basin

Alternative S (Stream Problem Site 26 and Stormwater Detention Structure Problem Site CH022)

Alternative S addresses degraded ecosystem conditions observed at stream problem site 26, combined with flow attenuation/peak discharge reduction opportunities identified for stormwater detention structure problem site CH022. Existing conditions at site 26 are discussed under Alternative F. Stormwater detention structure problem site CH022 was combined with the stream problem site because of its proximity to the stream segment (within one-half mile) and its potential to reduce peak flows released to the stream.

Stormwater detention structure problem site CH022 is a wet detention pond in Upper Flat Creek near Bradford Street Extension. The site does not provide adequate water quality and channel protection volume. Selected measures included retrofitting the site to an extended wet detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

The combined stream restoration and flow attenuation measures selected for Alternative S are listed below. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles J-hooks Cross vanes Boulders	Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	Expansion of existing detention basin

Alternative T (Stream Problem Sites 2, 28, and 29)

Alternative T addresses degraded ecosystem conditions at stream problem sites 2, 28, and 29. Existing conditions at those sites are discussed under Alternatives B, G, and H. A combined list of selected measures is provided below. Recognizing that the amount and success of habitat improvements may benefit from restoring multiple stream reaches in a similar part of the watershed, this alternative combines Alternatives B, G, and H. Implementation of stream restoration at these sites would introduce various measures aimed at restoring instream habitat communities, stabilizing eroded streambanks, and enhancing the riparian ecosystems. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures would not be necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles J-hooks Cross vanes Debris jam removal Boulders	Create bankfull bench Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	None selected

Alternative U (Stream Problem Sites 2, 28, 29, and 39)

Alternative U addresses degraded ecosystem conditions observed at stream problem sites 2, 28, 29 and 39. Existing conditions at those sites are discussed under Alternatives B, G, H, and K. A combined list of selected measures is listed below. Similar to Alternative T, and recognizing that the amount and success of habitat improvements may benefit from restoring multiple stream reaches in a similar part of the watershed, this alternative combines Alternatives B, G, H, and K. By including stream problem site 39, Alternative U introduces an additional highly affected problem site in the mid-Upper Flat Creek subwatershed. Implementation of stream restoration at the sites would introduce various measures aimed at restoring instream habitat communities, stabilizing eroded streambanks, and enhancing the riparian ecosystems. Based on watershed model results for erosivity and sediment production, which account for changing flow conditions, flow attenuation measures would not be necessary to sustainably address problems in this location, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles J-hooks Cross vanes Debris jam removal Boulders	Adjust stream meander Create bankfull bench Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	None selected

Alternative V (Stream Problem Sites 32 and 33, and Stormwater Detention Structure Problem Sites A14199, CH015, CH016, CH027, CH053, and CH106)

Alternative V addresses degraded ecosystem conditions observed at stream problem sites 32 and 33 combined with flow attenuation/peak discharge reduction opportunities identified for stormwater detention structure problem sites A14199, CH015, CH016, CH027, CH053, and CH106. Existing conditions at stream problem sites 32 and 33 are discussed under Alternatives I and J. Recognizing that the amount and success of habitat improvements may benefit from restoring multiple stream reaches in a similar area of the watershed, Alternative V combines Alternatives I and J. Stormwater detention structure problem sites A14199, CH015, CH016, CH027, and CH106 were combined primarily for stream problem site 33 because of their proximity to the stream segment (within one-half mile), their relative location immediately upstream of the stream site, and their potential to reduce peak flows released to the stream. Stormwater detention structure problem site CH053 was combined primarily for stream problem site 32 because of its proximity to the stream segment (within one-half mile), its relative location upstream of the stream site, and their potential to reduce peak flows released to the stream.

Stormwater detention structure problem site A14199 is a wet detention basin in Upper Flat Creek near Delta Drive. It does not provide adequate channel protection volume. Selected measures included retrofitting the site to a wet extended detention basin by retrofitting the outlet control structure orifice to reduce peak flow discharge rates.

Stormwater detention structure problem site CH015 is a dry detention pond in Upper Flat Creek near Shallowford Road (and near stormwater detention structure problem site CH016). The site does not provide adequate water quality and channel protection volume. Selected measures included retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH016 is a dry detention pond in Upper Flat Creek near Skelton Road and also near stormwater detention structure problem site CH015. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH027 is a dry detention basin in Upper Flat Creek near Lyman Street. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity. The outlet control structure requires maintenance to remove debris.

Stormwater detention structure problem site CH053 is a dry detention basin in Upper Flat Creek near Industrial Boulevard. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH106 is a dry detention basin in Upper Flat Creek near Browns Bridge Road and Pearl Nix Parkway. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity. The basin requires maintenance to remove sediment buildup from the bottom of the pond.

The combined stream restoration and flow attenuation measures selected for Alternative V are listed below. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*

Engineered riffles Boulders Stone toe protection	Rootwads Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	Retrofit of outlet control structure Expansion of existing detention basin

Alternative W (Stream Problem Sites 26 and 42, and Stormwater Detention Structure Problem Sites A15094, CH022, and CH025)

Alternative W addresses degraded ecosystem conditions observed at stream problem sites 26 and 42, combined with flow attenuation/peak discharge reduction identified for stormwater detention structure problem sites A15094, CH022, and CH025. Existing conditions at stream problem sites 26 and 42 are discussed under Alternatives F and L. Recognizing that the amount and success of habitat improvements may benefit from restoring multiple stream reaches in a similar part of the watershed, Alternative W combines Alternatives F and L. Stormwater detention structure problem sites A15094, CH022, and CH025 were combined primarily for stream problem site 42 because of their proximity to the stream segment (within one-half mile), their relative location to the stream site, and their potential to reduce peak flows released to the stream.

Stormwater detention structure problem site A15094 is a dry detention pond in Upper Flat Creek near Dean Street. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended dry detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH022 is a wet detention pond in Upper Flat Creek near Bradford Street Extension. The site does not provide adequate water quality and channel protection volume. Selected measures include retrofitting the site to an extended wet detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

Stormwater detention structure problem site CH025 is a wet detention pond in Upper Flat Creek near Marler Street. The site does not provide adequate water quality and channel protection volume. Selected measures included retrofitting the site to an extended wet detention pond to increase efficiency by retrofitting the outlet control structure and excavating the sides or bottom of basin to increase capacity.

The combined stream restoration and flow attenuation measures selected for Alternative W are listed below. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles J-hooks Boulders	Rootwads Create bankfull bench Bank grading Bank stabilization matting Streambank planting	Planting of native hardwoods Seeding and mulching	Expansion of existing detention basin

Riprap

Alternative X (Stream Problem Site 32 and 33)

Alternative X addresses degraded ecosystem conditions observed at stream problem sites 32 and 33. Conditions at these sites are discussed under Alternatives I and J. Selected measures are listed below. Recognizing that the amount and success of habitat improvements may benefit from restoring multiple stream reaches in a similar part of the watershed, Alternative X combines Alternatives I and J. Combining these stream problem sites into a stand-alone alternative was done partially because of proximity (each site is along the Flat Creek mainstem and within a half mile of each other) and because of similarities in degraded ecosystem conditions and selected measures necessary to address the current problems.

Alternative X includes restoration of a combined length of 2,500 feet of a highly degraded segment of Flat Creek. Based on watershed model results for erosivity and sediment production, which accounts for changing flow conditions, flow attenuation measures are not necessary to sustainably address problems, reduce sedimentation, and restore aquatic ecosystems. If this alternative were selected for implementation, a construction easement would be required to access the stream channel along whichever bank better facilitates site entry while minimizing removal of trees and other vegetation. Following construction, the easement would be maintained for future site access.

Instream Measures:	*Bank Stabilization Measures:*	*Riparian Measures:*	*Flow Attenuation Measures:*
Engineered riffles	Rootwads	Planting of native hardwoods	None selected
Boulders	Bank grading	Seeding and mulching	
Stone toe protection	Bank stabilization matting		
	Streambank planting		

TABLE 6-2
Ecosystem Restoration Alternatives
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Alternative	Stream Problem Sites												Stormwater Detention Structure Problem Sites																
	1	**2**	**18**	**23**	**25**	**26**	**28**	**29**	**32**	**33**	**39**	**42**	**A10687**	**A14199**	**A14911**	**A15015**	**A15094**	**CH015**	**CH016**	**CH022**	**CH025**	**CH027**	**CH033**	**CH036**	**CH048**	**CH053**	**CH062**	**CH106**
A	X																											
B		X																										
C			X																									
D				X																								
E					X																							
F						X																						
G							X																					
H								X																				
I									X																			
J										X																		
K											X																	
L												X																
M	X			X																								
N					X								X										X					
O										X				X				X	X			X						X
P									X																X			
Q															X	X								X	X		X	
R												X					X				X							
S						X														X								
T		X					X	X																				
U		X					X	X			X																	
V									X	X				X				X	X			X				X		X
W						X						X					X			X	X							
X									X	X																		

6.3 Evaluation of Reformulated Alternative Plans

In accordance with the P&G, alternatives should be screened and evaluated based on four criteria: completeness, effectiveness, efficiency, and acceptability. Alternatives must also meet at least one of the planning objectives or other screening criteria. Specific methods to evaluate these criteria depend on the planning problems and objectives. Section 7 (Analysis of Future with Project Conditions) details the methods used to evaluated effectiveness for the Flat Creek watershed alternatives. Completeness and acceptability are detailed in the Detailed Project Report, and efficiency is detailed in Appendix G (Economic Appendix) to the Detailed Project Report.

7. Analysis of Future with Project Conditions

Effectiveness of an alternative is "the extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities" (P&G Section VI.1.6.2(c)(2)). It is associated with the plan's contribution to solving the planning problems and meeting plan objectives. Effectiveness should be considered during the screening of alternatives as well as evaluation of alternatives (Planning Manual, 1996). During the screening process described in Section 6.1 (Screening Alternative Plans), effectiveness was evaluated based on the conditions at the alternative location, to identify alternatives that had limited potential to improve habitat and contribute to plan objectives. This process is detailed in the Environmental Appendix and summarized below.

During the evaluation process of reformulated alternatives, a more rigorous approach was used to quantify the effectiveness of remaining alternatives, in terms of habitat units predicted by the ERM. The ERM outputs habitat units which are a representation of fish, benthic macroinvertebrates, and physical habitat. Fish IBI scores are out of a possible 60 points for each sampling station, BMI scores out of 100 points, and physical habitat scores out of 200 points. The ERM outputs are presented as a percentage of the best possible score for the watershed as a whole. Each alternative's benefit to aquatic habitat was evaluated in terms of habitat units, or the amount of potential improvement the alternative may have on fish and benthic macroinvertebrate communities, as well as physical habitat diversity and availability. The approach to predict the benefits (in terms of habitat units) of alternative plans, and the predicted results are detailed below.

7.1 Approach to Predicting Habitat Units

The third step to identifying environmental outputs was to predict the future with project conditions of the watershed, and then to use best professional judgment to predict future biological scores for each alternative considered. This step was the basis of the benefit calculation for the alternatives. The resulting environmental outputs from the ERM were used in the cost-benefit analysis component of the planning process.

The process used to develop future with project biological scores, detailed below, included the following steps:

- **Future Biological Score Ranges—**Determine the minimum and maximum changes in biological scores, at the six sampling stations which could result from implementation of alternatives.
- **Hydrologic and Hydraulic Modeling—**Predict changes in environmental conditions at each alternative site, assuming that the plan is implemented.

The first step involved a review of historical environmental conditions and biological data in Hall County (CH2M HILL, 2000; CH2M HILL, 2003; Brown and Caldwell, 2006; and CH2M HILL, 2007b). Modeling was conducted using the watershed model described previously. From the results of these analyses, and the locations of the alternatives, future biological scores were predicted, and the benefits of each alternative were quantified using the ERM to predict the future habitat units. This section details the analysis conducted to predict future biological scores in Flat Creek, and summarizes the results for each potential alternative identified.

7.2 Future Biological Score Ranges

Scores from the 2007 biological monitoring conducted in Flat Creek were used to determine the minimum and maximum amount of improvement expected to result from the implementation of an alternative. Restoration measures were expected to reduce sediment, flow and velocity in localized reaches of Flat Creek, improving the habitat availability and quality. However, the aquatic species that can colonize the improved habitat also depends on other natural environmental variables such as climate, populations in other nearby watersheds, natural barriers to fish migration (i.e. Lake Lanier). As a result, possible future biological score ranges were based on historical species assemblages and biological scores, as well as biological communities in other, less degraded watersheds. For each biological score, individual metrics were examined with consideration to historical (1999–2003) Hall County data, which was assumed to be a fair representation of future with project implementation. Future fish IBI, BMI, and physical habitat score ranges were predicted based on current (2007) data and on historical sampling data. The results are summarized below.

7.2.1 Future Fish IBI Score Range

For each Flat Creek sampling station, the minimum and maximum amount of improvement in fish IBI scores resulting from an upstream ecosystem restoration project was approximated. The potential changes in each metric score are shown in Table 7-1. It was assumed that the minimum amount of improvement for each metric (which can be negative) was equal to the minimum amount of potential decline under future without project conditions. This minimum improvement, therefore, accounts for the potential for alternatives to provide minimal effects on certain sampling stations. A possible reason for this was the alternative's location relative to a sampling station. The maximum improvement, however, represents the most positive impact that an ecosystem restoration alternative could have on a downstream (or nearby) sampling station. A discussion of certain individual metric scores is provided below.

TABLE 7-1
Fish Community Predicted Score Analysis—with Project
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Metric and Minimum & Maximum Potential Future Improvement	Sampling Station							
	FLG-A		FLG-4		FLG-B		FLG-5	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Number of Native Fish Species	0	0	0	0	0	0	0	2
Number of Benthic Invertivore Species	0	0	0	0	0	0	0	0
Number of Native Sunfish Species	0	0	0	2	0	2	0	0
Number of Native Insectivorous Cyprinid Species	0	0	0	0	0	0	0	0
Number of Native Round-bodied Sucker Species	0	0	0	0	0	0	0	0
Number of Sensitive Species	0	0	0	0	0	0	0	0
Evenness	-2	0	0	4	0	2	-2	2
Proportion of Individuals as *Lepomis* Species	-2	0	0	2	-2	0	0	0
Proportion of Individuals as Insectivorous Cyprinids	0	0	0	0	-2	0	0	4
Proportion of Individuals as Generalist Feeders and Herbivores	0	2	0	4	-2	0	-2	0
Proportion of Individuals as Benthic Fluvial Specialists	0	0	0	0	0	0	0	0
Number of Individuals Collected per 200 Meters	0	2	0	2	0	0	0	2
Proportion of Individuals with External Anomalies	4	4	4	4	0	0	4	4
Sum of potential change	0	8	4	18	-6	4	0	14
2007 IBI Score	14	14	10	10	26	26	16	16
Predicted Scores w/ Minimum Change and Maximum Change	**14**	**22**	**14**	**28**	**20**	**30**	**16**	**30**

Number of Native Fish Species

During 1999 biological sampling, the maximum number of native fish species found in City of Gainesville streams was 10. Station FLG-5 was the only station which was expected to gain enough new native fish species to increase the score for this metric. The number of native fish species at this station could potentially increase from 8 to 11, resulting in an increase in metric score. Scores for the three other Flat Creek station were not expected to improve.

Number of Benthic Invertivore Species

Historically, no species of benthic invertivores have ever been found in Flat Creek. The most benthic invertivores that have ever been found in Gainesville streams is 1. The scores for this metric were not expected to increase.

Number of Native Sunfish Species

Based on a comparison between data at each sampling station, it assumed that an improvement in watershed conditions could lead to an increase in two native sunfish species at FLG-B (a bluegill and a warmouth) and one native sunfish species at FLG-4 (a warmouth). The number of species at the two other sampling stations was not expected to increase by an amount sufficient for score changes.

Number of Native Insectivorous Cyprinid Species

Flat Creek sampling stations have scored a 1 for this metric during all biological monitoring conducted to date. In addition, no City of Gainesville stream scored higher than a 1 for this metric in 2007. Despite ecosystem restoration, the increase in the number of native insectivorous cyprinid species which would be required for a score increase in not likely. Therefore, scores for this metric were not expected to increase with project implementation.

Number of Native Round-bodied Sucker Species

Historically, no species of round-bodied suckers have been found in any City of Gainesville stream. Therefore, no score change was expected.

Number of Sensitive Species

In 2007, no sensitive species were found in any City of Gainesville streams. In order for any of the Flat Creek sampling stations to score greater than a 1 for this metric, two species would need to be found. This was not expected based on historical sampling.

Evenness

It was possible for the evenness metric score at three of the Flat Creek sampling stations to improve (Station FLG-A scored a 5 in 2007). The 2007 score for Station FLG-4 was on the cusp of 1 and 3, so improvement at this station was expected to be as great as 4 points. Stations FLG-B and FLG-5 were both expected to score 2 points higher with an improvement in watershed conditions.

Proportion of Individuals as Lepomis Species

Consistent with the projections made about future native sunfish species, stations FLG-B and FLG-4 were expected to have an increase in Lepomis species with project. As a result, Station FLG-4 could score a 3 for this metric in the future. However, the increase in the proportion of individuals as *Lepomis* species at FLG-4 was not expected to be sufficient to result in a metric score increase.

Proportion of Individuals as Insectivorous Cyprinids

Station FLG-B scored a 5 proportion of individuals as insectivorous cyprinids during the 2007 biological monitoring. Due to the close proximity of this station to Station FLG-5, the number of spottail shiners at Station FLG-5 was expected to increase and result in an increase in this metric score. Scores at FLG-A and FLG-4 were not expected to improve.

Proportion of Individuals as Generalist Feeders and Herbivores

Based on 2007 scores for this metric at the downstream stations, it was expected that the proportion of individuals as generalist feeders and herbivores at Stations FLG-A and FLG-4 will decrease. The expected change would result in an increase of two points for this metric. Stations FLG-B and FLG-5 received the highest score for this metric in 2007, and so these scores cannot improve.

Proportion of Individuals as Benthic Fluvial Specialists

For this metric, Station FLG-5 received the maximum score of 5 in 2007, so the score at this location cannot increase. Though ecosystem restoration was expected to result in an increase in the proportion of individuals as benthic fluvial specialists at the three other Flat Creek stations, the current scores were so low that the increase was not expected to result in a metric score improvement. Therefore, this metric was not predicted to change for any Flat Creek sampling station.

Number of Individuals Collected per 200 Meters

In 2007, only 23 individuals were collected at Station FLG-B. The number of fish observed at this station was so low that an increase in this metric score was not expected. However, under future with project conditions, the number of individuals collected per 200 meters at the three other Flat Creek stations was predicted to increase a sufficient amount to result in a score change of 2 points.

Proportion of Individuals with External Anomalies

The proportion of individuals with external anomalies was expected to decline under future with project conditions. An improvement in water quality will cause a decrease in stress on the fish communities and therefore reduce the amount of disease. Note that this metric was expected to improve under future with and without project conditions due to the likely effect of drought conditions on the number of external anomalies in 2007.

7.2.2 Future BMI Score Range

For each Flat Creek sampling station, the minimum and maximum amount of improvement in BMI scores resulting from an upstream ecosystem restoration project was approximated. The potential changes in each metric score are shown in Table 7-2. In the same manner as fish IBI scores were predicted, it was assumed that the minimum amount of improvement for each metric was equal to the minimum amount of potential decline under future without project conditions. The maximum improvement represents the most positive impact that an ecosystem restoration alternative could have on a downstream (or nearby) sampling station. A discussion of certain individual metric scores is provided below.

TABLE 7-2
BMI Predicted Score Analysis—with Project
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Metric and Minimum & Maximum Potential Future Improvement	**Sampling Station**							
	FLG-A		**FLG-4**		**FLG-B**		**FLG-5**	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Plecoptera Taxa	0	18	0	18	0	18	0	18
Percent Trichoptera individuals	0	16	-16	38	-16	0	0	0
Percent *Chironomus* & *Cricotopus*/ Total Chironomidae	0	13	-14	4	-14	0	0	60
Tolerant taxa	0	78	-6	4	-6	56	-6	41
Percent Scraper	-1	12	0	9	0	10	-2	17
Clinger taxa	-5	30	-5	25	-5	51	-5	51
Average of Potential Change	-1	28	-7	16	-7	23	-2	31
2007 Score	17	17	36	36	40	40	37	37
Predicted Scores w/ Minimum Change and Maximum Change	**16**	**45**	**29**	**52**	**33**	**63**	**35**	**68**

Number of Plecoptera Taxa

In 2007, no Plecoptera taxa were found in Flat Creek. However, at all other City of Gainesville sampling stations, one Plecoptera taxon was found. Therefore it was expected that each Flat Creek station could gain 1 Plecoptera taxon; the associated score change is provided in Table 7-2.

Percent Trichoptera Taxa

The metric scores for percent of Trichoptera at stations FLG-5 and FLG-B were at a maximum value and cannot increase. Based on a comparison of scores between sampling stations, it was assumed that the percent of Trichoptera taxa at station FLG-4 could increase to 32 percent (resulting in a score of 100). In addition, with ecosystem restoration alternative implementation, the score as station FLG-A was expected to be comparable to the scores for FLG-4 in previous years. This would result in an increase in metric score of 16 points.

Percent *Chironomus* and *Cricotopus*/Total Chironomidae

As water quality increases, the number of *Chironomus* and *Cricotopus* per the total amount of Chironomidae was expected to decrease. The 2007 scores for this metric at stations FLG-4 and FLG-B were very high; therefore little to zero improvement in this metric score was expected at these locations. The predicted future score for station FLG-5 was based on the score at this station in 2003, with the assumption that conditions in 2003 were comparable to those with project. The predicted future score for station FLG-A was expected to increase and be comparable to the 2007 score at station FLG-5.

Tolerant taxa

When ecosystem restoration projects were implemented, the number of species which are tolerant to degradation was expected to decrease. It was predicted that the number of tolerant taxa can decrease up to 50 percent at any station affected by restoration measures. The change in score associated with this projection was shown in Table 7-2.

Percent Scraper

In 2007, all Flat Creek stations scored low for this metric. However, in previous years, the percent of scraper individuals was as high as 19 percent in Hall County streams. For future score predictions, it was assumed that the score for each station would improve to be comparable to higher scores at nearby stations, either during 2007 or previous biological monitoring.

Clinger taxa

Ecosystem restoration alternatives were expected to increase the availability of benthic macroinvertebrate habitat, including clean riffle substrate. It was expected that the number of clinger taxa will increase up to 9 taxa at the two upstream stations and that the downstream stations could have as many as 12 clinger taxa under future with project conditions. The respective increases in score for this metric are provided in Table 7-2.

7.2.3 Future Habitat Score Range

For each Flat Creek sampling station, the minimum and maximum amount of improvement in physical habitat scores resulting from an upstream ecosystem restoration project was approximated. The potential changes in each metric score are shown in Table 7-3. Again, it was assumed that the minimum amount of improvement for each was equal to the minimum amount of potential decline under future without project conditions. The maximum improvement represents the most positive impact that an ecosystem restoration project could have on a downstream (or nearby) sampling station.

A major goal of ecosystem restoration alternatives is to restore streams to a more natural state which can support a diverse and healthy aquatic community. These alternatives have the potential to significantly affect the physical habitat of streams. Of the 10 metrics by which habitat is rated, 7 were expected to improve at locations downstream of the restoration. The 3 metrics which were not predicted to change under future conditions were channel flow status, riparian zone conditions and channel alteration. These metrics are site-specific and would not be directly affected at a sampling station, when restorations are implemented in another location. For example, while stormwater detention structure projects affect stream flow, the downstream extent of such effects may be masked by flows from other parts of the drainage area at the downstream sampling stations included in the ERM. Likewise, though restoration measures may affect riparian conditions and channel alteration at the problem site, these factors will not necessarily change at the sampling stations.

For the 7 metrics which were expected to improve under future with project conditions, it was assumed that the maximum change possible was between 4 and 6 points (on average, an improvement in 1 qualitative condition category) at each station. Note that, in cases where a station's existing score was near the maximum value, the maximum change was limited to less than 4 points.

TABLE 7-3
Physical Habitat Predicted Score Analysis—with Project
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Metric and Minimum & Maximum Potential Future Improvement	Sampling Station							
	FLG-A		FLG-4		FLG-B		FLG-5	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Epifaunal substrate	-2.5	4.5	-3	5	-3	4	-5	5
Embeddedness	0	6	-4	5	-6	5	-7	5
Velocity/depth regime	-1.5	3.5	-1	4	-4	3	-1	4
Sediment deposition	-2	6	-4.5	5.5	-3.5	6.5	-7	5
Channel Flow Status	0	0	0	0	0	0	0	0
Channel Alteration	0	0	0	0	0	0	0	0
Frequency of riffles	0	5	0	6	0	3	0	2
Bank stability	-2	6	-3	4.5	-5	5	-4	2
Bank Vegetative protection	0	4	0	2.5	0	3.5	0	3
Riparian zone	0	0	0	0	0	0	0	0
Sum of potential change	-8	35	-15.5	32.5	-21.5	30	-24	26
2007 Score	81	81	98	98	129.5	129.5	153	153
Predicted Scores w/ Minimum Change and Maximum Change	**73**	**116**	**82.5**	**130.5**	**108**	**159.5**	**129**	**179**

7.3 Watershed Model Analysis

In order to determine the degree of improvement expected to result from each potential watershed alternative, the watershed model was used to project the reduction in TSS production resulting from implementation. Stream restoration implementation was characterized in the watershed model as a change to the base erosion rate. A stormwater detention structure retrofit was accounted for in the model by an increase in the efficiency value of that stormwater detention structure. The increase in efficiency resulted in a decrease in erosivity and upland TSS production in the stormwater detention structure's drainage area. Table 7-4 provides the reduction in TSS yield estimated at each Flat Creek sampling station, for each alternative, according to results of the watershed model. Each alternative was ranked according to its TSS yield reduction provided at each of the four Flat Creek sampling stations (Table 7-4). These ranks (4 representing the most TSS reduction and 1 representing the least TSS reduction) were based on 25^{th}, 50^{th} and 75^{th} percentiles at each station, and the values provide the basis of score predictions for future with project conditions.

TABLE 7-4
TSS Reduction at Sampling Stations for Rach Ecosystem Restoration Alternative
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Alternative	FLG-A (Flat Creek at Dorsey St.)		FLG-4 (Flat Creek at Hilton Dr.)		FLG-B (Flat Creek at Old Flowery Branch Rd.)		FLG-5 (Flat Creek at McEver Rd.)	
	TSS Yield Reduction (lb/acre/yr)[a]	Rank[b]	TSS Yield Reduction (lb/acre/yr)[c]	Rank[b]	TSS Yield Reduction (lb/acre/yr)[d]	Rank[b]	TSS Yield Reduction (lb/acre/yr)[e]	Rank[b]
A	--	--	--	--	25	3	19	3
B	78	4	55	3	32	3	25	3
C	--	--	--	--	--	--	3	1
D	--	--	--	--	12	2	9	2
E	--	--	--	--	12	2	9	2
F	37	3	26	2	15	2	12	2
G	24	2	17	1	10	1	8	1
H	21	2	15	1	9	1	7	1
I	--	--	108	4	64	4	49	4
J	--	--	48	3	28	3	22	3
K	6	1	4	1	2	1	2	1
L	20	1	14	1	8	1	6	1
M	--	--	--	--	37	3	28	3
N	--	--	--	--	12	2	9	2
O	--	--	49	3	29	3	23	3
P	--	--	108	4	64	4	49	4
Q	1	1	2	1	2	1	1	1
R	24	2	18	2	11	1	9	2
S	38	3	27	2	16	2	12	2
T	124	4	88	3	51	4	39	4
U	130	4	92	4	54	4	41	4
V	--	--	158	4	93	4	71	4
W	62	3	46	2	28	3	21	3
X	--	--	156	4	92	4	70	4
75th percentile	66	--	91	--	44	--	31	--
50th percentile	31	--	47	--	24	--	16	--
25th percentile	21	--	17	--	12	--	9	--

-- indicates stations which were not affected by the alternative (no TSS yield reduction)
[a] FLG-A reduction based on current TSS yield of 897 lb/acre/yr
[b] Rank 1 < 25th percentile; 25th percentile < Rank 2 ≤ 50th percentile; 50th percentile < Rank 3 ≤ 75th percentile; Rank 4 > 75th percentile
[c] FLG-4 reduction based on current TSS yield of 1,162 lb/acre/yr
[d] FLG-B reduction based on current TSS yield of 1,349 lb/acre/yr
[e] FLG-5 reduction based on current TSS yield of 1,401 lb/acre/yr

7.4 Predicted Benefits of Alternative Plans

Step 5 of the six-step planning process included evaluation of the effects of alternative plans based on the four criteria, as outlined in the P&G: completeness, effectiveness, efficiency, and acceptability. The Environmental Appendix has thus far detailed the methodology used to evaluate the effects of the alternative, as they relate to environmental impacts. Based on the analyses outlined in this appendix, the ecosystem impacts of the 24 restoration alternatives and the No Action Alternative were quantified in habitat units. The environmental impacts of each alternative were then evaluated Based on this analysis, all 25 alternatives were selected for further consideration in the economic analysis. This analysis was presented in Appendix G (Economics Appendix) to the Detailed Project Report. Based on the analysis of future with project conditions, future biological scores at each sampling station were predicted, for each alternative. Using the ERM, future Flat Creek combined stream health scores and habitat units were calculated for each ecosystem restoration alternative. Figure 7-1 presents the predicted future habitat units for each single-site or combination alternative. Table 7-5 summarizes the predicted combined stream health score and habitat units for each single-site or combination alternative. As shown, each alternative would provide some degree of biological improvement, meaning the habitat units for each would be greater than under future conditions with no alternative implementation. Some single-site or combination alternatives, however, would result in future conditions more severe than existing conditions because of the limited geographic extent of the alternatives for improving conditions at multiple sampling stations. The ERM uses weighted average scores from the sampling stations to derive the combined stream health score and habitat units; therefore, single-site or combination alternatives affecting relatively small parts of the watershed or far removed from downstream sampling stations would result in less ecological lift as predicted using the ERM tool.

The single-site or combination alternative with the greatest potential to improve overall watershed conditions was Alternative V, which included 2 stream restoration alternatives (32 and 33) and 6 stormwater detention structure alternatives located in the Upper Flat Creek subwatershed. Other alternatives demonstrating a high potential to improve overall watershed conditions were U, T, X, and P; however, in order to fully evaluate the alternatives, the habitat units must be evaluated with respect to other criterion. Detailed cost-benefit analysis is presented in Appendix G (Economics Appendix) to the Detailed Project Report, and the alternatives are evaluated further in the Detailed Project Report.

FIGURE 7-1
Predicted Future Habitat Units—Without Project and With Project
Flat Creek Watershed Detailed Project Report – Environmental Appendix

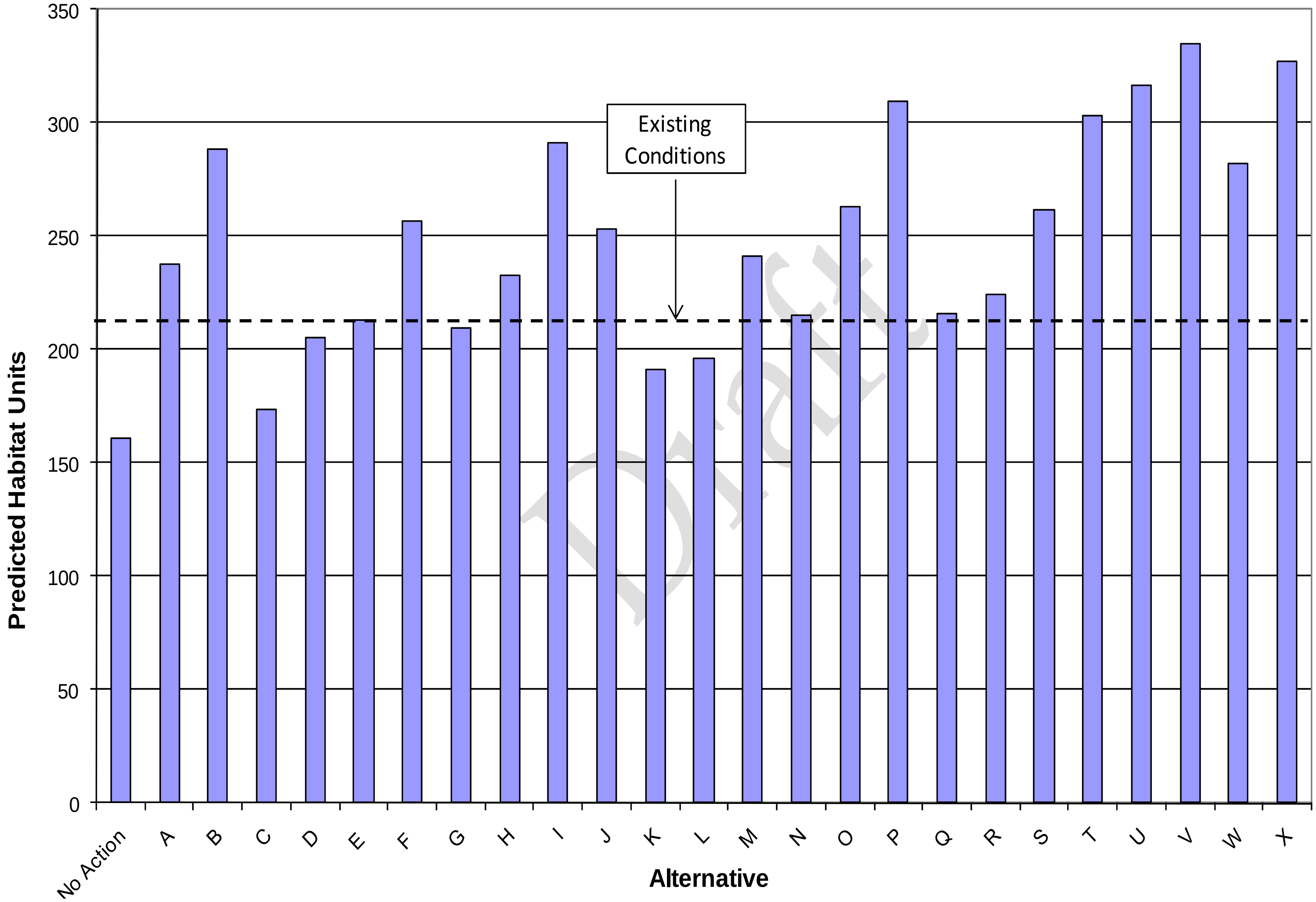

TABLE 7-5
Predicted Future Scores Summary (Existing Conditions, Without Project, and With Project)
Flat Creek Watershed Detailed Project Report – Environmental Appendix

	Fish IBI Score				**BMI Score**				**Physical Habitat Score**				Combined Stream Health Score	Habitat Units
	FLG-A	**FLG-4**	**FLG-B**	**FLG-5**	**FLG-A**	**FLG-4**	**FLG-B**	**FLG-5**	**FLG-A**	**FLG-4**	**FLG-B**	**FLG-5**		
Existing Conditions	14	10	26	16	17	36	40	37	81	98	130	153	36	213
Future without Restoration	12	10	18	12	16	22	25	30	73	73	90	114	27	160
Future with Project Conditions														
A	12	10	28	28	16	22	54	59	73	73	146	165	40	237
B	22	25	25	24	45	45	46	55	116	118	132	152	48	288
C	12	10	18	18	16	22	25	37	73	73	90	133	29	173
D	12	10	24	21	16	22	40	44	73	73	133	152	34	205
E	12	10	25	24	16	22	44	48	73	73	130	149	35	213
F	19	20	25	23	34	36	43	48	102	103	130	149	43	256
G	17	15	21	17	25	31	35	37	87	85	111	132	35	209
H	18	18	23	20	29	34	39	42	94	94	120	140	39	233
I	18	26	28	28	34	47	53	55	100	120	142	156	49	291
J	12	24	26	26	16	44	50	50	73	110	133	142	42	253
K	14	14	20	16	16	29	33	35	73	83	108	129	32	191
L	15	15	20	16	17	30	34	36	74	84	109	130	33	196
M	12	10	29	29	16	22	55	60	73	73	147	166	40	241

TABLE 7-5
Predicted Future Scores Summary (Existing Conditions, Without Project, and With Project)
Flat Creek Watershed Detailed Project Report – Environmental Appendix

	Fish IBI Score				**BMI Score**				**Physical Habitat Score**				Combined Stream Health Score	Habitat Units
	FLG-A	**FLG-4**	**FLG-B**	**FLG-5**	**FLG-A**	**FLG-4**	**FLG-B**	**FLG-5**	**FLG-A**	**FLG-4**	**FLG-B**	**FLG-5**		
Existing Conditions	14	10	26	16	17	36	40	37	81	98	130	153	36	213
Future without Restoration	12	10	18	12	16	22	25	30	73	73	90	114	27	160
N	12	10	26	25	16	22	44	48	73	73	129	149	36	215
O	12	26	27	28	16	46	52	52	73	114	135	145	44	263
P	19	28	30	30	23	55	55	57	105	135	163	183	51	309
Q	15	15	21	17	22	34	39	42	83	94	120	140	36	216
R	16	18	21	21	24	36	34	44	85	95	112	143	37	224
S	20	21	25	23	36	38	44	48	103	104	130	149	44	262
T	22	25	27	27	40	45	58	58	112	118	148	164	50	303
U	22	26	28	28	45	49	60	60	116	123	150	170	53	316
V	22	28	30	30	45	52	63	68	116	130.5	159.5	179	56	335
W	22	23	27	25	40	43	48	51	107	109	135	152	47	282
X	20	28	30	30	36	52	63	68	115	130.5	159.5	179	55	327

Future scores predicted for 25 years after ecosystem restoration implementation

8. Risk, Uncertainty, and Sensitivity Analyses

8.1 Potential Environmental Risks

Risk is inherent to water resources planning and ecosystem restoration projects, and must be defined to the extent practical throughout the planning process. Characterizing risk and uncertainty early in the planning process allows time to develop adaptive management and contingency plans to promptly address unforeseen conditions. Alternatives formulated for the Flat Creek watershed ecosystem restoration study were developed with these risks in mind, and risks were taken into consideration during the alternative selection process.

With regard to environmental impacts, potential risks to be considered when developing and comparing ecosystem restoration measures and alternatives include:

- risk of project failure,
- risk of ecosystem damage,
- natural disaster or catastrophic event, and
- residual risk.

These risks are described in more detail below, including a brief discussion of planning efforts established to minimize risks and potential impacts to the extent practical. Section 8 of the Detailed Project Report provides the Risk Management Plan, Monitoring Plan, and Adaptive Management and Contingency Plan that were prepared in response to the risks and uncertainties identified, and to establish plans to mitigate potential adverse effects.

8.1.1 Risk of Project Failure

The risks associated with project failure may include 1) site-specific failure of one or more of the restoration measures implemented within a project reach (may be either structural or non-structural failure), or 2) overall project success failure should monitoring results suggest that ecosystem restoration is not satisfactorily meeting the goals and objectives developed during Planning Step 2. Project failure may result from many factors, including not implementing the Tentatively Selected Plan. (such as if real estate acquisition does not occur), poor implementation of the Tentatively Selected Plan, or mischaracterization of existing conditions resulting the selection of restoration measures that do not sufficiently address problems.

The Plans provided in Section 8 of the Detailed Project Report outline strategies to address project failure, including the following mitigation actions:

- conducting scheduled site inspections on a regular basis to identify developing problems (if any)
- establishing an annual maintenance budget to repair any observed project damage
- maintaining construction access, should equipment entry be necessary to repair or replace materials

- implementing post-construction monitoring plan to track the success of established ecosystem restoration goals and objectives

8.1.2 Risk of Ecosystem Damage

As is typical for stream restoration projects, there is risk of initially causing some degree of damage to the local ecosystem before restoration measures fully take effect and conditions begin to improve. Ecosystem damages (including localized increases in turbidity and suspended sediment, initial/continued degradation of aquatic communities, or initial lack of physical habitat improvement) might result from construction activities necessary to install certain in-stream measures, or from grading activities necessary to re-shape the channel section to a more stable long-term condition. Further, a period of time will be required following construction to allow aquatic communities to re-establish themselves within the project area, and for vegetative measures to be established to provide habitat and stream stability benefits. Initial adverse impacts to the ecosystem such as those described above are expected to reverse upon construction completion, and conditions will begin to improve (risk reduced) as benefits from the completed ecosystem restoration measures begin to take effect.

Should initial ecosystem damage be observed during construction, such conditions will be noted and appropriate measures taken, prior to construction completion, to minimize such damages. Any continued ecosystem damages observed following construction completion will be noted through post-construction monitoring. Post-construction biological monitoring will be scheduled for the first and third years following construction completion. The Risk Management Plan describes regularly scheduled activities aimed at identifying potential ecosystem damage through construction observation and scheduled post-construction monitoring. This plan also describes measures that should be taken should ecosystem damage be observed, as well as responsibilities for implementation of corrective actions.

8.1.3 Natural Disaster or Catastrophic Event

USACE-Mobile and the City of Gainesville acknowledge the potential for natural disasters (e.g., flood, tornado, wildfire, drought, etc.) or other catastrophic events (e.g., vandalism, encroachment) to negatively impact project success. Both entities are aware that any such will require action to address the event. The likelihood of an event such as a hurricane-related storm event causing excessive flooding and streambank erosion is uncertain; however it is recognized that northern Georgia is subject to these weather events. At the other extreme, drought may limit instream baseflows and reduce the chances of successful establishment of vegetation. Risk associated with environmental conditions and its inherent uncertainty is similar among all project alternatives.

Should a natural disaster or catastrophic event take place prior to construction but following design altering the site conditions, during construction, or within the first three years following construction completion, USACE-Mobile and the City of Gainesville will collaborate to develop a mutually agreeable course of action to mitigate any adverse impacts caused by the event. This risk can be addressed, and the cost necessary to implement corrective action will be based on the federal (65 percent)/non-federal (35 percent) cost-share basis. Should a natural disaster or catastrophic event take place following the 3-year post-construction period, then any required corrective action would be the responsibility of the non-federal sponsor.

8.1.4 Residual Risks

By utilizing natural channel design techniques and re-establishing natural processes as part of the ecosystem restoration plan, minimal long-term management or maintenance beyond the 3-year post-construction monitoring period is anticipated. However, some degree of risk and uncertainty is inherent to the planning and implementation of any ecosystem restoration project. These risks and uncertainties should be characterized, to the extent possible, early-on in the planning process such that adaptive management and contingency plans can be established to promptly address unforeseen conditions. Ecosystem damages (if any) noted during this time will be address by USACE-Mobile and the City of Gainesville in a mutually agreeable, collaborative effort. Any ecosystem damage occurring beyond the 3-year post-construction monitoring period will be considered "residual risk." Residual risks (including prolonged or excessive maintenance or repairs) are possible, although unexpected, following project completion. One way to assess the likelihood of this risk is by implementing a post-construction monitoring plan (see Appendix I to the Detailed Project Report). The procedures to address these residual risks will be developed and outlined in an Adaptive Management and Contingency Plan and a Long-Term Management and Maintenance Plan. Addressing residual risks will be the responsibility of the non-federal sponsor.

8.2 Environmental Uncertainties

Similar to the potential environmental risks described above, environmental uncertainties are also inherent to water resources and ecosystem restoration projects. Uncertainties are primarily related to the variability of environmental conditions, including climate, land use, and hydrology, as well as the accuracy and consistency of data collection techniques. The uncertainties discussed below include:

- Physical performance
- Future environmental conditions (land use, meteorological conditions, etc.)
- Accuracy of data collection and analysis techniques

8.2.1 Physical Performance

Each of the alternatives formulated for Flat Creek watershed ecosystem restoration was evaluated based on predicted future benefits (quantified by habitat units), through processes described previously and utilizing the IWR Planning Suite. The predicted benefits were used to establish specific performance standards for the Tentatively Selected Plan, as identified in Section 2 of the Detailed Project Report. Although "actual" performance is expected to closely follow "predicted" performance, intermediate and long-term success could either lag behind or exceed predicted results. This uncertainty of physical performance must be considered throughout the planning process, including during alternative formulation, alternative plan selection, and Tentatively Selected Plan. implementation.

8.2.2 Future Environmental Conditions

Projected future environmental conditions were based on the City of Gainesville/Hall County Comprehensive Plan, and specifically the future land use plan that has been adopted (CH2M HILL, 2004). However, land use changes and development in the watershed may not follow these patterns, which would affect the accuracy of the model results as well as the accuracy of the potential change in biological metrics that was predicted for the habitat units. Hall County zoning and development ordinances will provide assurances to restoration benefits; however local impacts to the watershed may differ from the assumptions developed for modeling purposes. The effectiveness of Hall County's development ordinances also adds some uncertainty to the future watershed conditions developed in the modeling. In particular, this effectiveness could affect assumptions related to hydrology changes in the watershed, especially peak flows and velocities.

At a more local scale, upstream conditions may impact the ability of a restoration alternative to meet its success criteria. Stream physical habitat conditions on property outside the limits of a project reach may degrade due to localized conditions such as a erosion and sedimentation, leading to mass wasting of a streambank and sediment loading to the channel. Meteorological changes altering the long-term water cycle such as changes in precipitation and air temperature may influence stream base flows and other physical habitat characteristics within the watershed. These changes are slow to occur over time, however over the 25-year planning period may be significant enough to influence the potential success of ecosystem restoration.

Environmental risks and uncertainties at each potential site are being addressed by conducting Phase I and Phase II environmental site assessments. Considerations include previous land uses and the potential for any site contamination which could affect the health of aquatic ecosystems and safety of construction.

8.2.3 Accuracy of Data Collection and Analysis Techniques

The projection of future biological scores, which form the basis for selection of the Tentatively Selected Plan for Flat Creek, relies on evaluation of historical data and on current data collection and analysis. The biological data provides some degree of uncertainty, due to the subjective nature of some assessments as well as the consistency of the sampling team from year to year. In order to reduce the uncertainty from the data collection and analysis, sampling based on the GAEPD Standard Operating Procedures (SOPs) has been used for each year which data was analyzed, and data was evaluated for similar levels of effort and sampling season. However, the data collection and analysis is expected to provide some uncertainty in the prediction of future biological scores.

8.3 Sensitivity Analysis

A sensitivity analysis is provided to account the variability in predicted habitat units and to establish a range of uncertainty in the predicted values. Although extensive modeling and analysis were conducted to predict biological scores, subjectivity in applying judgment to the scoring process and unforeseen changes in environmental conditions contribute to uncertainty in actual scores. It was assumed that uncertainty in the future score prediction was less than 50 percent of the predicted change from existing conditions. Variability in predicted benefits for each of the alternatives is similar in terms of percent deviation from the predicted values. Overall variability therefore increases as either predicted benefits or estimated costs increase. Figure 8-1 represents the range of the risk of uncertainty that can be expected for the estimated costs and predicted future biological scores for each cost-effective alternative.

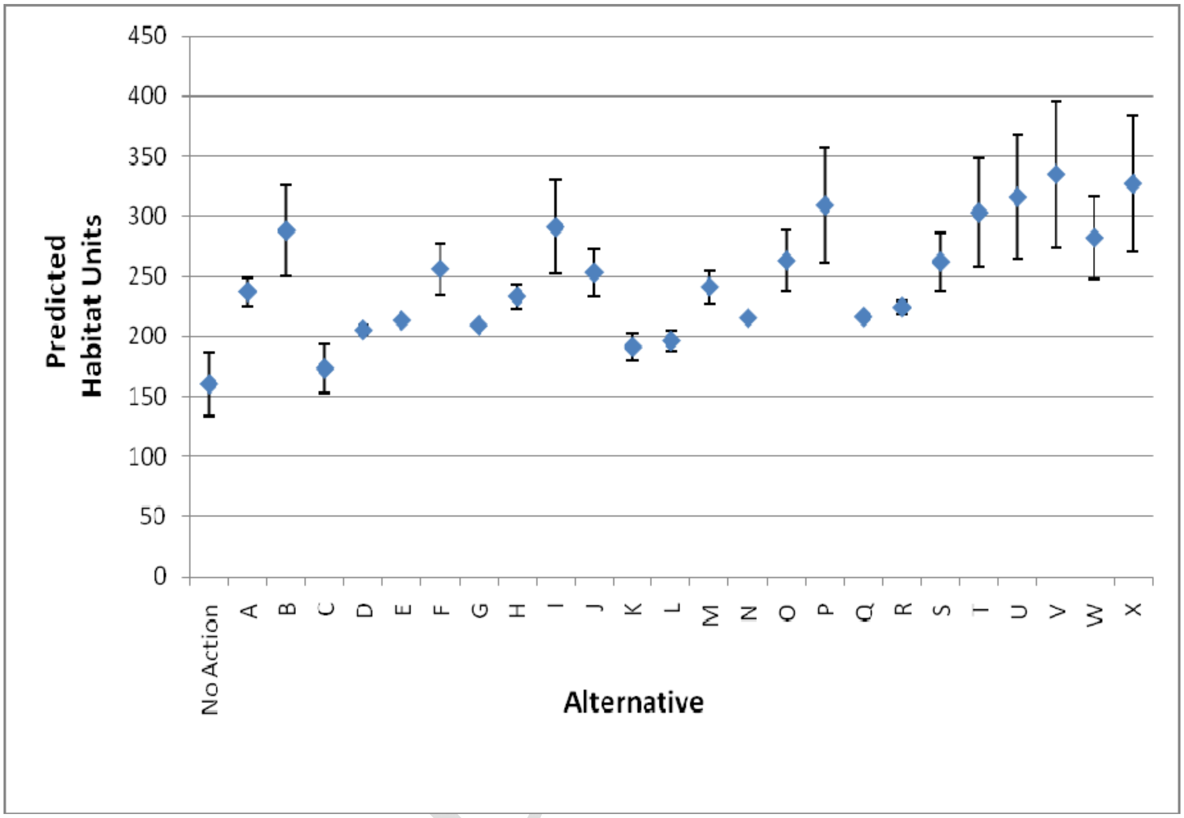

FIGURE 8-1
Estimated Range of Uncertainty Analysis in the Prediction of Habitat Units
Flat Creek Watershed Detailed Project Report – Environmental Appendix

Risks and uncertainties are associated with the implementation of any ecosystem restoration project in the Flat Creek watershed. While many of the risks are low as they can be mitigated to some extent during the planning and implementation phases of a project, risks may affect the ability of a restoration project to meet planning objectives. Uncertainties may also affect the ability of a restoration project to meet its planning objectives. However, these risks and uncertainties are not measurably different between the potential alternatives within the Flat Creek watershed and are not influential in the comparison of alternatives.

9. References

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