CDM

Camp Dresser & McKee

Report

Big Creek Watershed Study

Master Plan

Prepared For:
The Cities of Alpharetta, Cumming and Roswell as well as Cherokee, Forsyth and Fulton Counties

Facilitated By:
Atlanta Regional Commission

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Executive Summary

This report presents the results of the Big Creek Water Quality Management Plan cooperative effort between Cherokee, Forsyth and Fulton Counties as well as the Cities of Alpharetta, Cumming and Roswell to develop a mutually agreeable water quality protection plan for the Big Creek Watershed. Big Creek is located in urban and suburban portions of the Atlanta region and serves as a water supply for the City of Roswell. The watershed occupies an area of approximately 99 square miles at the Roswell Water treatment plant intake.

The study encompassed the following tasks:

Watershed Characterization -- including water quality, habitat assessment, and stream morphology assessment. The result of this task identified water quality and water quantity concerns as well as priorities for habitat and biological preservation.

Development of Computer Models – using the EPA Storm Water Management Model, computer simulations of water quantity (including assessment of floodplains) and water quality were developed for current and future land use conditions.

Selection of Best Management Practices (BMPs) – including identification of practices and policies to meet water quality, water quantity, habitat, and social goals.

Assessment of Watershed Management Alternatives – using computer models and input from the jurisdictions, scenarios of BMPs were assessed to find the combination of practice and policies that met project goals for water quality, water quantity, habitat, and social factors. A final alternative was recommended.

Development of a Watershed Management Plan – to meet the stated goals of the project: protect drinking water, protect aquatic life, enhance urban stormwater infrastructure, and help develop a sustainable resource in Big Creek.

Development of a Long-Term Monitoring Plan – for continued assessment of the physical, chemical, and biological characteristics of Big Creek which will assist jurisdictions in managing this resource.

Assessment of Administrative and Financial Options for Watershed Management – including a review of current ordinances and regulations and a review of funding and financing options for watershed management activities.

The study determined that the Big Creek watershed will urbanize nearly completely by the year 2020. The assessment of the Big Creek watershed found that the waterways are not only sensitive to the water quality impacts of urbanization, but also to the impacts of increased flow that impervious area creates. An assessment of the Big Creek stream channel found numerous segments where erosion from high flows was causing impacts to habitat and to property. The number of these segments will increase significantly as development occurs. Furthermore, the increase in flows will significantly increase flood episodes in the downstream portion of Big Creek (if flows are not attenuated).

In order to meet numeric water quality goals into the future, the study recommends the application of BMPs throughout the entire undeveloped portion of the Big Creek watershed. Specifically, the application of detention-based treatment of urban runoff is required for the watershed to meet water quality standards for lead and zinc (the two constituents to which Big Creek's waterways are most sensitive). Without these practices, moratoriums on development become a distinct possibility. This study recommends that these detention practices be designed to provide both water quality and water quantity benefits (i.e., flood protection and stream channel protection).

Because of the high returns on investment, several other watershed management practices and policies are recommended as they provide important social and habitat benefits. Pollution prevention controls (those controls that limit the generation of stormwater pollution) should always be integrated into jurisdictional programs. These controls include anti-dumping, public education, and industrial management activities.

Stream preservation, stabilization, and restoration are recommended for their direct and demonstrated benefit to increasing water quality and maintaining a healthy aquatic habitat. A minimum of 100 feet is recommended as a set-back or buffer away from streams. Stabilizing already eroding streams protects both property and habitat. It is recommended that jurisdictions develop proactive stream management programs.

Most people enjoy being near water and the watershed management plan recommended by this study recognizes this social element of the watershed. The plan recommends the development of greenways and other recreational opportunities associated with Big Creek

Acknowledgments

The Atlanta Regional Commission under the guidance of Tom Stanko, Jim Santo, and Pat Stevens coordinated this study. Project Advisors included Tom O'Bryant with the Georgia Mountains Regional Development Center and Nap Caldwell with the Georgia Environmental Protection Division. The team consisted of coordinators from each jurisdiction within the Big Creek watershed. The assistance and coordination between the jurisdictions is greatly acknowledged. The coordinators from the City of Alpharetta, Roswell and, Cumming, and the Counties of Forsyth, Fulton, and Cherokee are summarized below:

City of Alpharetta

- Dee West from Environmental Services

- Rob Warrilow from Recreation and Parks
- Kathi Cook with the Engineering Department
- Rebecca McDonough with the Engineering Department
- Dennis Woodling Director - Engineering Department

City of Roswell

- Stuart Moring, P.E. Director- Public Works Department
- Charles Richards, P.E. with the Department of Public Works
- Carter Lucas with the Department of Community Development
- David Llewellyn with the Department of Public Works

City of Cumming

- Jon Heard with the Engineering Department
- Scott Morgan with the Planning Department

Forsyth County

- John Cunard, P.E., County Engineer
- Anna White, Department of Engineering
- Jeff Chance, Department of Planning and Development

Fulton County

- Earl Burrell, Department of Public Works
- Bernard Bellinger, Department of Public Works
- Nick Ammons, P.E. Department of Public Works
- Betsy Start, Planning Department

Cherokee County

- Meredith Mason

Consultant Team

Camp Dresser & McKee Inc. was the lead consultant for the project. Dieter Franz was the Project Director. Bob Brashear served as Project Manager and Teresa Crisp served as Project Engineer. Other key CDM staff that contributed to the project includes Tom Quasebarth, Rich Wagner, Brett Cunningham, Andrew Romanek, Amy Ma and Carrie Chin.

Robbin B. Sotir and Associates led the stream reconnaissance study. This included assessing the condition of the streams, the fish, their habitat, and the wetlands. They then prioritized alternatives for Preservation and Streambank Protection Measures. The team consisted of Robbin Sotir and Alton Simms both from Robbin B. Sotir and Associates, and key members from FIScH, Hydroscape, and ICP EcoAnalysts.

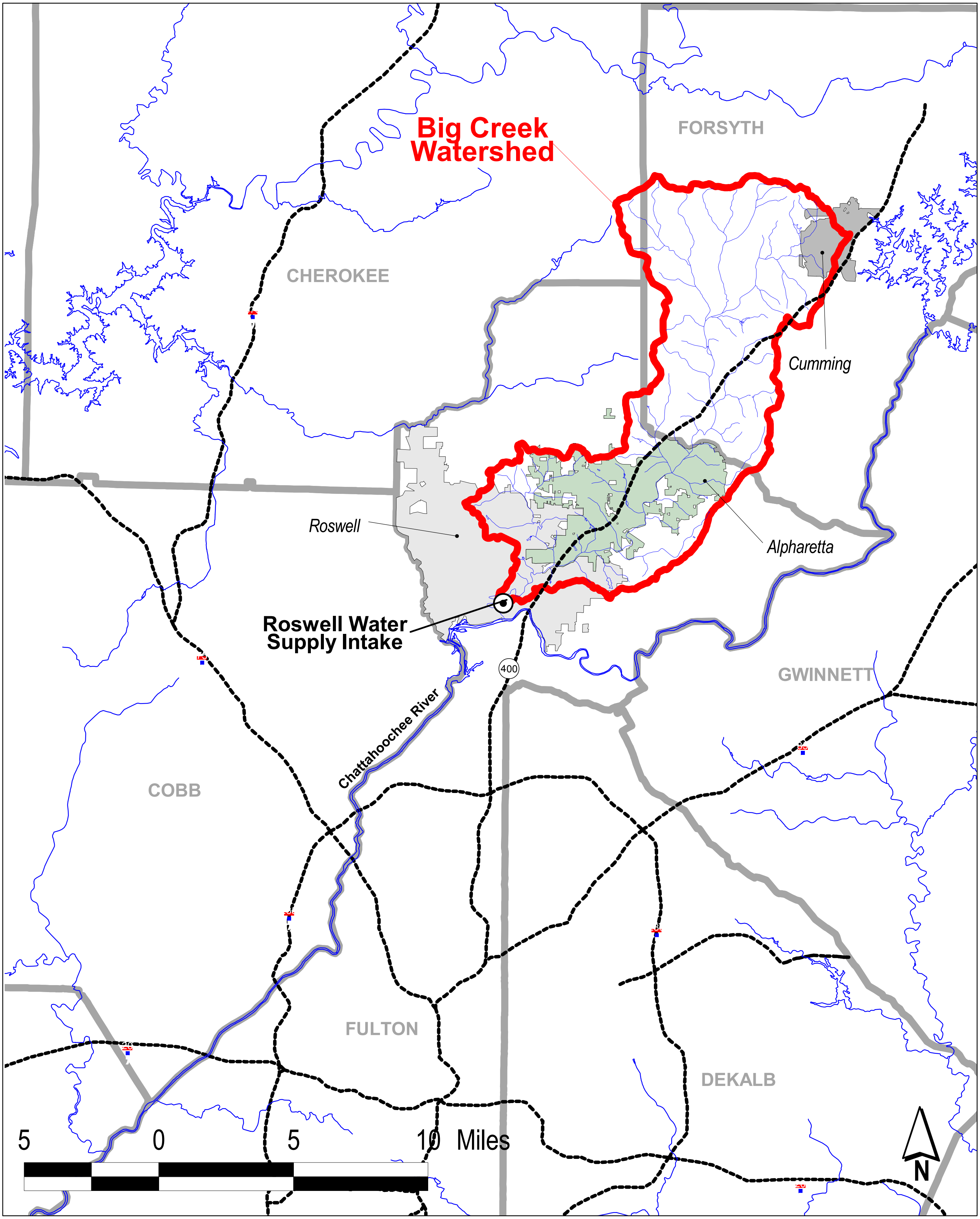
EDAW, Inc. performed the wetland analysis and developed the greenway plan. Paul Leonard and Marsha Tobin performed the wetland analysis, while Angie Moore led the development of the greenway plan.

Section 1
Introduction

This report presents the results of the Big Creek Water Quality Management Plan study. The study, facilitated by the Atlanta Regional Commission (ARC), is a cooperative effort between Cherokee, Forsyth and Fulton Counties as well as the Cities of Alpharetta, Cumming and Roswell to develop a mutually agreeable protection plan for the Big Creek Watershed. The report summarizes the work performed, findings, and recommendations for watershed protection measures in the Big Creek Watershed. Big Creek is located in urban and suburban portions of the Atlanta region and serves as a water supply for the City of Roswell. **Figure 1-1** presents a location map of the Big Creek Watershed.

Big Creek has only a few point discharges within the basin, including a Tyson's chicken processing plant, and the City of Cumming Waste Water Treatment Plant both of which are located in the upland reaches of the watershed. With continued growth, the principal concern is pollution caused by stormwater runoff. Stormwater runoff from urban and suburban areas carries many pollutants, including nutrients, oil and grease, heavy metals and organic pollutants such as residues from pesticides and fertilizers. Stormwater runoff pollution is usually referred to as "nonpoint source pollution" or "nonpoint pollution" because it enters streams at thousands of different places at intermittent times during and after rainfall. These nonpoint pollution sources contribute to water quality degradation and loss of aquatic habitat and are becoming a concern to water quality in the Big Creek watershed. Urban nonpoint pollution is directly related to the amount of imperviousness associated with each land use category within the watershed. Impervious surfaces such as roads, rooftops, parking lots, and driveways are major sources of nonpoint pollution. Numerous studies have shown the impact of urban impervious surfaces on water quality (WEF/ASCE 1998).

The federal National Pollutant Discharge Elimination System (NPDES) Storm Water Permit Program is specifically targeted at reducing the amount of nonpoint source pollution entering the nation waterways. In addition, the Safe Drinking Water Act requires that operators of municipal surface water treatment plants develop plans to protect the source of their water. This plan is intended to address and develop strategies for reducing nonpoint source pollution in the Big Creek watershed. Under this watershed planning approach, water quality problems will be addressed through: 1) regulations to protect streams and environmentally sensitive areas and 2) capital improvement projects for establishing of stormwater management Best Management Practice (BMP) facilities, stream channel erosion control, stream stabilization and restoration and 3) ongoing operation and maintenance programs such as storm drain inlet cleaning, illicit connection screening, and community outreach efforts.



Atlanta Regional Commission

Big Creek Watershed Study

Figure 1-1

Big Creek Watershed Location

1.1 Description of the Watershed

The Big Creek watershed lies in several political jurisdictions including Cherokee, Fulton, and Forsyth Counties and the Cities of Roswell, Alpharetta, and Cumming. The southern portion of watershed is more developed as it lies within the Cities of Roswell and Alpharetta and unincorporated Fulton County. Developed areas in the northern portion of the watershed are primarily within the City of Cumming. The watershed provides recreational and scenic value to the various jurisdictions and serves as a water supply source for the City of Roswell. The watershed occupies an area of approximately 99 square miles at the Roswell Water treatment plant intake.

Big Creek has an average discharge rate of 114 cubic feet per second (cfs) at the USGS gauging station at Kimball Bridge Road, i.e. represents 73 percent of the watershed. This equates to an annual runoff volume of 21.60 inches from the 72 square miles above the gauging station. The highest discharge recorded was a daily average of 4,480 cfs with an instantaneous peak of 6,100 cfs on February 3, 1982. The lowest recorded discharge of 1.7 cfs occurred on July 22, 1986.

The main stem of Big Creek originates in Forsyth County and drains southward to the Chattahoochee River. The watershed topography is typical of the Piedmont area with the upland tributaries and the upstream reaches of the main stem having fairly steep slopes. Main stem slopes become much flatter in the lower reaches of the stream. The stream channel shows evidence of erosion, severe in some cases, as a result of increased discharges and velocities caused by development within the watershed.

Most of the soils in the watershed consist of Cecil, Madison, and Habersham clay loams with small pockets of alluvial soils along and adjacent to the stream channels. The clay loams are classified as NRCS Type B soils and the alluvial deposits are Type C. The clay loams are moderately to highly erodible when disturbed. The actual degree of erodibilty depends on the slope of the area and the clay content of the soil deposit in question.

Much of the development that has taken place consists of single and multifamily residential land use. Significant commercial and light industrial development is also occurring along the Georgia 400 corridor and at other locations within the watershed. Approximately 60 percent of the Big Creek watershed lies within Forsyth County, one of the fastest growing counties in the United States. Currently 45 percent of the watershed is developed with predominately residential and commercial properties, the reminder is forested or used for agricultural activities. Future land use projections show that 86 percent of watershed will become developed by year 2020.

1.2 Background and Study Purpose

The Big Creek Watershed is experiencing the effects of urbanization and development, which include increased stream bank erosion, flooding, deteriorating water quality, and a decrease in the diversity of the habitat. This plan is designed to integrate opportunities to implement Best Management Practices (BMPs) with the continued growth in the watershed. This study has provided a forum for the multiple jurisdictions to integrate various ideas into a watershed wide plan.

The goals of this study were as follows:

- Improve / Maintain water quality of Big Creek and its tributaries;
- Maximize recreation potential / value;
- Minimize flooding, property damage, and stream impacts due to stormwater runoff;
- Educate the watershed's users about the resources;
- Develop the framework for intergovernmental cooperation in protecting the watershed; and
- Insure compatibility of watershed plans developed by individual jurisdictions.

1.3 Study Elements

The major elements of the study included:

- Compile Watershed Data, including a comprehensive data collection effort and review to assess the existing watershed resources. This task also included mapping the watershed's physical features and structural controls and a field reconnaissance. In addition, a review of existing policies, ordinances, regulations, and watershed plans was also conducted.
- Analysis of 1995 and 2020 Land Use and Impervious Surface Data
- Selection of Study Parameters, including identifying contaminants and physical parameters to study in order to assess the effect urbanization has on hydrology and hydraulics as well as water quality of the system.
- Estimating Current and Future Water Quantity and Water Quality Impacts, including developing models using USEPA Storm Water Management Model (SWMM). Erosion, flooding impacts, and water quality were evaluated.
- Identify and Analyze Alternative Watershed Protection Measures for Water Quantity and Quality Control, including source and treatment controls. This task included the ranking of various Management Scenarios and the economic impact of each scenario.
- Administrative and Regulatory Requirements included determining the capital improvement and operational needs and available funding sources.

- Final Plan, including criteria for recommended BMPs, an ongoing monitoring program, a wetland and greenways plan, and an overall Watershed Management Plan.

1.4 Scope of Report

This report summarizes the results of the work performed under this study and presents recommendations for the protection of water quality in the Big Creek Watershed. As described in the scope-of-work, this report is focused on the watershed area and major tributaries of Big Creek. The watershed plan does not address the specific water quality impacts on the downstream receiving waters of the Chattahoochee River. Although point source discharges are accounted for in the pollutant loading analyses, the recommendations of this water quality management plan are limited to management and control of nonpoint pollution discharges.

The remaining sections of the report and their content are:

- Section 2 of this report presents a summary of existing watershed characteristics including: topography, land use, soils, existing water quality information, and the results of the field investigations assessing stream conditions.
- Section 3 summarizes the local policies, ordinances, and regulations.
- Section 4 presents the approach, calibration and modeling results of the water quantity analyses.
- Section 5 summarizes the modeling approach and estimations of current and future water quality impacts.
- Section 6 provides an overview of the water quality control measures for watershed protection.
- Section 7 describes the analysis of the water management scenarios.
- Section 8 presents the recommended watershed management plan, and presents priorities for plan implementation including stream restoration/stabilization, BMPs, monitoring, and wetland and greenway projects.

Section 2
Watershed Characteristics

The purpose of this section is to provide a summary of existing watershed characteristics including: topography, land use, soils, existing water quality information and the results of the field investigations assessing habitat and streambank and channel conditions.

2.1 Land Cover in the Watershed

The Big Creek watershed, located in northern Fulton County and southern Forsyth County, Georgia, has a drainage area of approximately 99 square miles (Figure 1-1). Presently, this is one of the fastest growing areas in the Country. The watershed is undergoing a transition from agriculture and wooded land to residential and commercial/industrial development, primarily along State Road (SR) 400.

2.1.1 Existing Land Cover

At present, land use in the Big Creek Watershed is a mix of suburban and rural or undeveloped land. The majority of the developed areas are in Roswell and Alpharetta along SR 400 and the more undeveloped and rural areas are in the upland areas in Forsyth County. The development across the watershed is residential with commercial and industrial located along the major transportation corridors. The existing land use for the watershed is presented in **Table 2-1** and **Figure 2-1**. The information was derived from ARC's land cover database, which was developed using 1995 aerial photography. The 1995 land cover data correlated well with an extensive water quality monitoring data set from the same time period, both of which were later used to develop a water quality model for the watershed. As such, the 1995 land use data was not updated to reflect more current conditions.

2.1.2 Future Land Use

The planning period for this project was 20 years. Local comprehensive plans, zoning maps and additional input from the project coordinators were used to project land use within each jurisdiction for the year 2020 or buildout if it would occur before 2020. Future land use shows the watershed will change dramatically change over the next twenty years with an increase in developed area from 45 percent in 1995 to 86 percent in the year 2020. The future land use is presented in **Table 2-2**.

2.1.3 Impervious Surface Characteristics

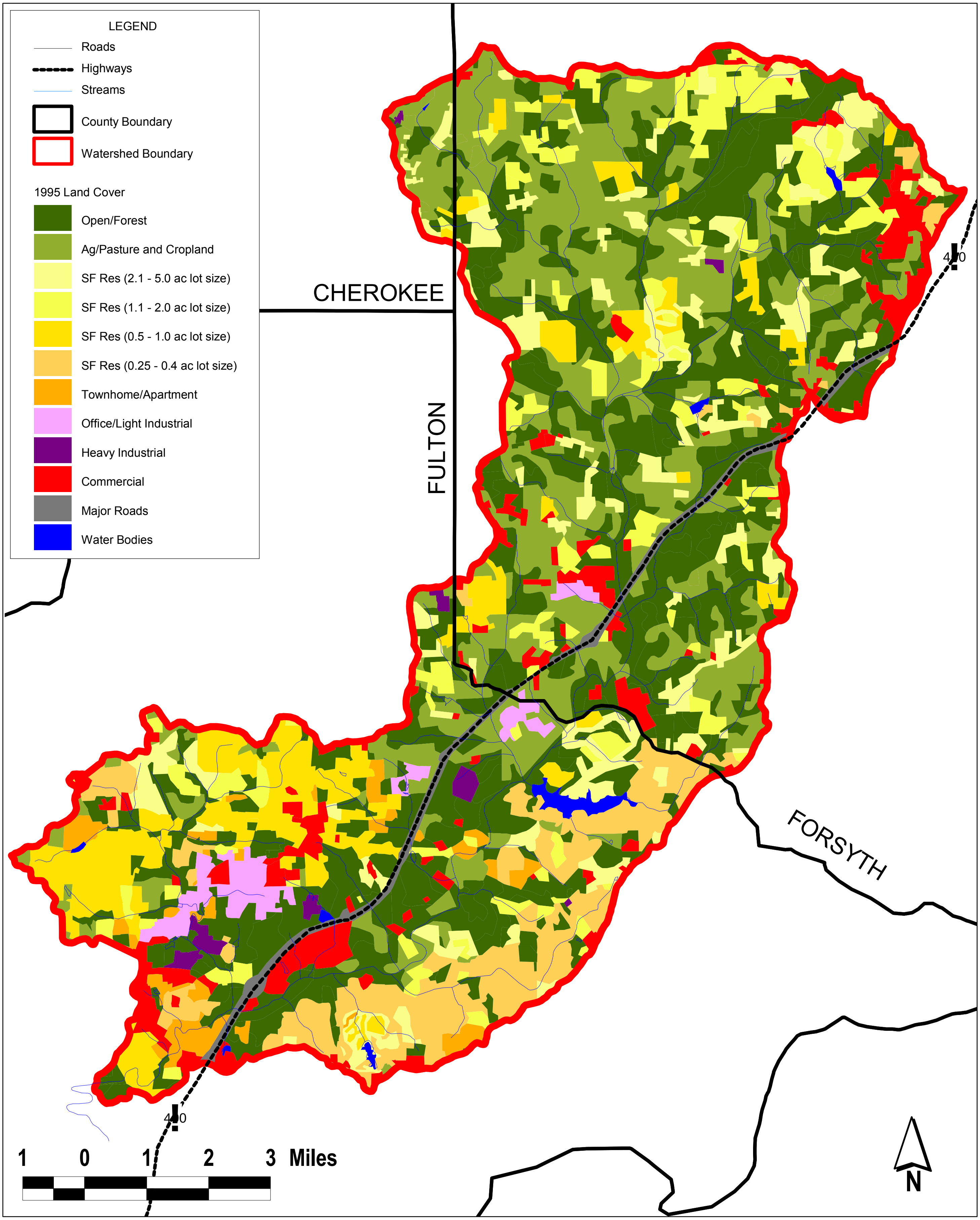
For the purpose of estimating impervious area and calculating amounts of stormwater runoff within the watershed, impervious surface factors were assigned to each land use category. The amount of impervious area within the watershed is projected to increase from 15 percent in 1995 to 35 percent in the year 2020. A summary of watershed impervious areas for existing (1995) and future (2020) conditions is presented in **Table 2-3**.

Table 2-1
1995 Land Cover in the Big Creek Watershed

Land Cover Category	Acres	Percent of Watershed
Ag/Pasture and Cropland	13,688	21.6%
Open/Forest	21,838	34.4%
SF Res (2.1 - 5.0 ac lot size)	5,205	8.2%
SF Res (1.1 - 2.0 ac lot size)	4,778	7.5%
SF Res (0.5 - 1.0 ac lot size)	5,250	8.3%
SF Res (0.25 - 0.4 ac lot size)	4,866	7.7%
Townhome/Apartment	1,220	1.9%
Office/Light Industrial	1,064	1.7%
Heavy Industrial	396	0.6%
Commercial	3,806	6.0%
Major Roads	1,073	1.7%
Water Bodies	313	0.5%
Watershed Total	63,498	100.0%

Table 2-2
2020 Land Cover in the Big Creek Watershed

Land Use Category	Acres	Percent of Watershed
Ag/Pasture and Cropland	656	1.0%
Open/Forest	7,697	12.1%
SF Res (2.1 - 5.0 ac lot size)	1,187	1.9%
SF Res (1.1 - 2.0 ac lot size)	418	0.7%
SF Res (0.5 - 1.0 ac lot size)	24,163	38.1%
SF Res (0.25 - 0.4 ac lot size)	9,340	14.7%
Townhome/Apartment	3,513	5.5%
Office/Light Industrial	7,796	12.3%
Heavy Industrial	56	0.1%
Commercial	6,923	10.9%
Major Roads	1,437	2.3%
Water Bodies	313	0.5%
Watershed Total	63,498	100.0%



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Big Creek Watershed Study

Figure 2 - 1

Exitsting (1995) Land Cover

Table 2-3
Estimated Impervious Area Percentages in the Big Creek Watershed

Jurisdiction	Watershed Area (acres)	% Impervious	
		1995 Conditions	2020 Conditions
Alpharetta	12,025	23%	48%
Cherokee County	1,126	7%	7%
Cumming	1,624	32%	56%
Forsyth County	33,846	9%	30%
Fulton County	8,461	17%	33%
Roswell	6,416	30%	36%
Watershed Total	63,498	15%	35%

2.2 Soils Characteristics

The majority of the soils in the watershed are clay soils in the following categories: Cecil-Madison, Lloyd Cecil-Madison, and Cecil-Lloyd Appling. Cecil-Madison soils are generally well-drained, gently sloping and sloping soils on uplands. The soil types were determined based on the SCS (NRCS) Soil Surveys for the counties.

- Cecil soils generally have a high erosion hazard. They are typically deep with moderate moisture-holding capacity. The natural drainage is good to excessive.
- Lloyd soils also have a high erosion hazard. They are generally deep with moderate moisture-holding capacity. The natural drainage is also good.
- Madison soils have a moderate to a high erosion hazard, are typically deep with a moderate moisture-holding capacity and are well to excessively drained.
- Appling soils have a moderate to a high erosion hazard, are typically deep with a moderate moisture-holding capacity and drain well to excessive.
- Along the corridor of the stream, the soils tend to be Congaree-Chewacla-Wickham. The water table in these areas is high and the soils are sandier and pose relatively low erosion hazards.

2.3 Hydraulic Characteristics

The physical characteristics of the stream were determined by data provided in FEMA studies of Big Creek and its tributaries as well as a field reconnaissance. The cross-sectional geometry, the Manning's roughness coefficients, the inverts, the channel length, and the bridge/culvert information used to develop HEC-2 models for the FEMA studies were input directly into the SWMM EXTRAN model used to evaluate hydrologic and hydraulic impacts as part of this study. In some cases, bridges or culverts have been replaced since the latest FEMA study and where that is true, the

SWMM EXTRN model used for this study will not account for that replacement. With more recent survey data, a more detailed analysis could be performed. Other data used to develop the hydraulic model were obtained from topographic maps and local jurisdictions as well as from a detailed field reconnaissance of some 31 reaches and 41 miles of stream within the watershed. The cross sectional information and model results are summarized in Section 4 and detailed in Appendix A. A summary of the field reconnaissance is presented as a separate document prepared by Robbin Sotir and Associates.

2.4 Floodplains

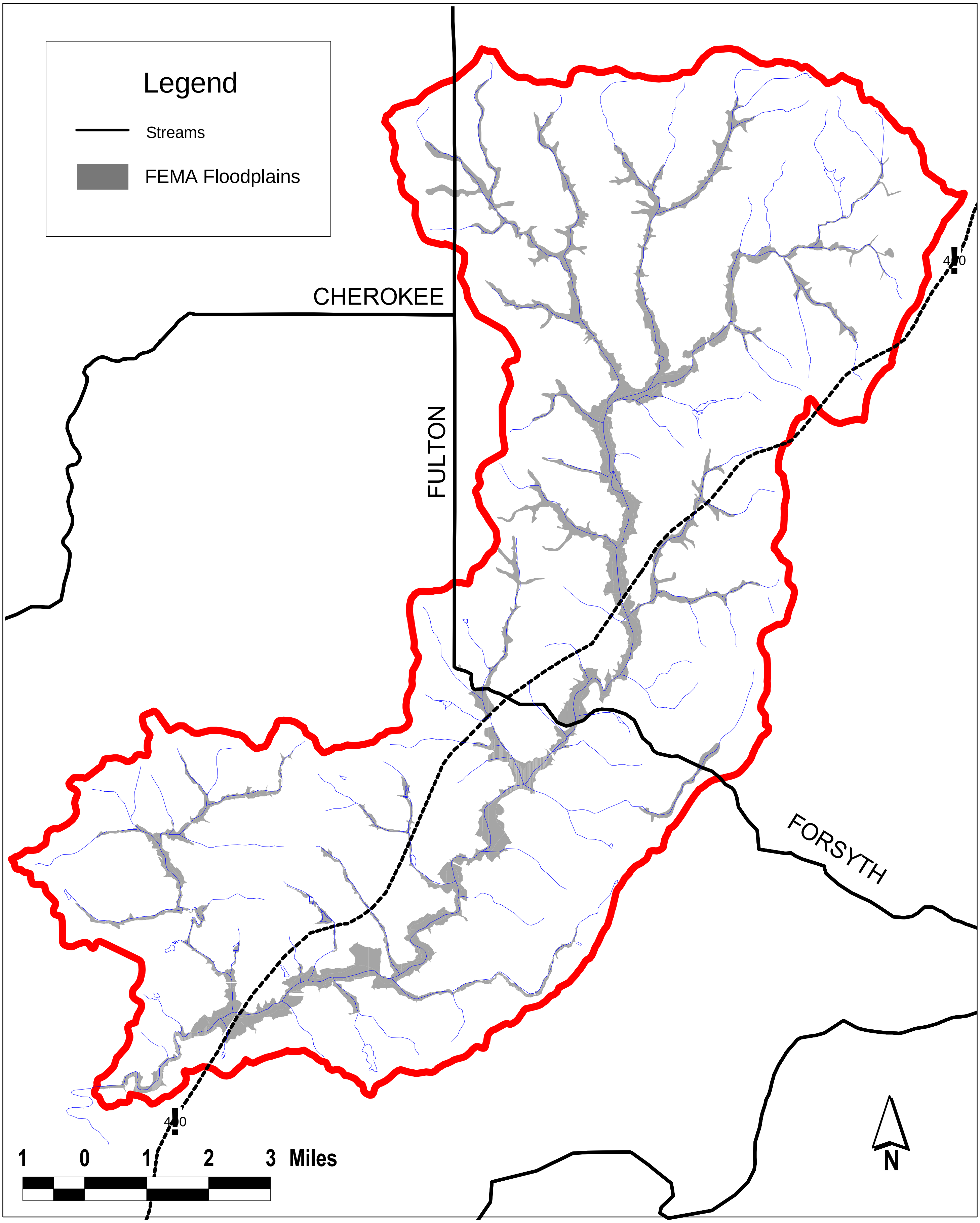
FEMA floodplain data for the Big Creek watershed is presented in **Figure 2-2**. Floodplain information was developed from digital Q3 Flood Data for Cherokee, Forsyth and Fulton Counties. Q3 Flood Data is derived from Flood Insurance Rate Maps published by FEMA and is intended to provide users with automated flood risk data. Q3 Flood Data for Cherokee, Forsyth Counties were obtained through the Georgia Emergency Management Agency (GEMA). Q3 Flood Data for Fulton County was obtained through the Georgia GIS Data Clearinghouse. The information on the floodplains was used in the study to evaluate buffers as well as validate the hydraulic model. The floodplain information is critical to the development of alternatives and when evaluating land use changes. The hydrologic and hydraulic model was used to update the floodplain mapping with 1995 and 2020 land use, as described in Section 4.

2.5 Stream Morphology and Habitat Assessment

2.5.1 Introduction

Land use changes and management actions in the past century including drainage, flood control, floodplain encroachment and land use conversion have significantly affected Big Creek and its tributaries. With the recent growth of metropolitan Atlanta, the watershed is rapidly undergoing a transition from agriculture and wooded land to residential and commercial/industrial development. As a result, fundamental changes to the watershed's hydrology are currently under way, which in turn, lead to changes in the stream channels. Increasing amount of impervious area associated with urbanization yields more runoff and delivers this runoff to the stream channels more quickly than in the past. These changes in hydrology lead to eroded bed and banks of stream channels until the channels reach a new equilibrium given the post-development hydrology. While the erosion process may take decades to complete, the resulting channels are often several times the size of their pre-development condition.

Flooding and property loss from erosion are only part of the picture. Nearly every bridge, culvert, pipeline crossing and other structure located within the erosion corridor will eventually require replacement or repair - a significant capital cost for the community. The erosion also causes environmental degradation and reduced quality of life for residents.



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Big Creek Watershed Study

Figure 2-2
FEMA Floodplains

Big Creek and its tributaries are currently experiencing these problems. Impacts from previous channelization and levee construction are contributing factors, but future developments within the watershed pose an even greater threat and measures to mitigate are required to prevent complete system degradation.

2.5.2 Methodology

The Big Creek watershed was partitioned into five sub-watersheds arranged from the mouth of the Creek to its headwaters, distinguishable on the basis of one or more landscape-level features. Within each sub-watershed, stream segments were divided into discrete reaches for data collection and analyses. A total of 31 reaches were established, as shown in **Table 2-4**. The team surveyed approximately 41 miles of stream.

A team including an engineer, biologist, geomorphologist, and a soil bioengineer surveyed the stream segments. Field data sheets were compiled for each reach noting physical characteristics, such as general channel stability, locations of ongoing and anticipated bank loss, specific modes of bank failure, bed and bank sediment composition, channel and streambank morphology, and riparian vegetation condition. Natural and anthropogenic features that impact channel stability and ecological character were located and described. An adaptation of EPA's Rapid Bioassessment Protocols (RBP) was used for an initial environmental assessment of the study area, the results of which were later employed in the development of recommendations and priorities. The data and assessment procedures are described in detail in the "Big Creek Reconnaissance Report."

Table 2-4
Big Creek Reaches and Subwatersheds

Watershed	Reach	Name	Begin	End
E (Kelley Mill/Sawmill)	1	Kelly 1	GA Highway 20	Hickory Knoll
E	2	Kelly 2	Hickory Knoll	Kelly Mill Road
D (Bentley/Cheatam)	3	Cheatam 1	Pittman	Polo Drive
D	4	Cheatam 2	Polo Drive	Big Creek
D	5	Bentley	GA Highway 371	Big Creek
B (Camp/Windward)	6	Camp Creek 1	GA Highway 400	Windward Parkway
B	7	Camp Creek 2	Windword Pkwy.	Big Creek
A (Alparetta/Roswell)	8	Long Indian 1	State Bridge	Buice Road
A	9	Long Indian 2	Buice Road	Waters Road
A	10	Long Indian 3	Waters	Big Creek
A	11	Foe Killer 1	Mid Broadwell Rd.	Rucker Road
A	12	Foe Killer 2	Rucker Road	Upper Hembree Rd.
A	13	Foe Killer 3	Upper Hembree Rd.	GA Highway 9
A	14	Foe Killer 4	GA Highway 9	Rock Mill Road
A	15	Foe Killer 5	Rock Mill Road	Big Creek
E	16	Big Creek 1	Kelly Mill Road	Barrett Downs Drv.
E	17	Big Creek 2	Barrett Downs Dr.	Bethelview Road
E	18	Big Creek 3	Bethelview Road	Cheatam Creek
D	19	Big Creek 4	Cheatam Creek	Bentley Creek
C (Bagley)	20	Big Creek 5	Bentley Creek	GA Highway 9
C	21	Big Creek 6	GA Highway 9	Union Hill Road

Watershed	Reach	Name	Begin	End
C	22	Big Creek 7	Union Hill Road	GA Highway 400
C	23	Big Creek 8	GA Highway 400	McFarland Road
C	24	Big Creek 9	McFarland Road	County Line
B	25	Big Creek 10	County Line	Windward Parkway
B	26	Big Creek 11	Windward Parkway	Camp Creek
A/B	27	Big Creek 12	Camp Creek	Webb Bridge Road
A/B	28	Big Creek 13	Webb Bridge Road	Long Indian Creek
A	29	Big Creek 14	Long Indian Creek	Foe Killer Creek
A	30	Big Creek 15	Foe Killer Creek	GA Highway 140
A	31	Big Creek 16	GA Highway 140	Hog Waller Creek

2.5.3 Reconnaissance and Assessment Results

The riparian and in-channel character of the sub-watersheds and reaches was judged by the condition and consequent functionality of stream reaches covered in the reconnaissance. Channel geometry, cover, and other habitat conditions are summarized in **Table 2-5**. **Figure 2-3** presents a summary of the habitat assessment. The Big Creek Reconnaissance Report describes the terms used in the table and figure.

Big Creek itself is a fourth-order stream for the lower 80 percent of its length. It has low sinuosity and flows through a valley that has a very low gradient, approximately 0.16 percent. Most of the main stem was channelized several decades ago, leaving it unstable today. Typical water depth during the reconnaissance ranged from 1.8 feet at the upper end of the fourth order section to 4.8 feet at the lower end. Representative bankfull depth varied from 4.5 to 8.7 feet. Characteristic channel depths appeared to trend weakly upward from 6.6 feet near the upper end to 10.5 feet at the lower end. Typical stream width varied from 34 to 57 feet. Representative bankfull width/depth ratio ranged from approximately 5 near the upper end to about 10 near the lower end. The streams of the Big Creek system are generally entrenched with a sandy bed, making them type F5 according to the Rosgen (1996) classification. They are generally unstable and typically widening, or in stage 3 of the Channel Evolution Model (Schumm et. al. 1984). Further characterization of these parameters is given in the main document “Big Creek Reconnaissance Study,” and is presented in the attached glossary.

The loss of pool and riffle habitat and center bar deposition was evident throughout the Big Creek and its tributaries. Evidence of channelization in the form of straightening and side-cast material was observed on all the surveyed reaches of Big Creek. Evidence of de-snagging operations was also observed on the main-stem of Big Creek. Large woody debris (LWD) and other in-stream cover were generally abundant and well distributed throughout the basin. The LWD plays a major role in stream channel morphology, in Big Creek and its tributaries and is the principal contributing factor to the formation of pools and other habitat features. But LWD also increases bank erosion, creates local flooding, and can be a threat to bridges when large debris jams occur on piers. Large woody debris coverage in the study reaches ranged from 0 to 80 percent, and averaged nearly 13 percent. Canopy closure ranged from 0 to 90 percent and averaged 52 percent. These values are considered good for

Table 2-5
Summary of Reach Characteristics

Watershed	Reach	Stream Type	CEM Stage	Canopy Closure	LWD Coverage	Pool Length	Run Length	Riffle Length	Glide Length
E	1	B	3-4	50-80%	5-15%	232.2	48.6	143.2	0
E	2	NA	3-4	30%	NA	519.6	254.9	500.5	0
D	3	NA	NA	0%	<1%	42.3	572.1	59	223.6
D	4	NA	3 to 4	70-80%	80%	--	--	--	--
D	5	F6	4	50-60%	10-15%	724.5	1700.4	47.2	0
B	6	F5/6	3-4	Typical	1%	NA	NA	NA	NA
B	7	F5	2-3-4-5	85%	5-10%	0	0	0	638.5
A	8	NA	3	80%	25%	117.4	0	88.8	79.3
A	9	F	3	80%	30%	194.4	53.8	76.9	94.7
A	10	C/F	3	60%	NA	261.8	0	164.1	137.3
A	11	C to F	3	90%	25%	0	0	0	284
A	12	F	3	75%	45%	224.5	41.4	103.2	0
A	13A	F	3	65-75%	40%	118.7	139.6	108.6	251.9
A	13B	F4	5	85%	25%	160.9	133.6	308.5	136.9
A	14	NA	NA	50%	NA	262.8	115.9	221	40
A	15	B3-4	3/5	75%	<1%	163.3	123	267.3	56.3
E	16	Stable C	5/2	75%	9.5%	0	94	99	35.7
E	17	F5	5, 3/4	60%	NA	144	125.7	76.7	124.8
E	18	F5/6	3	75%	25%	160	218.9	238.8	138.2
D	19	F5	3/4	<Typical	0%	0	0	0	1561.9
C	20	F5	5	Typical	<1%	1666.2	0	0	0
C	21	F5	4/5	24%	5%	0	0	573.6	296.9
C	22	F5	2/3	23%	NA	0	0	39.2	1663.9
C	23	F5	5	80%	<1 to 1%	0	0	0	2115.2
C	24	F5-6/F4	3-4/5	NA	NA	0	0	0	1662
B	25	F4-5	3-4	20%	NA	0	0	0	1423
B	26	F5	3/5	22%	NA	0	0	0	1873.8
A/B	27	F5	3	24%	NA	0	0	0	1029.4
A/B	28	F5	3-4-5	23%	NA	0	0	0	2485.2
A	29	F4-5-6	3	20%, 90%	1%, 10-15%, 60%	0	0	0	1902
A	30	F4-5-6	3/5	22%	NA	0	0	0	2059.5
A	31	F5	3	Typical	1%	0	0	0	1571.9

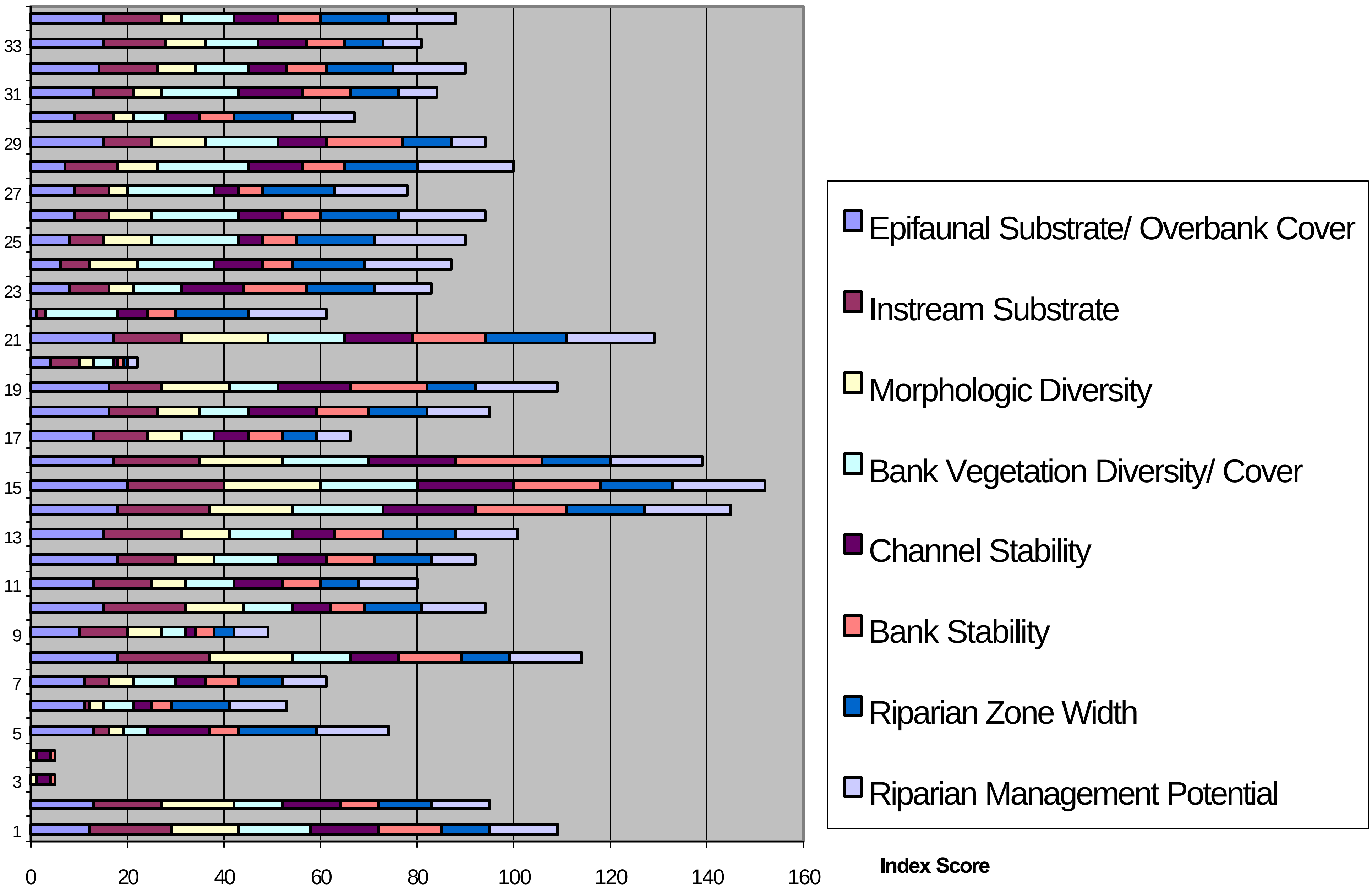


Figure 2-3
Habitat Assessment Scores by Reach

an urban stream, and the overall riparian and in-stream woody material conditions are respectable for a system with development exceeding 10 percent impervious area.

Canopy closure and gaps are both important processes in streams and associated wetlands. Canopy closure along stream banks and levees provide shading critical in mediating stream temperatures conducive to reproduction, growth, and maintenance of aquatic insects and fish. In turn, canopy gaps, adjacent to streams, allow light to reach the ground thus enhancing propagation of native vegetation and maintenance of characteristic riparian vegetation. In general, a majority of streams within the Big Creek watershed were well shaded with riparian vegetation intact.

All of the streams in the Big Creek basin are impaired by sediment. No difference was apparent among sub-watersheds. This result is not unexpected for a system that is cutting down through Piedmont clays in a disturbed watershed. However, most of the reaches examined in sub-watershed "B" and nearly half of those in "E" also appeared to be impaired by excessive nutrients and possibly fecal coliforms (field observations included undermined and failed sewer pipe crossings, algae blooms, and oily surface sheen).

All of the study reaches have been impacted by urbanization. Many of these impacts are superimposed upon impacts related to historic land use changes and channelization. Infrastructure including bank stabilization, floodway encroachments, pipeline crossings and transportation facilities has also affected the character of Big Creek and its tributaries. In the study area, for example, there are 39 bridge crossings or about one bridge per stream mile.

The environmental condition of the study reaches was better than expected for a watershed with impervious surfaces exceeding 15 percent of the watershed area. Water quality and aquatic habitat have suffered the greatest effects of urbanization, but for the moment, terrestrial habitat remains good for a suburban area. Aquatic habitat impacts have been somewhat mitigated by the influx of LWD material that enhances habitat diversity and provides substrate for invertebrates and cover for vertebrates. The fact that the channel is still responding to the increased runoff means that in many reaches, the existing conditions may be transitory, and further habitat degradation can be expected. The presence of fairly healthy riparian corridors in most study reaches is probably the most significant factor in the persistence of fair environmental conditions.

An index created for riparian habitat quality suggests that three clusters of sub-watersheds can be recognized. In order of increasing quality they are "A"/"B", "D"/"E", and "C". Results for these clusters correlate well with land use and watershed position. For example, the result for sub-watershed "C" can be expected from an area that is undeveloped, features riparian wetlands, and is in the middle reaches of the main stem.

2.6 Wetlands

Wetlands data provided by the ARC were created from US Fish and Wildlife Service 1998 National Wetlands Inventory (NWI) maps. The wetland areas are mapped in **Figure 2-4** and were used to help determine areas for certain alternatives in the management plan. Most of the wetland features are along the riparian corridors of the watershed.

2.7 Existing Water Quality Data and Trends

In general the available water quality data for the Big Creek Watershed falls into three categories: (1) surface runoff data, which characterizes event mean concentrations (EMCs) for runoff events, (2) ambient instream monitoring data, which may be reflective of wet weather or dry weather conditions and (3) point source discharge data from municipal and industrial wastewater discharges. Other related data includes biological sampling data.

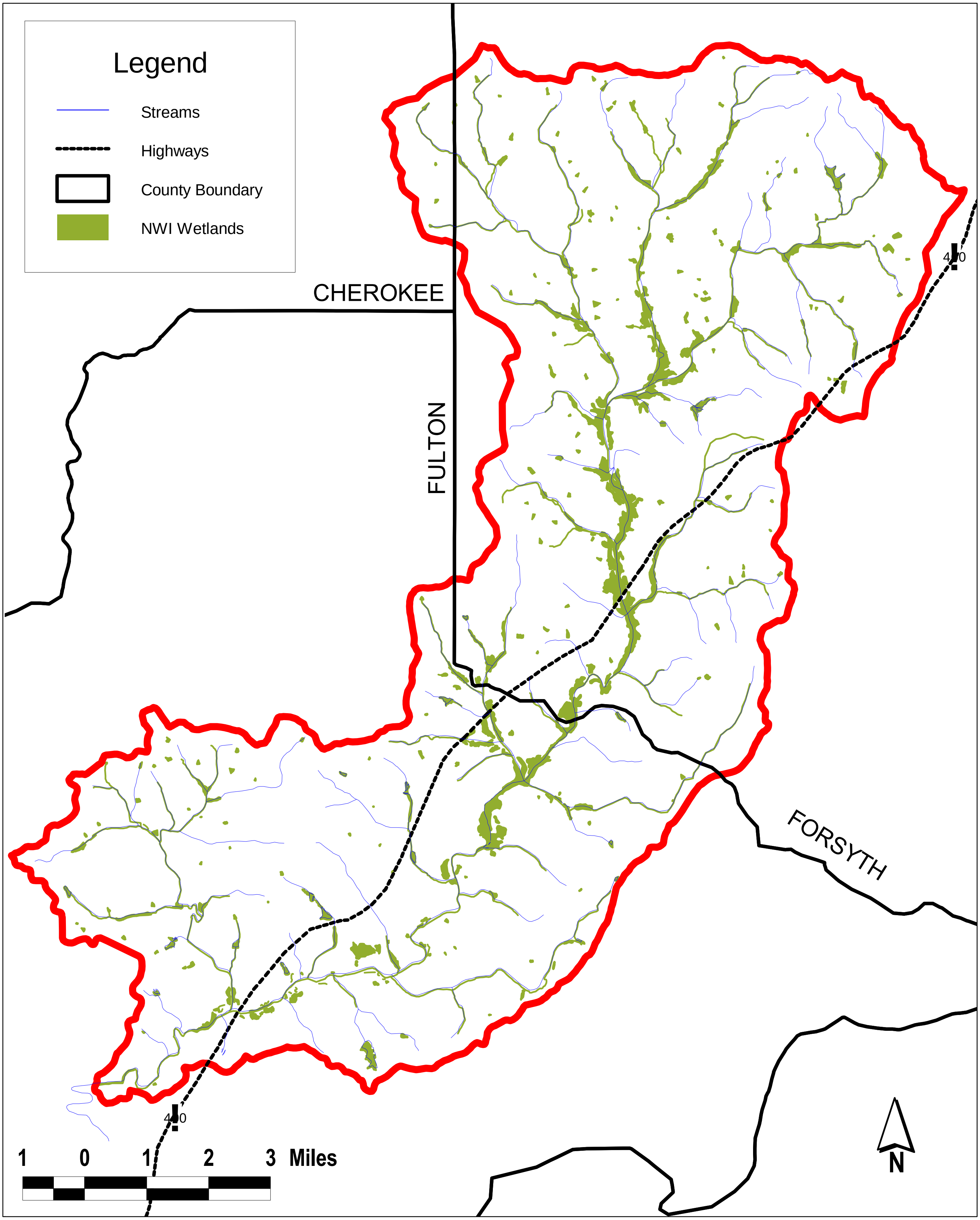
2.7.1 Surface Runoff Data

An evaluation of surface runoff water quality was conducted using local monitoring data. The majority of the data was included in two reports: Atlanta Region Stormwater Characterization Study (CDM, 1993) and Atlanta Region Storm Water Sampling Program Annual Report (ARC, 1998). Forsyth County also provided EMC sampling data from two surface runoff sites in the Big Creek watershed. A summary of each surface runoff data source is below.

- Atlanta Region Stormwater Characterization Study (CDM, 1993) - The report presented EMC data from three storm events sampled at 27 sites in the 5-county area designated as the Metro Atlanta Area. The number of sites located in each jurisdiction within the Metro Atlanta Area, and the description of each sampling station is presented in **Table 2-6**. The 27 sites were equally distributed between residential, commercial and industrial areas

- Atlanta Region Storm Water Sampling Annual Report (ARC, 1998) – The report summarizes listed EMC sampling results in the Metro Atlanta Area from December 1993 through April 1998. Samples were collected at 17 stations, with 10 sites sampling residential runoff, 4 sites sampling industrial runoff and 3 sites sampling agricultural runoff.

- Forsyth County Runoff Data - Data included results for sampling stations on Cheatam Creek (Polo Fields site) and Trotters Creek, both tributaries to Big Creek. At the Polo Fields station, runoff is sampled from a large residential development, which includes a golf course community with a privately operated land application wastewater treatment plant. The Trotters Creek site is downstream of a large industrial park.



Atlanta Regional Commission

Big Creek Watershed Study

Figure 2-4

USFWS NWI Wetlands

Table 2-6

Sampling Station Description And Land Use Category Atlanta Regional Storm Water Characterization Study

Station Number	*Station Description*	*Land Use Category*
AT-01	Outfall - Tributary to Nancy Creek	Commercial
	Southeast parking lot of Lenox Square on Old East Paces Ferry Road, draining commercial land use area.	
AT-02	Outfall - Tributary to Peachtree Creek	Commercial
	Armour Circle between Seaboard Coastline Railroad and Peachtree Creek, draining an area of commercial and light industrial land use.	
AT-03	Outfall - Tributary to Clear Creek	Residential
	Beverly Road at 126 Doncester Road in Momingside, draining residential area.	
AT-04	Outfall - Tributary to South River	Industrial
	1460 Ellsworth Industrial Drive, draining a light industrial use area.	
AT-05	Outfall - Tributary to South River	Industrial
	Zip Industrial Boulevard at Asbury Ferst, Inc., draining an area of industrial land use.	
AT-06	Outfall - Tributary to Chattahoochee River	Industrial
	Forest Park Road at Coastal Transport, draining an area of industrial/transportation land use.	
CL-01	Junction Box - Tributary to Flint River	Industrial
	Lake Mirror Road, east of 1-75, draining an area of heavy industry in the extreme headwaters of Flint River.	
CL-02	Outfall - Flint River Clark Howell Highway	Commercial
	Located south of 1-285, draining an area of commercial, business and transportation land use in extreme headwaters of Flint River.	
CO-01	Stream - OIley Creek Tributary to Sweetwater Creek - Cobb County	Commercial
	Water system water quality monitoring station at Callaway Road, draining an area of industrial and commercial activity south of Marietta, including a closed sanitary landfill.	
CO-02	Outfall - Unnamed Tributary to Rottenwood Creek	Commercial
	Circle 75 Parkway, draining a commercial/business park area.	
CO-03	Outfall -Tributary to Sope Creek	Residential
	Outfall draining moderate density residential area to Bishop Creek at Indian Hills Trail.	
CO-04	Stream - Noonday Creek Tributary to Lake Allatoona - Cobb County	Residential
	Water system water quality monitoring station at Worley Road draining an area of residential and commercial land uses.'	
DK-01	Stream - Bubblina Creek Tributary to Nancy Creek - DeKalb County	Residential
	Water quality monitoring station at Donaldson Drive draining an area of public parks and residential land uses.	
DK-02	Stream - Unnamed Tributary to North Fork Peachtree Creek	Industrial

Table 2-6

Sampling Station Description And Land Use Category Atlanta Regional Storm Water Characterization Study

Station Number	*Station Description*	*Land Use Category*
	Located at 1-85 Access Road, draining a heavy industrial area in the Chattahoochee Basin.	
DK-03	Stream - Unnamed Tributary to North Fork Peachtree Creek	Residential
	Located at Meadowcliff Road, draining a residential area in the Chattahoochee Basin.	
DK-04	Stream - Tributary to South Fork Peachtree Creek at Scott Boulevard	Residential
	Drains an area of residential and public land uses.	
DK-05	Stream - Tributary to Shoal Creek - Stream at Glendale Road	Residential
	Drains an area of residential land use.	
DK-06	Outfall - Tributary to Snapfinger Creek	Industrial
	Outfall of Truman Drive, draining an area of light industrial/commercial land uses.	
EP-01	Outfall - Tributary to South River	Industrial
	Oakleigh Drive near Fresh Prep Company, draining an industrial area inside the city.	
FL-01	Outfall - Tributary to Chattahoochee River	Industrial
	Purdue Drive in Fulton Industrial Park, draining area of light/moderate industrial land use.	
FL-02	Outfall - Tributary to Chattahoochee River	Commercial
	Hammond Drive near Roswell Road, draining area of commercial and transportation land use.	
FL-03	Outfall - Tributary to Chattahoochee River	Commercial
	Glenridge Drive at Lakeside Office Park, draining an area of commercial land use in the Nancy Creek Basin.	
GW-01	Stream - Tributary to Big Haynes Creek	Residential
	Roadway culvert under Temple-Johnson Road near Grand Central Drive, draining an area of moderate density residential land use south of Snellville.	
GW-02	Junction Box - Tributary to Chattahoochee River	Industrial
	Located on Pacific Drive at railroad crossing, draining an are of industrial land use.	
GW-03	Junction Box - Tributary to Sweetwater Creek/Yellow River	Commercial
	Located on Gwinnett Place Drive 1/4-mile off Pleasant Hill Road, draining a commercial area of Gwinnett Place Mall.	
MA-01	Outfall - Tributary to Rattenwood Creek	Commercial
	Northwest Parkway Tributary to Poor House Circle, draining a commercial/business park area.	
RO-01	Outfall - Tributary to Chattahoochee River	Residential
	Outfall No. 311 - Waterbrook Terrace - draining moderate density residential area.	

The data from the surface runoff water quality from local monitoring data were combined to form distinct data sets for residential, commercial, industrial and agricultural runoff. Each of the data sets was then statistically analyzed to determine key parameters such as mean, standard deviation and coefficient of variability for the monitored pollutants. In some cases, one or more individual data points were considered to be outliers (i.e., not representative) and were omitted from the analysis.

The results of the analysis, by land use category, are presented in **Tables 2-7** through **Table 2-10**. As shown in the table, statistics were calculated assuming normal and lognormal distribution. The NURP study (USEPA, 1987) indicates that water quality data often exhibits a lognormal distribution. As noted in the table footnotes, all measurements that were below the laboratory detection limit were assumed to be equal to one-half of the detection limit.

The recommended EMC values for the Big Creek Watershed study are presented in **Table 2-11**. In most cases, the EMC values are based on the values in Table 2-7 through Table 2-10. Some land uses were assigned values based on monitoring data from land uses that are considered similar (e.g., commercial EMCs were used for the major roads land use category).

The values in Table 2-7 through Table 2-10 form the basis for the calibration of pollutant buildup and washoff parameter values in the watershed computer model. Single land use model runs were conducted for an extended period, and EMC values from each runoff-producing event were analyzed and compared to the statistics developed from the local monitoring database. The parameter values were adjusted until the mean and distribution of the EMCs calculated in the model were similar to the values from the monitoring data.

2.7.2 Instream Water Quality Monitoring Data

Several sources of instream water quality data were reviewed. A water quality database provided by EPD included most of the available water quality data. Limited data were also available from the USGS. In addition, several wet weather turbidity and TSS measurements were available from the Upper Chattahoochee Riverkeeper.

The EPD database includes sampling at three stations, which are as follows:

- Big Creek at Roswell Intake (3/16/70 through 12/12/96)
- Big Creek 0.5 miles upstream of confluence with Chattahoochee River (5/3/94 through 12/2/96)
- Big Creek at Holcomb Bridge Road (8/3/93 through 10/5/93)

At all of these stations, the data values are based on grab samples. To assess whether the samples were characteristic of dry weather or wet weather conditions, the flows

Table 2-7
Summary of Local NPDES Monitoring Data for the Residential Land Use Category

Constituent	Units	N	Normal Statistics			Lognormal Statistics			
			Mean	SD	CV	Median	Mean	SD	CV
BOD	mg/l	138	9	11	1.27	5	9	12	1.40
COD	mg/l	140	45	45	1.01	30	47	55	1.17
TSS	mg/l	138	192	255	1.32	73	272	967	3.56
TDS	mg/l	140	100	155	1.55	65	109	145	1.33
Total-P	mg/l	142	0.29	0.37	1.28	0.17	0.30	0.42	1.41
Dissolved-P	mg/l	130	0.07	0.07	0.94	0.05	0.08	0.13	1.57
TKN-N	mg/l	134	1.21	1.01	0.83	0.82	1.38	1.87	1.35
NO2 + NO3-N	mg/l	140	0.79	1.11	1.42	0.49	0.79	1.00	1.27
Lead	mg/l	139	0.018	0.028	1.54	0.011	0.018	0.022	1.25
Copper	mg/l	140	0.022	0.037	1.66	0.012	0.022	0.033	1.51
Zinc	mg/l	140	0.092	0.097	1.05	0.063	0.094	0.104	1.11
Cadmium	mg/l	140	0.003	0.004	1.23	0.002	0.004	0.005	1.32
Fecal Coliform	#/100 ml	121	31,906	121,867	3.82	3,773	46,915	581,455	12.39

NOTES:
1. Measurements below detection limit were assigned values equal to one-half of the detection limit value.
2. N = number of samples; SD = standard deviation; CV = coefficient of variation.
3. Data are from following sources:
   NPDES Part II Stormwater Permit Application monitoring (1992 - 1993) and subsequent
   monitoring for the Counties of Clayton, Cobb, Dekalb, Fulton and Gwinnett, and
   the Cities of Atlanta, East Point, Marietta and Roswell.

Table 2-8

Summary of Local NPDES Monitoring Data for the Commercial Land Use Category

Constituent	Units	N	Normal Statistics			Lognormal Statistics			
			Mean	SD	CV	Median	Mean	SD	CV
BOD	mg/l	27	9	7	0.82	6	10	14	1.31
COD	mg/l	27	56	32	0.58	45	60	51	0.86
TSS	mg/l	28	112	122	1.09	62	121	200	1.66
TDS	mg/l	27	47	28	0.60	36	53	56	1.07
Total-P	mg/l	28	0.18	0.18	0.97	0.11	0.22	0.39	1.77
Dissolved-P	mg/l	27	0.10	0.11	1.14	0.05	0.13	0.31	2.30
TKN-N	mg/l	27	1.09	0.93	0.85	0.83	1.06	0.85	0.80
NO2 + NO3-N	mg/l	28	0.67	0.56	0.83	0.52	0.66	0.53	0.79
Lead	mg/l	28	0.015	0.006	0.42	0.014	0.015	0.005	0.31
Copper	mg/l	28	0.013	0.006	0.44	0.012	0.013	0.004	0.36
Zinc	mg/l	28	0.136	0.066	0.48	0.118	0.141	0.091	0.65
Cadmium	mg/l	28	0.005	0.001	0.19	0.005	0.005	0.001	0.14
Fecal Coliform	#/100 ml	25	5,333	6,423	1.20	2,306	7,215	21,392	2.97

NOTES:

1. Measurements below detection limit were assigned values equal to one-half of the detection limit value.
2. N = number of samples; SD = standard deviation; CV = coefficient of variation.
3. Data are from following sources:
   NPDES Part II Stormwater Permit Application monitoring (1992 - 1993) and subsequent monitoring for the Counties of Clayton, Cobb, Dekalb, Fulton and Gwinnett, and the Cities of Atlanta, East Point, Marietta and Roswell.

Table 2-9

Summary of Local NPDES Monitoring Data for the Industrial Land Use Category

Constituent	Units	N	Normal Statistics			Lognormal Statistics			
			Mean	SD	CV	Median	Mean	SD	CV
BOD	mg/l	77	12	16	1.28	7	12	15	1.24
COD	mg/l	78	64	58	0.91	46	65	65	0.99
TSS	mg/l	80	100	123	1.23	52	121	255	2.11
TDS	mg/l	78	68	51	0.76	56	74	64	0.86
Total-P	mg/l	77	0.22	0.19	0.89	0.15	0.25	0.32	1.30
Dissolved-P	mg/l	74	0.10	0.14	1.42	0.06	0.13	0.27	2.08
TKN-N	mg/l	76	1.48	1.39	0.94	0.99	1.59	2.00	1.26
NO2 + NO3-N	mg/l	76	0.55	0.58	1.05	0.36	0.56	0.65	1.16
Lead	mg/l	79	0.014	0.017	1.23	0.010	0.014	0.013	0.91
Copper	mg/l	79	0.017	0.021	1.22	0.012	0.016	0.014	0.87
Zinc	mg/l	79	0.172	0.144	0.84	0.134	0.172	0.139	0.81
Cadmium	mg/l	79	0.004	0.003	0.64	0.004	0.005	0.002	0.52
Fecal Coliform	#/100 ml	72	28,674	188,488	6.57	1,403	15,442	169,225	10.96

NOTES:

1. Measurements below detection limit were assigned values equal to one-half of the detection limit value.
2. N = number of samples; SD = standard deviation; CV = coefficient of variation.
3. Data are from following sources:
   NPDES Part II Stormwater Permit Application monitoring (1992 - 1993) and subsequent monitoring for the Counties of Clayton, Cobb, Dekalb, Fulton and Gwinnett, and the Cities of Atlanta, East Point, Marietta and Roswell.

Table 2-10
Summary of Local NPDES Monitoring Data for the Agricultural Land Use Category

Constituent	Units	N	Normal Statistics			Lognormal Statistics			
			Mean	SD	CV	Median	Mean	SD	CV
BOD	mg/l	15	4	1	0.27	4	4	1	0.28
COD	mg/l	17	26	15	0.55	23	27	19	0.70
TSS	mg/l	18	413	213	0.52	339	444	376	0.85
TDS	mg/l	18	47	14	0.29	46	47	12	0.26
Total-P	mg/l	18	0.27	0.13	0.47	0.22	0.33	0.37	1.13
Dissolved-P	mg/l	18	0.02	0.02	1.05	0.02	0.02	0.02	0.80
TKN-N	mg/l	18	1.35	0.74	0.55	1.12	1.41	1.09	0.77
NO2 + NO3-N	mg/l	18	0.49	0.14	0.29	0.47	0.49	0.14	0.28
Lead	mg/l	17	0.014	0.007	0.53	0.011	0.016	0.017	1.06
Copper	mg/l	16	0.007	0.005	0.71	0.005	0.008	0.009	1.10
Zinc	mg/l	17	0.046	0.021	0.45	0.042	0.047	0.023	0.49
Cadmium	mg/l	18	0.001	0.000	0.35	0.001	0.001	0.000	0.30
Fecal Coliform	#/100 ml	14	14,073	23,572	1.67	2,436	30,004	368,303	12.28

NOTES:
1. Measurements below detection limit were assigned values equal to one-half of the detection limit value.
2. N = number of samples; SD = standard deviation; CV = coefficient of variation.
3. Data are from following sources:
   NPDES Part II Stormwater Permit Application monitoring (1992 - 1993) and subsequent monitoring for the Counties of Clayton, Cobb, Dekalb, Fulton and Gwinnett, and the Cities of Atlanta, East Point, Marietta and Roswell.

Table 2-11
Recommended Event Mean Concentration for Big Creek Watershed Study

Land Use	% Impervious	Oxygen Demand and Sediment (mg/l)				Nutrients (mg/l)				Heavy Metals (mg/l)				Fecal Coliform [3]	SOURCE
		BOD	COD	TSS	TDS	TP	DP	TKN	NO23N	Lead	Copper	Zinc	Cadmium	(#/100 ml)	
Open/Forest	0.5%	4	27	444	47	0.33	0.02	1.41	0.49	0.016	0.008	0.047	0.001	2,436	A,B
Ag/Pasture and Cropland	0.5%	4	27	444	47	0.33	0.02	1.41	0.49	0.016	0.008	0.047	0.001	2,436	D
Single Family Residential:															
2.1 - 5.0 ac lot size [1]	10%	6	33	392	66	0.32	0.04	1.40	0.58	0.017	0.012	0.061	0.002	2,837	C,D
1.1 - 2.0 ac lot size [2]	12%	8	41	324	90	0.31	0.06	1.39	0.70	0.017	0.018	0.080	0.003	3,372	C,D
0.5 - 1.0 ac lot size	21%	9	47	272	109	0.30	0.08	1.38	0.79	0.018	0.022	0.094	0.004	3,773	C,D
0.25 - 0.4 ac lot size	26%	9	47	272	109	0.30	0.08	1.38	0.79	0.018	0.022	0.094	0.004	3,773	C,D
Townhouse/Garden Apartment	48%	10	60	121	53	0.22	0.13	1.06	0.66	0.015	0.013	0.141	0.005	2,306	C,D
Office/Light Industrial	70%	12	65	121	74	0.25	0.13	1.59	0.56	0.014	0.016	0.172	0.005	1,403	C,D
Heavy Industrial	80%	12	65	121	74	0.25	0.13	1.59	0.56	0.014	0.016	0.172	0.005	1,403	C,D
Commercial	85%	10	60	121	53	0.22	0.13	1.06	0.66	0.015	0.013	0.141	0.005	2,306	C,D
Major Roads	90%	10	60	121	53	0.22	0.13	1.06	0.66	0.015	0.013	0.141	0.005	2,306	C,D
Waterbodies	100%	3	22	26	100	0.03	0.01	0.60	0.60	0	0	0.11	0	100	A

SOURCES:

A: Nationwide Urban Runoff Program (1983)

B: "Chesapeake Bay Basin Model: Final Report," January 1983.

C: Atlanta Region Storm Water Characterization Study, 1993

D: Atlanta Region Storm Water Annual Sampling Program Report, 1998

NOTES:

[1] Recommended EMCs were based on 70% open/forest and 30% of 0.5 - 1.0 acre lot size

[2] Recommended EMCs were based on 30% open/forest and 70% of 0.5 - 1.0 acre lot size

[3] Fecal coliform EMCs are geometric means

measured on the sampling dates at the Big Creek USGS flow gage at Kimball Bridge Road were examined.

Figure 2-5 shows plots for several constituents measured at the Roswell Intake. The variability of the concentrations of the various pollutants is shown versus the range of streamflows experienced between 1994 and 1996.

The most obvious changes over time, as illustrated by the time series plots, appear to be increasing trends in total phosphorus (total P) and nitrite + nitrate nitrogen (NO23-N). For phosphorus, the typical concentrations during the 1970s are between 0 and 0.1 mg/l, whereas typical concentrations during the 1990s appear to be between 0.1 and 0.2 mg/l. Similarly, the typical NO23-N concentrations during the 1970s are between 0 and 1.0 mg/l, whereas typical concentrations during the 1990s appear to be between 0.5 and 1.5 mg/l. TSS and fecal coliform data show no apparent trend. The dissolved oxygen (DO) appears to show a slight trend toward decreasing DO, but all measurements are above the minimum instream DO requirement of 4.0 mg/l.

The Roswell intake data were further analyzed for dry weather and wet weather samples, based on flow data at the Kimball Bridge Road USGS gage. The USGS flow data were processed using the USGS computer program PART, which separates hydrographs into runoff and baseflow components. A sample was considered to be representative of dry weather conditions if the program indicated the 100 percent of the streamflow was baseflow on the sampling day. In contrast, if the program indicated that over 50 percent of the streamflow was attributable to runoff, and then the sample was considered representative of wet weather conditions. Samples on days with streamflow consisting of more than 50 percent but less than 100 percent baseflow were not considered representative of either wet weather or dry weather conditions.

The dry weather data are summarized in **Table 2-12**, and are displayed graphically in **Figure 2-6**. The number of samples, and the mean values, are presented for three time periods: 1970 through 1979, 1980 through 1989, and 1990 through 1998. The data are presented this way to facilitate the detection of any apparent trends over time. Trends that appear to be most significant include higher NO23-N concentrations in the 1980s and 1990s, and higher total P concentrations in the 1990s.

Wet weather data at the Roswell intake are summarized in **Table 2-13** and **Figure 2-7**, in the same manner used in Table 2-12 and Figure 2-6. Due to the limited number of samples, it is difficult to assess trends, but it does appear that NO23-N, total P and TSS concentrations are increasing with time.

A comparison of the values in Table 2-12 and Table 2-13 indicate that the wet weather concentrations are generally greater than the dry weather concentrations, particularly for TSS and fecal coliforms. One would expect this to be true, based on the EMC values in Tables 2-7 through Tables 2-10. Only the NO23-N concentration is lower

Figure 2-5
Relationship between Streamflow and Water Quality Constituent in Big Creek

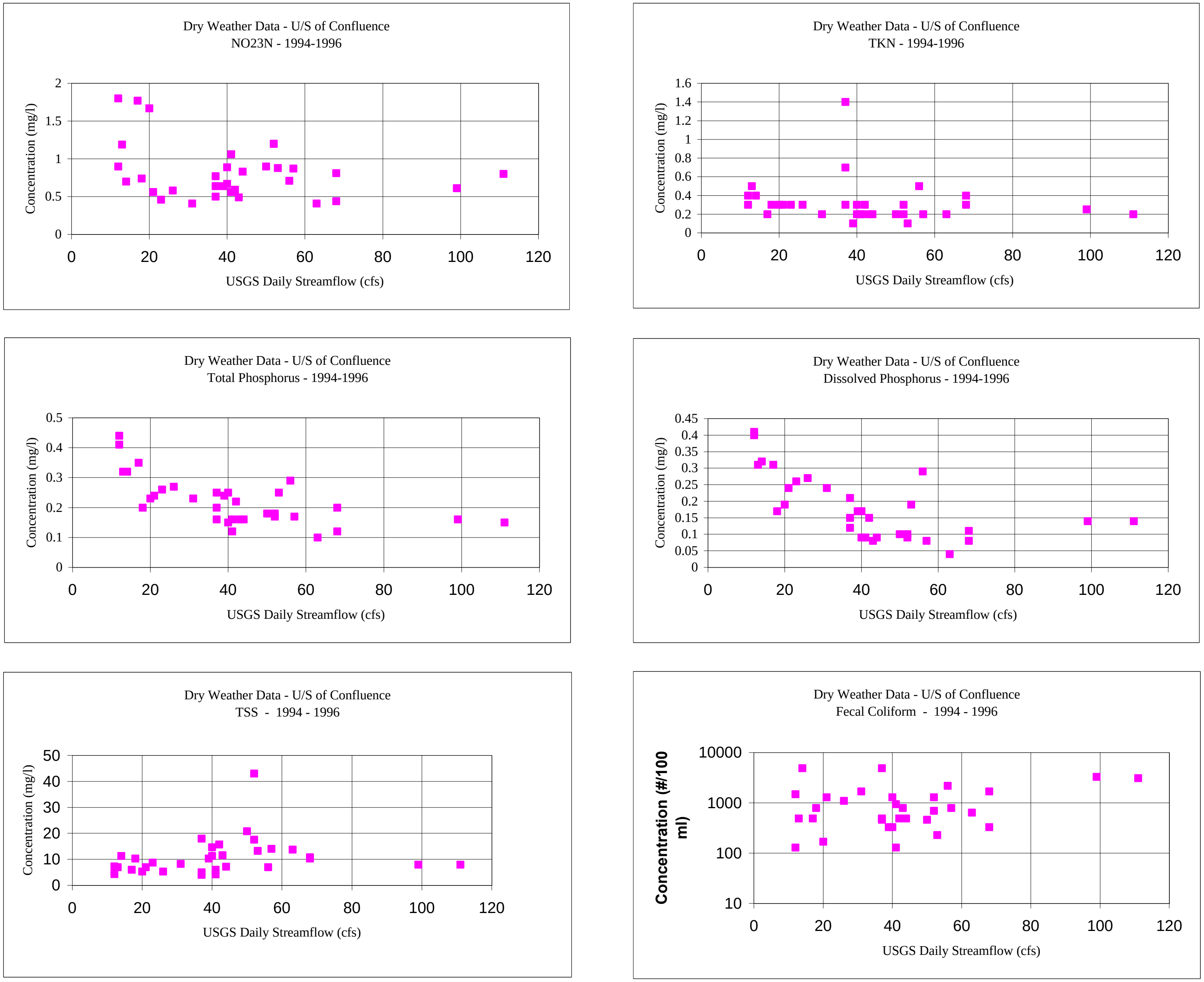


Table 2-12
Data Summary for Dry Weather Samples Only at Roswell Intake

Constituent	Units	1970 - 1979		1980 - 1989		1990 - 1998		ALL DATA	
		N	Average	N	Average	N	Average	N	Average
BOD	mg/l	43	0.9	66	0.9	34	0.9	143	0.9
Fecal Coliform	#/100 ml	44	430	64	604	34	565	142	535
NH3-N	mg/l	36	0.08	68	0.08	35	0.08	137	0.08
NO23-N	mg/l	44	0.41	66	0.84	35	0.96	145	0.74
Total P	mg/l	44	0.09	66	0.07	35	0.16	145	0.1
TSS	mg/l	44	21	65	11	35	23	144	17
TDS	mg/l	12	53	NA	NA	NA	NA	12	53
TS	mg/l	32	69	43	66	NA	NA	75	67

NOTES:
1. Fecal coliform average reflects a geometric mean.
2. All others are arithmetic averages.
3. N = number of samples.
4. NA = not applicable (no samples during period).
5. Samples were classified as dry weather if the USGS hydrograph separation program indicated that flow at Kimball Bridge Road gage consisted of 100% baseflow on the sampling date.

Figure 2-6
Average Dry Weather Constituent Concentrations at Roswell Intake.

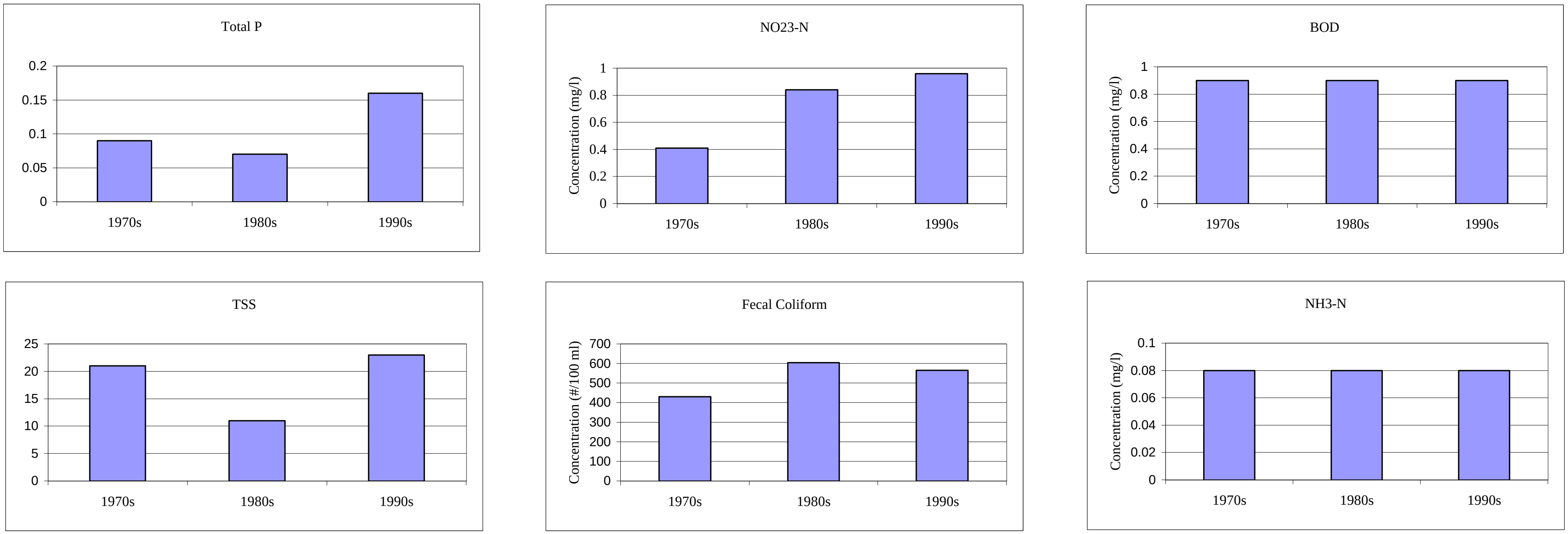
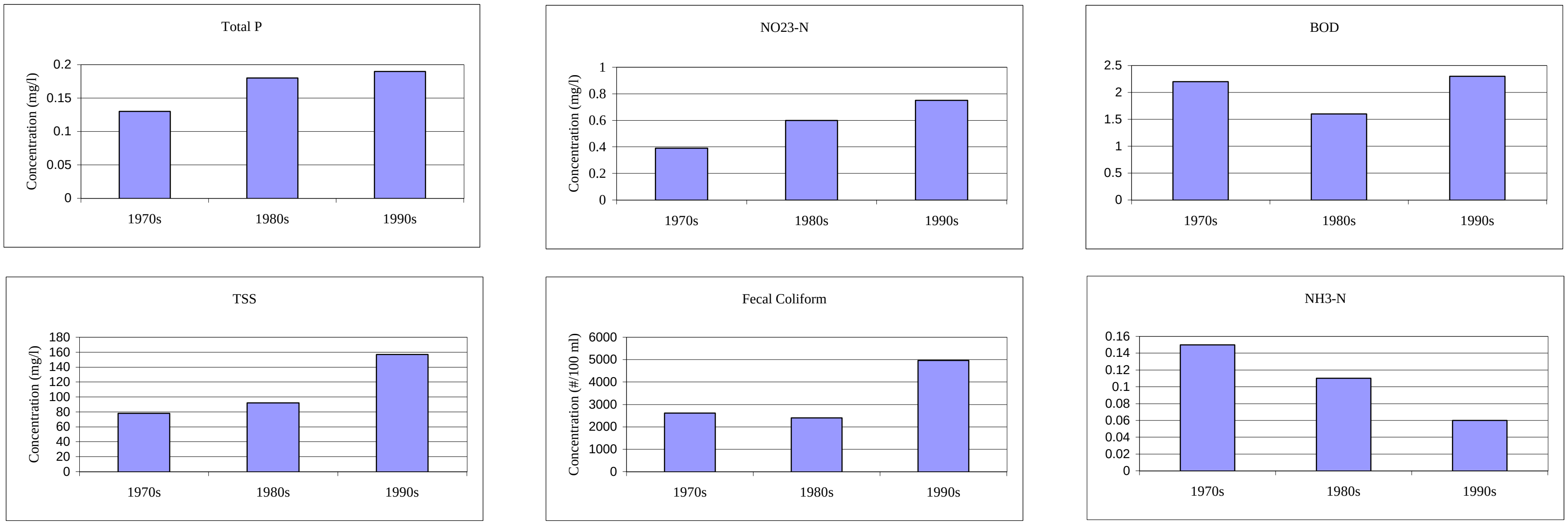


Table 2-13
Data Summary for Wet Weather Samples Only at Roswell Intake

Constituent	Units	1970 - 1979		1980 - 1989		1990 - 1998		ALL DATA	
		n	Average	n	Average	n	Average	n	Average
BOD	mg/l	11	2.2	10	1.6	8	2.3	29	2.0
Fecal Coliform	#/100 ml	13	2,613	10	2,397	8	4,963	31	2,999
NH3-N	mg/l	12	0.15	10	0.11	8	0.06	30	0.11
NO23-N	mg/l	13	0.39	10	0.6	8	0.75	31	0.55
Total P	mg/l	13	0.13	10	0.18	8	0.19	31	0.16
TSS	mg/l	12	78	10	92	8	157	29	104
TDS	mg/l	3	68	NA	NA	NA	NA	3	68
TS	mg/l	9	195	3	183	NA	NA	12	192

NOTES:
1. Fecal coliform average reflects a geometric mean.
2. All others are arithmetic averages.
3. N = number of samples.
4. NA = not applicable (no samples during period).
5. Samples were classified as wet weather if the USGS hydrograph separation program indicated that flow at Kimball Bridge Road gage consisted of less than 50% baseflow on the sampling date.

Figure 2-7
Average Wet Weather Constituent Concentrations at Roswell Intake.



during wet weather conditions. Higher dry weather NO23-N concentrations are likely due to contributions from point sources and/or septic tank discharges.

The most recent data, covering the years 1994 through 1996, are presented in **Tables 2-14 and 2-15** for dry weather and wet weather samples, respectively. The results are comparable to the results in Tables 2-12 and 2-13, with wet concentrations generally higher, except for NO23-N.

Dry weather data for the years 1994 through 1996 are plotted in **Figure 2-8**. The figure plots the data against the USGS streamflow on the sampling day. The results show little or no apparent relationship between streamflow and concentration for BOD, fecal coliform or TSS. However, there is an apparent trend of increasing concentration with decreasing streamflow for TKN, NO23-N, total P and dissolved P. Relatively constant loads from point sources and/or septic tanks are the likely cause of this trend, because those loads make up a larger percentage of the total streamflow under low flow conditions. The values presented in this section will be used to develop and validate the watershed model input parameters. Dry weather data will be used to establish baseflow (groundwater) pollutant concentrations, and to evaluate point source/septic tank concentrations if no monitoring data are available. The groundwater and point source/septic tank concentrations will be combined with groundwater discharge rates (calculated by the watershed model) and the point source/septic tank flows (constant or varying by month) to calculate dry weather loads in the watershed model.

2.7.3 NPDES Permitted Discharge Data

Four point source discharges and one land application system (LAS) with National Pollution Discharge Elimination System (NPDES) permits were identified in the Big Creek watershed. The two major point source dischargers are the City of Cumming WWTP and the Tyson Foods plant, which both discharge at the headwaters of Big Creek in Forsyth County. Over the past five years, these two plants have discharged at an average annual combined rate of about 1.5 to 2.0 million gallons per day (mgd). The other two point source NPDES permittees are the Sawnee Elementary School (Cheatam Creek) and Blue Circle Williams (Foe Killer Creek). The combined average annual discharge rate for these two permittees over the past five years has been 0.005 mgd or less. The one land application permittee is the Polo Fields Land Application System, which is permitted to apply 0.338 mgd to a golf course. The Polo Fields LAS serves a residential community surrounding the golf course.

Table 2-16 summarizes the Cumming WWTP plant performance data reported in monthly Discharge Monitoring Reports (DMRs), along with permit limits where applicable. For the years of record shown, the Cumming WWTP has monthly and weekly average limits for BOD, TSS, ammonia-N, fecal coliform bacteria, and total P, with corresponding measurements for these constituents plus zinc. The Tyson Foods discharge has mass limits (lb/day) for BOD, TSS and total P, and concentration limits for ammonia-N and fecal coliform bacteria. For constituents with mass limits,

Table 2-14
Data Summary for Dry Weather Samples Only 1994-1996 Data

Constituent	Units	U/S OF CONFLUX		ROSWELL		1990 - 1998	
		N	Average	N	Average	N	Average
BOD	mg/l	33	1.0	10	1.0	43	1.0
Fecal Coliform	#/100 ml	32	762	10	397	42	652
NH3-N	mg/l	33	0.05	11	0.09	44	0.06
TKN	mg/l	33	0.32	NA	NA	33	0.32
NO23-N	mg/l	33	0.83	11	1.01	44	0.88
Total P	mg/l	33	0.22	11	0.25	44	0.23
Dissolved P	mg/l	33	0.18	NA	NA	33	0.18
TSS	mg/l	33	11	11	16	44	12
TDS	mg/l	4	62	NA	NA	4	62

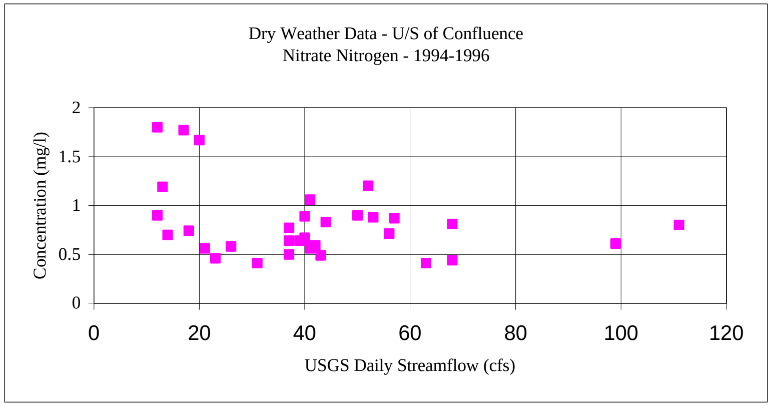
NOTES:
1. Sampling stations include: (a) Big Creek 0.5 miles upstream of confluence with Chattahoochee River, and (b) Big Creek at Roswell intake.
2. Fecal coliform average reflects a geometric mean.
3. All others are arithmetic averages.
4. N = number of samples.
5. NA = not applicable (no samples during period).
6. Samples were classified as dry weather if the USGS hydrograph separation program indicated that flow at Kimball Bridge Road gage consisted of 100% baseflow on the sampling date.

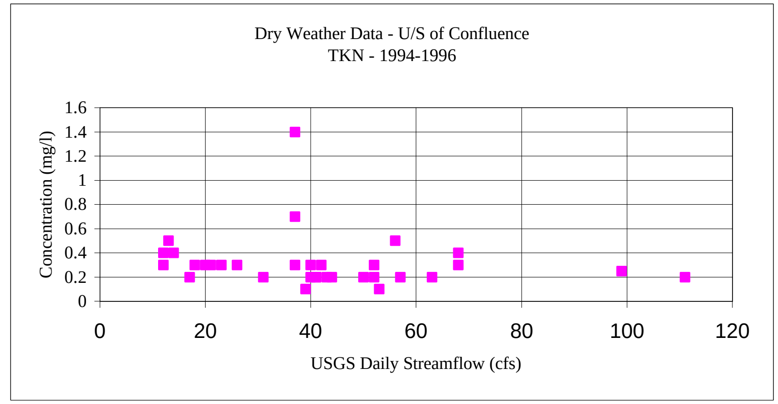
Table 2-15
Data Summary for Wet Weather Samples Only 1994-1996 Data

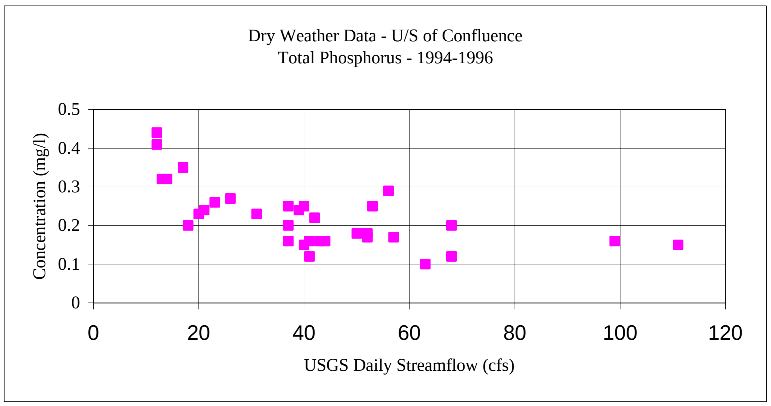
Constituent	Units	U/S OF CONFL		ROSWELL		1990 - 1998	
		N	Average	N	Average	N	Average
BOD	mg/l	19	2.9	3	2.3	22	2.8
Fecal Coliform	#/100 ml	18	6,096	3	2,343	21	5,318
NH3-N	mg/l	19	0.08	3	0.08	22	0.08
TKN	mg/l	19	0.63	NA	NA	19	0.63
NO23-N	mg/l	19	0.47	3	0.55	22	0.48
Total P	mg/l	19	0.34	3	0.26	22	0.33
Dissolved P	mg/l	19	0.11	NA	NA	19	0.11
TSS	mg/l	19	124	3	199	22	134
TDS	mg/l	1	52	NA	NA	1	52

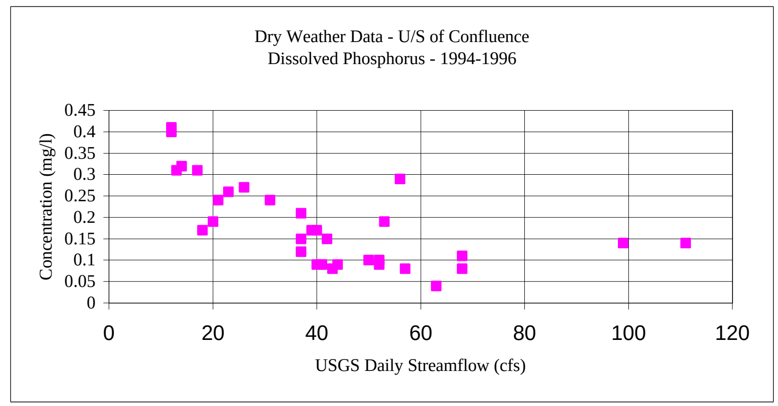
NOTES:
1. Sampling stations include: (a) Big Creek 0.5 miles upstream of confluence with Chattahoochee River, and (b) Big Creek at Roswell intake.
2. Fecal coliform average reflects a geometric mean.
3. All others are arithmetic averages.
4. N = number of samples.
5. NA = not applicable (no samples during period).
6. Samples were classified as wet weather if the USGS hydrograph separation program indicated that flow at Kimball Bridge Road gage consisted of less than 50% baseflow on the sampling date.

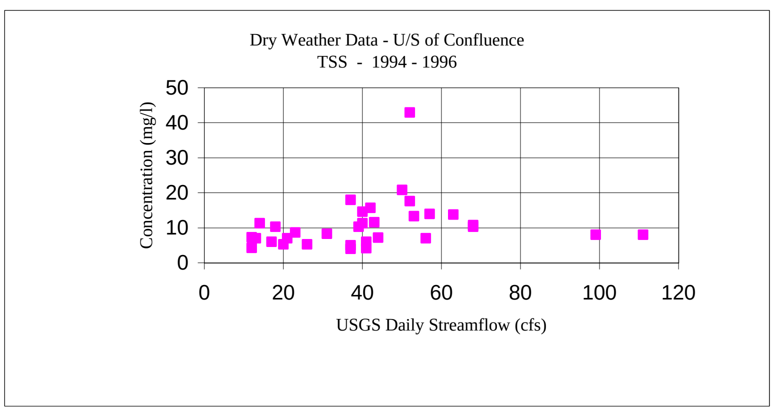
Figure 2-8
Dry Weather Concentrations of Various Constituents At Roswell Intake











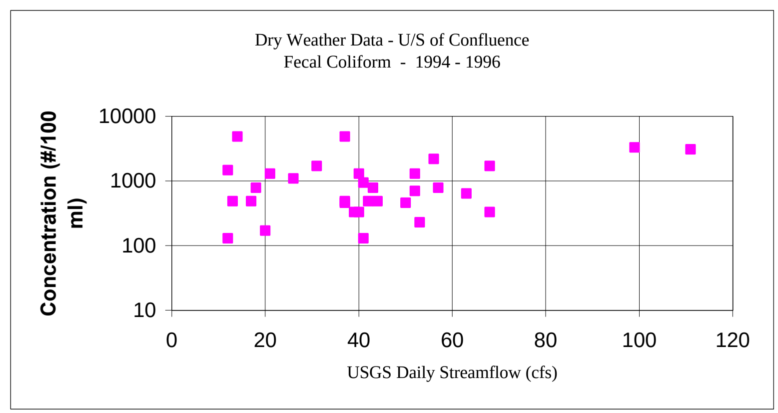


Table 2-16
Point Source Wastewater Discharges

Cumming WWTP

Constituent	Units	Monthly Average Limit	Weekly Average Limit	Average Concentrations 1994-1998				
				Jan-May 1998	1997	1996	1995	1994
Flow	mgd	2	2.5	0.94	0.62	0.94	0.67	0.5
5-Day BOD	mg/l	18	27	6.4	4.2	3	1.7	3.7
TSS	mg/l	30	45	8.4	5.3	9.4	9.2	11.5
NH3-N	mg/l	5	7.5	0.42	0.18	0.27	0.19	2
Fecal Coliform	#/100 ml	200	400	2.8	2.3	3.2	5	44
Total P	mg/l	0.75	1.12	0.35	0.48	0.44	0.19	0.4
Zinc	mg/l	NA	NA	0.12	0.16	0.08	0.09	NA

Tyson Foods

Constituent	Units	Daily Average Limit	Daily Maximum Limit	Average Concentrations 1994-1998				
				Jan-May 1998	1997	1996	1995	1994
Flow	mgd	NA	NA	1.20	0.95	0.87	0.81	NA
5-Day BOD	mg/l	15.8/16.8	23.7/25.2	2.87	5.89	6.36	4.16	NA
TSS	mg/l	22.8	45.6	10.91	13.88	11.17	9.34	NA
NH3-N	mg/l	2.0/10.0	NA	1.16	2.50	1.07	1.14	NA
Fecal Coliform	#/100 ml	NA	400	1.40	4.00	79.00	16.01	NA
Total P	mg/l	NA	NA	NA	NA	NA	NA	NA
Zinc	mg/l	NA	NA	NA	NA	NA	NA	NA

Sawnee Elementary School

Constituent	Units	Daily Average Limit	Daily Maximum Limit	Average Concentrations 1994-1998				
				Jan-May 1998	1997	1996	1995	1994
Flow	mgd	0.025	0.031	0.0049	0.0017	0.0020	0.0018	NA
5-Day BOD	mg/l	30	45	33	20	22	25	NA
TSS	mg/l	90	120	68	50	38	43	NA
NH3-N	mg/l	NA	NA	NA	NA	NA	NA	NA
Fecal Coliform	#/100 ml	NA	NA	NA	NA	NA	NA	NA
Total P	mg/l	NA	NA	NA	NA	NA	NA	NA
Zinc	mg/l	NA	NA	NA	NA	NA	NA	NA

Blue Circle Williams

Constituent	Units	Daily Average Limit	Daily Maximum Limit	Average Concentrations 1994-1998				
				Jan-May 1998	1997	1996	1995	1994
Flow	mgd	NA	NA	0.0000	0.0002	0.0012	0.0015	NA
5-Day BOD	mg/l	NA	NA	NA	NA	NA	NA	NA
TSS	mg/l	40	NA	NA	5	6	8	NA
NH3-N	mg/l	NA	NA	NA	NA	NA	NA	NA
Fecal Coliform	#/100 ml	NA	NA	NA	NA	NA	NA	NA
Total P	mg/l	NA	NA	NA	NA	NA	NA	NA
Zinc	mg/l	NA	NA	NA	NA	NA	NA	NA

NOTES:
1. NA = not applicable.
2. Tyson Foods permit limits for BOD and TSS are expressed in lb/day. Equivalent concentrations were calculated for this table, assuming a discharge rate of 1 mgd.
3. For Tyson Foods, entries with two values represent seasonal limits. The first value applies between May and November, and the second value applies between December and April.

discharge concentration values were calculated from the reported flow rate and mass load. The Sawnee Elementary School has limits and measurements for only BOD and TSS, and Blue Circle Williams has limits and measurements for only TSS.

Because of the very low discharge rates at the Sawnee Elementary School and the Blue Circle Williams discharges, only the Cumming WWTP and the Tyson Foods discharges will be included in the watershed water quality model. The two larger discharges account for virtually 100 percent of the discharge quantity and about 99 percent of the total point source loads from the four discharges.

Figure 2-9 illustrates areas in the Big Creek watershed currently served and will be served in year 2020 by sanitary sewer and the locations of NPDES permitted discharges are also shown in Figure 2-9. It is assumed that any areas of low- to medium density residential development not within the current service area shown in Figure 2-9 are served by septic tanks.

The sewer service area and 1995 land use data were overlaid in the GIS to provide a summary of residential land use presumed to be served by septic tanks. For each residential land use, wastewater rates were estimated based on literature values and previous experience. Dwelling unit densities were defined by land use categories, and estimated values of persons per dwelling unit and per capita wastewater rates will be used to estimate the total wastewater flow from the residential areas. Pollution loading from septic tank discharges is extremely difficult to estimate. In previous projects such as the Big Haynes Creek Watershed Management Plan Study, annual septic tank pollution loads focused on nutrient loading from failing septic tanks, presuming that the loads from the failing tanks would far outweigh the loads from properly-working tanks. Concentrations of total N and total P were estimated based on literature values, and flow values for urban areas were estimated as described above.

In this study, septic tank loads were treated as a point source discharge in each subbasin with areas served by septic tanks. An overall set of septic tank discharge concentrations, reflecting the failure rate and estimated contribution of failing and properly-functioning septic tanks, were developed using literature values and by comparing modeled and measured instream dry weather concentrations.

2.7.4 Biological Data

Two sources of biological data in Big Creek watershed were identified. One is a 1982 EPD study in the Big Creek headwaters, and the other is a 1996 USGS report on the Apalachicola-Chattahoochee-Flint River Basin NAWQA Study.

The 1982 EPD study was designed to document existing stream conditions in the stream headwaters and main stem, by collecting physical, chemical and biological data. The biological sampling used a qualitative technique to obtain chironomid midges, and evaluated stream degradation by evaluating the diversity and number of

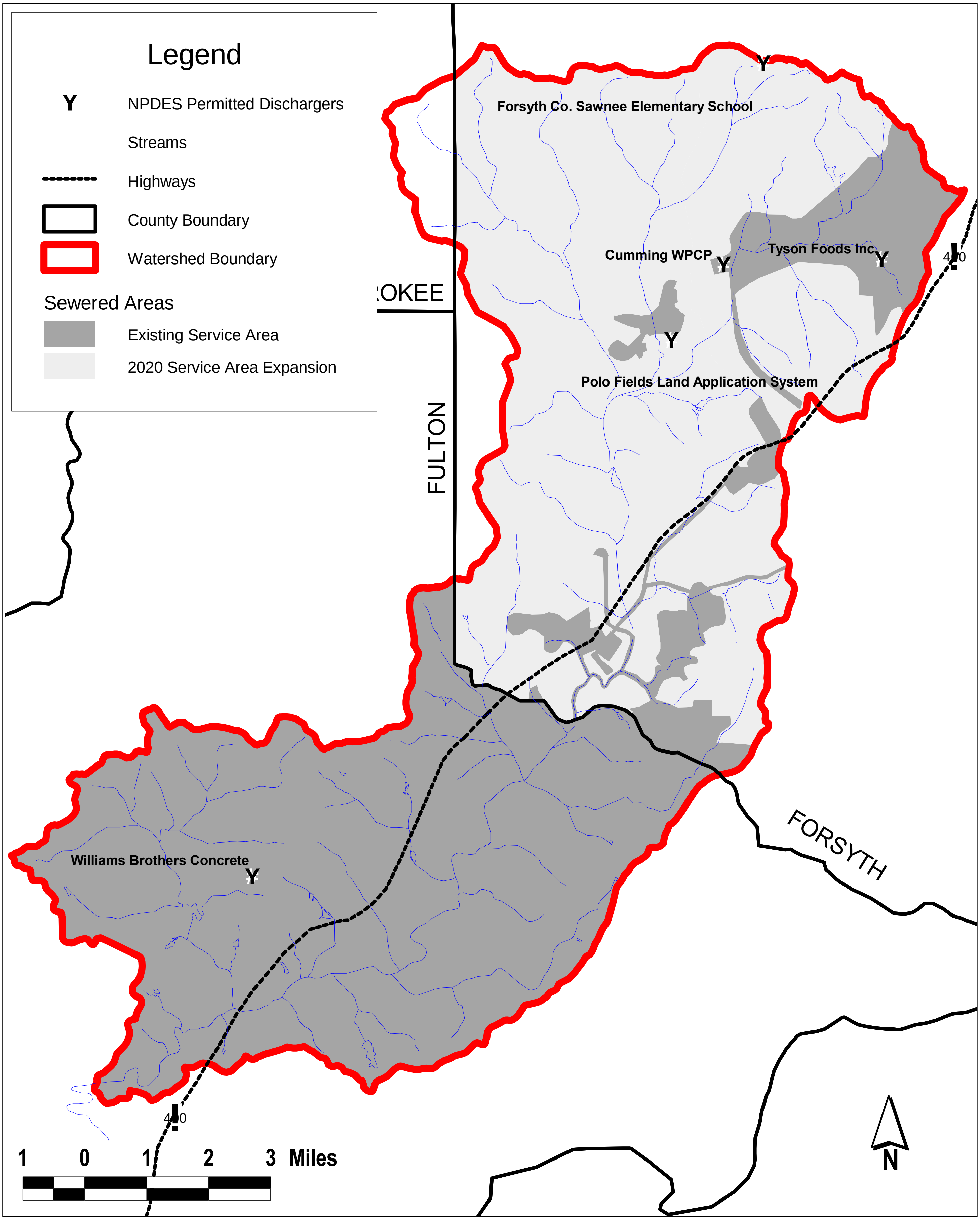


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Figure 2-9
NPDES Permitted Dischargers and Existing and Future Sewered Areas

individuals per species. A high quality stream would be expected to have a high diversity of species and a low number of individuals per species, whereas few species and large numbers of individuals indicate degradation.

The study concluded that the impacts of the wastewater treatment plant discharges were limited to Big Creek above Bethelview Road. The presence of highly tolerant species and large numbers of individuals per species in Big Creek at Tolbert Road indicated an organically enriched environment, due to the wastewater discharges. At stations below Bethelview Road, however, the highly tolerant species were not observed, and numbers of individuals were reduced.

It should be noted that the current discharge concentrations from the Cumming WWTP and the Tyson Foods plant appear to be substantially lower than during the 1982 study. The study reports effluent BOD concentrations of 6.5 and 18 mg/l for the two plants, whereas recent monitoring data show that concentrations of 3 to 6 mg/l are more typical in the present. Ammonia-N and total P discharge concentrations are also substantially higher in the 1982 study, compared to recent discharge data.

In the Apalachicola-Chattahoochee-Flint River Basin Study, biological samples were collected at indicator sites and respective comparison sites, and terrestrial and instream habitat were measured. In the Big Creek watershed, fish taxonomy data are available at three sites, which are as follows:

- Kelley Mill Branch at Kelley Mill Road
- Big Creek at State Road 29
- Big Creek below Roswell intake

At the three sites, between 10 and 13 fish species were found. At Kelley Mill Road, 11 species were detected, predominantly bluegill and bluehead chub. Blackbanded darter, bluegill and highscale shiner was detected most frequently at State Road 29, where a total of 13 species were detected. Below the Roswell intake, ten species were detected. Redbreast sunfish, green sunfish and blackbanded darter were the most frequently detected species.

2.8 Groundwater Recharge Areas

Data for the groundwater recharge areas in the watershed is based on Georgia DNR's determination of the most significant groundwater recharge areas in Georgia. The groundwater recharge areas are mapped on **Figure 2-10.** The groundwater recharge areas are expected to decrease as the impervious area increases in the watershed. If no action is taken, runoff rates will continue to increase as development occurs. This will result in increased flooding especially for lower frequency storms. The increased rates of runoff will increase the erosion potential throughout the watershed. The hydrologic pulses associated with more frequent flooding tend to damage fish habitat

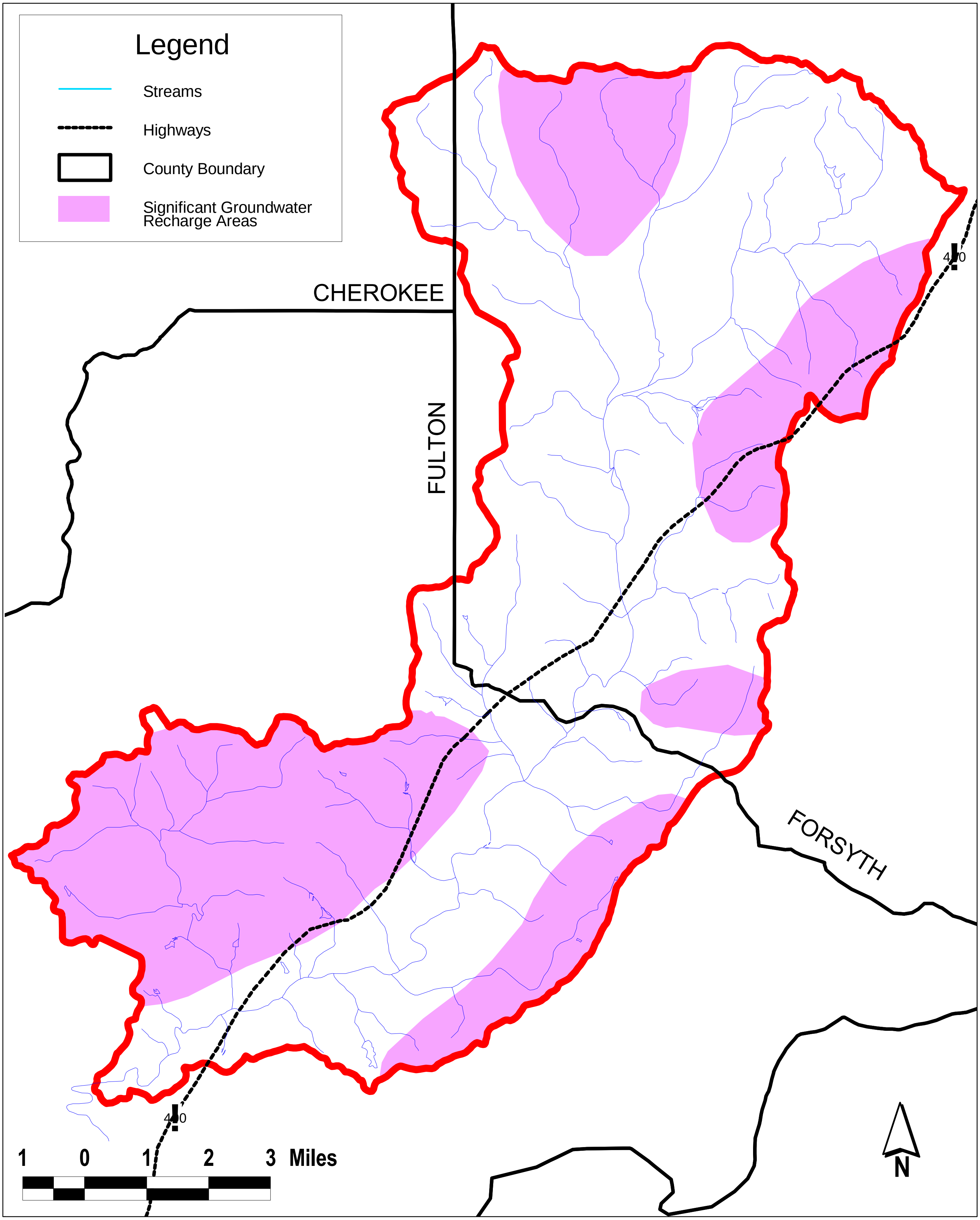

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Figure 2-10

Significant Groundwater Recharge Areas

and could destroy aquatic habitat. Decreased groundwater recharge will result in lower base flow and have adverse impacts on aquatic life. Increased erosion will result in deposition of sediments further degrading the aquatic habitat.

Development of the basin with its associated increase in impervious area will result in a significant decrease in the amount of rainfall which infiltrates into the soil and a corresponding increase in direct runoff to the stream system. The water, which infiltrates into the soil, sustains streamflow during dry periods as interflow during the period immediately following the storm and as ground water inflow during later times. Development of the Big Creek watershed will result in higher streamflows during storm events due to the increased volume of direct runoff from the impervious surfaces. During dry periods, streamflows will be lower than those currently observed during dry weather conditions due to the reduced volume of water available for ground water recharge. One example of the impact of development in the watershed is illustrated by the fact that in the period between water years 1960 and 1969, the annual mean discharge in Big Creek was 123 cubic feet per second (cfs) (USGS, 1971). If the period between water years 1960 and 1997 is considered, the annual mean is 114 cfs (USGS, 1998). While some portion of the decrease in the mean is due to climatic fluctuations, some of it is also attributable to the increase in impervious area in the watershed in recent years. The period of record that was chosen to compare to the long range had approximately the same amount of average annual rainfall and can significantly be used to look at the development.

2.9 Existing Structural Controls

The purpose of identifying and mapping the existing structural controls is to determine the location of current water quantity and / or quality control. Structural control data used to support analyses include safe dam and additional detention pond locations. Safe dam data was obtained from EPD’s Safe Dam Program and were converted into GIS data. **Figure 2-11** locates the dams from the Safe Dams Program as well as other regional facilities. The dam names are identified if included in EPD’s Safe Dam Program.

The regional facilities providing water quality benefits were labeled with a star and are included in the water quality model. In general, a lake or pond having a drainage area greater than 100 acres and a permanent pool that provides an average two-week residence time was considered to provide a water quality benefit. Removal efficiencies typical of detention BMPs were applied to the loads entering the selected lakes and ponds and are described in Section 5.

2.10 Existing Greenways

This portion of the study was tasked to develop a conceptual greenway component in the form of a greenway policy that could be adopted by local governments for incorporation into the watershed protection plan for the Big Creek watershed. Use existing information, and developed goals, in consideration of the multiple uses and

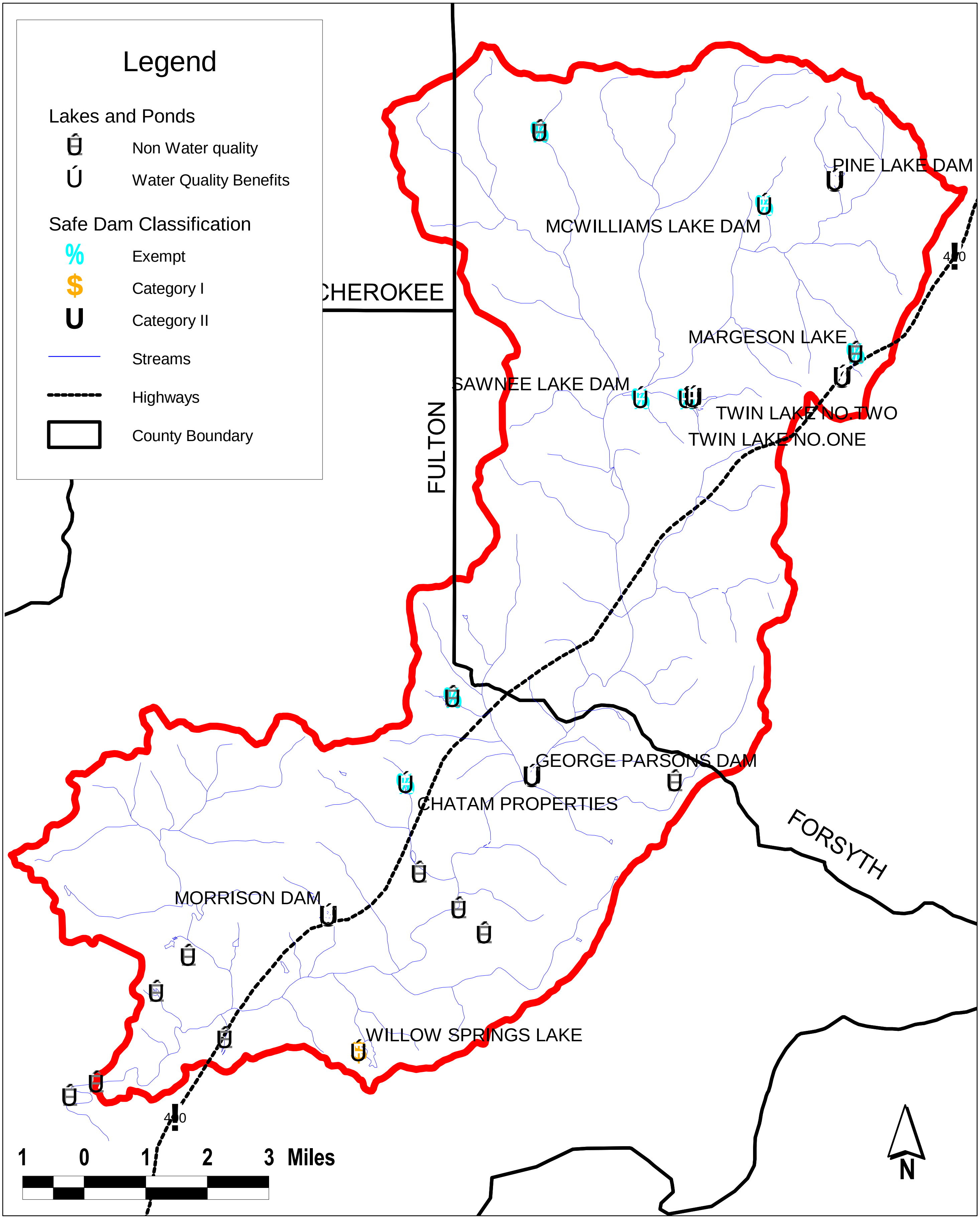

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Figure 2-11
Dam Locations

benefits of greenways for recreation, habitat protection, species diversity, water quality, flood control, transportation, air quality, and environmental education in the watershed. Meetings with the greenway representatives of the affected local jurisdictions were conducted to obtain input on the this effort and to delineate current and proposed greenways.

The identification of existing and proposed greenway facilities in the Big Creek Watershed were developed by conducting data collection for mapping and research regarding greenway approaches and policies both regionally and nationally. The following documents were reviewed for both policies and greenway projects in the study area:

- Georgia Trail Corridors and Greenways Plan
- Atlanta Region Bicycle Transportation and Pedestrian Walkways Plan
- The Fulton County Bicycle and Pedestrian Plan
- Atlanta Parks Open Space and Greenways Plan
- The Conceptual Greenways Plan: A Greenways Vision for Alpharetta
- Historic Roswell Trail System Master Plan for the Roswell Riverwalk
- The Big Creek Greenway (Alpharetta)

Other documents were reviewed for general information regarding greenway approaches and policies.

A greenways GIS coverage was developed for the study using projects found in the above documents and is shown in Section 8 in **Figure 8-3**. Parks and open space mapped by ARC were also digitized to supplement parks and open space coverages and land use data that previously existed. Threatened and Endangered species element occurrences were obtained from the Georgia Department of Natural Resources Natural Heritage Program.

Section 3
Existing Watershed Policies and Regulations

3.1 Introduction

Portions of the Big Creek watershed come under the jurisdiction of the Cities of Alpharetta, Roswell, and Cumming and Fulton, Forsyth, and Cherokee Counties. In addition, the entire watershed is subject to state and federal regulations concerning various aspects of stormwater management and water quality protection.

The ordinances and regulations vary from one jurisdiction to another. For example, one jurisdiction may require a certain level of service for stormwater management facilities while the adjacent government requires a completely different level of service. These varying requirements can have an adverse impact on the goal of managing the water resources in the Big Creek watershed.

The purpose of this section is to review the current stormwater and water quality policies and regulations affecting the watershed. Copies of the various ordinances, regulations, and policies were obtained from the each government having jurisdiction in the Big Creek watershed and as well as from the appropriate state and federal agencies. Existing federal, state and local policies and regulation affecting water quality in the Big Creek watershed are summarized in **Table 3-1**. **Table 3-2** presents the local policies and regulations organized by topic.

3.2 Comparison of Erosion and Sedimentation Control Requirements

In the case of erosion and sedimentation control, all jurisdictions have adopted the state model ordinance with slight modifications. The most notable changes were Cherokee County's creation of a Soil Erosion Advisory Board to advise the Board of Commissioners and the City of Roswell's requirement for training prior to issuance of a permit.

3.3 Comparison of Stormwater Management and Flood Control Requirements

Those jurisdictions that have adopted flood damage reduction or floodplain management ordinances have generally followed the FEMA model ordinance. Some of these ordinances are based on Flood Insurance Studies that are over twenty years old. The major differences arise when specifying how far above the base flood elevation the lowest floor of residential or nonresidential structure should be and what activities, if any are allow within the floodway. Lowest floor elevations varied from 1 to 4 feet. Some jurisdictions allow development in the floodway if hydraulic analysis shows that no increase in base flood elevations and floodway elevation will occur. On the other hand, Fulton County allows no construction in the floodway except to improve the channel hydraulics or remove an obstruction.

The level of service for stormwater management facilities varies from one jurisdiction to another. The City of Alpharetta and Forsyth County require facilities to be designed to control runoff from storms with return intervals between 2 and 100 years. Other jurisdictions refer only to the 100-year storm or do not specifically state a level of service. It should be noted that most engineers engaged in the design of stormwater management facilities in the Atlanta area generally analyze a range of storms having return intervals between 2 and 100 years. Furthermore, not all jurisdictions require an analysis of downstream impacts.

A wider variation exists between stormwater management ordinances in the matter of water quality. With the exception of the Cities of Alpharetta and Roswell and Forsyth County, existing ordinances and manuals do not address water quality issues except as they relate to erosion and sedimentation control. The City of Roswell's Lakes and Pond Partnership Policy which is intended to increase capacity of existing lakes and ponds to improve both water quality and flood control is unique to the study area.

3.4 Comparison of Buffer Requirements

Specific buffer requirements vary considerably across the watershed. Most jurisdictions, with the exception of Cumming, have adopted minimum buffer requirements more stringent than the 25 foot minimum buffer specified in the erosion and sedimentation control ordinances. The City of Roswell and Forsyth County have essentially adopted the State DNR's Rules for Environmental Planning Criteria, Minimum Planning Criteria, which includes a 100 foot buffer and 150 foot impervious setback area within a 7-mile radius of the water supply intake and a 50 foot buffer and 75 foot impervious setback area outside of a 7-mile radius of the water supply intake.

Table 3-1

Big Creek Watershed
Summary of Policies and Regulations Affecting the Watershed Organized by Jurisdiction

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
Federal	Clean Water Act and Amendments	1. Requires that water quality standards are established and met. 2. Establishes NPDES permits for municipal and private point source discharges. 3. Establishes NPDES permits for municipal stormwater discharges. 4. Establishes requirements for wetland protection and preservation. 5. Establishes requirement for TMDLs to be developed.
	Safe Drinking Water Act and Amendments	1. Requires Source Water Assessment Plans to be developed for all surface water intakes, which includes an inventory of potential pollutant sources and a determination of pollution susceptibility.
State	Metropolitan River Protection Act	1. Creates a stream corridor extending 2,000 feet from either side of the Chattahoochee River and its impoundments. 2. Within the corridor, all development activity must be reviewed by ARC for consistency with the standards of the Chattahoochee Corridor Plan. Local governments certify development activity based on the ARC findings. 3. Outside of the 2,000 foot corridor, the Act requires local governments to adopt tributary buffer zone ordinances for the tributaries of the Chattahoochee.
	Chapter 391-3-16, Rules for Environmental Planning Criteria	1. Places an upper limit of 25 percent on total impervious area in a small (less than 100 square miles) water supply watershed. Big Creek qualifies as a small water supply watershed. 2. Requires 100 foot buffers on each sidesof streams for a distance of 7 miles upstream of a small water supply intake and 50 foot buffers outside of seven miles. 3. Requires 150 foot impervious surface setback area for a distance of 7 miles upstream of a small water supply intake and 75 foot setbacks outside of 7 miles. 4. Alternative minimum criteria may be approved by the State if an equivalent level of protection and if at least as much buffer and setback area are provided for within the watershed.
	Chapter 391-3-6, Water Quality Control	1. Establishes rules and criteria for water quality control. 2. Establishes water use classifications and assigns a classification to all streams in the state. 3. Establishes maximum levels for various pollutants. 4. Establishes general water quality criteria for all streams. 5. Establishes requirements for NPDES stormwater permits.
	Erosion and Sediment Control Act	1. Requires an erosion and sediment control plan for land disturbing activities. 2. Requires local governments to adopt an erosion and sediment control ordinance. 3. The Manual for Erosion and Sediment Control in Georgia, which is a standard engineering tool, presents example calculations, engineering data, and standard BMPs. 4. Requires a 25-foot buffer along all state waters.
City of Alpharetta	Flood Damage Control Ordinance	1. Establishes standards and guidelines for development and construction in flood prone areas. 2. Requires lowest floor elevations to be 1 foot above base flood elevation in those areas where base flood elevations are published. 3. Limits proximity of structures to streams in areas without published base flood elevations to the greater of 5 times the width of the stream at the top of the banks or twenty feet, unless a study is provided certifying that locating closer to the stream will not increase base flood elevations. 4. Permits floodway encroachment with supporting documentation of no increases in elevation.

Table 3-1 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
	Soil Erosion and Sediment Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations.
	Chattahoochee River Tributary Protection Ordinance	1. Establishes a protection area consisting of the stream channel and extending 35 feet from each bank on all flowing streams tributary to the Chattahoochee River. It should be noted that the Storm Water Design Manual establishes a 100 foot buffer on perennial streams and a 35 foot buffer on intermittent streams. 2. Requires permits for land disturbing activities in the protection area. 3. Applicants must post a performance bond.
	Storm Water Management Ordinance	1. Establishes a stormwater management program. 2. Requires control of both water quantity and quality. 3. Requires the Engineering/Public Works Department to produce a Stormwater Management Design Manual. 4. Unless exempted by the ordinance, all developments must submit a stormwater management plan for review and approval. 5. Establishes maintenance responsibilities. 6. Establishes inspection procedures and penalties for violations.
	Storm Water Management Design Manual	1. Provides technical guidance for preparing stormwater master plans. 2. Requires that both water quantity and quality be addressed. 3. The first ½ inch of runoff must be captured and released over a minimum of 24 hours. A second-stage outlet is used to discharge the remainder of the inflow. 4. Requires the evaluation of downstream impacts. 5. Establishes minimum specifications for construction of drainage facilities. 6. Establishes development restrictions along stream corridors through buffers of 100 ft on perennial streams and 35 ft on intermittent streams. 7. Requires 2- through 25-year storms for design of street drainage facilities and 2- through 100-year for major facilities. 8. Provides guidance for the design of water quality BMPs. 9. Lists the required contents of a stormwater management plan.
	Tree Protection Ordinance	1. Establishes procedures for removal of trees and for the maintenance of tree density through preservation or replacement. 2. Defines tree density requirements. 3. Establishes procedures for approval of non-developmental tree removal. 4. Establishes application procedure for tree removal associated with developmental activity. 5. Requires protection of specimen trees and others which will not be removed and presents tree preservation standards. 6. Requires replanting to achieve required density.
City of Cumming	Subdivision Regulations and Construction Specifications	1. Procedures and standards for subdivision development. 2. Does not address stormwater management except as it pertains to the design of the storm drainage

Table 3-1 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
		system. 3. The City Engineer is given considerable leeway as to what is acceptable.
	Soil and Sediment Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond. 5. Lists required information to be shown on erosion and sediment control plans. 6. Establishes inspection procedures and penalties for violations.
	Floodplain Damage Prevention Ordinance	1. Establishes standards and guidelines for development and construction in flood prone areas. 2. Requires lowest floor elevations to be 2 feet above base flood elevation for residential structures and 1 foot for industrial or commercial structures in those areas where base flood elevations are published. 3. Lowest floor elevation of structures adjacent to streams in areas without published base flood elevations to be 2 feet above highest adjacent grade. 4. Permits floodway encroachment with supporting documentation of no increases in elevation. 5. Essentially follows the FEMA model ordinance. In fact the ordinance makes reference to coastal flooding. It would probably be advantageous to revise the ordinance to remove non-applicable material.
City of Roswell	Flood Damage Prevention Ordinance	1. Establishes standard and guidelines for development and construction in flood prone areas. 2. In those areas where base flood elevations have been established, requires the lowest floor of residential structures to be 4 feet above the base flood elevation. Non-residential structures may be flood proofed to 2 feet above the base flood elevation. 3. Limits proximity of structures to streams in areas without published base flood elevations to width of stream or 20 feet, whichever is greater. Lowest floor elevation 4 feet above highest adjacent grade. 4. Permits floodway encroachment with supporting documentation of no increases in elevation. 5. Essentially follows the FEMA model ordinance. More stringent in terms of lowest floor elevations.
	Streambank Protection Ordinance	1. Establishes Georgia DNR, EPD – Rules for Environmental Planning Criteria for small water supply watersheds. 2. Requires a buffer of 100 feet be maintained on both sides of a the stream as measured from the stream bank of all perennial stream corridors. 3. Does not permit impervious surface to be constructed within 150 foot setback are on both sides of the stream as measured from the stream bank of all perennial stream corridors. 4. Prohibits septic and septic tank drainfields within the setback area of #3 above. 5. Requires permits for land disturbing activities in the protection area.
	Erosion and Sediment Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations.

Table 3-1 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
	Roswell Tree Ordinance	1. Establishes procedures for removal of trees and for the maintenance of tree density through preservation or replacement. 2. Defines tree density requirements. 3. Establishes procedures for approval of non-developmental tree removal. 4. Establishes application procedure for tree removal associated with developmental activity. 5. Requires protection of specimen trees and others which will not be removed and presents tree preservation standards. 6. Requires replanting to achieve required density. 7. Arborist may withhold certificate of occupancy. 8. Presents example calculations and list of acceptable trees.
	Roswell Lakes and Ponds Partnership Policy	1. Intended to increase the capacity of lakes and ponds in order to satisfy water quality and quantity regulations. 2. City will assist owners by paying a portion of the costs associated with silt removal and/or upgrading of control structures and other features. 3. City will conduct seminars for owners during the program on identifying and eliminating sources of siltation. 4. A lake or pond must have a drainage area of 100 acres or design storage of 20 acre-feet to qualify. 5. Owners of smaller lakes or ponds may petition the Mayor and Council to be included. 6. Presents application requirements. 7. Program is unique to the area. Other jurisdictions should give it serious consideration.
	Water Resource Protection Ordinance	1. Requires disconnection of impervious area to 15% directly connected impervious area if the total site imperviousness is greater than 25% and use of best management practices 2. Requires use of selected structural best management practices or otherwise approved by the Engineering Division Manager and treatment of 1.2 inches of rainfall. 3. Also requires monitoring of best management practice effectiveness.
	Subdivision Ordinance and Standard Construction Specifications	4. Procedures and standards for subdivision development. 5. Does not address stormwater management except to require the 10-year storm to be used for the design of the street drainage system and the 100-year storm for major facilities.
Cherokee County	Erosion and Sediment Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations. 6. Establishes a Soil Erosion Advisory Board to advise the Commission and Zoning Department.
	Stormwater Detention Regulations	1. Requires Stormwater Management Report for all development projects. 2. Detention requirements may be waived if certain conditions are met. 3. Downstream impacts must be analyzed for a distance of approximately ½ mile downstream. 4. Detention facilities must be designed to control runoff from the 2-, 10-, 25-, and 50-year storms. Control of the 100-year storm may be required if conditions warrant. 5. No specific requirements for water quality control.

Table 3-1 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
	Flood Damage Prevention Ordinance	1. Establishes standards and guidelines for development and construction in flood prone areas. 2. Requires lowest floor elevations to be 1 foot above base flood elevation for residential structures in those areas where base flood elevations are published. Nonresidential structures may be flood proofed to 1 foot above the base flood elevation. 3. Limits proximity of structures to streams in areas without published base flood elevations to the greater of the width of the stream at the top of the banks or twenty feet, unless a study is provided certifying that locating closer to the stream will not increase base flood elevations. Lowest floor must be 3 feet above highest adjacent ground elevation. 4. Permits floodway encroachment with supporting documentation of no increases in elevation. 5. Essentially follows FEMA model program set forth in the National Flood Insurance Program..
	Stream Buffer Regulations Ordinance	1. Establishes a 50 foot buffer along each bank of all primary and secondary streams. 2. Establishes a 100 foot buffer along each bank of the Etowah River.
Forsyth County	Soil Erosion and Sedimentation Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations.
	Big Creek Flood Plain Ordinance	1. Established Big Creek floodplain by specifying elevations at road crossings. 2. Prohibited development in the floodplain as defined. 3. Passed in 1980. 4. Elevations were revised downward in 1984 as the result of a new study.
	Road Drainage Code Ordinance	1. Established procedures for regulating the construction of driveway culverts, ditches, and other structures which discharge onto public rights-of-way. 2. Established permitting procedures. 3. Prohibited the discharge of sediment, trash, and other foreign material.
	Flood Damage Prevention Ordinance	1. Establishes standards and guidelines for development and construction in flood prone areas. 2. In those areas where base flood elevations are published, requires lowest floor elevations of residential structures to be 2 feet above base flood elevation and 1 foot for nonresidential structures. 3. Prohibits development in areas without published base flood elevations without supporting study. 4. Permits floodway encroachment with supporting documentation of no increases in elevation. 5. Essentially follows FEMA model program.
	Storm Water Management Ordinance	1. Establishes a stormwater management program. 2. Requires control of both water quantity and quality. 3. Requires the Public Works Department to produce a Stormwater Management Design Manual. 4. Unless exempted by the ordinance, all developments must submit a stormwater management plan for review and approval. 5. Establishes maintenance responsibilities. 6. Establishes inspection procedures and penalties for violations.
	Storm Water Management	1. Provides technical guidance for the preparation of stormwater management plans.

Table 3-1 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
	Design Manual	2. Requires the post-development peak rate of runoff not to exceed the pre-developed peak for the 2-, 10-, 25- and 100-year storms. 3. Allows use of the Rational method up to 100 acres, SCS methods up to 10,000 acres, and USGS regression equations above 10,000 acres. Other methods may used if approved in advance. 4. Presents storm sewer design standards. 5. Requires analysis of downstream impacts. 6. Establishes site and detention design criteria for water quality enhancement. Developers must select one set of each. 7. Encourages the use of regional detention structures to enhance water quality.
	Big Creek Protected Water Supply Watershed Overlay District	1. Specifies buffer, impervious area setback and septic tank requirements for areas within and outside a seven-mile radius of the Big Creek water supply intake consistent with the Georgia DNR, EPD Environmental Planning Criteria for small water supply watersheds. 2. Also includes provisions for landfills and hazardous materials handling. 3. Establishes categories and provisions for exemptions (previously established land uses, mining activities, forestry practices and utility construction)
	Tributary Protection Code	4. Established 35 foot buffer along each bank of permanent tributaries of the Chattahoochee. 5. Prohibits land disturbing activities within the buffer without a permit. 6. Establishes procedure for permit issuance.
	Tree Preservation and Replacement Ordinance/Administrative Guidelines	1. Establishes procedures for removal of trees and for the maintenance of tree density through preservation or replacement. 2. Defines tree density requirements. 3. Establishes procedures for approval of non-developmental tree removal. 4. Establishes application procedure for tree removal associated with developmental activity. 5. Requires protection of specimen trees and others which will not be removed and presents tree preservation standards. 6. Requires replanting to achieve required density. 7. Establishes a Tree Preservation Commission. 8. Presents example calculations and list of acceptable trees.
Fulton County	Soil Erosion and Sedimentation Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations. 6. Requires biweekly report to the County.
	Resolution Establishing the Chattahoochee River Tributary Protection Area	1. Establishes a protection area consisting of the streams channel and extending 35 feet from each bank on all flowing streams tributary to the Chattahoochee River. The first 15 feet of the buffer area adjacent to the banks must remain undisturbed. The remaining 20 feet may be disturbed provided that the area is revegetated. 2. Requires permits for land disturbing activities in the protection area.

Table 3-1 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
		3. Provides for inspections and specifies penalties for violations.
	Floodplain Management Ordinance	1. Established Special Flood Hazard Zone as designated in Flood Insurance Study date June 22, 1998. 2. Establishes permitted uses in the flood hazard zone. 3. No new structures allowed in special flood hazard areas. If adjacent, lowest floor must be 3 feet above base flood elevation. 4. No development allowed in floodway except to improve conveyance. 5. Presents list of studies and other information required to support proposed development.
	Comprehensive Stormwater Management Ordinance	1. Establishes a comprehensive stormwater management program considering both water quantity and quality. 2. Requires preparation of a stormwater concept plan and a stormwater management plan by all developers. 3. Establishes review and inspection procedures. 4. Establishes maintenance requirements. 5. Public Works Department to develop and maintain Fulton County Comprehensive Storm Drainage Design and Criteria Manual.
	Manual On Drainage Design	1. Presents procedures and examples for the design of stormwater management and erosion and sediment control facilities. 2. Other than erosion and sediment control, no consideration of water quality. 3. Largely based on manual calculations. 4. Fulton County plans to develop a new manual as part of the ongoing watershed assessment projects.
	Tree Preservation Ordinance/Administrative Guidelines	1. Provides for the tree preservation and protection within defined protection zones on development sites and for the replacement of other trees. 2. Administrative Guidelines define the permitting process and detail the information which must be submitted. 3. Administrative Guidelines provide detailed examples and criteria for various methods of tree replacement. 4. The administrative guidelines are the most comprehensive of any reviewed.
Atlanta Regional Commission	Metropolitan River Protection Act Review Administrative Manual	1. Describes ARC review process. 2. Contains application forms. 3. Describes ARC enforcement provisions.

Table 3-2

Big Creek Watershed
Summary of Policies and Regulations Affecting the Watershed Organized by Topic

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
City of Alpharetta	Flood Damage Control Ordinance	1. Establishes standards and guidelines for development and construction in flood prone areas. 2. Requires lowest floor elevations to be 1 foot above base flood elevation in those areas where base flood elevations are published. 3. Limits proximity of structures to streams in areas without published base flood elevations to the greater of 5 times the width of the stream at the top of the banks or twenty feet, unless a study is provided certifying that locating closer to the stream will not increase base flood elevations. 4. Permits floodway encroachment with supporting documentation of no increases in elevation.
City of Roswell	Flood Damage Prevention Ordinance	1. Establishes standard and guidelines for development and construction in flood prone areas. 2. In those areas where base flood elevations have been established, requires the lowest floor of residential structures to be 4 feet above the base flood elevation. Non-residential structures may be flood proofed to 2 feet above the base flood elevation. 3. Limits proximity of structures to streams in areas without published base flood elevations to width of stream or 20 feet, whichever is greater. Lowest floor elevation 4 feet above highest adjacent grade. 4. Permits floodway encroachment with supporting documentation of no increases in elevation. 5. Essentially follows the FEMA model ordinance. More stringent in terms of lowest floor elevations.
Cherokee County	Flood Damage Prevention Ordinance	1. Establishes standards and guidelines for development and construction in flood prone areas. 2. Requires lowest floor elevations to be 1 foot above base flood elevation for residential structures in those areas where base flood elevations are published. Nonresidential structures may be flood proofed to 1 foot above the base flood elevation. 3. Limits proximity of structures to streams in areas without published base flood elevations to the greater of the width of the stream at the top of the banks or twenty feet, unless a study is provided certifying that locating closer to the stream will not increase base flood elevations. Lowest floor must be 3 feet above highest adjacent ground elevation. 4. Permits floodway encroachment with supporting documentation of no increases in elevation. 5. Essentially follows FEMA model program set forth in the National Flood Insurance Program..
Forsyth County	Flood Damage Prevention Ordinance	1. Establishes standards and guidelines for development and construction in flood prone areas. 2. In those areas where base flood elevations are published, requires lowest floor elevations of residential structures to be 2 feet above base flood elevation and 1 foot for nonresidential structures. 3. Prohibits development in areas without published base flood elevations without supporting study. 4. Permits floodway encroachment with supporting documentation of no increases in elevation. 5. Essentially follows FEMA model program.
City of Cumming	Floodplain Damage Prevention Ordinance	1. Establishes standards and guidelines for development and construction in flood prone areas. 2. Requires lowest floor elevations to be 2 feet above base flood elevation for residential structures and 1 foot for industrial or commercial structures in those areas where base flood elevations are published. 3. Lowest floor elevation of structures adjacent to streams in areas without published base flood elevations to be 2 feet above highest adjacent grade. 4. Permits floodway encroachment with supporting documentation of no increases in elevation. 5. Essentially follows the FEMA model ordinance. In fact the ordinance makes reference to coastal flooding. It would probably be advantageous to revise the ordinance to remove non-applicable material.

Table 3-2 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
Forsyth County	Big Creek Flood Plain Ordinance	1. Established Big Creek floodplain by specifying elevations at road crossings. 2. Prohibited development in the floodplain as defined. 3. Passed in 1980. 4. Elevations were revised downward in 1984 as the result of a new study.
Fulton County	Floodplain Management Ordinance	1. Established Special Flood Hazard Zone as designated in Flood Insurance Study date June 22, 1998. 2. Establishes permitted uses in the flood hazard zone. 3. No new structures allowed in special flood hazard areas. If adjacent, lowest floor must be 3 feet above base flood elevation. 4. No development allowed in floodway except to improve conveyance. 5. Presents list of studies and other information required to support proposed development.
City of Alpharetta	Soil Erosion and Sediment Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations.
City of Cumming	Soil and Sediment Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond. 5. Lists required information to be shown on erosion and sediment control plans. 6. Establishes inspection procedures and penalties for violations.
City of Roswell	Erosion and Sediment Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations.
Cherokee County	Erosion and Sediment Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations. 6. Establishes a Soil Erosion Advisory Board to advise the Commission and Zoning Department.

Table 3-2 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
Forsyth County	Soil Erosion and Sedimentation Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations.
Fulton County	Soil Erosion and Sedimentation Control Ordinance	1. Establishes erosion and sediment control regulations. 2. Essentially follows the state Erosion and Sediment Control Act. 3. Requires BMPs to control erosion and sedimentation from all storms up to and including a 25-year, 24-hour event. Establishes procedures in the Manual for Erosion and Sediment Control in Georgia as the minimum standard. 4. Can require applicants to post a performance bond if there is a past history of violations. 5. Establishes inspection procedures and penalties for violations. 6. Requires biweekly report to the County.
City of Alpharetta	Chattahoochee River Tributary Protection Ordinance	1. Establishes a protection area consisting of the stream channel and extending 35 feet from each bank on all flowing streams tributary to the Chattahoochee River. It should be noted that the Storm Water Design Manual establishes a 100 foot buffer on perennial streams and a 35 foot buffer on intermittent streams. 2. Requires permits for land disturbing activities in the protection area. 3. Applicants must post a performance bond.
Fulton County	Resolution Establishing the Chattahoochee River Tributary Protection Area	1. Establishes a protection area consisting of the streams channel and extending 35 feet from each bank on all flowing streams tributary to the Chattahoochee River. The first 15 feet of the buffer area adjacent to the banks must remain undisturbed. The remaining 20 feet may be disturbed provided that the area is revegetated. 2. Requires permits for land disturbing activities in the protection area. 3. Provides for inspections and specifies penalties for violations.
City of Alpharetta	Storm Water Management Ordinance	1. Establishes a stormwater management program. 2. Requires control of both water quantity and quality. 3. Requires the Engineering/Public Works Department to produce a Stormwater Management Design Manual. 4. Unless exempted by the ordinance, all developments must submit a stormwater management plan for review and approval. 5. Establishes maintenance responsibilities. 6. Establishes inspection procedures and penalties for violations.
City of Roswell	Water Resource Protection Ordinance	1. Requires disconnection of impervious area to 15% directly connected impervious area if the total site imperviousness is greater than 25% and use of best management practices 2. Requires use of selected structural best management practices or otherwise approved by the Engineering Division Manager and treatment of 1.2 inches of rainfall. 3. Also requires monitoring of best management practice effectiveness.

Table 3-2 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
City of Roswell	Subdivision Ordinance and Standard Construction Specifications	1. Procedures and standards for subdivision development. 2. Does not address stormwater management except to require the 10-year storm to be used for the design of the street drainage system and the 100-year storm for major facilities.
Cherokee County	Stormwater Detention Regulations	1. Requires Stormwater Management Report for all development projects. 2. Detention requirements may be waived if certain conditions are met. 3. Downstream impacts must be analyzed for a distance of approximately ½mile downstream. 4. Detention facilities must be designed to control runoff from the 2-, 10-, 25-, and 50-year storms. Control of the 100-year storm may be required if conditions warrant. 5. No specific requirements for water quality control.
Forsyth County	Road Drainage Code Ordinance	1. Established procedures for regulating the construction of driveway culverts, ditches, and other structures which discharge onto public rights-of-way. 2. Established permitting procedures. 3. Prohibited the discharge of sediment, trash, and other foreign material.
Forsyth County	Storm Water Management Ordinance	1. Establishes a stormwater management program. 2. Requires control of both water quantity and quality. 3. Requires the Public Works Department to produce a Stormwater Management Design Manual. 4. Unless exempted by the ordinance, all developments must submit a stormwater management plan for review and approval. 5. Establishes maintenance responsibilities. 6. Establishes inspection procedures and penalties for violations.
Fulton County	Comprehensive Stormwater Management Ordinance	1. Establishes a comprehensive stormwater management program considering both water quantity and quality. 2. Requires preparation of a stormwater concept plan and a stormwater management plan by all developers. 3. Establishes review and inspection procedures. 4. Establishes maintenance requirements. 5. Public Works Department to develop and maintain Fulton County Comprehensive Storm Drainage Design and Criteria Manual.
City of Alpharetta	Storm Water Management Design Manual	1. Provides technical guidance for preparing stormwater master plans. 2. Requires that both water quantity and quality be addressed. 3. The first ½inch of runoff must be captured and released over a minimum of 24 hours. A second-stage outlet is used to discharge the remainder of the inflow. 4. Requires the evaluation of downstream impacts. 5. Establishes minimum specifications for construction of drainage facilities. 6. Establishes development restrictions along stream corridors through buffers of 100 ft on perennial streams and 35 ft on intermittent streams. 7. Requires 2- through 25-year storms for design of street drainage facilities and 2- through 100-year for major facilities. 8. Provides guidance for the design of water quality BMPs. 9. Lists the required contents of a stormwater management plan.

Table 3-2 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
City of Cumming	Subdivision Regulations and Construction Specifications	1. Procedures and standards for subdivision development. 2. Does not address stormwater management except as it pertains to the design of the storm drainage system. 3. The City Engineer is given considerable leeway as to what is acceptable.
Forsyth County	Storm Water Management Design Manual	1. Provides technical guidance for the preparation of stormwater management plans. 2. Requires the post-development peak rate of runoff not to exceed the pre-developed peak for the 2-, 10-, 25- and 100-year storms. 3. Allows use of the Rational method up to 100 acres, SCS methods up to 10,000 acres, and USGS regression equations above 10,000 acres. Other methods may used if approved in advance. 4. Presents storm sewer design standards. 5. Requires analysis of downstream impacts. 6. Establishes site and detention design criteria for water quality enhancement. Developers must select one set of each. 7. Encourages the use of regional detention structures to enhance water quality.
Fulton County	Manual On Drainage Design	1. Presents procedures and examples for the design of stormwater management and erosion and sediment control facilities. 2. Other than erosion and sediment control, no consideration of water quality. 3. Largely based on manual calculations. 4. Fulton County plans to develop a new manual as part of the ongoing watershed assessment projects.
City of Alpharetta	Tree Protection Ordinance	1. Establishes procedures for removal of trees and for the maintenance of tree density through preservation or replacement. 2. Defines tree density requirements. 3. Establishes procedures for approval of non-developmental tree removal. 4. Establishes application procedure for tree removal associated with developmental activity. 5. Requires protection of specimen trees and others which will not be removed and presents tree preservation standards. 6. Requires replanting to achieve required density.
City of Roswell	Roswell Tree Ordinance	1. Establishes procedures for removal of trees and for the maintenance of tree density through preservation or replacement. 2. Defines tree density requirements. 3. Establishes procedures for approval of non-developmental tree removal. 4. Establishes application procedure for tree removal associated with developmental activity. 5. Requires protection of specimen trees and others which will not be removed and presents tree preservation standards. 6. Requires replanting to achieve required density. 7. Arborist may withhold certificate of occupancy. 8. Presents example calculations and list of acceptable trees.

Table 3-2 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
Forsyth County	Tree Preservation and Replacement Ordinance/Administrative Guidelines	1. Establishes procedures for removal of trees and for the maintenance of tree density through preservation or replacement. 2. Defines tree density requirements. 3. Establishes procedures for approval of non-developmental tree removal. 4. Establishes application procedure for tree removal associated with developmental activity. 5. Requires protection of specimen trees and others which will not be removed and presents tree preservation standards. 6. Requires replanting to achieve required density. 7. Establishes a Tree Preservation Commission. 8. Presents example calculations and list of acceptable trees.
Fulton County	Tree Preservation Ordinance/Administrative Guidelines	1. Provides for the tree preservation and protection within defined protection zones on development sites and for the replacement of other trees. 2. Administrative Guidelines define the permitting process and detail the information which must be submitted. 3. Administrative Guidelines provide detailed examples and criteria for various methods of tree replacement. 4. The administrative guidelines are the most comprehensive of any reviewed.
City of Roswell	Streambank Protection Ordinance	1. Establishes Georgia DNR, EPD – Rules for Environmental Planning Criteria for small water supply watersheds. 2. Requires a buffer of 100 feet be maintained on both sides of a the stream as measured from the stream bank of all perennial stream corridors. 3. Does not permit impervious surface to be constructed within 150 foot setback are on both sides of the stream as measured from the stream bank of all perennial stream corridors. 4. Prohibits septic and septic tank drainfields within the setback area of #3 above. 5. Requires permits for land disturbing activities in the protection area.
Cherokee County	Stream Buffer Regulations Ordinance	1. Establishes a 50 foot buffer along each bank of all primary and secondary streams. 2. Establishes a 100 foot buffer along each bank of the Etowah River.
Forsyth County	Tributary Protection Code	1. Established 35 foot buffer along each bank of permanent tributaries of the Chattahoochee. 2. Prohibits land disturbing activities within the buffer without a permit. 3. Establishes procedure for permit issuance.
City of Roswell	Roswell Lakes and Ponds Partnership Policy	1. Intended to increase the capacity of lakes and ponds in order to satisfy water quality and quantity regulations. 2. City will assist owners by paying a portion of the costs associated with silt removal and/or upgrading of control structures and other features. 3. City will conduct seminars for owners during the program on identifying and eliminating sources of siltation. 4. A lake or pond must have a drainage area of 100 acres or design storage of 20 acre-feet to qualify. 5. Owners of smaller lakes or ponds may petition the Mayor and Council to be included. 6. Presents application requirements. 7. Program is unique to the area. Other jurisdictions should give it serious consideration.

Table 3-2 (continued)

Government	Policy, Ordinance, or Regulation	Key Requirements and Comments
Forsyth County	Big Creek Protected Water Supply Watershed Overlay District	4. Specifies buffer, impervious area setback and septic tank requirements for areas within and outside a seven-mile radius of the Big Creek water supply intake consistent with the Georgia DNR, EPD Environmental Planning Criteria for small water supply watersheds. 5. Also includes provisions for landfills and hazardous materials handling. 6. Establishes categories and provisions for exemptions (previously established land uses, mining activities, forestry practices and utility construction)
Atlanta Regional Commission	Metropolitan River Protection Act Review Administrative Manual	1. Describes ARC review process. 2. Contains application forms. 3. Describes ARC enforcement provisions.

Section 4
Estimating Current and Future Runoff and Flooding Impacts

4.1 Introduction

This section describes the water quantity analysis performed for this project and presents the results of the analysis. The analysis consists of both hydrologic and hydraulic modeling. The USEPA Storm Water Management Model (SWMM) was selected to assess the hydrology and hydraulics of the Big Creek watershed. The model was run for several design storms (2, 10, 25, and 100-year) to determine peak discharges, surface elevations and peak velocities under existing (1995) and future (2020) land use conditions. Modeling results allowed for an evaluation of flooding and stream erosion potential and to some degree the ability of groundwater to replenish streams at low flow.

4.2 Model Description and Approach

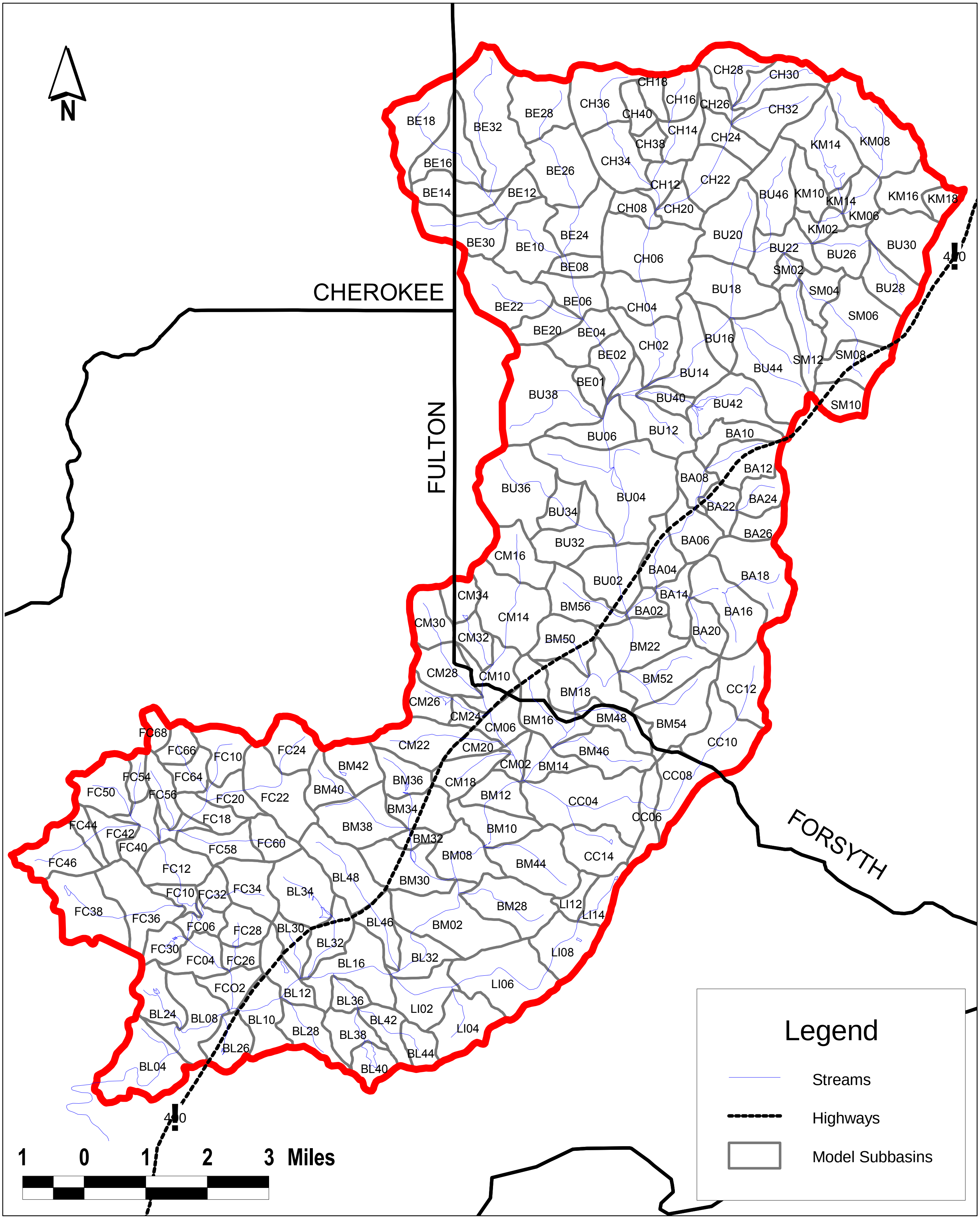
The RUNOFF and EXTRAN modules of SWMM were used to simulate hydrograph and routing characteristics of the Big Creek watershed. The RUNOFF module was set up to calculate the volume and rate of surface runoff occurring in model subbasins based on rainfall and subbasin physical characteristics (e.g., slope, roughness, impervious area). The EXTRAN module of SWMM receives runoff hydrograph input and routes the runoff through the conveyance system (streams) of the watershed.

4.2.1 Subbasin Delineation

The initial step in SWMM model setup is the delineation of subbasins. Using USGS quad sheets, subbasins were delineated based on physical features such as ponds, wetlands, roads, and problem areas and at confluences of major strea ms and then digitized using ArcINFO GIS. Effort was made to limit the average subbasin size to approximately 300 acres so that a regional vs. on-site structural control approach could be evaluated. Watershed subbasins are shown in **Figure 4-1**. Each subbasin was assigned an alphanumeric identification according to the tributary name.

4.2.2 Rainfall

Rainfall data were used to generate the flows for stormwater evaluations. Data are generally characterized by amount (inches), intensity (inches per hour), frequency (years) and duration (hours), The nearest long-term continuous rain gauge is located at The National Weather Service station at Hartsfield Atlanta International Airport (HAIA). Design rainfall data were based on the 1963 US Weather Bureau Technical Paper 40 (TP-40). Rainfall quantities for the design storms used for this study are presented in **Table 4-1**. Rainfall intensities were then generated by CDM for each design storm using the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) Type II rainfall distribution.



Atlanta Regional Commission

Big Creek Watershed Study

Figure 4-1
Model Subbasins

Table 4-1
Rainfall Quantities for the Big Creek Design Storms, SCS TYPE II Distribution

Design Storm (years)	Inches /24 hour storm
2	3.74
5	4.8
10	5.65
25	6.5
50	7.4
100	7.75
500	8.84

4.2.3 Pervious and Impervious Area

Land use data were used to estimate impervious areas for use in runoff calculations. Existing land use data was assumed as the 1995 land use from ARC. The watershed is located in one of the most developing areas in the Country and will dramatically change over the next twenty years. ARC developed the future land use from local comprehensive plans and interviews with the local jurisdictions. Using the existing and future land use data in ArcView, the percentage of each land use category within each subbasin was determined and an area-weighted average percent imperviousness assigned to each subbasin for the existing and future conditions. A summary of the existing and future impervious area within each subbasin is presented in **Table 4-2.**

4.2.4 Depression Storage

The SWMM model uses a parameter called depression storage, which is the volume that must be filled before runoff can occur on pervious or impervious areas in a subbasin. For pervious areas, water contained in depression storage will be depleted by infiltration and evaporation, and thus will be depleted rapidly during dry weather periods. In contrast, water contained in depression storage on directly connected impervious area (DCIA) is depleted only by evaporation, and thus will not be rapidly depleted during dry weather periods. Distinct depression storage values can be specified for pervious and DCIA areas.

4.2.5 Evaporation

Evaporation rates are used in RUNOFF to deplete pervious and impervious area depression storage and area also subtracted from rainfall during storm events. Evaporation data input to RUNOFF may be a single value, monthly values, or a time series of evaporation rates. The NWS, the National Oceanic and Atmosphere Administration (NOAA), or other local sources may have climatological summaries or pan evaporation data that can be used to develop model inputs. Evaporation rates

Table 4-2
Subbasin Input Summary

Subbasin	Load Point	Subbasin Width (ft)	Area Acres	% imperv. Existing	Ground Slope	% imperv. Future	Change in Impervious %
'BA02'	'3003100'	2537	121	0.7	0.04	40.8	40.1
'BA04'	'3008100'	6062	290	17.3	0.06	26.7	9.4
'BA06'	'30011200'	7051	338	9.3	0.07	21.8	12.5
'BA08'	'30012200'	4423	212	5.8	0.05	18.2	12.4
'BA10'	'30021700'	5394	258	6.8	0.04	37	30.2
'BA12'	'30014400'	7657	367	21.4	0.03	55.9	34.5
'BA14'	'3208200'	4814	231	2	0.03	19.3	17.3
'BA16'	'32012800'	11705	561	1.7	0.05	18	16.3
'BA18'	'32028000'	12855	616	8.9	0.05	22.5	13.6
'BA20'	'32028000'	4501	216	2.3	0.05	20	17.7
'BA22'	'3105500'	4032	193	14.1	0.06	28.3	14.2
'BA24'	'3107100'	4910	235	13.5	0.03	56	42.5
'BA26'	'BA26'	4035	193	5.3	0.05	24.5	19.2
'BE02'	'130840'	3074	147	4.1	0.03	14.6	10.5
'BE04'	'130840'	5249	251	8.9	0.03	14.5	5.6
'BE06'	'130840'	6569	315	9.6	0.02	18.7	9.1
'BE08'	'130840'	6098	292	3.2	0.03	17.9	14.7
'BE10'	'130840'	3069	147	0.5	0.04	62.6	62.1
'BE12'	'60030800'	10804	517	0.7	0.04	26.3	25.6
'BE14'	'60030800'	4249	203	4.8	0.06	15.8	11
'BE16'	'60030800'	7247	347	5.2	0.03	6.5	1.3
'BE18'	'60030800'	8973	430	1.6	0.03	8.5	6.9
'BE20'	'60033900'	11558	553	5	0.02	8.7	3.7
'BE22'	'60033900'	5111	245	10.5	0.03	14.2	3.7
'BE24'	'60036700'	12210	585	2.6	0.03	17.7	15.1
'BE26'	'60038900'	9076	435	0.9	0.05	38.7	37.8
'BE28'	'60041600'	12707	609	2.7	0.03	15.4	12.7
'BE30'	'7002900'	10094	483	4.6	0.04	20.4	15.8
'BL02'	'12925'	19487	933	4.9	0.06	24.8	19.9
'BL04'	'18490'	8886	426	42.3	0.07	42.3	0
'BL08'	'24100'	13792	660	21.8	0.04	25.6	3.8
'BL10'	'31735'	10599	508	45.8	0.06	53.8	8
'BL12'	'34150'	7842	376	27.5	0.02	44.8	17.3
'BL16'	'40870'	5874	281	32.9	0.03	55.9	23
'BL22'	'47150'	11855	568	15.8	0.03	44.3	28.5
'BL24'	'BL24'	6022	288	1.2	0.04	1.2	0
'BL26'	'BL26'	6340	304	55.9	0.04	81.8	25.9
'BL28'	'BL28'	6021	288	53.1	0.03	53.1	0
'BL30'	'BL30'	6662	319	26.1	0.04	72.5	46.4
'BL32'	'BL32'	4192	201	52.1	0.05	52.1	0
'BL40'	'BL40'	6090	292	39	0.03	64.2	25.2
'BL42'	'BL42'	4320	207	32.7	0.03	37.3	4.6
'BL44'	'BL44'	4780	229	24.1	0.03	29.2	5.1
'BL46'	'9804200'	3795	182	27.6	0.02	32.9	5.3
'BL48'	'98011705'	5157	247	13.7	0.04	28.8	15.1
'BM02'	'53860'	10214	489	22.2	0.06	30.7	8.5
'BM08'	'59100'	16022	767	4.5	0.03	63.2	58.7

Table 4-2
Subbasin Input Summary

Subbasin	Load Point	Subbasin Width (ft)	Area Acres	% imperv. Existing	Ground Slope	% imperv. Future	Change in Impervious %
'BM10'	'63015'	8244	395	18.7	0.03	71.6	52.9
'BM12'	'66840'	6940	332	4.6	0.05	47.2	42.6
'BM14'	'71090'	5885	282	12.6	0.05	60.3	47.7
'BM16'	'99988'	4895	234	3.7	0.04	32.7	29
'BM18'	'107170'	9614	460	25.1	0.02	47	21.9
'BM22'	'113650'	11389	545	15.6	0.04	30.5	14.9
'BM28'	'113970'	9580	459	7.6	0.02	52.5	44.9
'BM30'	'BM30'	10657	510	8.8	0.03	48.9	40.1
'BM32'	'BM32'	9862	472	19.5	0.04	54.7	35.2
'BM34'	'BM34'	2094	100	29	0.05	35.9	6.9
'BM36'	'BM36'	6691	320	17.4	0.02	72.1	54.7
'BM38'	'BM38'	5319	255	24.3	0.02	71.2	46.9
'BM40'	'BM40'	10453	501	20.7	0.02	65.8	45.1
'BM42'	'BM42'	4743	227	19.1	0.02	71.2	52.1
'BM44'	'BM44'	6540	313	22.4	0.03	37.4	15
'BM46'	'BM46'	11967	573	18	0.05	43	25
'BM48'	'BM48'	8347	400	9.3	0.03	38.3	29
'BM50'	'BM50'	5642	270	15.6	0.04	32.6	17
'BM52'	'BM52'	7803	374	24.9	0.05	24.9	0
'BM54'	'BM54'	9402	450	14.3	0.02	33	18.7
'BM56'	'BM56'	11252	539	10	0.04	70.7	60.7
'BU02'	'118000'	7549	361	34.3	0.02	67.8	33.5
'BU04'	'124020'	10770	516	35.6	0.02	35.6	0
'BU06'	'127860'	26590	1273	5.3	0.03	70.7	65.4
'BU12'	'132830'	6861	329	2.9	0.03	48.1	45.2
'BU14'	'136960'	10302	493	1.7	0.03	19.5	17.8
'BU16'	'140230'	9947	476	2.7	0.03	20.6	17.9
'BU18'	'145300'	4871	233	1.1	0.04	16.2	15.1
'BU20'	'148900'	11448	548	7.1	0.04	14	6.9
'BU22'	'151980'	11059	530	4.3	0.11	18.5	14.2
'BU26'	'BU26'	7544	361	2.4	0.09	30.2	27.8
'BU28'	'BU28'	6263	300	6	0.05	16	10
'BU30'	'BU30'	6731	322	35.1	0.04	35.1	0
'BU32'	'BU32'	10239	490	49.3	0.05	49.3	0
'BU34'	'BU34'	8805	422	12.8	0.05	70.2	57.4
'BU36'	'BU36'	4531	217	7.6	0.03	65.9	58.3
'BU38'	'BU38'	15421	738	11.7	0.03	20.4	8.7
'BU40'	'BU40'	19293	924	3.5	0.02	15.8	12.3
'BU42'	'BU42'	2906	139	3.6	0.04	39.5	35.9
'BU44'	'BU44'	10361	496	16.1	0.02	18	1.9
'BU46'	'BU46'	17618	844	7	0.05	13.6	6.6
'CC04'	'CC04'	9641	462	3.4	0.07	36	32.6
'CC06'	'CC06'	19429	930	35.3	0.03	51.4	16.1
'CC08'	'CC08'	4790	229	21.8	0.03	21.8	0
'CC10'	'CC10'	8431	404	21.3	0.05	39.1	17.8
'CC12'	'CC12'	10849	520	11.2	0.06	31.1	19.9
'CC14'	'CC14'	9031	432	2.7	0.02	27.3	24.6

Table 4-2
Subbasin Input Summary

Subbasin	Load Point	Subbasin Width (ft)	Area Acres	% imperv. Existing	Ground Slope	% imperv. Future	Change in Impervious %
'CH02'	'8003600'	8114	389	16.1	0.05	23.6	7.5
'CH04'	'8005200'	8722	418	17.2	0.01	20.1	2.9
'CH06'	'8007675'	8986	430	7.7	0.04	23.2	15.5
'CH08'	'80011200'	15869	760	2.1	0.04	17.4	15.3
'CH08'	'80013100'	3494	167	3.1	0.04	23.1	20
'CH12'	'80018850'	3810	182	1.9	0.03	49.6	47.7
'CH14'	'80023750'	5124	245	4.3	0.04	12.6	8.3
'CH16'	'CH18'	4729	226	10	0.05	13.1	3.1
'CH18'	'8102700'	2645	127	2.7	0.03	19	16.3
'CH20'	'8107900'	3817	183	3.3	0.05	25.3	22
'CH22'	'8109900'	8715	417	1.2	0.07	20.8	19.6
'CH24'	'CH26'	5771	276	3.3	0.05	11.8	8.5
'CH26'	'CH28'	3288	157	9.7	0.04	9.7	0
'CH28'	'81024750'	6781	325	22.3	0.05	22.3	0
'CH30'	'81015350'	6288	301	10.4	0.1	23.6	13.2
'CH32'	'8208300'	9259	443	3.5	0.14	47.9	44.4
'CH34'	'8208300'	9571	458	6.3	0.06	17	10.7
'CH36'	'CH38'	10398	498	3.9	0.03	5.4	1.5
'CH38'	'CH40'	2461	118	3	0.04	14.4	11.4
'CH40'	'CM02'	3347	160	1.8	0.04	21.9	20.1
'CM02'	'CM06'	2864	137	0.7	0.04	18.7	18
'CM06'	'CM10'	4680	224	32.8	0.02	32.8	0
'CM10'	'CM14'	7333	351	9.7	0.03	43.6	33.9
'CM14'	'CM16'	13603	651	13.1	0.03	64.6	51.5
'CM16'	'CM18'	7730	370	33.3	0.04	34.3	1
'CM18'	'CM20'	5914	283	14	0.04	17.8	3.8
'CM20'	'CM22'	2889	138	7.4	0.02	29	21.6
'CM22'	'CM24'	9232	442	15.5	0.03	70.6	55.1
'CM24'	'CM26'	2116	101	6.2	0.02	69.4	63.2
'CM26'	'CM28'	4564	219	9	0.02	75.6	66.6
'CM28'	'CM30'	7348	352	12.2	0.03	55.7	43.5
'CM30'	'CM32'	6222	298	9.7	0.04	67.7	58
'CM32'	'CM34'	3996	191	24.5	0.04	43.9	19.4
'CM34'	'9007160'	4142	198	44.4	0.03	44.4	0
'FC04'	'90011115'	5566	267	38.4	0.04	38.4	0
'FC06'	'90014950'	3250	156	21.8	0.03	42.1	20.3
'FC10'	'90014950'	6354	304	21.6	0.04	64.1	42.5
'FC12'	'90022850'	2620	125	10.7	0.05	58	47.3
'FC16'	'90025470'	7535	361	11.2	0.05	29.8	18.6
'FC18'	'90028500'	2061	99	12.4	0.04	30.4	18
'FC20'	'90032300'	4626	222	25.6	0.02	25.6	0
'FC22'	'90035600'	4496	215	17.2	0.03	22	4.8
'FC24'	'FC26'	11974	573	8.3	0.01	28.6	20.3
'FC26'	'FC28'	6595	316	13.3	0.01	23.4	10.1
'FC28'	'FC30'	2730	131	36.9	0.03	36.9	0
'FC30'	'FC32'	4671	224	54.6	0.05	66.3	11.7
'FC32'	'FC34'	3890	186	66.4	0.02	69.5	3.1

Table 4-2
Subbasin Input Summary

Subbasin	Load Point	Subbasin Width (ft)	Area Acres	% imperv. Existing	Ground Slope	% imperv. Future	Change in Impervious %
'FC34'	'FC36'	3167	152	23.7	0.04	59.1	35.4
'FC36'	'FC38'	7192	344	14.9	0.03	74.8	59.9
'FC38'	'FC40'	10757	515	13.6	0.04	73.8	60.2
'FC40'	'FC42'	12521	600	16.7	0.02	39.5	22.8
'FC42'	'FC44'	5517	264	31.6	0.04	31.6	0
'FC44'	'FC46'	4113	197	21.2	0.04	21.2	0
'FC46'	'FC50'	2699	129	34.8	0.03	34.8	0
'FC50'	'FC54'	8844	424	14.1	0.03	26.2	12.1
'FC54'	'FC56'	8047	385	6.4	0.04	23.6	17.2
'FC56'	'FC58'	2558	122	24.8	0.04	29.2	4.4
'FC58'	'FC60'	4448	213	19.1	0.05	19.6	0.5
'FC60'	'FC64'	6537	313	11.2	0.03	19.9	8.7
'FC64'	'FC66'	4535	217	5.3	0.02	42.9	37.6
'FC66'	'FC68'	3880	186	17.1	0.02	24.1	7
'FC68'	'9002765'	3579	171	28.4	0.03	28.4	0
'FCO2'	'9002230'	2470	118	51.3	0.01	51.3	0
'HW02'	'13961'	4625	221	55.6	0.01	55.6	0
'HW04'	'HW04'	4846	232	19.9	0.06	61.4	41.5
'HW06'	'HW06'	6952	333	22.1	0.03	32.8	10.7
'HW08'	'HW08'	4996	239	13.3	0.04	53	39.7
'HW10'	'HW10'	9114	436	19.1	0.02	30.3	11.2
'HW12'	'HW12'	1350	65	25.1	0.05	28.7	3.6
'HW14'	'HW14'	8139	390	17.2	0.03	17.7	0.5
'HW16'	'HW16'	9434	452	8.9	0.01	23.7	14.8
'HW18'	'HW18'	3048	146	1.9	0.03	47.5	45.6
'KM02'	'1001400'	6190	296	16.2	0.03	27.6	11.4
'KM06'	'1006900'	3431	164	11.1	0.05	19	7.9
'KM08'	'1008000'	4806	230	7.1	0.04	15.1	8
'KM10'	'1002000'	15786	756	6.3	0.05	31	24.7
'KM12'	'1003400'	5110	245	21.8	0.04	24	2.2
'KM14'	'KM14'	1231	59	44.7	0.07	44.7	0
'KM16'	'1006900'	11557	553	20.1	0.12	20.1	0
'KM18'	'KM18'	6629	317	20.7	0.03	20.7	0
'LI02'	'9505520'	2677	128	29.4	0.06	68.9	39.5
'LI04'	'9507100'	8113	389	21.1	0.05	34.8	13.7
'LI06'	'95010700'	15505	742	23.9	0.04	25.9	2
'LI08'	'95013964'	8681	416	26	0.03	26.1	0.1
'LI12'	'95018230'	2769	133	23.6	0.02	25	1.4
'LI14'	'95021300'	4457	213	0.5	0.02	41	40.5
'SM02'	'2002200'	2067	99	2.4	0.07	39.3	36.9
'SM04'	'2005200'	4858	233	11.2	0.05	29.5	18.3
'SM06'	'2009100'	11924	571	24.2	0.04	24.2	0
'SM08'	'20010950'	7300	350	37.9	0.02	37.9	0
'SM10'	'20010950'	4915	235	9.1	0.04	38.6	29.5
'SM12'	'2107800'	6779	325	15.9	0.08	68.8	52.9

used to calibrate a SWMM model developed by the Georgia EPD were also used for this study.

4.2.6 Soil Storage and Infiltration

Soils data were used to evaluate stormwater runoff, infiltration, and recharge potential for pervious areas. Information on soil types was obtained from the SCS Soil Survey of Forsyth County, Georgia (SCS, 1960) and Soil Survey of Fulton County, Georgia (SCS, 1958). Each soil type has been assigned to a soil association, a soil series, and to one of the four Hydrologic Soil Groups (A, B, C, or D) established by the SCS. Hydrologic Soil Group A is comprised of soils with very high infiltration potential and low runoff potential. Hydrologic Soil Group D is characterized by soils with a very low infiltration potential and a high runoff potential. The other two categories fall between A and D soil groups. Dual class soils (e.g., A/D) mean that a hardpan or layer limits vertical infiltration, but the surface soils are highly permeable and could infiltrate as a Class A soil if the confining layer was cut with a ditch or swale.

Most soils in the Big Creek watershed consist of clay loams with small pockets of alluvial soils along the stream channels. The clay loams are classified as NRCS Type B soils and the alluvial deposits are Type C. The clay loams are moderately to highly erodible when disturbed. The actual degree of erodibilty depends on the slope of the area and the clay content of the soil deposit in question.

RUNOFF uses both soil storage and infiltration rates to determine the volume of surface water runoff. Soil capacity (or soil storage) is a measure of the amount of storage (in inches) available in the soil type for a given antecedent moisture condition. The average antecedent moisture condition (AMC II) was used for all design storm analyses.

Rainfall water that has accumulated on the pervious areas of the watershed is subject to infiltration into the soil profile. The Horton soil infiltration equation was used to simulate infiltration into the soil. The Horton equation uses an initial infiltration rate to account for moisture already in the soil, a maximum infiltration rate, and a decay infiltration rate. Additionally, a total maximum infiltration depth is computed based on the moisture capacity of the soil.

4.2.7 Overland Flow (Surface Runoff)

Rainfall that is not captured through depression storage, evaporation or infiltration will accumulate on the surface of the watershed and will be subject to surface runoff. In RUNOFF, the rate at which runoff will occur depends upon each subbasin's physical characteristics, which include slope, width and Manning's roughness coefficients for impervious and pervious areas.

To calculate subbasin width, the subbasin area was divided by the subbasin's weighted-average travel length estimated from USGS quad sheets. Subbasin slope was also estimated from USGS quad sheets. Values for width and slope of each subbasin are also presented in **Table 4-2**.

Manning's n roughness is used for the overland flow routing using Manning's equation. The Management Plan outlines typical values for shallow overland flow Manning's n. Note that pervious land use coverages appear "rough" because the depth of overland flow (a few inches) is equal to or less than the height of the roughness feature. Mannning's roughness coefficient values for pervious and impervious areas for each land use category are presented in **Table 4-3**.

Table 4-3
Manning's Roughness Coefficient Values

Land Use Category	Manning's Roughness Coefficient	
	Impervious	Pervious
Open/Forest	0.015	0.300
Ag/Pasture and Cropland	0.015	0.400
Single Family Residential		
2.1 – 5.0 acre lot size	0.015	0.250
1.1 – 2.0 acre lot size	0.015	0.250
0.5 – 1.0 acre lot size	0.015	0.250
0.25 – 0.4 acre lot size	0.015	0.250
Townhouse/Apartment	0.015	0.250
Office/Light Industrial	0.015	0.250
Heavy Industrial	0.015	0.250
Commercial	0.015	0.250
Major Roads	0.015	0.250
Waterbodies	0.400	0.250

4.2.8 Routing Techniques

Once runoff hydrographs have been computed using the RUNOFF, they must be routed through the watershed to the most downstream point in the watershed. As the hydrographs are routed, they are attenuated, that is the peak discharge decreases as a result of floodplain storage and travel through the various hydraulic reaches. In addition, during the routing, the individual hydrographs are combined with those from other subbasins within the watershed.

In the case of the Big Creek model, the majority of the routings were accomplished using the EXTRAN Block. EXTRAN uses a dynamic wave solution of the equations of motion to accomplish the routing. This is the most accurate method as it accounts for all factors which might influence the flow in a channel including, backwater and downstream control effects, channel and floodplain storage and flow reversals.

The EXTRAN model requires detailed data concerning channel cross-sections and hydraulic structures. For this project, that information was obtained from the HEC-2 models used by FEMA to prepare Flood Insurance Studies for Big Creek and its major tributaries. However, FEMA data was not available for reaches located in the uppermost regions of the watershed. For these reaches, the decision was made to accomplish the routings using RUNOFF until the calculations reached a location represented by a node in the EXTRAN model. At that point, the RUNOFF routings would cease and the final routed hydrograph would be input to the EXTRAN model. Since the reaches in question were generally in upland areas, backwater effects were considered unlikely to occur and the simplified RUNOFF methodology could be used without a significant loss of accuracy.

RUNOFF accomplishes hydrograph routings using the non-linear reservoir method. Each routing reach is characterized as a trapezoidal or parabolic channel or as a circular pipe. The runoff hydrograph from a subarea and, if appropriate, the routed hydrographs from any upstream channels serve as inflow to the non-linear reservoir. At each time step, an iterative computation scheme is used to solve the non-linear equation used to approximate the differential equation of the non-linear reservoir in question. This calculation yields the reservoir outflow, which is the routed hydrograph at each time step.

Stage-area information was developed by planimetering topographic contours for major detention ponds. Any information from the Safe Dams Program was also incorporated into the model. The stage-area relationship is used by SWMM to calculate the volume of storage for these ponds for various design storms.

4.3 Model Verification

The model calibration and/or verification can be separated into the two modeling components: hydrologic and hydraulic.

- Hydrologic - this generally involves the calibration of total soil storage, overland flow lengths and/or slopes, overland flow roughness, imperviousness, depression storage values, and maximum/minimum soil infiltration rates, and rainfall.

- Hydraulic - this generally involves the calibration of channel/conduit roughness and inverts, tailwater elevations, stage-area data, initial water surface elevations, and channel geometrics due to floodplain encroachments and debris/silt blockages.

Calibration and/or verification are desirable to establish a "reality check" of predicted stages, flows, and velocities. For calibration, data must be available in the form of rainfall, stage, flow, and/or highwater marks for specific storm events, land use, and hydraulic conditions. This information was not readily available for this study but model verification was performed in order to obtain confidence in the model results. The confidence gained is that the model represents the flows, the velocities and the timing of the response to rainfall accurately.

For this study, two sources of data were available for verification of hydrologic and hydraulic model results. The USGS Region 1 regional equations for flood discharge are suitable for comparison to model results from areas within the Big Creek watershed where urbanization is not significant. The USGS regional equations are presented in **Table 4-4**. The most recent FEMA flows and flood elevations are also available for comparison to model results for existing (1995) conditions.

It was not within the scope of this project to update FEMA cross-sections or bridge sections and this hydraulic model represents bridges from the best available FEMA data, which in some cases are up to 23 years old. New bridges and modified bridges may not be accounted for in some portions of this model.

Table 4-4
USGS Regional Flood Equations for Region 1

Recurrence Interval	Regional Equations (A=drainage area in square miles)
2-year	$Q_2 = (207 * A)^{0.654}$
5-year	$Q_5 = (357 * A)^{0.632}$
10-year	$Q_{10} = (482 * A)^{0.619}$
25-year	$Q_{25} = (666 * A)^{0.605}$
50-year	$Q_{50} = (827 * A)^{0.595}$
100-year	$Q_{100} = (1010 * A)^{0.584}$
500-year	$Q_{500} = (1530 * A)^{0.563}$

Note: Q_n = peak discharge for n-year recurrence interval

The model results were comparable to the USGS regional equations, were within the tolerance limits (31 percent) of the regional equations and seem reasonable with expected differences where development has occurred. The existing model results were also compared to the latest FEMA studies for all studied streams. The existing model results were very similar to the most current FEMA flows and flood elevations studies. The model results were higher in locations where development has occurred since the latest FEMA studies.

4.4 Current and Future Runoff and Flooding Impacts

The watershed is one of the fastest growing watersheds in the Metro area. The hydrology of the watershed is the primary factor influencing the streams. Model results indicated that the flooding and erosion problems currently being experienced throughout the watershed would also increase as development occurs and the amount of impervious area increases unless the proper best management practices are put into place.

4.4.1 Peak Discharges

Table 4-5 illustrates existing and future peak flow rates for the 2,10, 25 and 100-year design storms for different stream reaches (model conduits) within the watershed. Where model conduits intersected roads, the road name was also included in Table 4-5. Peak discharges will increase due to increases in impervious area associated with development. **Figure 4- 2** and **Figure 4-3** show this increase at the Roswell Intake and near the Fulton /Forsyth County Line (Station 10225). A 25-year storm with 1995 land use conditions will occur closer to every 10 years with the 2020 land use conditions.

4.4.2 Flood Elevations

Table 4-6 summarizes flood elevations for existing and future conditions. The existing flood profiles for the 2, 10, 25, and 100-year design storms are shown in Appendix B. These profiles can be compared to roadtop elevations to predict the level of service. Some of the roads that were shown to overtop have been upgraded since the last FEMA study and the level of service for those new roads was not determined by this study. Flood profiles for future conditions are shown in Appendix C.

4.4.3 Floodplain Delineation

The FEMA floodplains were shown in Section 2, Figure 2-2. With the updated land use, the 1995 and projected 2020 floodplains were mapped. Appendix D illustrates the 1995 and 2020 projected floodplains. The model results for the 1995 hydrologic condition shows 4249 acres of floodplains within the Big Creek watershed. There are two large floodplain areas along the main stem of Big Creek, one near the Forsyth / Fulton County line and the other downstream of North Point Mall. These areas are the flattest reaches of Big Creek.

The model for 2020 land use conditions predicts an additional 296 acres that will be inundated. This increase is slight but occurs in areas, which are currently developed which could increase the probability of structural flooding.

With more recent surveying data, a more detailed analysis could be performed. Some of the jurisdictions have updated their FEMA studies and with the continuous development. It is recommended that all of the jurisdictions evaluate the current FEMA studies.

Table 4-5
Summary of Peak Flows

Road Crossing	Model Conduit	2-Year Peak Flows			10-Year Peak Flows			25-Year Peak Flows			100-Year Peak Flows		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
Indian Village Drive	LI18177	355	422	19%	478	531	11%	523	570	9%	580	596	3%
Morrison Pkwy	Ta9240	209	329	58%	388	752	94%	516	764	48%	757	768	1%
Waters Rd	LI6428	727	867	19%	1228	1364	11%	1478	1578	7%	1749	1853	6%
Buice Road	LI17240	234	281	20%	318	354	11%	349	380	9%	387	470	21%
Mall Parking Lot	Ta3440	344	402	17%	595	668	12%	687	732	7%	757	810	7%
Entrance Road to Mall	Ta5171	154	274	78%	337	603	79%	427	680	59%	641	777	21%
GA 400	Ta6515	155	276	78%	340	631	86%	434	702	62%	663	798	20%
	LI181771	0	0	N/A	0	0	N/A	0	0	N/A	0	229	279102%
	Ta92401	0	0	N/A	0	1002	N/A	0	1217	N/A	1063	1632	54%
	LI64281	0	0	N/A	0	0	N/A	0	3	N/A	38	95	149%
	LI172401	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Ta34401	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Ta51711	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Ta65151	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	KM9800	1133	1879	66%	2382	3574	50%	3055	4415	45%	4105	5690	39%
	KM9565	440	479	9%	485	486	0%	488	482	-1%	484	481	-1%
	KM95651	76	942	1137%	1512	2868	90%	2288	3835	68%	3474	5311	53%
	KM9475	-925	-1736	88%	-2210	-3455	56%	-2914	-4312	48%	-3982	-5600	41%
	KM9200	1099	1990	81%	2651	4051	53%	3469	5058	46%	4710	6553	39%
	KM8000	998	1716	72%	2391	3706	55%	3170	4680	48%	4348	6105	40%
	KM6900	1794	2298	28%	3441	4791	39%	4481	6126	37%	6149	8112	32%
	KM4800	3513	4091	16%	5627	8089	44%	6640	9697	46%	8947	10603	19%
	KM4325	406	424	4%	458	-710	-255%	-514	-826	61%	-685	-775	13%
	KM43251	1225	1742	42%	2628	3552	35%	3281	4278	30%	4513	5149	14%
	KM4284	1095	1487	36%	2110	2548	21%	2530	2991	18%	3305	3730	13%
	KM3400	1059	1440	36%	2101	2473	18%	2529	2945	16%	3213	3651	14%
	KM2000	1638	3044	86%	3397	4960	46%	4240	6099	44%	5667	7900	39%
	KM1400	1624	2637	62%	3311	4791	45%	4200	5909	41%	5602	7688	37%
	BAG19100	111	445	301%	318	907	185%	437	1134	159%	624	1465	135%
	BAG14400	441	1219	176%	887	2225	151%	1185	2752	132%	1574	3427	118%
	BAG12200	819	2035	148%	1910	3989	109%	2523	4898	94%	3453	6437	86%
	BAG11200	759	1894	150%	1817	3571	97%	2304	4300	87%	3202	5584	74%
	BAG8100	772	1750	127%	1944	3240	67%	2482	3942	59%	3307	4953	50%
	BAG3100	1221	2326	90%	3395	4940	46%	4461	6179	39%	6065	8028	32%
	CAN01150	356	451	27%	883	1036	17%	1145	1323	16%	1559	1772	14%
	CAN02900	380	464	22%	898	1053	17%	1158	1347	16%	1582	1800	14%
	CAN03800	693	833	20%	1262	1450	15%	1542	1752	14%	1966	2228	13%
	CAN05200	940	1125	20%	1716	1956	14%	2099	2363	13%	2675	2995	12%
	CAN09800	421	565	34%	820	1088	33%	1082	1406	30%	1493	1945	30%
	CAN10560	556	764	37%	1099	1401	28%	1401	1767	26%	1864	2447	31%
	CAN11015	476	668	40%	945	1216	29%	1200	1549	29%	1608	2146	33%
	CAN11045	476	668	40%	945	1216	29%	1201	1550	29%	1609	2147	33%
	CAN11046	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	CAN11395	476	669	40%	945	1217	29%	1201	1551	29%	1610	2149	34%
	CAN12185	483	677	40%	952	1226	29%	1208	1570	30%	1621	2201	36%
	CAN13185	510	713	40%	995	1316	32%	1307	1641	26%	1744	2258	29%
	CAN13985	600	833	39%	1165	1494	28%	1486	1836	24%	1949	2370	22%
	CAN14160	259	448	73%	500	780	56%	695	1062	53%	998	1491	49%
	CAN14190	259	448	73%	500	780	56%	695	895	29%	874	1020	17%
	CAN14565	266	454	71%	500	797	59%	702	1067	52%	1001	1493	49%
	CAN14955	267	460	72%	516	864	67%	732	1097	50%	1022	1511	48%
	CAN15430	266	453	70%	500	866	73%	734	1099	50%	1023	1514	48%
	CAN16945	289	490	70%	517	1022	98%	788	1290	64%	1114	1845	66%
	CMP0816	362	458	27%	620	806	30%	768	955	24%	956	1252	31%
	CMP1890	414	563	36%	770	937	22%	920	1119	22%	1223	1675	37%
	CMP2723	436	652	49%	885	1107	25%	1073	1356	26%	1454	2024	39%
	CMP3055	405	619	53%	854	1084	27%	1044	1344	29%	1437	2025	41%
	CMP3255	405	619	53%	854	1084	27%	1044	1250	20%	1266	1293	2%
	CMP3783	-369	-584	58%	-819	-1050	28%	-1010	-1308	30%	-1401	-1989	42%
	CMP4742	415	663	60%	926	1209	31%	1160	1426	23%	1464	2017	38%
	CMP5565	378	702	86%	1057	1407	33%	1353	1689	25%	1745	2093	20%
	CMP5986	-379	-680	80%	-1022	-1385	35%	-1317	-1685	28%	-1731	-2131	23%
	CMP6186	190	340	78%	509	692	36%	657	842	28%	865	1067	23%

Table 4-5
Summary of Peak Flows

Road Crossing	Model Conduit	2-Year Peak Flows			10-Year Peak Flows			25-Year Peak Flows			100-Year Peak Flows		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
	CMP6501	346	642	86%	979	1347	38%	1275	1649	29%	1694	2101	24%
	CMP7227	394	714	81%	1020	1417	39%	1331	1737	31%	1770	2229	26%
	CMP9927	460	815	77%	1149	1591	38%	1516	1964	30%	2020	2593	28%
	CMP11727	332	605	82%	850	1190	40%	1124	1497	33%	1515	1985	31%
	CMP17127	358	665	86%	923	1301	41%	1199	1685	41%	1658	2198	33%
	CMP19827	287	563	96%	652	1077	65%	826	1375	66%	1141	1750	53%
	BEN11600	1241	2453	98%	3816	5648	48%	5334	7110	33%	7144	7735	8%
	BEN8900	840	1498	78%	2410	3385	40%	3209	4348	36%	4654	5493	18%
	BEN7400	797	1420	78%	2533	3396	34%	3384	4281	27%	4492	5564	24%
Hwy 371	BEN5600	383	701	83%	1284	1703	33%	1707	2117	24%	2235	2566	15%
	BEN5450	776	1396	80%	2649	3474	31%	3487	4280	23%	4498	5106	14%
	BEN2300	909	1492	64%	3028	3939	30%	3961	4751	20%	5015	5217	4%
	BEN1000	827	1326	60%	2516	3213	28%	3185	3848	21%	4143	4819	16%
	CH2000	1375	1776	29%	3622	4387	21%	4758	5951	25%	6849	8270	21%
	CH4400	1388	2327	68%	4484	5814	30%	6070	7614	25%	8539	10368	21%
	CH6100	1587	2562	61%	4789	6242	30%	6415	8111	26%	8952	10928	22%
	CH8300	1701	2738	61%	5148	6615	28%	6905	8581	24%	9600	11519	20%
	CH9750	1547	2536	64%	4750	6320	33%	6442	8314	29%	9134	11277	23%
Pitman Rd	CH9850	1555	2547	64%	4762	6340	33%	6458	8338	29%	9156	11301	23%
	CH9889	-474	-778	64%	-835	-831	0%	-847	-846	0%	-857	-858	0%
	CH12300	1585	2592	63%	4775	6358	33%	6472	8356	29%	9173	11319	23%
	CH14200	1536	2306	50%	4565	6175	35%	6245	8145	30%	8855	10999	24%
	CH15400	1480	2425	64%	4682	6433	37%	6436	8444	31%	9116	11402	25%
	CH18850	346	832	141%	1094	1770	62%	1471	2213	50%	2043	2989	46%
	CH22050	209	574	175%	633	1154	82%	856	1436	68%	1200	1944	62%
	CH23750	128	296	131%	298	576	94%	398	726	83%	542	938	73%
	FK1300	1905	2535	33%	3741	4481	20%	4639	5333	15%	5978	6649	11%
	FK2230	2033	2689	32%	3958	4696	19%	4879	5618	15%	6278	6976	11%
Mansell Rd	FK2660	1986	2622	32%	3856	4599	19%	4749	5512	16%	6102	6850	12%
	FK2865	-1990	-2627	32%	-3877	-4635	20%	-4793	-5552	16%	-6158	-6904	12%
Rock Mill Way	FK3700	1882	2450	30%	3588	4340	21%	4419	5205	18%	5654	6497	15%
	FK4200	1896	2460	30%	3615	4362	21%	4450	5226	17%	5684	6525	15%
Old Roswell Rd	FK4370	1895	2460	30%	3618	4366	21%	4456	5231	17%	5690	6535	15%
	FK4600	1896	2460	30%	3618	4367	21%	4456	5232	17%	5691	6539	15%
	FK5810	1908	2476	30%	3640	4390	21%	4481	5255	17%	5714	6576	15%
	FK7160	1780	2310	30%	3372	4061	20%	4137	4911	19%	5352	6183	16%
	FK8370	1734	2202	27%	3219	3866	20%	4022	4667	16%	5188	5866	13%
	FK9130	1743	2216	27%	3235	3884	20%	4023	4686	16%	5189	5884	13%
New Rd	FK11115	1717	2185	27%	3198	3849	20%	3979	4642	17%	5129	5815	13%
	FK12100	1268	1699	34%	2991	3341	12%	3788	4133	9%	4887	5251	7%
Alpharetta Rd	FK13040	1270	1736	37%	2994	3344	12%	3791	4136	9%	4889	5253	7%
	FK14950	1108	1345	21%	2562	2873	12%	3210	3535	10%	4121	4458	8%
	FK15600	1103	1336	21%	2541	2855	12%	3180	3510	10%	4080	4420	8%
	FK18420	1188	1521	28%	2855	3365	18%	3746	4313	15%	5039	5772	15%
	FK19510	1175	1480	26%	2702	3252	20%	3573	4153	16%	4868	5721	18%
	FK22850	685	812	19%	1601	1861	16%	2040	2370	16%	2725	3119	14%
Rucker Rd	FK23645	591	692	17%	1279	1439	13%	1584	1801	14%	2039	2297	13%
	FK24190	626	701	12%	1288	1446	12%	1590	1809	14%	2046	2314	13%
	FK25230	646	752	16%	1392	1668	20%	1697	2273	34%	2426	3233	33%
Private Foot Br	FK25475	634	720	14%	1289	1454	13%	1553	2040	31%	2159	2884	34%
	FK25540	640	724	13%	1290	1449	12%	1552	3022	95%	3035	3457	14%
	FK26430	488	526	8%	744	758	2%	830	858	3%	1016	1056	4%
	FK26880	512	543	6%	756	762	1%	818	842	3%	993	1164	17%
	FK28500	375	405	8%	581	625	8%	668	718	7%	812	869	7%
Mid Broadwell Rd	FK28870	401	437	9%	601	641	7%	679	731	8%	822	879	7%
	FK29100	414	463	12%	608	652	7%	692	740	7%	828	889	7%
	FK30500	557	636	14%	1003	1123	12%	1236	1363	10%	1585	1755	11%
	FK31400	546	585	7%	987	1094	11%	1217	1349	11%	1580	1752	11%
Maple Lane	FK32350	144	170	18%	249	311	25%	338	417	24%	476	536	12%
Mayfield Road	FK32750	145	174	20%	326	397	22%	415	467	13%	521	559	7%
Private Dr	FK33810	145	175	21%	330	404	22%	423	480	14%	570	728	28%
Private Dr	FK34875	150	188	25%	363	448	24%	470	568	21%	630	744	18%
	FK35300	255	303	19%	455	536	18%	556	651	17%	713	833	17%

Table 4-5
Summary of Peak Flows

Road Crossing	Model Conduit	2-Year Peak Flows			10-Year Peak Flows			25-Year Peak Flows			100-Year Peak Flows		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
	FK35600	261	310	19%	464	545	18%	566	663	17%	727	845	16%
	LI725	855	942	10%	1942	2034	5%	2419	2504	4%	3081	3287	7%
	LI3350	898	1040	16%	2024	2218	10%	2541	2728	7%	3350	3579	7%
	LI5520	766	941	23%	1437	1596	11%	1760	1958	11%	2379	2616	10%
	LI6000	556	870	56%	1224	1362	11%	1477	1581	7%	1786	1946	9%
	LI6400	563	882	57%	1225	1364	11%	1478	1582	7%	1787	1947	9%
	LI6500	779	861	11%	1230	1364	11%	1478	1582	7%	1787	1948	9%
	LI7100	579	825	42%	1243	1366	10%	1480	1584	7%	1789	1952	9%
	LI7600	635	792	25%	1265	1373	9%	1484	1637	10%	1891	2141	13%
	LI8400	673	799	19%	1281	1436	12%	1552	1782	15%	2049	2325	13%
	LI9885	687	811	18%	1282	1465	14%	1582	1816	15%	2084	2364	13%
	LI10700	816	944	16%	1463	1668	14%	1795	2033	13%	2316	2602	12%
	LI12335	450	627	39%	850	964	13%	966	1070	11%	1100	1256	14%
	LI13500	606	780	29%	940	1050	12%	1039	1131	9%	1155	1374	19%
	LI13900	639	811	27%	948	1056	11%	1043	1135	9%	1157	1387	20%
	LI14030	640	811	27%	948	1056	11%	1043	1135	9%	1158	1387	20%
	LI14600	649	817	26%	950	1057	11%	1043	1136	9%	1158	1393	20%
	LI15035	657	821	25%	950	1058	11%	1044	1137	9%	1158	1397	21%
	LI16135	661	818	24%	949	1058	12%	1044	1137	9%	1158	1394	20%
	LI16700	695	839	21%	954	1061	11%	1046	1139	9%	1159	1402	21%
	LI17160	702	842	20%	955	1062	11%	1047	1139	9%	1160	1406	21%
	LI17990	707	844	19%	955	1062	11%	1047	1140	9%	1160	1411	22%
	LI18640	1098	1412	29%	1536	1660	8%	1622	1628	0%	1629	1654	2%
	LI19260	764	1049	37%	1345	1909	42%	1689	2306	37%	2178	2840	30%
	LI20080	377	460	22%	662	763	15%	795	938	18%	1053	1253	19%
	LI20472	394	482	22%	696	800	15%	830	1008	21%	1139	1388	22%
	LI20585	399	489	23%	716	810	13%	848	1032	22%	1160	1425	23%
	LI20800	426	524	23%	774	895	16%	933	1100	18%	1243	1483	19%
	LI21300	265	302	14%	542	591	9%	671	728	9%	870	944	9%
	Ta1100	579	684	18%	1007	1248	24%	1232	1350	10%	1419	1470	4%
	Ta1455	671	789	18%	1166	1324	14%	1351	1462	8%	1497	1617	8%
	Ta3600	694	814	17%	1204	1390	15%	1460	1665	14%	1831	1935	6%
	Ta3850	689	804	17%	1209	1395	15%	1465	1673	14%	1873	2117	13%
	Ta4200	742	847	14%	1258	1442	15%	1516	1732	14%	1911	2164	13%
	Ta4650	807	936	16%	1402	1596	14%	1673	1901	14%	2088	2343	12%
	Ta4850	309	548	78%	674	1205	79%	854	1358	59%	1281	1553	21%
	Ta4990	309	548	78%	674	1206	79%	854	1359	59%	1282	1553	21%
	Ta5350	309	549	78%	675	1208	79%	856	1361	59%	1284	1554	21%
	Ta5630	309	550	78%	679	1239	82%	866	1385	60%	1308	1574	20%
	Ta6030	309	551	78%	679	1268	87%	868	1411	63%	1331	1602	20%
	Ta6700	310	557	80%	687	1366	99%	875	1540	76%	1427	1763	24%
	Ta6785	310	557	80%	687	1481	116%	875	1706	95%	1560	2036	31%
	Ta6830	310	557	80%	687	1496	118%	876	1758	101%	1582	2120	34%
	Ta7200	361	598	66%	715	1599	124%	923	1945	111%	1708	2499	46%
	Ta7900	361	598	66%	715	1601	124%	924	1948	111%	1711	2502	46%
	Ta8445	-366	-602	64%	-719	-1644	129%	-932	-1998	114%	-1751	-2559	46%
	Ta9000	380	616	62%	733	2136	191%	956	2278	138%	2155	2684	25%
	Ta9385	418	658	58%	775	3584	362%	1032	3357	225%	3534	3757	6%
	Ta10900	728	1190	63%	1465	2231	52%	1827	2701	48%	2371	3396	43%
	Ta11705	794	1292	63%	1602	2447	53%	2002	2957	48%	2594	3705	43%
	12925	3425	4404	29%	6348	7931	25%	7978	10224	28%	11319	13774	22%
	13550	3425	4405	29%	6349	7931	25%	7978	10224	28%	11319	13775	22%
Grimes Br Rd	13961	3425	4405	29%	6349	7932	25%	7979	10224	28%	11320	13776	22%
	18490	3430	4410	29%	6355	7934	25%	7981	10229	28%	11326	13783	22%
	19880	3418	4401	29%	6314	7938	26%	7985	10236	28%	11333	13794	22%
Riverside Apt Br	21120	3423	4420	29%	6322	7942	26%	7989	10242	28%	11339	13802	22%
	21200	-3427	-5795	69%	-6679	-7945	19%	-9105	-10247	13%	-11344	-13808	22%
Old Holcomb Br Rd	21960	-3426	-5054	48%	-6326	-7944	26%	-8062	-10245	27%	-11343	-13806	22%
	24100	3428	6581	92%	6333	7947	25%	7995	10250	28%	11348	13811	22%
	25760	3413	4414	29%	6315	7952	26%	7999	10258	28%	11354	13815	22%
	26390	3415	4418	29%	6321	7955	26%	8003	10264	28%	11359	13819	22%
GA 400	30120	3402	4426	30%	6298	7984	27%	8030	10306	28%	11402	13844	21%
	31135	2280	3359	47%	6008	8042	34%	8145	10384	27%	11517	13783	20%

Table 4-5
Summary of Peak Flows

Road Crossing	Model Conduit	2-Year Peak Flows			10-Year Peak Flows			25-Year Peak Flows			100-Year Peak Flows		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
	31735	2266	3356	48%	6029	8091	34%	8208	10511	28%	11679	13921	19%
	34150	2248	3353	49%	6052	8141	35%	8270	10634	29%	11836	14059	19%
Mansell Rd	34930	2238	3355	50%	6056	8149	35%	8280	10675	29%	11905	14143	19%
	35655	2307	3359	46%	6063	8161	35%	8293	10709	29%	11957	14208	19%
	36730	2291	3365	47%	6075	8178	35%	8314	10750	29%	12017	14269	19%
	39780	2181	3390	55%	6126	8236	34%	8396	10873	29%	12205	14460	18%
Haynes Br Rd	40870	2140	3402	59%	6159	8281	34%	8454	10945	29%	12309	14582	18%
	41000	2111	3406	61%	6171	8296	34%	8473	10956	29%	12330	14605	18%
	42850	2183	3416	56%	6199	8321	34%	8502	10982	29%	12363	14668	19%
	44420	2363	3431	45%	6253	8366	34%	8552	11018	29%	12407	14742	19%
	47150	1978	3441	74%	6305	8395	33%	8620	10987	27%	12405	14717	19%
	49000	1992	3455	73%	6347	8452	33%	8688	11034	27%	12458	14774	19%
Kimball Br Rd	49964	2013	3470	72%	6383	8502	33%	8748	11084	27%	12511	14827	19%
	50450	2019	3477	72%	6398	8523	33%	8771	11116	27%	12544	14860	18%
	51920	2026	3486	72%	6412	8544	33%	8793	11161	27%	12594	14910	18%
	53860	2034	3504	72%	6440	8583	33%	8836	11246	27%	12692	15009	18%
	56400	2032	3513	73%	6457	8576	33%	8852	11263	27%	12715	15025	18%
	57350	2005	3502	75%	6440	8507	32%	8813	11179	27%	12636	14905	18%
State Bridge Rd	58505	2015	3515	74%	6464	8540	32%	8849	11226	27%	12684	14956	18%
	59100	2028	3532	74%	6501	8589	32%	8903	11293	27%	12753	15026	18%
	60420	2034	3536	74%	6522	8606	32%	8936	11325	27%	12794	15060	18%
	61440	2052	3542	73%	6541	8634	32%	8969	11369	27%	12841	15110	18%
	62230	2054	3544	73%	6544	8633	32%	8973	11370	27%	12845	15108	18%
	63015	2068	3551	72%	6561	8658	32%	9003	11406	27%	12884	15149	18%
	64800	2118	3596	70%	6651	8777	32%	9145	11561	26%	13053	15317	17%
Webb Bridge Rd	65195	2138	3641	70%	6757	8931	32%	9325	11759	26%	13272	15529	17%
	66840	2156	3673	70%	6834	8999	32%	9403	11844	26%	13398	15626	17%
	68195	2158	3696	71%	6923	9040	31%	9461	11889	26%	13475	15680	16%
	69950	1907	3396	78%	6581	8604	31%	9009	11326	26%	12841	15002	17%
	70049	1909	3402	78%	6598	8622	31%	9028	11342	26%	12858	15022	17%
	70165	1910	3408	78%	6616	8641	31%	9050	11361	26%	12877	15043	17%
	71090	1914	3423	79%	6669	8701	30%	9113	11416	25%	12932	15100	17%
Winward Pkwy	72134	1927	3456	79%	6784	8834	30%	9263	11543	25%	13053	15213	17%
	72229	1938	3479	80%	6850	8914	30%	9353	11626	24%	13132	15288	16%
	72700	1939	3481	80%	6859	8929	30%	9370	11643	24%	13142	15297	16%
	74070	1942	3488	80%	6874	8946	30%	9388	11649	24%	13133	15276	16%
	75173	1947	3501	80%	6893	8979	30%	9420	11687	24%	13135	15276	16%
	75268	1951	3513	80%	6912	9009	30%	9453	13206	40%	13175	15315	16%
	99988	1953	3518	80%	6926	9030	30%	9475	11753	24%	13195	15329	16%
	100220	1954	3525	80%	6939	9057	31%	9503	11782	24%	13225	15347	16%
	102225	1970	3578	82%	7049	9168	30%	9618	11886	24%	13344	15414	16%
	103740	1973	3654	85%	7285	9447	30%	9895	12117	22%	13600	15610	15%
	106830	1976	3630	84%	7381	9638	31%	10101	12287	22%	13764	15767	15%
McFarland Rd	107120	1980	3645	84%	7406	9680	31%	10147	12339	22%	13816	15831	15%
	108140	1981	3639	84%	7402	9664	31%	10125	12303	22%	13749	15766	15%
	109965	1994	3690	85%	7496	9802	31%	10263	12439	21%	13862	15899	15%
	111980	1998	3707	86%	7562	9927	31%	10376	12564	21%	13931	15994	15%
SR 400	113650	1993	3708	86%	7597	10021	32%	10428	12600	21%	13814	15867	15%
	113970	2012	3782	88%	7743	10306	33%	10720	12909	20%	14169	16150	14%
	115739	2014	3809	89%	7922	10785	36%	11244	13464	20%	14878	16711	12%
	117130	2060	3748	82%	7902	10691	35%	11181	13650	22%	15299	17595	15%
Shiloh Rd	118000	2250	3774	68%	7937	10677	35%	11183	13784	23%	15547	18092	16%
	119510	2422	3961	64%	7900	10572	34%	11039	13674	24%	15395	18050	17%
	120540	2540	4180	65%	8002	10619	33%	11077	13722	24%	15438	18119	17%
	122240	2507	4283	71%	8165	10702	31%	11153	13787	24%	15491	18180	17%
	124020	2533	4405	74%	8485	10842	28%	11258	13836	23%	15434	18093	17%
US 19	126315	2556	4490	76%	8813	11305	28%	11731	14328	22%	15934	18531	16%
	126470	2536	4443	75%	8705	11184	28%	11606	14202	22%	15820	18449	17%
	127860	2535	4438	75%	8650	11121	29%	11540	14132	22%	15756	18408	17%
	130840	2878	4687	63%	8435	10835	28%	11175	13718	23%	15223	17921	18%
	132330	2553	3968	55%	6410	8009	25%	8226	10023	22%	11046	13195	19%
	132830	4029	4029	0%	6352	7945	25%	8140	9930	22%	10911	13060	20%
Majors Road	133065	4930	4930	0%	6406	8014	25%	8210	10006	22%	10998	13135	19%

Table 4-5
Summary of Peak Flows

Road Crossing	Model Conduit	2-Year Peak Flows			10-Year Peak Flows			25-Year Peak Flows			100-Year Peak Flows		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
	135505	2009	3160	57%	5060	6593	30%	6575	8223	25%	8838	10764	22%
	136960	2233	3428	53%	5310	6823	28%	6787	8492	25%	9104	11055	21%
	138905	2417	3715	54%	5752	7263	26%	7243	8896	23%	9511	11402	20%
Bethelview Rd	140120	2376	3584	51%	5490	7059	29%	6974	8700	25%	9264	11240	21%
	141855	2416	3636	50%	5518	7119	29%	7010	8771	25%	9317	11365	22%
	143000	2490	3720	49%	5604	7289	30%	7104	8986	26%	9416	11604	23%
	145300	2275	3584	58%	5398	7207	34%	6844	8895	30%	9083	11476	26%
	147114	2281	3592	57%	5223	7045	35%	6576	8670	32%	8693	11140	28%
	147525	2264	3603	59%	5244	7102	35%	6609	8741	32%	8740	11231	29%
	148900	2325	3764	62%	5379	7342	36%	6750	8990	33%	8891	11484	29%
	150320	2172	3564	64%	5044	6994	39%	6342	8582	35%	8378	10984	31%
	151980	2272	3833	69%	4845	6958	44%	6027	8447	40%	7930	10694	35%
	FK2765	1989	2625	32%	3872	4627	20%	4783	5544	16%	6148	6895	12%
	FK3740	1894	2458	30%	3610	4357	21%	4444	5222	18%	5667	6185	9%
	FK4420	1896	2460	30%	3618	4366	21%	4456	5231	17%	5690	6536	15%
	FK11145	1739	2219	28%	3226	3883	20%	3980	4679	18%	5130	5858	14%
	FK13160	318	435	37%	748	836	12%	948	1034	9%	1222	1313	7%
	FK131602	318	435	37%	748	836	12%	948	1034	9%	1222	1313	7%
	FK131603	318	435	37%	748	836	12%	948	1034	9%	1222	1313	7%
	FK131604	318	435	37%	748	836	12%	948	1034	9%	1222	1313	7%
	FK15650	-1105	-1339	21%	-2546	-2862	12%	-3186	-3517	10%	-4087	-4430	8%
	FK19550	1200	1502	25%	2730	3288	20%	3613	4202	16%	4827	5230	8%
	FK23675	598	693	16%	1280	1440	12%	1585	1802	14%	2040	2298	13%
	FK25480	-638	-722	13%	-1213	-1254	3%	-1317	-1426	8%	-1430	-1449	1%
	FK28895	202	220	9%	301	322	7%	341	365	7%	411	439	7%
	FK288952	202	220	9%	301	322	7%	341	365	7%	411	439	7%
	FK32400	144	172	19%	301	358	19%	369	391	6%	407	434	7%
	FK32795	145	174	20%	326	398	22%	415	467	12%	522	559	7%
	FK33825	145	163	13%	183	186	1%	186	187	1%	188	189	1%
	FK34890	-167	-171	3%	-176	-178	1%	-178	-179	0%	-178	-176	-1%
Willow Meadow Circle	LI13964	160	203	27%	237	264	11%	261	284	9%	289	347	20%
	LI13964A	160	203	27%	237	264	11%	261	284	9%	289	347	20%
	LI13964B	160	203	27%	237	264	11%	261	284	9%	289	347	20%
	LI13964C	160	203	27%	237	264	11%	261	284	9%	289	347	20%
State Bridge Road	LI20500	396	485	22%	701	803	15%	833	906	9%	918	922	0%
	FK27651	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK37401	0	0	N/A	0	0	N/A	0	0	N/A	12	336	2713%
	FK44201	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK111451	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK131601	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK236751	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK254801	0	1	10652%	77	198	158%	236	1165	395%	1170	1514	29%
	FK288951	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK324001	0	0	N/A	7	36	391%	46	106	131%	144	196	36%
	FK327951	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK338251	0	11	7068%	152	249	64%	274	380	39%	451	580	29%
	FK348901	33	107	228%	313	413	32%	439	550	25%	623	757	22%
	LI139641	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	LI205001	0	0	N/A	0	0	N/A	2	124	4952%	297	615	107%
	13985	3426	4405	29%	6349	7932	25%	7979	10224	28%	11320	13610	20%
	21150	3425	4836	41%	6324	7943	26%	7990	10244	28%	11341	13804	22%
	21960	3427	5554	62%	7204	7944	10%	10193	10246	1%	11344	13807	22%
	22444	3428	7027	105%	8499	7945	-7%	8976	10142	13%	10442	10456	0%
	30270	2301	3354	46%	5980	8002	34%	8095	10303	27%	11419	13710	20%
	35040	2243	3356	50%	6058	8154	35%	8285	10690	29%	11928	14171	19%
	40898	2109	3405	61%	6169	7874	28%	7953	8204	3%	8239	7884	-4%
	49990	2019	3475	72%	4351	4353	0%	4362	4849	11%	4246	5174	22%
	58555	2027	3530	74%	6494	8578	32%	8891	11276	27%	12736	15009	18%
	65223	2138	3644	70%	6766	7661	13%	7762	7721	-1%	7817	8321	6%
	70066	1835	2164	18%	1969	2164	10%	1933	2228	15%	1973	2307	17%
	72315	1909	2393	25%	2504	2632	5%	-2783	-7433	167%	-9978	-13315	33%
	72415	1938	3480	80%	6856	8925	30%	9365	11639	24%	13067	14701	13%
	75280	1951	3515	80%	4453	4392	-1%	4440	4666	5%	4640	4394	-5%

Table 4-5
Summary of Peak Flows

Road Crossing	Model Conduit	2-Year Peak Flows			10-Year Peak Flows			25-Year Peak Flows			100-Year Peak Flows		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
	100012	1954	3521	80%	6932	7702	11%	7772	7587	-2%	7526	7712	2%
	107170	1981	3648	84%	7412	9688	31%	10155	12348	22%	13761	15152	10%
	113700	2010	3776	88%	7724	10243	33%	10650	12821	20%	14036	16036	14%
	113810	2011	3778	88%	7729	10275	33%	10688	12877	20%	14122	15822	12%
	118050	2334	3848	65%	6308	6724	7%	6838	7048	3%	7220	7117	-1%
	126375	2437	2573	6%	2645	2688	2%	2731	2757	1%	2860	2826	-1%
	133090	2580	2580	0%	2580	2580	0%	2580	2580	0%	2580	2580	0%
	140160	2394	3595	50%	5487	7061	29%	6971	8702	25%	9262	11242	21%
	147126	691	748	8%	827	909	10%	885	960	8%	963	1014	5%
	139851	0	0	N/A	0	0	N/A	0	0	N/A	0	166	N/A
	211501	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	220481	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	224441	0	0	N/A	0	0	N/A	0	151	N/A	1004	4802	378%
	302701	0	0	N/A	0	0	N/A	0	0	N/A	0	3	N/A
	350401	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	408981	0	0	N/A	0	447	N/A	562	3798	575%	6226	13423	116%
	499901	0	0	N/A	3458	10269	197%	10882	13805	27%	14130	14374	2%
	585551	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	652231	0	0	N/A	9	1608	18273%	2020	6709	232%	11525	20919	82%
	700661	76	1548	1949%	6110	8287	36%	8710	11082	27%	12621	14811	17%
	723151	31	1262	3959%	5559	10644	91%	11739	18739	60%	22782	28277	24%
	724151	0	0	N/A	0	0	N/A	0	0	N/A	75	598	698%
	752801	0	0	N/A	4210	7296	73%	7898	10664	35%	12302	14552	18%
	1000121	0	0	N/A	0	2107	N/A	2838	7775	174%	11972	17462	46%
	1071701	0	0	N/A	0	0	N/A	0	0	N/A	66	754	1036%
	1137001	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	1138101	0	0	N/A	0	0	N/A	0	0	N/A	0	568	N/A
	1180501	0	0	N/A	1826	4840	165%	5400	8393	55%	10704	14887	39%
	1263751	106	3084	2815%	7817	10374	33%	10811	13456	24%	15104	17769	18%
	1330901	1250	3420	174%	7785	8857	14%	8839	9947	13%	10884	13054	20%
	1401601	0	0	N/A	0	0	N/A	0	0	N/A	0	1	N/A
	1471261	1672	2963	77%	4596	6466	41%	5974	8128	36%	8138	10649	31%
	11560	3425	4404	29%	6348	7931	25%	7978	10224	28%	11319	13774	22%

Figure 4-2
Flow Frequency at Roswell Intake

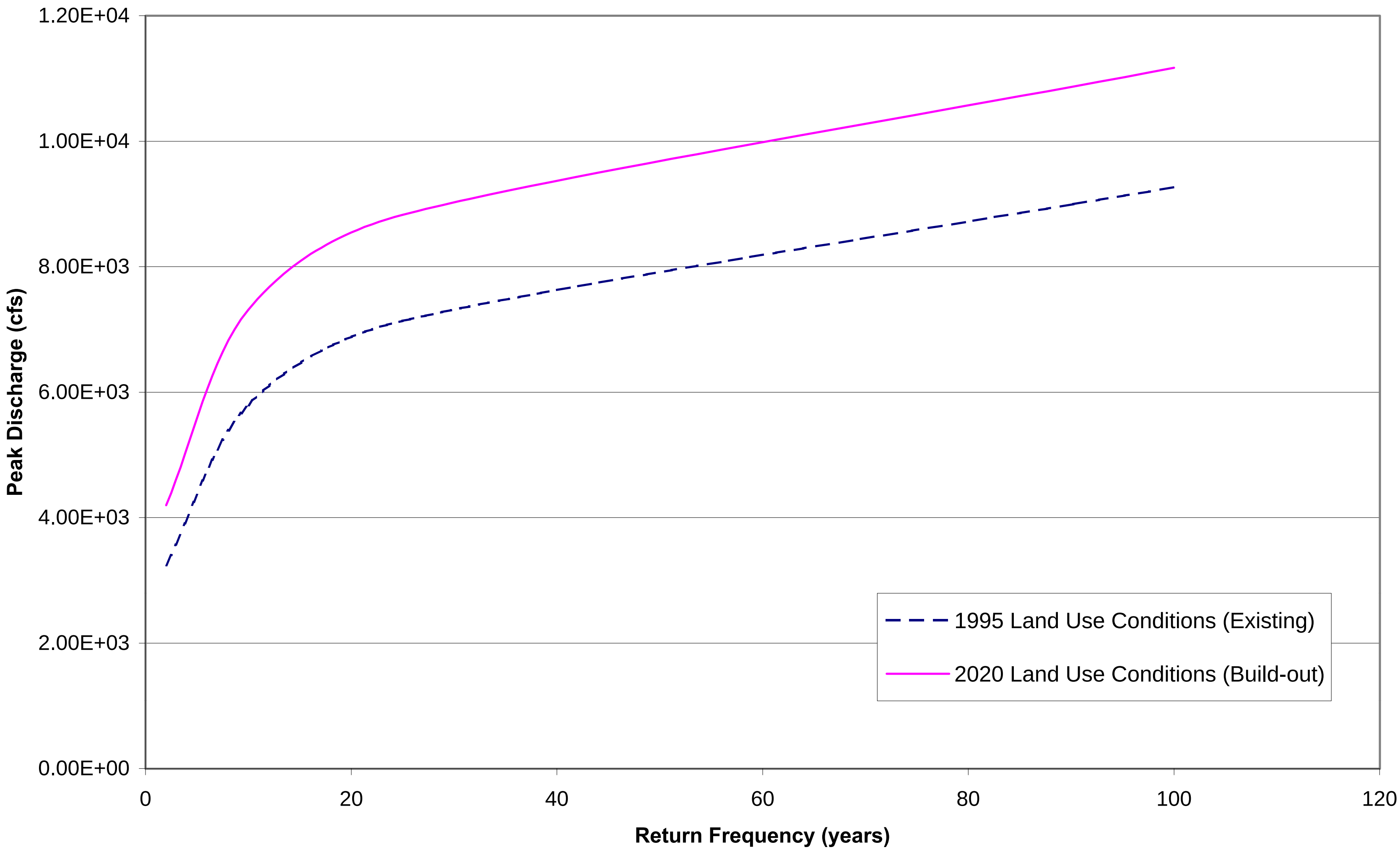


Figure 4-3
Flow Frequency at Big Creek Station 102225
(near Fulton/Forstyh County Line)

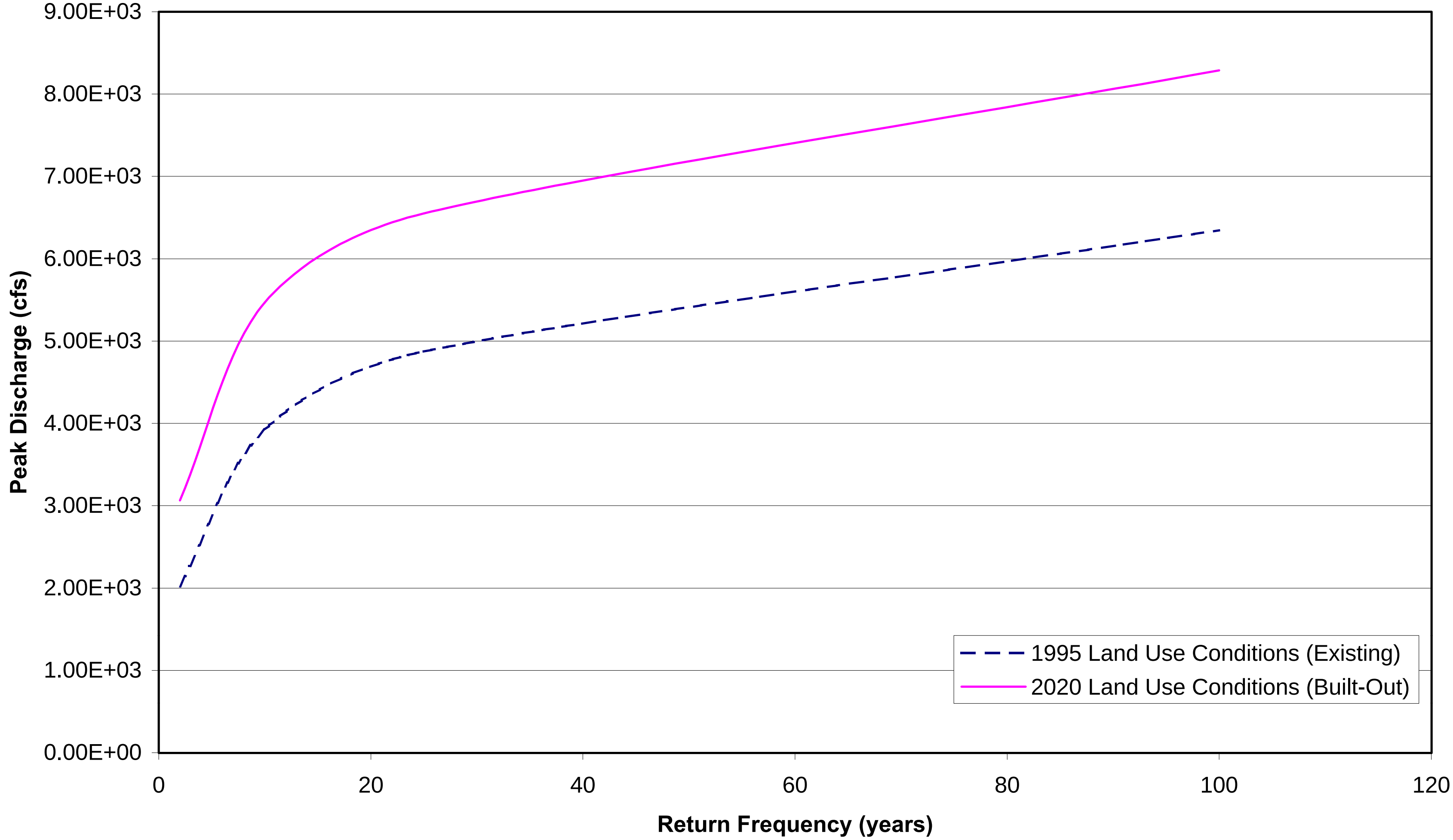


Table 4-6
Summary of Flood Levels

Model	Road	2-Year Flood Levels			10-Year Flood Levels			25-Year Flood Levels			100-Year Flood Levels		
Node	Names	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference
11490		931.42	932.01	0.6	933	933.73	0.7	933.75	934.7	1.0	935.14	936.04	0.9
11560		932.8	933.3	0.6	934.4	935.1	0.7	935.1	936.0	0.9	936.5	937.3	0.9
12925	x-section C	937.4	938.5	1.1	940.2	941.5	1.2	941.5	943.1	1.6	943.8	945.3	1.5
12935		938.1	938.5	0.4	940.2	941.5	1.2	941.5	943.1	1.6	943.8	945.3	1.5
13550		938.7	939.9	1.2	941.8	943.1	1.3	943.2	944.8	1.7	945.6	947.2	1.6
13961	Grimes Bridge Road	939.2	940.5	1.3	942.4	943.8	1.4	943.8	945.5	1.7	946.3	947.9	1.6
13985		939.7	941.0	1.3	943.1	944.6	1.5	944.7	946.5	1.9	947.4	949.1	1.7
18490		945.7	946.9	1.2	949.0	950.4	1.4	950.5	952.3	1.8	953.0	954.5	1.5
19880		947.2	948.34	1.1	950.27	951.66	1.4	951.7	953.47	1.8	954.22	955.72	1.5
21120	Riverside Apartment Bridge	948.9	950.0	1.1	952.0	953.4	1.4	953.4	955.1	1.8	955.9	957.4	1.5
21150		949.3	950.5	1.2	952.6	954.1	1.5	954.1	956.0	1.9	956.8	958.5	1.7
21960		949.9	951.2	1.3	953.1	954.6	1.5	954.7	956.5	1.9	957.3	959.0	1.7
22048		950.1	951.4	1.3	953.4	955.0	1.5	955.2	957.0	1.7	957.8	959.5	1.8
22420	Old Holcomb Bridge Road	950.3	951.8	1.4	953.6	955.2	1.5	955.2	957.1	1.9	958.0	959.7	1.8
22444		950.6	952.9	2.3	954.2	956.0	1.8	956.0	958.5	2.4	959.4	960.8	1.4
24100		951.5	953.1	1.6	955.3	957.0	1.7	957.1	959.4	2.3	960.3	961.8	1.5
25760		953.7	955.1	1.5	957.3	959.0	1.7	959.1	961.3	2.2	962.2	963.8	1.6
26390		954.2	955.7	1.4	957.9	959.5	1.7	959.6	961.7	2.2	962.6	964.3	1.6
30120	Georgia 400	956.0	957.2	1.3	959.3	960.8	1.6	960.9	963.0	2.1	963.8	965.5	1.6
30270		956.1	957.4	1.3	959.5	961.4	1.9	961.5	964.1	2.7	965.3	967.6	2.3
31135		957.1	958.7	1.6	960.1	961.8	1.6	961.8	964.3	2.4	965.4	967.6	2.3
31735		957.3	958.9	1.6	960.4	962.0	1.6	962.1	964.5	2.4	965.5	967.8	2.2
34150		960.3	962.2	1.9	964.4	965.7	1.3	965.8	967.2	1.5	968.0	969.7	1.7
34930	Mansell Road	960.5	962.3	1.8	964.6	965.9	1.3	966.0	967.4	1.5	968.2	969.8	1.7
35040		960.6	962.4	1.8	964.8	966.2	1.4	966.3	967.8	1.5	968.6	970.2	1.7
35655		961.1	962.6	1.5	964.9	966.3	1.3	966.4	967.9	1.5	968.7	970.3	1.6
36730		961.2	962.8	1.5	965.1	966.5	1.4	966.6	968.1	1.5	968.9	970.5	1.6
39780		963.3	964.8	1.4	967.0	968.4	1.4	968.5	969.9	1.4	970.6	972.0	1.4
40870	Haynes Bridge Road	963.7	965.2	1.5	967.5	968.9	1.4	969.0	970.4	1.4	971.2	972.5	1.4
40898		963.9	965.7	1.8	968.6	970.3	1.7	970.4	971.3	0.9	971.7	972.5	0.9
41000		964.0	965.7	1.8	968.6	970.3	1.7	970.4	971.3	0.9	971.7	972.6	0.9
42850		964.2	966.0	1.8	968.9	970.6	1.7	970.7	971.7	1.0	972.2	973.1	0.9
44420		965.4	967.3	1.9	970.3	972.0	1.8	972.2	973.5	1.3	974.1	975.1	1.1
47150		967.5	969.7	2.2	972.6	974.2	1.7	974.4	975.8	1.5	976.6	977.7	1.2
49000		968.2	970.5	2.3	973.3	974.9	1.6	975.1	976.5	1.5	977.3	978.5	1.2
49964	Kimball bridge Road	968.6	970.9	2.3	973.8	975.4	1.7	975.6	977.1	1.5	977.8	979.0	1.2
49990		968.9	971.5	2.6	974.1	975.3	1.2	975.4	977.1	1.7	977.8	979.1	1.2
50450		969.3	971.8	2.6	974.6	975.9	1.2	976.0	977.6	1.6	978.4	979.5	1.2
51920		970.5	972.8	2.3	975.6	976.9	1.3	977.1	978.6	1.5	979.3	980.5	1.2
53860		973.0	975.0	2.0	977.6	978.9	1.3	979.0	980.4	1.4	981.1	982.2	1.1
53870		986.9	987.9	1.0	987.7	988.9	1.2	988.1	989.4	1.3	988.6	990.2	1.6
56400		975.1	977.3	2.2	980.4	982.0	1.6	982.2	983.8	1.6	984.6	985.9	1.3
56410		995.1	996.2	1.1	995.9	997.4	1.5	996.3	998.0	1.7	996.9	998.8	1.9
57350		976.6	978.5	1.9	981.3	982.9	1.6	983.0	984.6	1.5	985.4	986.7	1.3
58505	State Bridge Road	977.2	978.9	1.7	981.6	983.1	1.5	983.3	984.8	1.5	985.6	986.9	1.3
58555		977.4	979.2	1.8	982.1	983.8	1.7	984.0	985.7	1.7	986.6	987.9	1.4
59100		977.8	980.0	2.2	982.6	984.2	1.6	984.4	986.0	1.6	986.8	988.2	1.3
60420		978.5	980.7	2.3	983.3	984.9	1.6	985.1	986.7	1.6	987.6	988.9	1.3
61440		979.5	981.8	2.4	984.8	986.5	1.7	986.7	988.4	1.7	989.3	990.7	1.4
62230		980.0	982.4	2.4	985.4	987.1	1.7	987.3	989.0	1.7	989.9	991.3	1.4
63015		980.1	982.5	2.4	985.5	987.2	1.7	987.4	989.1	1.7	990.1	991.5	1.4
64800		981.1	983.0	2.0	985.9	987.5	1.7	987.8	989.4	1.7	990.4	991.7	1.4
65195	Webb Bridge Road	981.6	983.5	1.9	986.2	987.8	1.6	988.0	989.6	1.6	990.6	991.9	1.4
65223		982.0	984.3	2.3	987.8	989.1	1.4	989.3	990.0	0.8	990.6	991.4	0.8
66840		983.4	985.1	1.7	988.3	989.6	1.3	989.8	990.6	0.8	991.2	992.0	0.8
68195		986.3	988.2	1.8	991.1	992.6	1.5	992.8	994.1	1.3	994.9	996.0	1.1
69950		987.8	989.9	2.1	993.0	994.6	1.6	994.9	996.4	1.5	997.2	998.4	1.2
70049		987.8	990.0	2.1	993.1	994.7	1.6	994.9	996.4	1.5	997.3	998.4	1.2
70066		987.9	990.0	2.1	993.1	994.7	1.6	994.9	996.4	1.5	997.3	998.4	1.2
70165		987.9	990.0	2.1	993.1	994.7	1.6	995.0	996.4	1.5	997.3	998.4	1.2
71090		988.2	990.3	2.0	993.2	994.8	1.6	995.1	996.5	1.5	997.4	998.5	1.2
72134		988.5	990.4	2.0	993.4	994.9	1.5	995.2	996.6	1.5	997.5	998.6	1.1
72229		988.7	990.9	2.2	993.7	995.2	1.5	995.4	996.8	1.4	997.7	998.8	1.1
72315	Winward Parkway	989.3	991.3	2.0	993.7	995.1	1.4	995.4	996.6	1.3	997.3	998.1	0.8
72415		990.0	992.4	2.3	995.6	997.3	1.7	997.7	999.3	1.6	1000.1	1001.1	1.0
72700		990.5	992.6	2.1	995.8	997.5	1.7	997.8	999.4	1.6	1000.3	1001.2	1.0
74070		991.0	993.1	2.1	996.2	997.9	1.7	998.2	999.8	1.6	1000.7	1001.7	1.0
75173		991.5	993.5	2.0	996.6	998.3	1.6	998.6	1000.2	1.6	1001.2	1002.2	1.0
75268		991.6	993.6	2.0	996.7	998.3	1.7	998.6	1000.3	1.6	1001.2	1002.2	1.0

Table 4-6
Summary of Flood Levels

Model	Road	2-Year Flood Levels			10-Year Flood Levels			25-Year Flood Levels			100-Year Flood Levels		
Node	Names	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference
75280		991.6	993.6	2.0	996.7	998.3	1.6	998.7	1000.3	1.6	1001.2	1002.2	1.0
99988		991.9	993.9	2.0	996.9	998.5	1.6	998.8	1000.4	1.6	1001.3	1002.3	1.0
100012		992.3	994.4	2.1	997.8	999.4	1.6	999.6	1000.7	1.1	1001.4	1002.2	0.9
100220		992.5	994.5	2.1	997.8	999.4	1.6	999.6	1000.7	1.1	1001.4	1002.3	0.9
102225		994.3	995.6	1.3	998.4	999.9	1.5	1000.1	1001.2	1.1	1001.9	1002.8	0.9
103740		996.72	997.8	1.1	999.56	1000.74	1.2	1000.96	1001.98	1.0	1002.62	1003.47	0.9
106830		998.9	1000.6	1.7	1003.2	1004.4	1.2	1004.6	1005.6	1.0	1006.2	1007.0	0.8
107120		999.3	1000.9	1.6	1003.4	1004.5	1.2	1004.8	1005.8	1.0	1006.4	1007.2	0.8
107170	McFarland Road	999.4	1001.1	1.7	1003.8	1005.2	1.3	1005.4	1006.6	1.2	1007.3	1008.3	1.0
108140		999.8	1001.5	1.7	1004.1	1005.5	1.3	1005.7	1006.8	1.1	1007.5	1008.5	0.9
109965		1001.7	1003.1	1.4	1005.3	1006.5	1.2	1006.7	1007.7	1.0	1008.4	1009.3	0.9
111980		1003.4	1005.0	1.6	1007.5	1008.7	1.2	1008.9	1009.9	1.0	1010.6	1011.4	0.9
113650	400 Northbound	1003.8	1005.3	1.5	1007.7	1008.9	1.2	1009.1	1010.2	1.0	1010.8	1011.7	0.9
113760	400 Southbound	1003.9	1005.5	1.6	1008.2	1009.6	1.4	1009.8	1011.0	1.2	1011.8	1013.0	1.2
113810		1004.0	1005.8	1.8	1008.8	1010.3	1.6	1010.6	1011.9	1.3	1013.0	1014.4	1.5
113970		1004.4	1006.0	1.6	1008.9	1010.4	1.5	1010.7	1012.0	1.3	1013.0	1014.5	1.5
115739		1008.8	1010.3	1.6	1011.8	1012.4	0.6	1012.5	1013.1	0.6	1013.8	1015.0	1.2
117130		1008.8	1010.4	1.6	1012.0	1012.7	0.7	1012.8	1013.4	0.7	1014.0	1015.2	1.2
118000	Shiloh Road	1008.9	1010.6	1.6	1012.3	1013.0	0.8	1013.2	1013.8	0.7	1014.4	1015.5	1.1
118050		1009.2	1011.1	2.0	1013.9	1014.5	0.6	1014.6	1015.1	0.5	1015.3	1015.7	0.4
119510		1009.5	1011.5	2.0	1014.3	1015.0	0.8	1015.1	1015.7	0.6	1016.0	1016.5	0.5
120540		1011.2	1012.5	1.3	1015.1	1016.0	0.9	1016.2	1016.9	0.8	1017.3	1018.0	0.6
122240		1011.99	1013.28	1.3	1015.81	1016.86	1.1	1017.02	1017.88	0.9	1018.38	1019.11	0.7
124020		1013.46	1014.58	1.1	1016.71	1017.76	1.0	1017.93	1018.82	0.9	1019.34	1020.11	0.8
126315	US Route 19	1020.83	1022.34	1.5	1023.84	1024.47	0.6	1024.59	1025.16	0.6	1025.52	1026.05	0.5
126375		1021.33	1022.49	1.2	1023.9	1024.53	0.6	1024.64	1025.21	0.6	1025.57	1026.09	0.5
126470		1021.33	1022.5	1.2	1023.91	1024.54	0.6	1024.65	1025.22	0.6	1025.58	1026.11	0.5
127860		1021.38	1022.58	1.2	1024.09	1024.78	0.7	1024.9	1025.53	0.6	1025.92	1026.5	0.6
130840		1021.63	1022.98	1.4	1024.76	1025.6	0.8	1025.73	1026.5	0.8	1026.95	1027.65	0.7
132330		1024.35	1025.77	1.4	1027.57	1028.55	1.0	1028.67	1029.62	0.9	1030.12	1031.07	1.0
132830		1024.52	1025.9	1.4	1027.69	1028.67	1.0	1028.79	1029.74	1.0	1030.24	1031.19	1.0
132840		1025.41	1025.9	0.5	1027.69	1028.67	1.0	1028.79	1029.74	1.0	1030.24	1031.19	1.0
133065	Majors Road	1025.4	1026.02	0.6	1027.77	1028.74	1.0	1028.86	1029.82	1.0	1030.31	1031.26	1.0
133090		1025.41	1026.12	0.7	1027.8	1028.76	1.0	1028.87	1029.82	1.0	1030.32	1031.26	0.9
135505		1029.16	1030.36	1.2	1031.63	1032.31	0.7	1032.3	1032.88	0.6	1033.09	1033.66	0.6
136960		1029.5	1030.69	1.2	1032.02	1032.77	0.8	1032.76	1033.42	0.7	1033.66	1034.31	0.6
138905		1036.77	1037.48	0.7	1038.44	1038.85	0.4	1038.95	1039.37	0.4	1039.65	1040.12	0.5
140120	Bethelview Road	1038.37	1039.51	1.1	1040.86	1041.74	0.9	1041.71	1042.56	0.8	1042.84	1043.69	0.9
140160		1038.78	1040.18	1.4	1041.98	1043.26	1.3	1043.2	1044.46	1.3	1044.83	1046.06	1.2
141855		1040.94	1042.43	1.5	1044.14	1045.28	1.1	1045.21	1046.32	1.1	1046.64	1047.71	1.1
143000		1043.03	1043.79	0.8	1045.1	1046.13	1.0	1046.06	1047.09	1.0	1047.38	1048.41	1.0
145300		1048.6	1049.68	1.1	1050.73	1051.54	0.8	1051.39	1052.2	0.8	1052.27	1053.11	0.8
147114		1053.1	1054.4	1.3	1055.72	1057.01	1.3	1056.68	1058	1.3	1058.01	1059.3	1.3
147126		1053.7	1055.07	1.4	1056.4	1057.64	1.2	1057.34	1058.57	1.2	1058.58	1059.81	1.2
147525		1053.97	1055.34	1.4	1056.68	1057.93	1.3	1057.62	1058.88	1.3	1058.88	1060.13	1.3
148900		1058.01	1059.19	1.2	1060.19	1061.3	1.1	1060.98	1062.15	1.2	1062.12	1063.33	1.2
150320		1059	1060.6	1.6	1061.96	1063.45	1.5	1063	1064.53	1.5	1064.43	1065.98	1.5
151980		1060.66	1062.07	1.4	1063.17	1064.59	1.4	1064.12	1065.61	1.5	1065.48	1067.01	1.5
500816		986.4	988.2	1.8	991.1	992.6	1.5	992.8	994.1	1.3	994.9	996.0	1.1
950725		966.0	967.3	1.2	970.3	972.0	1.8	972.2	973.5	1.3	974.1	975.1	1.1
1001400		1065.9	1067.4	1.5	1068.2	1069.4	1.2	1069.0	1070.2	1.2	1070.0	1071.2	1.3
1002000		1069.8	1071.1	1.3	1071.3	1072.4	1.0	1072.0	1072.8	0.8	1072.7	1073.5	0.8
1003400		1071.8	1072.7	0.9	1073.9	1074.5	0.6	1074.6	1075.2	0.6	1075.5	1076.1	0.5
1004284		1097.0	1100.0	3.0	1103.5	1105.8	2.2	1105.6	1107.7	2.0	1109.0	1110.7	1.6
1004325		1096.7	1099.7	3.0	1103.2	1105.2	2.0	1105.3	1107.2	1.9	1108.2	1110.0	1.8
1004800		1096.3	1099.2	3.0	1102.7	1104.6	1.8	1104.8	1106.6	1.8	1107.7	1109.4	1.7
1006900		1100.8	1101.4	0.6	1102.8	1104.6	1.8	1104.8	1106.5	1.7	1107.5	1109.2	1.7
1008000		1103.3	1104.7	1.5	1105.6	1106.9	1.3	1106.4	1107.6	1.3	1107.7	1109.3	1.6
1009200		1117.78	1119.5	1.7	1120.52	1122.22	1.7	1121.59	1123.27	1.7	1122.93	1124.64	1.7
1009475		1117.83	1119.57	1.7	1120.58	1122.3	1.7	1121.66	1123.36	1.7	1123.02	1124.74	1.7
1009565		1120.82	1122.51	1.7	1123.04	1123.96	0.9	1123.58	1124.48	0.9	1124.3	1125.16	0.9
1009800		1123.72	1124.29	0.6	1124.71	1125.2	0.5	1124.99	1125.51	0.5	1125.4	1125.92	0.5
2002200		1061.3	1063.5	2.3	1064.2	1066.5	2.2	1065.3	1067.6	2.3	1066.9	1069.1	2.3
2005200		1072.9	1075.6	2.7	1075.2	1078.0	2.8	1076.1	1078.8	2.7	1077.2	1079.9	2.7
2009100		1100.1	1103.5	3.4	1102.5	1106.8	4.2	1103.6	1107.9	4.3	1105.0	1109.5	4.4
2009110		1115.6	1116.1	0.5	1116.0	1116.7	0.7	1116.2	1116.9	0.7	1116.4	1117.2	0.8
2107800		1158.0	1159.9	1.9	1160.2	1161.7	1.6	1160.9	1162.4	1.5	1161.8	1163.2	1.4
3003100		1007.5	1010.1	2.5	1011.7	1013.3	1.6	1013.0	1014.4	1.5	1014.5	1015.8	1.3
3008100		1019.7	1022.2	2.5	1022.6	1024.7	2.1	1023.6	1025.6	2.0	1024.8	1026.7	2.0

Table 4-6
Summary of Flood Levels

Model Node	Road Names	2-Year Flood Levels			10-Year Flood Levels			25-Year Flood Levels			100-Year Flood Levels		
		Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference
3103300		1058.6	1061.1	2.5	1060.9	1063.2	2.3	1061.7	1064.0	2.3	1062.7	1064.9	2.2
3105500		1115.2	1117.6	2.4	1116.5	1119.3	2.8	1117.1	1119.9	2.9	1117.8	1120.7	2.9
3107100		1120.8	1124.2	3.5	1122.8	1126.3	3.5	1123.5	1127.0	3.5	1124.4	1127.9	3.4
4001150		1022.1	1022.2	0.2	1022.7	1022.8	0.1	1022.9	1023.0	0.1	1023.2	1023.3	0.1
4001151		1026.8	1027.0	0.1	1027.5	1027.7	0.2	1027.8	1028.0	0.2	1028.2	1028.4	0.2
4002900		1026.8	1027.0	0.1	1027.5	1027.7	0.2	1027.8	1028.0	0.2	1028.3	1028.5	0.2
4003800		1026.8	1027.0	0.1	1027.5	1027.7	0.2	1027.8	1028.0	0.2	1028.3	1028.5	0.2
4005200		1026.8	1027.0	0.2	1027.6	1027.7	0.2	1027.9	1028.0	0.2	1028.3	1028.5	0.2
4009800		1026.9	1027.0	0.1	1027.6	1027.8	0.2	1027.9	1028.1	0.2	1028.3	1028.6	0.2
5001890		986.4	988.2	1.8	991.1	992.6	1.5	992.8	994.1	1.3	994.9	996.0	1.1
5002723		989.4	990.0	0.6	991.1	992.6	1.5	992.8	994.1	1.3	994.9	996.0	1.1
5003055		991.1	992.0	1.0	992.9	993.6	0.7	993.5	994.3	0.8	994.9	996.0	1.1
5003255		992.9	994.9	1.9	996.7	998.5	1.7	998.2	999.7	1.6	999.8	1000.2	0.4
5003783		994.2	995.8	1.6	997.2	998.8	1.5	998.5	1000.0	1.5	1000.1	1000.6	0.6
5004742		994.6	995.8	1.2	997.3	998.8	1.5	998.5	1000.0	1.5	1000.1	1000.7	0.6
5005565		999.4	1000.2	0.8	1000.7	1000.7	0.1	1000.9	1001.0	0.1	1001.1	1001.7	0.6
5005986		999.9	1000.8	0.9	1001.4	1001.9	0.5	1001.9	1002.3	0.5	1002.4	1003.0	0.6
5006186		1000.0	1001.1	1.1	1002.1	1003.0	0.9	1002.8	1003.9	1.0	1004.0	1005.1	1.1
5006501		1000.1	1001.2	1.1	1002.2	1003.1	0.9	1003.0	1004.0	1.0	1004.1	1005.2	1.0
5007227		1000.1	1001.3	1.1	1002.2	1003.2	0.9	1003.0	1004.0	1.0	1004.1	1005.2	1.1
5009927		1009.1	1010.8	1.6	1011.9	1012.9	1.0	1012.8	1013.6	0.8	1013.8	1014.5	0.7
6001000		1021.6	1023.0	1.4	1024.8	1025.6	0.8	1025.8	1026.5	0.8	1027.0	1027.7	0.7
6002300		1025.7	1026.5	0.7	1027.8	1028.0	0.3	1028.1	1028.3	0.2	1028.5	1028.4	-0.1
6005450		1026.0	1027.0	1.0	1028.5	1029.1	0.6	1029.1	1029.6	0.5	1029.8	1030.1	0.3
6005600	Highway 371	1026.2	1027.5	1.3	1029.8	1031.4	1.6	1031.3	1033.0	1.7	1033.5	1035.2	1.7
6007400		1027.4	1029.0	1.6	1031.2	1032.7	1.5	1032.7	1034.0	1.4	1034.5	1035.9	1.4
6009500		1027.6	1029.2	1.6	1031.3	1032.8	1.5	1032.8	1034.1	1.3	1034.6	1035.9	1.4
7002900		1040.6	1043.2	2.7	1043.7	1045.7	2.0	1044.7	1046.7	1.9	1046.1	1048.0	2.0
7007300		1059.4	1061.5	2.1	1062.3	1063.6	1.3	1063.0	1064.4	1.4	1064.2	1065.5	1.3
8002000		1025.4	1026.2	0.8	1027.9	1028.8	1.0	1028.9	1029.9	0.9	1030.4	1031.3	0.9
8004400		1026.5	1027.4	0.8	1028.8	1029.5	0.7	1029.7	1030.4	0.7	1030.7	1031.5	0.7
8006100		1029.7	1030.6	0.8	1032.0	1032.7	0.8	1032.8	1033.6	0.8	1033.9	1034.7	0.8
8008300		1032.8	1033.6	0.8	1035.0	1035.6	0.6	1035.7	1036.4	0.7	1036.8	1037.5	0.7
8009750		1038.6	1039.4	0.8	1040.8	1041.6	0.8	1041.6	1042.5	0.8	1042.8	1043.6	0.8
8009850	Pitman Road	1038.9	1039.7	0.8	1041.1	1041.9	0.8	1041.9	1042.8	0.8	1043.1	1043.9	0.8
8009889		1040.5	1042.5	2.0	1044.0	1044.6	0.6	1044.6	1045.2	0.6	1045.4	1046.0	0.5
9001300		956.2	957.4	1.2	959.5	960.8	1.4	960.9	963.0	2.1	963.8	965.5	1.6
9002230		958.3	959.2	0.9	960.4	961.2	0.8	961.5	963.0	1.5	963.8	965.5	1.6
9002660		959.3	960.2	0.9	961.3	961.9	0.6	962.0	963.0	0.9	963.8	965.5	1.6
9002765	Mansell Road	960.1	961.2	1.0	962.7	963.5	0.8	963.7	964.5	0.8	965.0	965.7	0.7
9002865		960.3	961.4	1.0	962.9	963.7	0.8	963.8	964.6	0.8	965.1	965.8	0.7
9003700		961.3	962.5	1.2	964.2	965.2	1.0	965.3	966.2	0.9	966.8	967.6	0.8
9003740	Rock Mill Way	962.7	964.1	1.4	966.4	967.8	1.4	968.0	969.3	1.3	969.9	971.3	1.4
9004200		966.4	967.3	0.9	969.1	970.1	1.1	970.3	971.3	1.1	971.9	973.1	1.1
9004370		969.5	970.4	0.9	972.0	972.9	0.9	973.0	973.8	0.9	974.3	975.2	0.9
9004420	Old Roswell Road	970.0	971.0	1.1	973.0	974.1	1.1	974.2	975.4	1.1	976.0	977.3	1.3
9004600		972.8	973.9	1.1	975.8	976.8	1.0	976.9	977.9	1.0	978.5	979.5	1.0
9005810		975.4	976.2	0.9	977.7	978.4	0.7	978.5	979.3	0.8	979.8	980.8	1.0
9007160		982.8	983.7	0.8	984.9	985.7	0.8	985.8	986.5	0.7	986.9	987.5	0.6
9008370		987.4	988.3	0.9	989.7	990.5	0.8	990.7	991.4	0.7	991.9	992.6	0.6
9009130		991.8	992.6	0.8	994.0	994.8	0.8	995.0	995.7	0.7	996.3	997.0	0.7
9503350		977.1	977.3	0.2	978.5	978.4	-0.1	979.1	978.8	-0.2	979.7	979.4	-0.3
9505520		985.0	985.7	0.7	986.9	987.1	0.2	987.4	987.7	0.3	988.2	988.5	0.3
9506000		986.9	988.2	1.3	989.4	989.8	0.4	990.1	990.4	0.3	990.9	991.3	0.4
9506400		993.9	994.5	0.6	995.0	995.2	0.2	995.3	995.5	0.1	995.7	995.9	0.2
9506428	Waters Road	994.1	994.6	0.5	995.2	995.4	0.2	995.6	995.8	0.2	996.1	996.3	0.2
9506500		994.2	994.7	0.5	995.5	995.7	0.2	995.9	996.0	0.2	996.4	996.6	0.2
9507100		994.5	995.1	0.6	996.0	996.3	0.3	996.5	996.7	0.2	997.0	997.3	0.3
9507600		995.0	995.6	0.7	996.7	997.0	0.3	997.2	997.4	0.2	997.8	998.1	0.3
9508400		1000.8	1001.1	0.2	1001.8	1002.0	0.2	1002.1	1002.4	0.3	1002.7	1003.0	0.3
9509885		1012.9	1013.5	0.5	1015.1	1015.7	0.6	1016.0	1016.6	0.6	1017.2	1017.8	0.6
9801100		961.4	962.8	1.3	965.1	966.5	1.4	966.6	968.1	1.5	968.9	970.5	1.6
9801455		963.4	963.9	0.5	965.2	966.5	1.3	966.6	968.1	1.5	968.9	970.5	1.6
9803440	Mall Parking Lot	968.9	969.3	0.5	970.8	971.7	0.9	972.1	974.8	2.7	975.4	977.2	1.7
9803600		972.5	972.8	0.3	973.5	973.8	0.4	973.9	975.1	1.2	975.7	977.3	1.6
9803850		975.0	975.4	0.3	976.3	976.7	0.3	976.8	977.2	0.4	977.4	978.0	0.5
9804200		975.9	976.2	0.3	977.2	977.5	0.4	977.6	978.0	0.4	978.3	978.6	0.4
9804650		978.5	978.8	0.3	979.6	979.9	0.3	980.0	980.3	0.3	980.5	980.8	0.3
9804850		979.1	980.1	1.0	980.4	981.6	1.2	980.9	981.9	1.0	981.8	982.2	0.4

Table 4-6
Summary of Flood Levels

Model	Road	2-Year Flood Levels			10-Year Flood Levels			25-Year Flood Levels			100-Year Flood Levels		
Node	Names	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference
9804990		979.6	980.8	1.2	981.2	982.6	1.4	981.7	982.9	1.1	982.7	983.2	0.5
9805171	Entrance Road to Mall	980.1	981.7	1.6	982.4	985.1	2.7	983.4	985.8	2.5	985.5	986.7	1.2
9805350		981.1	982.2	1.1	982.8	985.3	2.5	983.7	986.0	2.3	985.7	986.8	1.2
9805630		983.0	983.9	0.9	984.3	986.1	1.8	984.9	986.6	1.7	986.3	987.3	1.0
9806030		987.2	989.1	1.9	990.0	992.5	2.5	991.0	992.9	1.9	992.6	993.3	0.7
9806515	Georgia 400	987.8	990.0	2.3	991.5	997.6	6.1	993.4	999.1	5.7	998.2	1001.4	3.2
9806700		993.3	994.2	0.9	994.5	997.8	3.2	995.1	999.3	4.2	998.4	1001.5	3.1
9806785		995.0	996.2	1.2	996.4	998.2	1.8	996.9	999.5	2.6	998.7	1001.6	2.9
9806830		995.2	996.4	1.2	996.7	998.4	1.7	997.2	999.6	2.4	998.9	1001.6	2.8
9807200		1010.7	1010.8	0.1	1010.9	1011.1	0.2	1010.9	1011.1	0.2	1011.1	1011.3	0.1
9807900		1012.7	1013.2	0.6	1013.5	1014.8	1.3	1013.8	1015.2	1.4	1014.9	1015.8	0.9
9808445		1014.4	1015.4	1.1	1015.9	1018.1	2.3	1016.5	1018.7	2.2	1018.3	1019.5	1.2
9809000		1014.4	1015.5	1.1	1015.9	1018.2	2.3	1016.6	1018.8	2.2	1018.4	1019.6	1.2
9809240	Morrison Parkway	1021.8	1022.5	0.8	1022.9	1033.2	10.3	1023.6	1033.4	9.8	1033.2	1033.8	0.6
9809385		1029.8	1032.1	2.4	1033.1	1034.8	1.7	1034.3	1035.0	0.7	1034.9	1035.3	0.5
20010950		1139.5	1141.6	2.1	1141.2	1143.3	2.1	1141.8	1144.0	2.2	1142.6	1144.7	2.1
30011200		1029.7	1032.4	2.7	1032.0	1034.7	2.7	1033.0	1035.6	2.6	1034.0	1036.6	2.6
30012200		1040.2	1042.5	2.4	1042.4	1044.8	2.5	1043.2	1045.7	2.5	1044.3	1046.8	2.5
30014400		1052.4	1054.8	2.4	1054.1	1056.7	2.6	1054.7	1057.3	2.6	1055.5	1058.2	2.8
30019100		1076.7	1083.7	7.0	1081.7	1090.5	8.8	1083.9	1093.1	9.2	1086.9	1096.4	9.5
40010560		1032.1	1032.7	0.6	1033.6	1034.2	0.6	1034.2	1034.7	0.5	1034.8	1035.5	0.7
40011015		1035.0	1035.9	0.9	1036.9	1037.7	0.9	1037.7	1038.6	1.0	1038.8	1040.0	1.2
40011045		1035.0	1035.9	0.9	1036.9	1037.7	0.9	1037.7	1038.6	1.0	1038.8	1040.0	1.2
40011395		1036.6	1037.5	0.9	1038.5	1039.3	0.8	1039.3	1040.2	1.0	1040.4	1041.6	1.2
40012185		1041.4	1042.0	0.7	1042.7	1043.2	0.5	1043.2	1043.8	0.6	1043.8	1044.6	0.8
40013185		1046.9	1047.5	0.6	1048.1	1048.6	0.5	1048.6	1049.1	0.5	1049.2	1049.7	0.6
40013985		1053.6	1054.2	0.6	1054.9	1055.3	0.5	1055.3	1055.8	0.5	1055.9	1056.4	0.5
40014160		1054.7	1055.4	0.7	1055.5	1056.3	0.8	1056.1	1056.9	0.8	1056.7	1057.6	0.9
40014190		1058.6	1060.7	2.1	1061.2	1064.6	3.4	1063.2	1065.7	2.4	1065.5	1066.3	0.8
40014565		1060.0	1060.8	0.9	1061.3	1064.6	3.3	1063.3	1065.7	2.4	1065.6	1066.4	0.8
40014955		1066.4	1067.2	0.8	1067.3	1067.7	0.5	1067.5	1068.0	0.5	1067.9	1068.6	0.8
40015430		1068.6	1069.4	0.8	1069.7	1070.8	1.1	1070.5	1071.3	0.9	1071.2	1072.1	0.9
40016945		1072.6	1073.7	1.1	1074.1	1075.3	1.2	1074.7	1075.9	1.2	1075.4	1076.6	1.2
50011727		1019.8	1021.1	1.3	1022.1	1022.9	0.8	1022.7	1023.7	0.9	1023.7	1024.6	0.9
50017127		1041.6	1043.3	1.7	1044.0	1045.5	1.5	1045.0	1046.4	1.5	1046.2	1047.6	1.4
50019827		1066.9	1068.3	1.4	1068.6	1070.0	1.4	1069.2	1070.5	1.3	1070.1	1071.3	1.2
60011600		1031.7	1033.2	1.5	1034.2	1035.1	0.9	1035.1	1035.8	0.7	1035.9	1036.5	0.6
70012200		1078.6	1081.3	2.8	1081.5	1083.6	2.0	1082.6	1084.4	1.8	1083.7	1085.5	1.7
80012300		1045.7	1047.0	1.2	1049.4	1050.9	1.5	1051.0	1052.5	1.5	1053.1	1054.5	1.4
80014200		1051.9	1052.6	0.8	1054.2	1055.1	0.9	1055.2	1056.1	0.9	1056.4	1057.3	0.9
80015400		1058.9	1060.4	1.4	1062.4	1063.8	1.3	1063.7	1065.0	1.3	1065.3	1066.6	1.2
80018850		1078.8	1080.8	2.0	1081.6	1083.1	1.5	1082.5	1084.0	1.5	1083.7	1085.2	1.5
80022050		1094.6	1096.9	2.3	1096.9	1098.8	1.9	1097.7	1099.6	1.8	1098.7	1100.5	1.9
80023750		1098.6	1100.4	1.8	1100.4	1102.2	1.8	1101.1	1102.9	1.8	1102.0	1103.8	1.8
90011115		997.6	998.1	0.5	998.9	999.2	0.4	999.3	999.7	0.4	999.9	1000.2	0.3
90011145	New Road	998.1	998.8	0.6	999.9	1000.5	0.6	1000.6	1001.2	0.6	1001.6	1002.2	0.6
90012100		1000.4	1000.7	0.3	1001.8	1002.1	0.3	1002.4	1002.6	0.3	1003.2	1003.4	0.3
90013040		1003.7	1004.4	0.7	1006.1	1006.5	0.4	1007.0	1007.4	0.3	1008.1	1008.3	0.3
90013160	Alpharetta Road	1004.6	1005.7	1.1	1008.3	1008.9	0.7	1009.7	1010.3	0.5	1011.5	1012.0	0.5
90014950		1011.6	1012.2	0.6	1014.2	1014.6	0.4	1015.1	1015.5	0.4	1016.3	1016.7	0.4
90015600		1013.7	1014.4	0.7	1017.0	1017.6	0.5	1018.1	1018.6	0.5	1019.4	1019.9	0.5
90015650		1014.0	1014.7	0.7	1017.7	1018.3	0.6	1018.9	1019.5	0.6	1020.6	1021.1	0.6
90018420		1016.9	1017.3	0.5	1019.1	1019.6	0.5	1020.0	1020.5	0.5	1021.4	1021.9	0.5
90019510		1018.2	1018.8	0.6	1020.6	1021.2	0.5	1021.5	1022.0	0.5	1022.6	1023.1	0.5
90019550		1018.6	1019.3	0.8	1021.7	1022.5	0.9	1023.0	1024.1	1.0	1025.3	1026.2	0.9
90022850		1025.8	1026.1	0.3	1027.6	1028.0	0.4	1028.2	1028.6	0.4	1029.0	1029.4	0.4
90023645		1028.7	1029.0	0.3	1030.1	1030.3	0.2	1030.5	1030.8	0.3	1031.0	1031.3	0.3
90023675	Rucker Road	1029.4	1029.9	0.5	1031.8	1032.3	0.5	1032.7	1033.3	0.6	1034.0	1034.8	0.8
90024190		1029.9	1030.3	0.3	1032.1	1032.5	0.5	1032.9	1033.5	0.6	1034.2	1034.9	0.7
90025230		1033.4	1033.6	0.2	1034.4	1034.9	0.5	1034.8	1035.5	0.7	1035.6	1036.4	0.8
90025475	Private Foot Bridge	1033.8	1034.1	0.2	1035.0	1035.4	0.4	1035.4	1036.1	0.7	1036.3	1037.1	0.8
90025480		1034.9	1035.2	0.3	1036.7	1037.5	0.8	1037.6	1038.6	0.9	1038.8	1039.5	0.8
90025540		1034.9	1035.3	0.3	1036.7	1037.5	0.7	1037.7	1038.6	0.9	1038.8	1039.6	0.8
90026430		1037.4	1037.5	0.1	1038.1	1038.1	0.0	1038.4	1039.0	0.6	1039.2	1039.9	0.8
90026880		1042.2	1042.2	0.0	1042.3	1042.2	-0.1	1042.2	1042.2	0.0	1042.3	1042.6	0.3
90028500		1043.5	1043.6	0.1	1044.2	1044.3	0.1	1044.4	1044.6	0.1	1044.8	1044.9	0.1
90028870		1045.1	1045.3	0.2	1045.7	1045.9	0.1	1046.0	1046.2	0.2	1046.3	1046.4	0.1
90028895	Mid Broadwell Road	1046.1	1046.4	0.4	1047.8	1048.3	0.4	1048.7	1049.3	0.5	1050.2	1050.9	0.6
90029100		1046.4	1046.6	0.3	1047.9	1048.3	0.4	1048.7	1049.3	0.5	1050.2	1050.9	0.6

Table 4-6
Summary of Flood Levels

Model	Road	2-Year Flood Levels			10-Year Flood Levels			25-Year Flood Levels			100-Year Flood Levels		
Node	Names	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference
90030500		1052.2	1052.3	0.1	1052.8	1052.9	0.1	1053.0	1053.1	0.1	1053.3	1053.5	0.2
90031400		1055.4	1055.6	0.2	1056.4	1056.6	0.2	1056.8	1057.0	0.2	1057.3	1057.5	0.2
90032350		1060.1	1060.5	0.4	1062.2	1062.5	0.3	1062.6	1062.9	0.3	1063.0	1063.1	0.1
90032400	Maple Lane	1060.3	1060.7	0.4	1062.4	1062.7	0.3	1062.8	1063.0	0.3	1063.2	1063.3	0.1
90032750		1062.3	1062.6	0.3	1063.6	1064.1	0.4	1064.1	1064.4	0.3	1064.6	1064.8	0.2
90032795	Mayfield Road	1063.1	1063.4	0.3	1064.8	1065.3	0.5	1065.4	1065.8	0.4	1066.1	1067.1	0.9
90033810		1070.0	1070.3	0.3	1071.6	1072.0	0.5	1072.1	1072.5	0.4	1072.8	1073.1	0.3
90033825	Private Drive	1071.7	1072.1	0.4	1072.8	1073.0	0.2	1073.0	1073.2	0.2	1073.3	1073.5	0.2
90034875		1079.3	1080.0	0.7	1081.1	1081.4	0.3	1081.5	1081.8	0.3	1082.0	1082.3	0.3
90034890	Private Drive	1080.8	1081.2	0.3	1081.7	1081.9	0.2	1081.9	1082.1	0.2	1082.2	1082.4	0.2
90035300		1081.7	1081.9	0.2	1082.5	1082.7	0.2	1082.7	1083.0	0.2	1083.1	1083.4	0.3
90035600		1085.1	1085.5	0.4	1086.6	1087.1	0.5	1087.3	1087.8	0.5	1088.1	1088.7	0.6
95010700		1018.9	1019.3	0.3	1020.4	1020.7	0.3	1020.9	1021.3	0.4	1021.7	1022.1	0.4
95012335		1027.1	1028.0	0.9	1028.4	1028.9	0.4	1028.8	1029.0	0.2	1029.0	1029.3	0.3
95013500		1031.5	1032.0	0.5	1032.3	1032.5	0.2	1032.5	1032.7	0.2	1032.8	1033.1	0.3
95013900		1034.3	1034.6	0.3	1034.9	1035.1	0.2	1035.1	1035.2	0.2	1035.3	1035.6	0.3
95013964	Willow Meadow Circle	1035.1	1035.6	0.5	1036.0	1036.3	0.3	1036.3	1036.5	0.3	1036.6	1037.2	0.6
95014030		1035.4	1035.9	0.5	1036.3	1036.6	0.3	1036.5	1036.8	0.2	1036.8	1037.4	0.5
95014600		1038.2	1038.5	0.3	1038.8	1038.9	0.2	1038.9	1039.1	0.2	1039.1	1039.5	0.4
95015035		1041.3	1041.6	0.3	1041.8	1041.9	0.2	1041.9	1042.0	0.1	1042.0	1042.3	0.2
95016135		1047.9	1048.3	0.4	1048.6	1048.8	0.2	1048.8	1049.0	0.2	1049.0	1049.4	0.4
95016700		1049.6	1049.9	0.3	1050.1	1050.2	0.2	1050.2	1050.4	0.1	1050.4	1050.7	0.3
95017160		1051.6	1052.2	0.6	1052.6	1053.0	0.4	1052.9	1053.2	0.3	1053.3	1054.3	1.0
95017240	Buice Road	1051.9	1052.6	0.6	1053.0	1053.5	0.4	1053.4	1053.8	0.4	1053.8	1054.9	1.1
95017990		1054.8	1055.4	0.6	1055.9	1056.3	0.4	1056.3	1056.7	0.4	1056.7	1057.7	1.0
95018177	Indian Village Drive	1059.6	1062.3	2.7	1064.8	1067.3	2.5	1066.9	1069.3	2.3	1069.8	1071.4	1.6
95018640		1063.6	1063.7	0.1	1064.9	1067.4	2.5	1067.0	1069.3	2.3	1069.8	1071.4	1.6
95019260		1065.9	1066.9	1.0	1067.6	1068.6	1.0	1068.3	1069.6	1.3	1070.1	1071.6	1.5
95020080		1069.3	1069.7	0.5	1070.7	1071.1	0.4	1071.2	1071.6	0.5	1072.0	1072.5	0.5
95020472		1072.0	1072.7	0.6	1073.8	1074.3	0.4	1074.4	1075.1	0.7	1075.5	1076.2	0.7
95020500	State Bridge Road	1073.3	1074.1	0.8	1075.9	1076.7	0.8	1076.9	1077.5	0.6	1077.9	1078.3	0.4
95020585		1073.5	1074.3	0.8	1076.0	1076.8	0.8	1077.0	1077.6	0.6	1078.0	1078.4	0.4
95020800		1074.5	1074.9	0.3	1076.2	1076.9	0.7	1077.1	1077.7	0.6	1078.1	1078.6	0.5
95021300		1079.7	1079.9	0.2	1080.9	1081.0	0.0	1081.2	1081.4	0.2	1081.8	1081.9	0.2
98010900		1036.0	1036.7	0.7	1037.1	1038.0	0.9	1037.5	1038.4	0.9	1038.1	1039.0	0.9
98011705		1055.8	1056.5	0.7	1056.8	1057.4	0.6	1057.1	1057.7	0.6	1057.5	1058.1	0.6

4.4.4 Peak Velocities

Table 4-7 summarizes the peak velocities for the various design storms along key locations in the watershed for 1995 and 2020 land uses.

Velocities calculated by the model for the 2-year storm were compared to literature values of velocities for stable channels, to determine where streambank erosion is expected now (1995 land use) and in the future (year 2020).

For this study, it is assumed that the critical velocity is 5 ft/s and that any areas with velocities exceeding this for a 2-year design storm could experience stream bank erosion. Within this region, a channel velocity of 5 feet per second appears to produce shear stresses that are capable of eroding the majority of the soils encountered in stream channels**.** **Figure 4-4** and **Figure 4-5** show where the velocity exceeds 5 ft/s for the 2-year design storm under existing and future land use conditions respectively. The number of stream segments experiencing erosive velocities (2-year design storm peak velocities that exceed 5 ft/sec) increases under the future land use conditions.

4.4.5 Erosion Ratio Analysis

The peak 2-year storm streamflows for future land use (year 2020) were compared to 2-year storm streamflows under 1995 land conditions as another method of identifying erosion potential. Camp Dresser & McKee has developed an "erosion ratio" screening method, which is based on hydraulic geometry relationships developed by Leopold and Maddock (1953) for stream channels.

The erosion ratio method is based on relationships that reflect changes in channel width caused by changes in the 2-year peak flow (Q). The stream width is assumed proportional to Q^n, where the value of the exponent "n" varies from stream to stream, typically in the range of 0.35 to 0.50 (Leopold and Maddock, 1953). The relationship between stream width and 2-year peak flow is used as a guideline in assessing the impacts of urbanization on streambank erosion. Assuming that channel slope, width/depth ratio, and Manning's roughness coefficient remain constant, the stream width after development (W_2) can be evaluated based on the 2-year post-development peak flow (Q_2) and the stream width (W_1) and 2-year peak flow (Q_1) for 1995 land use conditions.

The equation is as follows:

$$W_2 = (Q_2 / Q_1)^n (W_1) \qquad (1)$$

The ratio $(Q_2 / Q_1)^n$ is called the "erosion ratio". This ratio is used to categorize increases in stream channel erosion potential as follows:

- "Minimal" erosion potential: Erosion ratio less than 1.25 (i.e., less than a 25% increase in stream width compared to natural stream conditions).

Table 4-7
Summary of Peak Velocities

Road Crossing	Model Conduit	2-Year Peak Velocities			10-Year Peak Velocities			25-Year Peak Velocities			100-Year Peak Velocities		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
Indian Village Drive	LI18177	16.42	17.77	8%	20.11	22.36	11%	22.03	23.99	9%	24.41	25.09	3%
Morrison Pkwy	Ta9240	10.21	12.23	20%	13.24	19.55	48%	15.38	19.94	30%	19.7	20.04	2%
Waters Rd	LI6428	2.64	2.95	12%	3.95	4.04	2%	4.29	4.51	5%	4.84	5.01	4%
Buice Road	LI17240	4.92	5.24	7%	5.48	5.7	4%	5.67	5.85	3%	5.88	6.22	6%
Mall Parking Lot	Ta3440	9.05	9.67	7%	11.3	11.88	5%	11.99	12.13	1%	12.24	12.66	3%
Entrance Road to Mall	Ta5171	5.81	7.26	25%	7.93	10.35	31%	8.82	11.42	29%	10.88	12.75	17%
GA 400	Ta6515	5.03	5.88	17%	7.08	13.15	86%	9.04	14.63	62%	13.82	16.62	20%
	LI181771	0	0	N/A	0	0	N/A	0	0	N/A	0.08	1.69	2013%
	Ta92401	0	0	N/A	0	3.44	N/A	0	3.7	N/A	3.52	4.13	17%
	LI64281	0	0	N/A	0	0	N/A	0	0.36	N/A	1.23	1.87	52%
	LI172401	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Ta34401	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Ta51711	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	Ta65151	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	KM9800	2.12	1.85	-13%	1.94	1.85	-5%	1.87	1.95	4%	1.85	2.31	25%
	KM9565	13.11	14.26	9%	14.43	14.46	0%	14.51	14.36	-1%	14.39	14.31	-1%
	KM9565A	13.11	14.26	9%	14.43	14.46	0%	14.51	14.36	-1%	14.39	14.31	-1%
	KM95651	1.84	4.01	118%	4.66	5.83	25%	5.35	6.43	20%	6.24	7.13	14%
	KM9475	-0.73	-0.88	21%	10.2	10.57	4%	10.79	10.5	-3%	-1.23	-1.43	16%
	KM9200	7	6.98	0%	23.84	24.72	4%	25.22	24.55	-3%	7.05	7.62	8%
	KM8000	4.18	4.16	0%	4.22	3.84	-9%	4.04	4.05	0%	3.91	4.23	8%
	KM6900	6.5	6.59	1%	6.93	6.15	-11%	6.92	5.81	-16%	6.76	5.41	-20%
	KM4800	2.14	1.81	-15%	1.99	2.95	48%	2.09	3.01	44%	2.61	2.84	9%
	KM4325	2.36	2.46	4%	2.66	-4.12	-255%	-2.99	-4.8	61%	-3.98	-4.5	13%
	KM43251	3.97	4.2	6%	4.46	5.62	26%	4.69	5.82	24%	5.39	5.82	8%
	KM4284	10.51	11.5	9%	12.68	13.43	6%	13.37	14.01	5%	14.43	14.92	3%
	KM3400	3.9	4.12	6%	4.81	5.04	5%	5.03	5.18	3%	5.3	5.55	5%
	KM2000	8.33	8.54	3%	8.56	8.6	0%	8.61	8.56	-1%	8.6	8.53	-1%
	KM1400	6.04	5.87	-3%	6.12	5.55	-9%	5.99	5.45	-9%	5.81	5.69	-2%
	BAG19100	12.47	5.56	-55%	12.56	12.35	-2%	5.57	12.66	127%	6.17	7.87	28%
	BAG14400	4.98	5.63	13%	5.4	5.93	10%	5.37	5.62	5%	5.43	5.55	2%
	BAG12200	7.77	8.2	6%	8.26	13.19	60%	8.28	8.17	-1%	8.26	8.15	-1%
	BAG11200	4.6	5.38	17%	5.27	5.28	0%	5.24	5.25	0%	4.96	5.23	5%
	BAG8100	9.26	9.34	1%	3.81	3.7	-3%	3.9	28.47	630%	32.66	32.92	1%
	BAG3100	3.44	3.44	0%	3.67	3.39	-8%	3.66	3.41	-7%	5.02	5.04	0%
	CAN01150	0.43	0.43	0%	0.74	0.69	-7%	0.86	0.8	-7%	1.02	0.95	-7%
	CAN02900	0.07	0.08	14%	0.13	0.15	15%	0.16	0.18	13%	0.21	0.23	10%
	CAN03800	0.13	0.15	15%	0.22	0.24	9%	0.26	0.29	12%	0.32	0.35	9%
	CAN05200	0.17	0.2	18%	0.3	0.33	10%	0.36	0.39	8%	0.44	0.47	7%
	CAN09800	0.13	0.17	31%	0.22	0.28	27%	0.28	0.35	25%	0.35	0.45	29%
	CAN10560	3.37	3.6	7%	3.58	3.58	0%	3.58	3.56	-1%	3.57	3.65	2%
	CAN11015	5.09	5.74	13%	6.29	6.79	8%	6.77	7.3	8%	7.41	7.98	8%
	CAN11045	4.48	4.9	9%	5.37	5.69	6%	5.67	5.94	5%	6	6.34	6%
	CAN11046	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	CAN11395	4.79	5.22	9%	5.69	5.99	5%	5.97	6.25	5%	6.29	6.63	5%
	CAN12185	5.15	5.21	1%	5.31	5.25	-1%	5.4	5.2	-4%	5.23	5.19	-1%
	CAN13185	4.7	4.69	0%	4.85	4.54	-6%	4.61	4.62	0%	4.67	4.69	0%
	CAN13985	8.46	8.46	0%	4.89	4.89	0%	4.62	4.32	-6%	4.36	4.34	0%
	CAN14160	4.44	5.27	19%	5.1	5.57	9%	5.39	5.9	9%	5.64	6.23	10%
	CAN14190	8.43	9.99	19%	10.39	13.45	29%	12.2	14.8	21%	14.58	16.01	10%
	CAN14565	2.32	2.4	3%	2.55	2.4	-6%	2.62	2.47	-6%	2.62	2.55	-3%
	CAN14955	5.74	6.37	11%	6.43	6.48	1%	6.46	6.49	0%	6.48	6.49	0%
	CAN15430	3.6	3.72	3%	3.93	4.14	5%	4.12	4.29	4%	4.23	4.53	7%
	CAN16945	11.88	11.87	0%	3.18	3.08	-3%	3.19	3.12	-2%	3.11	3.15	1%
	CMP0816	1.73	2.39	38%	2.44	2.96	21%	2.85	3.05	7%	3.04	3	-1%
	CMP1890	0.89	1.01	13%	1.05	12.11	1053%	1.11	1.27	14%	11.68	1.36	-88%
	CMP2723	3.06	3.07	0%	3.04	2.99	-2%	3.04	2.98	-2%	3.05	2.98	-2%
	CMP3055	4.68	5.5	18%	6.17	6.66	8%	6.6	7.07	7%	7.29	8.12	11%
	CMP3255	9.92	11.26	14%	12.79	15.1	18%	14.62	16.94	16%	17.02	17.07	0%
	CMP3783	-3.58	-3.66	2%	-3.69	-3.75	2%	-3.69	-3.79	3%	-3.68	-3.86	5%
	CMP4742	0.53	0.72	36%	1.18	5.62	376%	0.72	5.69	690%	5.51	0.78	-86%
	CMP5565	2.14	2.18	2%	2.31	2.19	-5%	2.34	2.18	-7%	2.35	2.15	-9%
	CMP5986	-2.12	-2.42	14%	-2.43	-2.55	5%	-2.53	-2.64	4%	-2.65	-2.7	2%
	CMP6186	3.06	4.68	53%	6.33	7.9	25%	7.6	8.96	18%	9.15	10.98	20%
	CMP6501	0.94	1.14	21%	1.21	1.29	7%	1.26	1.33	6%	1.31	1.38	5%
	CMP7227	0.55	0.47	-15%	0.54	0.58	7%	0.55	0.62	13%	0.56	0.67	20%

Table 4-7
Summary of Peak Velocities

Road Crossing	Model Conduit	2-Year Peak Velocities			10-Year Peak Velocities			25-Year Peak Velocities			100-Year Peak Velocities		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
	CMP9927	4.58	4.87	6%	5.24	5.48	5%	5.47	5.64	3%	5.66	5.81	3%
	CMP11727	4.84	5.43	12%	5.54	5.52	0%	5.53	5.53	0%	5.53	5.54	0%
	CMP17127	4.46	4.64	4%	4.67	4.65	0%	4.69	4.63	-1%	4.68	4.6	-2%
	CMP19827	12.56	13.81	10%	4.73	5	6%	4.82	5.05	5%	30.66	30.86	1%
	BEN11600	4.32	4.42	2%	4.55	4.3	-5%	4.58	4.22	-8%	4.61	3.87	-16%
	BEN8900	11.76	12.05	2%	0.63	0.67	6%	0.68	0.68	0%	11.81	11.72	-1%
	BEN7400	2.35	2.57	9%	2.61	2.69	3%	8.66	9.06	5%	2.79	2.79	0%
Hwy 371	BEN5600	3.35	5.02	50%	8.54	11.33	33%	11.36	14.08	24%	14.87	17.08	15%
	BEN5450	1.23	1.29	5%	1.78	2.02	13%	2.04	2.23	9%	2.27	2.39	5%
	BEN2300	4	3.98	-1%	4.02	3.99	-1%	4.03	3.99	-1%	4.03	3.96	-2%
	BEN1000	-1.37	-1.37	0%	-1.37	-1.37	0%	-1.37	-1.37	0%	-1.37	-1.37	0%
	CH2000	2.23	2.16	-3%	2.12	2.11	0%	2.12	2.11	0%	2.13	2.12	0%
	CH4400	2.14	1.9	-11%	2.03	1.89	-7%	2	1.9	-5%	1.91	1.91	0%
	CH6100	1.52	1.92	26%	1.82	1.99	9%	2.02	2.19	8%	2.28	2.42	6%
	CH8300	2.21	2.07	-6%	2.24	2.08	-7%	2.24	2.28	2%	2.48	2.52	2%
	CH9750	2.41	3.02	25%	3.35	3.71	11%	3.71	4.12	11%	4.22	4.6	9%
Pitman Rd	CH9850	4.62	4.39	-5%	4.97	4.27	-14%	4.94	4.25	-14%	4.83	4.67	-3%
	CH9889	-8.98	-13.53	51%	-14.53	-14.46	0%	-14.74	-14.71	0%	-14.91	-14.93	0%
	CH12300	7.76	7.78	0%	4.07	4.59	13%	7.15	6.9	-3%	7.09	7.39	4%
	CH14200	4.39	4.08	-7%	4.08	4.12	1%	4.09	4.12	1%	4.1	4.13	1%
	CH15400	6.84	7.73	13%	9.92	9.88	0%	7.83	7.77	-1%	7.83	7.69	-2%
	CH18850	3.7	5.31	44%	4.79	5.61	17%	4.95	5.62	14%	5.02	5.6	12%
	CH22050	4.2	5.14	22%	5.19	5.21	0%	5.22	5.2	0%	5.23	5.13	-2%
	CH23750	2.84	3.18	12%	3.33	3.67	10%	3.49	3.81	9%	3.7	3.88	5%
	FK1300	1.47	1.64	12%	1.67	1.8	8%	1.71	1.85	8%	1.87	1.91	2%
	FK2230	12.07	4.53	-62%	4.52	4.21	-7%	11.82	4.02	-66%	11.76	11.63	-1%
Mansell Rd	FK2660	3.79	3.92	3%	3.92	3.55	-9%	3.9	3.53	-9%	3.69	3.49	-5%
	FK2865	-3.46	-3.36	-3%	-3.46	-3.45	0%	-3.46	-3.47	0%	-3.45	-3.45	0%
Rock Mill Way	FK3700	3.17	3.11	-2%	3.38	3.51	4%	3.53	3.62	3%	3.66	3.77	3%
	FK4200	7.42	7.52	1%	7.6	7.39	-3%	7.58	7.29	-4%	7.66	7.3	-5%
Old Roswell Rd	FK4370	8.95	9.66	8%	10.61	11.02	4%	11.07	11.35	3%	11.5	11.73	2%
	FK4600	3.77	4.01	6%	4.33	4.44	3%	4.46	4.53	2%	4.56	4.6	1%
	FK5810	4.23	4.32	2%	4.54	4.58	1%	4.59	4.66	2%	4.76	4.83	1%
	FK7160	6.58	6.57	0%	6.58	6.59	0%	6.58	6.59	0%	6.58	6.58	0%
	FK8370	5.99	5.84	-3%	5.91	5.9	0%	5.96	6.07	2%	6.24	6.37	2%
	FK9130	7	7.03	0%	7.07	7.04	0%	7.07	7	-1%	7.04	7.16	2%
New Rd	FK11115	3	3	0%	3.21	3.32	3%	3.36	3.41	1%	3.48	3.55	2%
	FK12100	3.06	3.05	0%	3.06	3.05	0%	3.06	3.05	0%	3.06	3.05	0%
Alpharetta Rd	FK13040	4.69	5.29	13%	6.63	6.94	5%	7.12	7.23	2%	7.41	7.52	1%
	FK14950	5.4	5.4	0%	5.39	5.4	0%	5.39	5.4	0%	5.39	5.39	0%
	FK15600	3.54	3.25	-8%	3.36	3.46	3%	3.53	3.61	2%	3.69	3.77	2%
	FK15650R	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK18420	3.11	3.17	2%	5.96	6.01	1%	6.05	6.04	0%	3.05	2.92	-4%
	FK19510	1.9	1.95	3%	1.9	1.97	4%	1.9	2	5%	1.98	1.99	1%
	FK19550R	0	0	N/A	0	0	N/A	0	0	N/A	2.44	4.15	70%
	FK22850	2.22	2.31	4%	2.32	2.35	1%	7.81	7.78	0%	7.79	7.76	0%
Rucker Rd	FK23645	2.94	2.92	-1%	2.97	2.95	-1%	2.97	2.95	-1%	2.98	2.95	-1%
	FK24190	2.84	2.83	0%	2.83	2.83	0%	2.83	2.82	0%	2.83	2.82	0%
	FK25230	15.58	15.57	0%	15.46	15.45	0%	15.63	15.62	0%	1.81	1.84	2%
Private Foot Br	FK25475	1.37	1.44	5%	1.94	1.98	2%	2.1	2.37	13%	2.38	2.63	11%
	FK25540	1.61	1.51	-6%	1.51	1.49	-1%	1.5	1.49	-1%	1.49	1.65	11%
	FK26430	1.33	1.3	-2%	1.25	1.29	3%	1.3	1.33	2%	1.37	1.4	2%
	FK26880	3.51	3.51	0%	3.51	3.51	0%	3.51	3.51	0%	23.25	22.89	-2%
	FK28500	0.76	0.69	-9%	0.87	0.88	1%	0.93	0.97	4%	1.05	1.09	4%
Mid Broadwell Rd	FK28870	2.62	2.67	2%	2.69	2.68	0%	2.66	2.59	-3%	2.53	2.44	-4%
	FK29100	2.03	2.03	0%	2.02	2.01	0%	2.01	1.98	-1%	1.98	1.97	-1%
	FK30500	2.79	2.78	0%	2.75	2.73	-1%	2.73	2.7	-1%	2.7	2.7	0%
	FK31400	1.68	1.68	0%	1.72	1.79	4%	100	100	0%	100	100	0%
Maple Lane	FK32350	2.05	2.17	6%	2.2	2.2	0%	2.2	2.21	0%	2.22	2.23	0%
Mayfield Road	FK32750	3.22	3.22	0%	4.05	4.31	6%	4.38	4.53	3%	4.59	4.64	1%
Private Dr	FK33810	3.68	3.92	7%	4.78	5	5%	5.04	5.08	1%	5.1	5.11	0%
Private Dr	FK34875	25.64	28.1	10%	27.45	2.28	-92%	2.28	2.27	0%	2.28	2.28	0%
	FK35300	2.19	2.06	-6%	1.9	1.91	1%	2.01	2.01	0%	2.01	2.01	0%
	FK35600	5.3	5.66	7%	6.5	6.9	6%	6.99	7.37	5%	7.61	7.99	5%
	LI725	2.63	1.89	-28%	2.52	1.7	-33%	2.45	1.77	-28%	2.3	1.88	-18%
	LI3350	16.1	16.09	0%	4.05	3.98	-2%	4.05	3.96	-2%	15.64	15.63	0%

Table 4-7
Summary of Peak Velocities

Road Crossing	Model Conduit	2-Year Peak Velocities			10-Year Peak Velocities			25-Year Peak Velocities			100-Year Peak Velocities		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
	LI5520	4.17	4.26	2%	4.46	4.55	2%	4.4	4.53	3%	4.3	4.48	4%
	LI6000	4.72	5.27	12%	5.2	5.38	3%	5.42	5.49	1%	5.54	5.62	1%
	LI6400	6.77	6.74	0%	6.75	6.75	0%	6.75	6.75	0%	6.75	6.75	0%
	LI6500	4.02	4.06	1%	4.07	4.16	2%	4.21	4.2	0%	4.24	4.19	-1%
	LI7100	1.3	1.27	-2%	1.41	1.4	-1%	1.43	1.47	3%	1.54	1.59	3%
	LI7600	2.39	2.3	-4%	2.29	2.26	-1%	2.31	2.28	-1%	2.34	2.35	0%
	LI8400	3.68	3.8	3%	4.07	4.19	3%	4.27	4.33	1%	4.4	4.47	2%
	LI9885	5.55	5.67	2%	5.98	6.08	2%	6.15	6.28	2%	6.43	6.59	2%
	LI10700	7.61	7.61	0%	4.69	4.73	1%	4.76	4.77	0%	4.79	4.75	-1%
	LI12335	3.95	3.94	0%	3.83	3.83	0%	3.82	3.82	0%	3.81	3.81	0%
	LI13500	3.08	3	-3%	3.06	2.94	-4%	3.03	2.92	-4%	3.01	2.9	-4%
	LI13900	3.17	3.48	10%	3.66	3.76	3%	3.73	3.79	2%	3.78	3.8	1%
	LI14030	3.6	3.74	4%	3.83	3.85	1%	3.84	3.86	1%	3.86	3.86	0%
	LI14600	2.98	3.02	1%	3.03	3.05	1%	3.05	3.06	0%	3.05	3.05	0%
	LI15035	4.3	4.31	0%	4.31	4.3	0%	4.3	4.29	0%	4.3	4.28	0%
	LI16135	3.39	3.38	0%	3.39	3.47	2%	3.45	3.57	3%	3.6	3.94	9%
	LI16700	2.51	2.51	0%	2.52	2.48	-2%	2.51	2.48	-1%	2.5	2.47	-1%
	LI17160	4.65	5.11	10%	5.45	5.72	5%	5.68	5.9	4%	5.93	6.14	4%
	LI17990	4.41	4.66	6%	4.85	5.03	4%	5	5.16	3%	5.18	5.5	6%
	LI18640	4.89	4.89	0%	4.89	4.89	0%	4.89	4.89	0%	4.89	4.89	0%
	LI19260	3.94	4.16	6%	8.25	8.04	-3%	8.47	8.39	-1%	4.31	4.39	2%
	LI20080	3.05	2.78	-9%	2.9	2.71	-7%	2.72	2.68	-1%	2.71	2.64	-3%
	LI20472	3.56	3.77	6%	4	4.08	2%	4.07	4.13	1%	4.12	4.13	0%
	LI20585	3.03	3.07	1%	3.13	3.05	-3%	3.02	2.96	-2%	3	3.05	2%
	LI20800	3.23	3.32	3%	3.44	3.37	-2%	3.46	3.42	-1%	3.47	3.36	-3%
	LI21300	4.89	4.87	0%	8.47	8.47	0%	8.92	8.91	0%	9.08	9.08	0%
	Ta1100	1.48	1.49	1%	1.61	1.64	2%	1.69	1.75	4%	1.83	1.89	3%
	Ta1455	3.62	3.87	7%	4.43	4.61	4%	4.64	4.72	2%	4.73	4.74	0%
	Ta3600	7.81	7.93	2%	7.99	7.97	0%	8	7.99	0%	7.98	7.94	-1%
	Ta3850	4.2	4.2	0%	4.2	4.19	0%	4.19	4.2	0%	4.2	4.19	0%
	Ta4200	2.71	2.56	-6%	2.5	2.5	0%	2.5	2.49	0%	2.51	2.48	-1%
	Ta4650	1.96	2	2%	4.99	5.17	4%	5.04	4.98	-1%	2.29	2.31	1%
	Ta4850	3.83	3.94	3%	3.91	3.89	-1%	3.9	3.88	-1%	3.89	3.85	-1%
	Ta4990	2.52	2.98	18%	3.08	3.22	5%	3.14	3.24	3%	3.22	3.24	1%
	Ta5350	3.51	3.69	5%	3.75	3.95	5%	3.81	3.93	3%	3.95	3.77	-5%
	Ta5630	3.88	4.16	7%	4.21	4.44	5%	4.28	4.47	4%	4.45	4.48	1%
	Ta6030	5.32	6.42	21%	6.57	6.71	2%	6.63	6.73	2%	6.72	6.75	0%
	Ta6700	6.01	6.06	1%	6.16	6.44	5%	6.26	6.48	4%	6.7	6.28	-6%
	Ta6785	4.55	4.93	8%	4.95	5.1	3%	4.99	5.13	3%	5.11	5.15	1%
	Ta6830	2.96	3.11	5%	3.14	3.29	5%	3.19	3.38	6%	3.36	3.55	6%
	Ta7200	0.39	0.45	15%	0.43	0.69	60%	0.48	0.78	63%	0.74	0.88	19%
	Ta7900	1.44	1.83	27%	1.99	2.87	44%	2.24	3.13	40%	2.95	3.48	18%
	Ta8445	-2.63	-3.28	25%	-3.5	-4.5	29%	-3.82	-4.72	24%	-4.56	-5.03	10%
	Ta9000	0.69	0.79	14%	0.84	1.79	113%	0.91	1.95	114%	1.84	2.04	11%
	Ta9385	8.71	9.23	6%	9.37	12.1	29%	9.67	10.84	12%	11.96	12.16	2%
	Ta10900	2.04	2.35	15%	2.52	2.64	5%	2.62	2.66	2%	2.68	2.61	-3%
	Ta11705	7.68	4.29	-44%	4.41	4.75	8%	19.36	20.29	5%	19.88	20.82	5%
	12925	5.65	6.27	11%	7.27	7.94	9%	7.96	8.75	10%	9.09	9.75	7%
	13550	5.64	5.91	5%	6.26	6.56	5%	6.56	6.96	6%	7.15	7.49	5%
Grimes Br Rd	13961	4.37	4.52	3%	4.86	5.12	5%	5.12	5.44	6%	5.57	5.78	4%
	18490	6.35	6.35	0%	4	3.95	-1%	4	3.92	-2%	3.97	3.83	-4%
	19880	3.96	3.91	-1%	3.89	3.91	1%	3.9	4.14	6%	3.92	4.21	7%
Riverside Apt Br	21120	3.45	3.52	2%	3.53	3.54	0%	3.48	3.59	3%	3.49	3.56	2%
	21200	-2.62	-3.55	35%	-3.97	-3.45	-13%	-4.03	-4.81	19%	-3.79	-3.73	-2%
Old Holcomb Br Rd	21960	-2.93	-3.53	20%	-3.65	-3.42	-6%	-3.69	-3.9	6%	-3.69	-3.86	5%
	24100	5.25	6.2	18%	5.97	5.93	-1%	5.99	5.96	-1%	6.22	5.96	-4%
	25760	3.07	3.26	6%	3.27	3.35	2%	3.35	3.42	2%	3.45	3.64	6%
	26390	3.49	3.88	11%	6.07	6.08	0%	4.63	4.63	0%	4.15	3.56	-14%
GA 400	30120	2.63	2.67	2%	2.63	2.63	0%	2.62	2.62	0%	2.59	2.6	0%
	31135	4.75	4.79	1%	4.97	4.54	-9%	4.96	4.43	-11%	4.79	4.37	-9%
	31735	3.6	3.95	10%	4.01	3.48	-13%	3.94	3.41	-13%	3.74	3.27	-13%
	34150	4.67	4.72	1%	4.66	4.68	0%	4.65	4.7	1%	4.73	4.65	-2%
Mansell Rd	34930	1.49	1.4	-6%	1.34	1.35	1%	1.32	1.36	3%	1.31	1.37	5%
	35655	4.69	4.65	-1%	4.6	3.67	-20%	4.57	4.54	-1%	4.56	4.58	0%
	36730	0.73	0.8	10%	0.92	1.05	14%	1.06	1.17	10%	1.22	1.26	3%
	39780	2.9	2.92	1%	2.74	3.02	10%	2.83	3	6%	2.91	2.99	3%

Table 4-7
Summary of Peak Velocities

Road Crossing	Model Conduit	2-Year Peak Velocities			10-Year Peak Velocities			25-Year Peak Velocities			100-Year Peak Velocities		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
Haynes Br Rd	40870	1.81	4.41	144%	4.18	4.26	2%	4.25	4.3	1%	1.53	4.35	184%
	41000	2.01	2.15	7%	2.05	2.15	5%	2.06	2.15	4%	2.07	2.19	6%
	42850	1.98	1.82	-8%	1.83	1.46	-20%	1.76	1.32	-25%	1.67	1.24	-26%
	44420	4.04	4.07	1%	4.1	3.89	-5%	4.09	3.86	-6%	4.07	3.79	-7%
	47150	2.83	3.17	12%	6.43	6.42	0%	6.51	6.5	0%	3.08	3.26	6%
	49000	2.42	2.52	4%	2.23	2.53	13%	2.26	2.52	12%	2.42	2.52	4%
Kimball Br Rd	49964	2.7	2.3	-15%	2.3	2.24	-3%	2.22	2.23	0%	2.2	2.23	1%
	50450	4.69	5.61	20%	5.4	6.16	14%	5.57	6.26	12%	5.79	6.29	9%
	51920	3.23	3.12	-3%	3.16	3.2	1%	3.16	3.22	2%	3.18	3.26	3%
	53860	4.33	4.6	6%	4.6	4.53	-2%	4.63	4.44	-4%	4.66	4.3	-8%
	56400	2.65	2.72	3%	2.78	3.02	9%	3.06	3.3	8%	3.43	3.6	5%
	57350	4.6	4.54	-1%	4.5	4.52	0%	4.5	4.51	0%	4.51	4.52	0%
State Bridge Rd	58505	1.89	1.94	3%	1.91	1.97	3%	1.92	1.98	3%	1.93	1.99	3%
	59100	3.49	3.64	4%	3.74	4.49	20%	3.6	4.6	28%	3.94	4.74	20%
	60420	2.18	2.19	0%	2.11	2.26	7%	2.16	2.26	5%	2.17	2.26	4%
	61440	3.23	3.18	-2%	3.25	3.37	4%	3.42	3.66	7%	3.8	3.97	4%
	62230	2.89	2.79	-3%	2.68	2.91	9%	2.67	2.91	9%	2.7	2.91	8%
	63015	2.59	2.63	2%	2.59	2.65	2%	2.6	2.65	2%	2.6	2.64	2%
	64800	2.08	2.09	0%	2.06	2.11	2%	2.07	2.11	2%	2.07	2.1	1%
Webb Bridge Rd	65195	3.69	3.75	2%	3.82	3.97	4%	3.81	3.96	4%	3.82	3.9	2%
	66840	6.74	6.74	0%	6.68	6.66	0%	6.78	6.73	-1%	3.78	3.54	-6%
	68195	3.46	3.46	0%	3.44	3.61	5%	3.69	4.08	11%	4.33	4.56	5%
	69950	3.04	2.97	-2%	2.94	2.79	-5%	2.88	2.7	-6%	2.8	2.83	1%
	70049	4.36	4.15	-5%	4.05	3.37	-17%	3.8	3	-21%	3.42	2.7	-21%
	70165	2.81	2.77	-1%	2.7	2.55	-6%	2.63	2.48	-6%	2.54	2.48	-2%
	71090	5.53	5.58	1%	5.48	5.46	0%	5.41	5.39	0%	5.49	5.43	-1%
Winward Pkwy	72134	2.46	2.2	-11%	2.19	2.21	1%	2.19	2.21	1%	2.2	2.21	0%
	72229	5.69	7.52	32%	8	8.55	7%	8.25	8.96	9%	8.4	9.27	10%
	72700	3.74	3.87	3%	3.99	3.75	-6%	4.03	3.72	-8%	4.04	3.7	-8%
	74070	2.43	2.28	-6%	2.17	3.17	46%	2.11	2.09	-1%	3.05	3.06	0%
	75173	3.3	3.23	-2%	3.14	3.29	5%	3.07	3.29	7%	3.14	3.3	5%
	75268	3.95	3.77	-5%	3.63	3.43	-6%	3.51	3.43	-2%	3.4	3.42	1%
	99988	2.95	2.95	0%	2.95	2.95	0%	2.95	2.95	0%	2.94	2.95	0%
	100220	3.55	3.63	2%	3.53	3.43	-3%	3.52	3.42	-3%	3.53	3.47	-2%
	102225	2.68	2.68	0%	2.68	2.68	0%	2.68	2.68	0%	2.67	2.67	0%
	103740	3.22	3.09	-4%	6.94	6.87	-1%	3.08	6.95	126%	3.09	3.08	0%
	106830	2.31	2.13	-8%	2.09	2.24	7%	2.27	2.36	4%	2.44	2.5	2%
McFarland Rd	107120	4.49	4.64	3%	5.92	4.37	-26%	5.86	4.43	-24%	5.59	4.49	-20%
	108140	2.77	2.76	0%	2.77	2.75	-1%	2.77	2.73	-1%	2.77	2.68	-3%
	109965	4.46	3.14	-30%	4.34	3.15	-27%	4.4	4.31	-2%	4.41	4.44	1%
	111980	2.85	2.85	0%	2.85	2.87	1%	2.86	2.88	1%	2.86	2.91	2%
SR 400	113650	2.41	2.39	-1%	2.37	2.31	-3%	2.34	2.24	-4%	2.28	2.11	-7%
	113970	4.56	4.78	5%	4.54	4.56	0%	4.54	4.56	0%	4.53	4.54	0%
	115739	4.67	4.48	-4%	4.45	4.46	0%	4.45	4.46	0%	4.45	4.46	0%
	117130	2.35	2.34	0%	2.32	2.27	-2%	2.31	2.24	-3%	2.29	2.22	-3%
Shiloh Rd	118000	2.37	2.37	0%	2.37	2.39	1%	2.38	2.39	0%	2.38	2.4	1%
	119510	5	4.84	-3%	2.79	2.67	-4%	2.63	2.67	2%	2.64	2.67	1%
	120540	3.39	3.39	0%	3.39	3.39	0%	3.39	3.39	0%	3.39	3.39	0%
	122240	1.57	1.57	0%	4.26	4.23	-1%	4	3.98	-1%	3.98	4.31	8%
	124020	2.52	2.51	0%	2.52	2.5	-1%	2.52	2.49	-1%	2.51	2.49	-1%
US 19	126315	4.67	4.65	0%	4.62	4.63	0%	4.62	4.63	0%	4.61	4.65	1%
	126470	4.32	4.32	0%	4.32	4.32	0%	4.32	4.32	0%	4.32	4.32	0%
	127860	3	3	0%	3	3	0%	3	3	0%	3	3	0%
	130840	2.57	2.57	0%	2.58	2.58	0%	2.58	2.58	0%	2.58	2.58	0%
	132330	5.72	5.72	0%	5.72	5.72	0%	5.72	5.72	0%	5.72	5.72	0%
	132830	6.94	6.94	0%	6.94	6.94	0%	6.94	6.94	0%	6.94	6.94	0%
Majors Road	133065	6.5	6.5	0%	6.5	6.5	0%	6.5	6.5	0%	6.5	6.5	0%
	135505	4.6	4.8	4%	4.65	4.58	-2%	4.68	4.42	-6%	4.66	4.28	-8%
	136960	2.17	2.23	3%	2.23	2.26	1%	2.25	2.26	0%	2.27	2.27	0%
	138905	4.43	4.4	-1%	4.4	4.4	0%	4.38	4.41	1%	4.35	4.41	1%
Bethelview Rd	140120	4.58	4.96	8%	4.98	4.59	-8%	5.21	4.53	-13%	5.3	4.44	-16%
	141855	4.5	4.53	1%	4.53	4.69	4%	4.6	4.78	4%	4.69	4.76	1%
	143000	4.53	4.54	0%	4.53	4.54	0%	4.54	4.54	0%	4.54	4.54	0%
	145300	3.47	2.72	-22%	7.97	8.09	2%	8.27	8.2	-1%	3.18	3.36	6%
	147114	3.52	3.59	2%	3.61	3.59	-1%	3.62	3.59	-1%	3.62	3.6	-1%
	147525	2.58	1.8	-30%	1.8	1.77	-2%	1.78	1.77	-1%	1.75	1.81	3%

Table 4-5
Summary of Peak Velocities

Road Crossing	Model Conduit	2-Year Peak Velocities			10-Year Peak Velocities			25-Year Peak Velocities			100-Year Peak Velocities		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
	148900	4.51	4.27	-5%	11.61	11.44	-1%	11.96	11.8	-1%	10.95	10.78	-2%
	150320	2.3	2.42	5%	2.43	2.64	9%	2.51	2.91	16%	2.86	3.26	14%
	151980	7.42	3.76	-49%	6.85	6.82	0%	6.74	6.75	0%	6.94	6.54	-6%
	FK2765	4.49	5.06	13%	6.08	6.61	9%	6.73	7.09	5%	7.44	7.71	4%
	FK3740	7.75	8.35	8%	9.72	10.45	8%	10.54	11.63	10%	12.34	13.07	6%
	FK4420	5.01	5.89	18%	7.42	8.26	11%	8.35	9.12	9%	9.54	10.52	10%
	FK11145	5.1	5.69	12%	6.65	7.23	9%	7.27	7.83	8%	8.07	8.57	6%
	FK13160	6.6	7.6	15%	9.55	9.98	5%	10.7	11.46	7%	13.03	13.79	6%
	FK131602	6.6	7.6	15%	9.55	9.98	5%	10.7	11.46	7%	13.03	13.79	6%
	FK131603	6.6	7.6	15%	9.55	9.98	5%	10.7	11.46	7%	13.03	13.79	6%
	FK131604	6.6	7.6	15%	9.55	9.98	5%	10.7	11.46	7%	13.03	13.79	6%
	FK15650	-2.68	-3.03	13%	-4.51	-4.85	8%	-5.17	-5.48	6%	-5.99	-6.31	5%
	FK19550	3.37	3.9	16%	5.72	6.64	16%	7.19	8.21	14%	9.41	10.2	8%
	FK23675	4.77	5.07	6%	7.13	7.56	6%	7.93	8.41	6%	9	9.93	10%
	FK25480	-5.8	-6.21	7%	-8.94	-8.98	0%	-9.35	-10.13	8%	-10.16	-10.29	1%
	FK28895	10.33	11.22	9%	15.32	16.39	7%	17.37	18.57	7%	20.92	22.37	7%
	FK288952	10.33	11.22	9%	15.32	16.39	7%	17.37	18.57	7%	20.92	22.37	7%
	FK32400	2.69	2.73	1%	3.63	3.95	9%	4.07	4.33	6%	4.51	4.66	3%
	FK32795	5.28	5.53	5%	6.56	6.95	6%	7.04	7.29	4%	7.57	7.89	4%
	FK33825	7.13	7.57	6%	8.08	8.16	1%	8.17	8.22	1%	8.23	8.27	0%
	FK34890	-10.47	-10.74	3%	-11.09	-11.19	1%	-11.21	-11.24	0%	-11.21	-11.08	-1%
Willow Meadow Circle	LI13964	5.93	6.47	9%	6.86	7.14	4%	7.11	7.34	3%	7.39	7.91	7%
	LI13964A	5.93	6.47	9%	6.86	7.14	4%	7.11	7.34	3%	7.39	7.91	7%
	LI13964B	5.93	6.47	9%	6.86	7.14	4%	7.11	7.34	3%	7.39	7.91	7%
	LI13964C	5.93	6.47	9%	6.86	7.14	4%	7.11	7.34	3%	7.39	7.91	7%
State Bridge Road	LI20500	5.95	6.47	9%	7.79	8.68	11%	8.92	9.41	5%	9.48	9.53	1%
	FK27651	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK37401	0	0	N/A	0	0	N/A	0	0.25	N/A	1.44	3.57	148%
	FK44201	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK111451	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK131601	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK236751	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK254801	0.1	1.05	950%	3.74	4.74	27%	4.9	7.88	61%	7.89	7.56	-4%
	FK288951	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK324001	0	0	N/A	0.79	1.38	75%	1.5	1.94	29%	2.13	2.34	10%
	FK327951	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	FK338251	0.17	1.37	706%	2.78	3.15	13%	3.27	3.71	13%	3.93	4.22	7%
	FK348901	1.76	2.67	52%	3.81	4.13	8%	4.21	4.51	7%	4.66	4.94	6%
	LI139641	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	LI205001	0	0	N/A	0	0	N/A	0.43	2.02	370%	2.73	3.43	26%
	13985	4.88	5.36	10%	6.16	6.68	8%	6.7	7.31	9%	7.56	7.95	5%
	21150	4.43	5.54	25%	5.79	6.34	9%	6.57	6.97	6%	7.24	7.79	8%
	21960	2.84	4.02	42%	5.3	4.13	-22%	5.47	5.24	-4%	4.73	5.08	7%
	22444	3.25	5.94	83%	7.23	5.74	-21%	7.34	7.5	2%	7.55	7.56	0%
	30270	2.94	3.71	26%	4.57	4.92	8%	4.99	6.08	22%	6.73	8.09	20%
	35040	2.21	2.39	8%	3.14	3.65	16%	3.68	4.11	12%	4.29	4.42	3%
	40898	4.12	5.46	33%	7.61	8.56	12%	8.64	8.6	0%	8.64	8.22	-5%
	49990	4.42	5.95	35%	7.02	7.2	3%	7.04	7.82	11%	6.85	8.37	22%
	58555	2.99	3.96	32%	5.27	5.92	12%	6.03	6.61	10%	6.92	7.31	6%
	65223	5.13	6.75	32%	9.23	9.57	4%	9.71	10.14	4%	10.21	10.6	4%
	70066	3.42	3.16	-8%	3.08	2.86	-7%	2.99	2.72	-9%	2.86	2.71	-5%
	72315	5.4	5.91	9%	5.9	6.32	7%	6.06	6.4	6%	6.27	6.54	4%
	72415	4.74	6.06	28%	8.21	8.94	9%	9.12	9.69	6%	10.05	10.61	6%
	75280	3.4	3.46	2%	3.42	3.47	1%	3.43	3.47	1%	3.44	3.47	1%
	100012	4.99	6.09	22%	7.43	8.14	10%	8.21	8.02	-2%	7.95	8.15	3%
	107170	2.45	3.59	47%	5.41	6.23	15%	6.39	7.04	10%	7.4	7.74	5%
	113700	2.04	3.1	52%	4.81	5.64	17%	5.77	6.28	9%	6.64	7.43	12%
	113810	2.26	3.33	47%	4.92	5.67	15%	5.78	6.31	9%	6.78	7.6	12%
	118050	4.59	6.07	32%	9.32	9.93	7%	10.1	10.41	3%	10.67	10.52	-1%
	126375	4.87	5.15	6%	5.29	5.38	2%	5.46	5.51	1%	5.72	5.65	-1%
	133090	9.48	9.48	0%	9.48	9.48	0%	9.48	9.48	0%	9.48	9.48	0%
	140160	4.64	5.83	26%	7.3	8.31	14%	8.24	9.35	13%	9.81	11.4	16%
	147126	7.38	7.98	8%	8.83	9.71	10%	9.45	10.24	8%	10.28	10.82	5%
	139851	0	0	N/A	0	0	N/A	0	0	N/A	0	3.47	N/A
	211501	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	220481	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A

Table 4-7
Summary of Peak Velocities

Road Crossing	Model Conduit	2-Year Peak Velocities			10-Year Peak Velocities			25-Year Peak Velocities			100-Year Peak Velocities		
		Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference	Existing	Future	% Difference
	224441	0	0	N/A	0	0	N/A	0	2.07	N/A	3.43	5.89	72%
	302701	0	0	N/A	0	0	N/A	0	0	N/A	0	0.2	N/A
	350401	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	408981	0	0	N/A	0	2.07	N/A	2.27	4.13	82%	4.83	6.27	30%
	499901	0	0	N/A	4.49	6.2	38%	6.31	6.79	8%	6.85	6.8	-1%
	585551	0	0	N/A	0	0	N/A	0	0	N/A	0	0	N/A
	652231	0	0	N/A	0.55	2.98	442%	3.18	4.65	46%	5.67	7.02	24%
	700661	1.26	1.84	46%	1.78	2.02	13%	1.83	2.08	14%	1.94	2.18	12%
	723151	1.12	4.39	292%	6.4	7.48	17%	7.67	8.8	15%	9.29	9.75	5%
	724151	0	0	N/A	0	0	N/A	0	0	N/A	1.36	2.94	116%
	752801	0	0	N/A	4.08	4.31	6%	4.36	5.03	15%	4.99	4.33	-13%
	1000121	0	0	N/A	0	4.17	N/A	4.69	6.79	45%	7.75	8.47	9%
	1071701	0	0	N/A	0	0	N/A	0	0	N/A	1.37	2.96	116%
	1137001	0	0	N/A	0	0	N/A	0	0	N/A	0	0.2	N/A
	1138101	0	0	N/A	0	0	N/A	0	0	N/A	0	2	N/A
	1180501	0	0	N/A	3.11	4	29%	4.05	4.69	16%	4.98	5.57	12%
	1263751	0.8	2.89	261%	3.47	3.6	4%	3.65	3.73	2%	3.89	3.82	-2%
	1330901	3.74	4.98	33%	5.54	5.79	5%	5.79	6.02	4%	6.08	6.27	3%
	1401601	0	0	N/A	0	0	N/A	0	0	N/A	0	0.16	N/A
	1471261	8	9.33	17%	10.45	11.37	9%	11.15	12.02	8%	12.02	12.81	7%
	11560	9.32	10.07	8%	11.31	12.11	7%	12.13	13.04	8%	13.41	14.16	6%

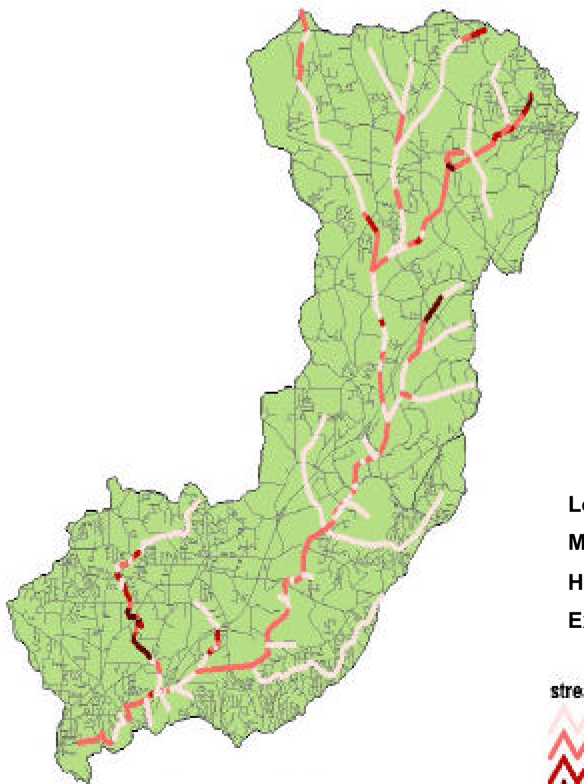


Figure 4-4
Erosion Potential Based on Existing Velocities

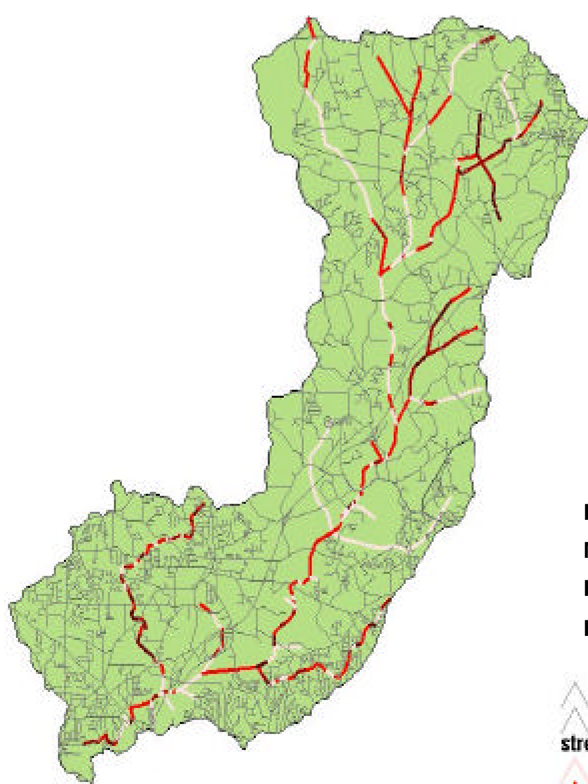


Figure 4-5
Erosion Potential Based on Future Velocities

- "Moderate" erosion potential: Erosion ratio between 1.25 and 1.50 (i.e., a 25% to 50% increase in stream width compared to natural stream conditions).

- "Excessive" erosion potential: Erosion ratio greater than 1.50 (i.e., more than a 50% increase in stream width compared to natural stream conditions).

Figure 4-6 shows the erosion potential for the Big Creek Watershed. Several segments along the main stem and various tributaries have excessive erosion potential.

4.4.6 Effects on Groundwater Recharge and Baseflow

The groundwater recharge areas are expected to decrease as the impervious area increases in the watershed. If no action is taken, runoff rates will continue to increase as development occurs. This will result in increased flooding especially for lower frequency storms. Decreased groundwater recharge will result in lower base flow and have adverse impacts on aquatic life.

Development of the basin with its associated increase in impervious area will result in a significant decrease in the amount of rainfall, which infiltrates into the soil and a corresponding increase in direct runoff to the stream system. The water, which infiltrates into the soil, sustains streamflow during dry periods as interflow during the period immediately following the storm and as ground water inflow during later times. Development of the Big Creek watershed will result in higher streamflows during storm events due to the increased volume of direct runoff from the impervious surfaces. During dry periods, streamflows will be lower than those currently observed during dry weather conditions due to the reduce volume of water available for ground water recharge

Isolating dry weather flow periods under 1995 and 2020 land use conditions and determining the percent reduction in discharges would provide an estimate of the impacts of future land use changes on dry weather flows.

4.4.7 Impacts on Wetlands

Development of the Big Creek watershed will impact wetland hydrology several ways. The reduced groundwater recharge will result in lower water tables and may result in the drying out of upland wetland areas. Wetlands immediately adjacent to stream channels will also be impacted but to a lesser degree. The increased streamflow rates caused by the increased impervious area will result in more frequent inundation of wetland areas and will, to some extent tend to offset the decrease in groundwater levels. However, runoff will contain higher amounts of sediments and other pollutants, which can adversely impact wetland vegetation and, if present in sufficient volumes for long enough periods, ultimately destroy the wetlands. Increased channel incision could potentially lower ground water levels in the areas adjacent to the streams, which could cause a decrease in the wetland areas.

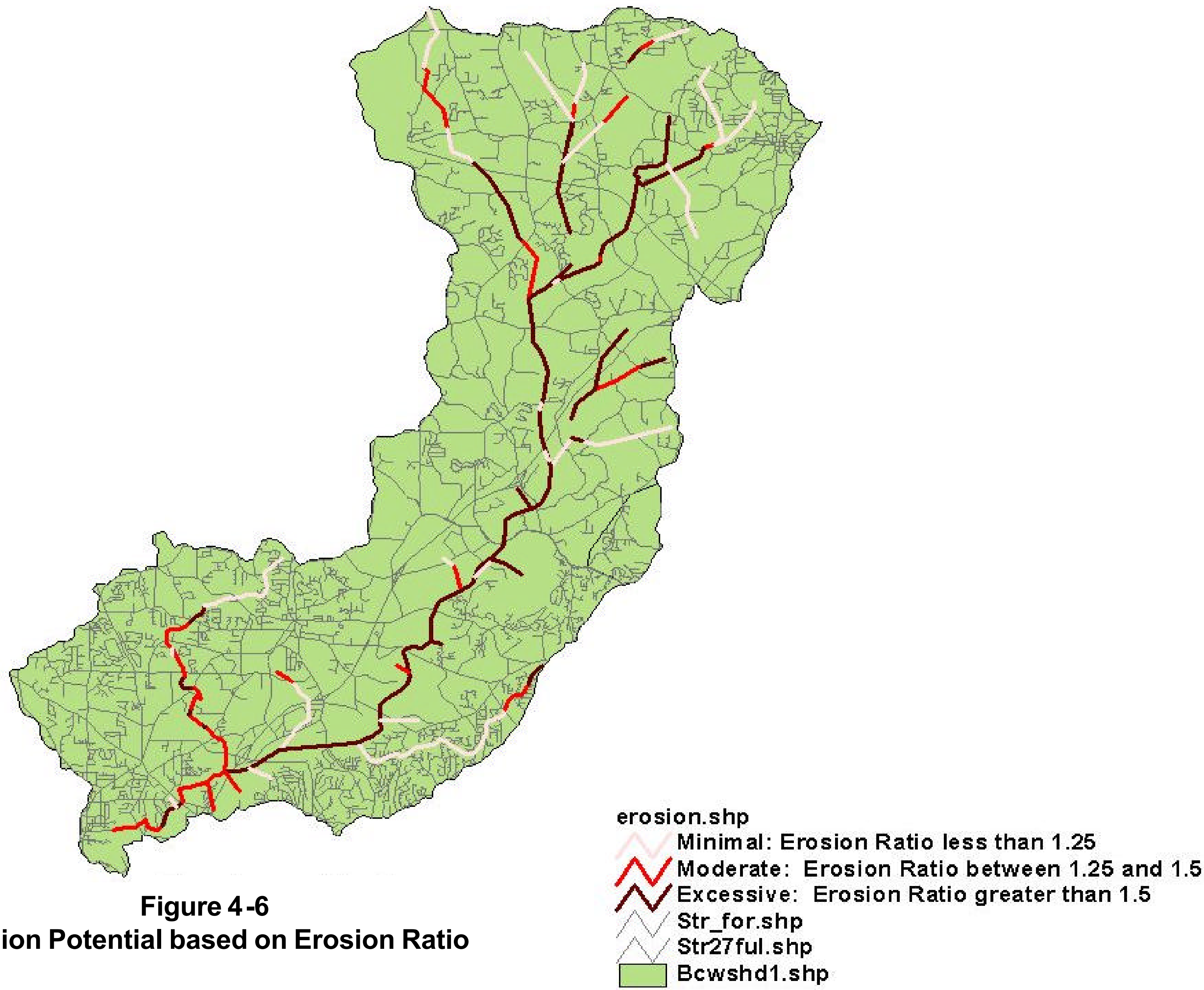


Figure 4-6
Erosion Potential based on Erosion Ratio

Section 5
Estimating Current and Future Water Quality Impacts

5.1 Introduction

This section describes the development of the USEPA Storm Water Management Model (SWMM) for analyzing water quality impacts in the Big Creek watershed under existing (1995) and future (2020) conditions and presents the results of that analysis. The SWMM representation of the Big Creek watershed was developed and calibrated to local NPDES stormwater data and ambient monitoring data.

Pollutant buildup and washoff algorithms within SWMM were applied to simulate stormwater pollution loadings from individual land uses within the watershed. These algorithms assume that pollutant loads accumulate on the land surface during dry weather periods prior to a storm event and are washed off by stormwater runoff during each rainfall event. The model was driven by 1995 rainfall data, which was considered representative of average annual conditions. The SWMM representation also accounts for point source discharges and failing septic tanks.

5.2 Selection of Water Quality Parameters

The water quality impacts analysis is limited to the following constituents or parameters:

- Sediment (TSS, TDS)
- Nutrients (total P, dissolved P, TKN and NO23-N)
- Pathogens (fecal coliforms)
- Heavy metals (lead, copper, zinc, cadmium)
- Oxygen demand (BOD, COD)

These parameters represent the twelve EPA NPDES stormwater indicator parameters, plus fecal coliform. The thirteen parameters also represent all of the pollutants monitored as part of the Atlanta Region Storm Water Sampling Program's ongoing long-term trend monitoring program. Consequently, data are available to estimate land use-specific surface runoff concentrations. However, instream data will not be available for several of the parameters, such as the metals. Calibration to instream pollutant concentrations is limited to those parameters for which instream data are available (e.g., TSS, BOD, COD, nutrients, coliforms).

The above pollutants and their potential impacts on water quality and aquatic habitat are described below.

Sediment: Sediment from surface runoff is the most common pollutant in receiving waters. Many other toxic contaminants adsorb to sediment particles or solids suspended in the water column. Excessive sediment can lead to the destruction of habitat for fish and aquatic life, and depletion of storage capacity of lakes and reservoirs. TSS is a measurement of the amount of sediment particles suspended in the water column. In developing areas such as the Big Creek watershed, excessive sediment pollution can often be attributed to poor erosion and sediment control at construction sites or channel erosion due to peak flows increasing with urbanization. Sedimentation occurs when a low instream velocity allows sediment to settle out of the water column to the streambed or reservoir bottom. These toxic pollutants can be remobilized into the water column under suitable environmental conditions (e.g., high velocity, dissolved oxygen or pH). Big Creek monitoring data from 1970 to the present suggests that wet weather TSS concentrations are increasing.

Nutrients: Nutrients (nitrogen and phosphorus). Within a receiving water, excessive concentrations of nutrients can result in the undesirable overproduction of algae and other aquatic vegetation. An excessive level of algae in a receiving water, especially in impoundments, known as an algae bloom, typically occurs during the summer when sunlight and water temperature are ideal for algal growth. Water quality problems associated with algae blooms range from simple nuisance or unaesthetic conditions, to water column oxygen depletion and fish kills. Collectively, the impacts associated with excess levels of nutrients in a receiving water are referred to as eutrophication impacts. Control of nutrients discharged to receiving waters can help limit algal productivity and minimize potential eutrophication problems. Big Creek monitoring data from 1970 to the present suggests that nutrient concentrations are increasing.

Oxygen demand: BOD represents the depletion of dissolved oxygen (DO) levels due to the decomposition of organic material in stormwater discharges. Low DO levels can cause fish kills in streams and rivers. The potential for DO depletion is measured by the BOD test, which quantifies the amount of easily oxidizable organic matter present in the water. The COD test measures all of the oxidizable matter present in the water, and is typically greater than BOD.

Heavy metals: Heavy metals in stormwater discharge can be toxic to aquatic life and may bioaccumulate in fish. Lead, copper, zinc and cadmium are the metals that typically exhibit greater concentrations than other metals found in urban runoff. The presence of these heavy metals in tributary streams in the watershed may also be indicative of problems with a wide range of other toxic chemicals, like synthetic organics, that have been identified in previous field monitoring studies of urban runoff pollution (USEPA, 1983).

Pathogens: Levels of bacteria and viruses in stormwater runoff typically exceed public health standards. In some areas, domestic pets and birds have been suggested as the primary source of contamination in stormwater. Leaking sanitary sewers and failing septic tanks are also potential sources. Fecal coliforms are often monitored as an indicator organism to provide evidence of fecal contamination from warm-blooded mammals. Big Creek monitoring data from 1970 to the present suggests that wet weather fecal coliform concentrations are increasing. The State of Georgia 303d list includes Foe Killer Creek, the lower main stem of Big Creek and Hog Wallow Creek on the non-attainment list for fecal coliform.

5.3 Water Quality Model Description and Approach

The watershed water quality model consists of a combination of the RUNOFF and TRANSPORT modules of SWMM. The RUNOFF module calculates surface runoff and groundwater flows and water quality constituent concentrations discharged to the watershed stream conveyance system from the land. These flows and constituent concentrations, in addition to flows and concentrations associated with point source discharges and failing septic tanks, are routed through the stream network in the TRANSPORT module. TRANSPORT is also used to account for instream constituent loss or removal in water quality best management practices (BMPs).

The RUNOFF module of SWMM accounts for the watershed's response to rainfall events, by calculating how much of the rainfall is converted to surface runoff, how much infiltrates into the soil, and the rate at which infiltrated water is converted to groundwater inflow to the watershed's receiving streams. Some physical RUNOFF hydrology parameters such as subbasin drainage areas, slopes and impervious cover were determined using available land use and topography data for the watershed. Other RUNOFF hydrology parameters such as infiltration rates and groundwater routing factors were calibrated by running the model for 1995 conditions, driven by hourly rainfall data from a precipitation gage in Duluth, Georgia.

The RUNOFF model also accounts for the water quality constituent loads associated with surface runoff and groundwater flows to the watershed receiving streams. For surface runoff, local NPDES stormwater data were analyzed to determine the distribution of event mean concentrations (EMCs) for various land uses and water quality constituents. The RUNOFF model was then run for the simulation period of 1992 through 1996 to calibrate constituent buildup and washoff rates, such that the modeled distribution of EMCs was representative of the measured distributions. (In the model, buildup parameters determine how constituent mass is accumulating on the land surface, and washoff parameters determine how much mass is being washed off with runoff.) For groundwater inflows, constant concentrations were assigned for each water quality constituent, based on an analysis of dry weather sampling data.

The constituent concentrations assigned to groundwater flows into the watershed stream network are listed in **Table 5-1**. Again, these were based on analysis of dry weather monitoring data, as well as comparison between instream data and modeling results.

The TRANSPORT module of SWMM accounts for the routing of inflows and constituent loads through the watershed stream network. Flow and load sources include surface runoff and groundwater (from the RUNOFF model), as well as point sources and failing septic tanks (**Table 5-1**). TRANSPORT also accounts for water quality treatment at several large regional lakes and ponds in the watershed.

Because the travel time through the watershed is rather brief (in most cases less than 1 day), significant loss of mass within the main transport system is not expected for most constituents. The exception is fecal coliform bacteria, which has a relatively rapid die-off rate compared to the decay of other constituents. A first-order decay rate of 0.69/day (equivalent to 50% die-off per day) was used based on discussion with ARC staff and previous studies.

Removal of constituent mass was estimated at major regional lakes and ponds. These lakes and ponds are listed in **Table 5-2.** These lakes and ponds have a large drainage area (greater than 100 acres) and are large enough to have sufficient residence time to achieve substantial pollutant removal. Removal efficiencies typical of wet detention ponds (see **Table 5-3**) were applied to the outflow concentrations from the lakes and ponds.

5.3.1 Point Source and Septic Tank Loading Estimates in TRANSPORT

Load sources from point sources and failing septic tanks used in TRANSPORT are described below.

The two major point sources in the watershed are the City of Cumming and Tyson Foods wastewater-dischargers, both located in the Upper Big Creek subwatershed in Forsyth County. Existing flow rates and constituent concentrations from the discharges (also see Table 5-1) were estimated using monthly Discharge Monitoring Report (DMR) data if available. For most constituents, however, concentration values were estimated based on instream monitoring data and/or typical wastewater concentrations. Future flow rates and concentrations were based on best available information and Project Team input. A new permit for the City of Cumming wastewater treatment plant was issued recently, which includes even lower future effluent concentrations. Although not reflected in this analysis, the lower effluent concentrations will benefit water quality in Big Creek, in particular during dry weather flow periods.

Many areas of Forsyth County are served by septic tanks, some of which can be expected to fail. Septic tank impacts were assumed to affect only lower density residential areas. Consistent with the Big Haynes Creek study, it was assumed that 15 percent of septic tanks in the Big Creek watershed are failing. Flows from these failing septic tanks were assigned constituent concentrations based on previous studies, as well as evaluation of measured instream concentrations. Flows from failing septic tanks were estimated by assuming a typical flow rate of 50 gallons per

Table 5-1
Estimated Flows and Concentrations for Non-Runoff Sources Existing Conditions

Constituent	Units	Estimated Values by Source			
		Baseflow	City of Cumming	Tyson Foods	Septic Tanks
Flow	mgd	(a)	0.67	0.81	0.08
BOD	mg/l	0.7	2.8	5.3	30
COD	mg/l	4.0	15	30	50
TSS	mg/l	10.0	10	10	30
TDS	mg/l	40.0	100	305	1000
Total-P	mg/l	0.08	0.20	6.10	1.50
Dissolved-P	mg/l	0.02	0.18	5.49	1.40
TKN	mg/l	0.20	1.00	2.40	0.0
NO2+NO3-N	mg/l	0.45	2.60	2.60	30.0
Lead	mg/l	0.005	0.005	0.005	0.005
Copper	mg/l	0.0025	0.010	0.010	0.010
Zinc	mg/l	0.100	0.090	0.090	0.090
Cadmium	mg/l	0.0005	0.001	0.001	0.001
Fecal Coliform	#/100 ml	225	5	16	250,000

(a) Value calculated by RUNOFF model

Table 5-2
Major Lakes/Ponds Providing Water Quality Treatment

Major Lake/Pond	Subwatershed	Drainage Area (acres)
Margeson Lake	Sawmill Branch	235
McWilliams Lake Dam	Upper Big Creek	462
Pine Lake Dam	Kelley Mill Branch	553
Sawnee Lake Dam	Upper Big Creek	493
Cumming Twin Lakes	Upper Big Creek	496
Chatam Properties	Middle Big Creek	255
Lake Windward	Caney Creek	2,904
Willow Springs Lake	Lower Big Creek	207
Morrison Dam	Lower Big Creek	532

Table 5-3
Average Annual Pollutant Removal Rates for Wet Detention Basin BMPs

Constituent	Pollutant Removal Rate (%)
BOD	30%
COD	30%
TSS	90%
TDS	30%
Total-P	50%
Dissolved-P	65%
TKN	25%
NO2+NO3-N	35%
Lead	80%
Copper	65%
Zinc	45%
Cadmium	80%
Fecal Coliform	75%

NOTES:
1. Wet detention basin efficiencies assume a permanent pool volume which achieves average hydraulic residence time of at least two weeks.
2. Efficiencies based on findings of EPA NURP Study and other BMP monitoring studies.

capita per day (gpcd), and further assuming 2 persons per dwelling unit. Dwelling unit densities for various residential land uses are listed below:

- Residential 2.1 - 5.0 acres: 0.4 dwelling units/acre
- Residential 1.1 - 2.0 acres: 0.8 dwelling units/acre
- Residential 0.3 - 1.0 acres: 2.0 dwelling units/acre
- Residential < 0.25 acres: 6 dwelling units/acre

GIS data were used to evaluate the area of residential development that is believed to be served by septic tanks. ARC provided a GIS coverage showing limits of sewered service areas in the watershed. Any residential area outside the service area is assumed to be served by septic tanks. The areas within each subbasin of residential land uses outside the sewered area were calculated in the GIS by overlaying the 1995 land use, subbasin boundary, and service area layers.

Flows and concentrations of constituents associated with failing septic tank discharge were summarized in Table 5-1. The septic tank discharge is most critical in estimating fecal coliform concentrations, which are often above State standards for body contact even during dry weather conditions. For other constituents, the impact of failing septic tanks will likely be small compared to point sources and surface runoff.

5.3.2 Pollutant Buildup and Washoff

For surface runoff, local NPDES stormwater data were analyzed to determine the distribution of event mean concentrations (EMCs) for various land uses and water quality constituents. The RUNOFF model was then run for the simulation period of 1992 through 1996 to calibrate constituent buildup and washoff rates, such that the modeled distribution of EMCs was representative of the measured distributions

Buildup algorithms typically rely upon a pollutant accumulation rate function that imposes a maximum buildup ceiling that is asymptotically reached after an extended dry period. Pollutant buildup on the land surface is usually assumed to occur over a long period (e.g., days to weeks). The following exponential pollutant buildup function was used for the SWMM calibration for the Big Creek Watershed:

PSHED = QFACT(1) * (1.0-EXP(-QFACT(2)*t)

Where:

PSHED	=	Pollutant mass available for washoff at time “t”, lbs/ac
QFACT(1)	=	Maximum pollutant accumulation, lbs/ac
QFACT(2)	=	Daily Pollutant accumulation growth rate, day-1
T	=	time, days

Initially, QFACT (2) was set at 0.1 based on typical pollutant accumulation growth curves presented in the SWMM User's Manual (Huber and Dickinson, 1988 pp.143-151). Therefore, calibration of loading rate factors for each land use category will be based upon adjustments to QFACT(1), which is the upper limit on pollutant accumulations on the land surface literature values. QFACT(1) is the primary calibration parameter used to either increase or decrease the mean EMC over the simulation period.

Nonpoint pollution washoff was simulated by algorithms which relate the washoff of accumulated pollutants to the runoff rate during each time-step. In comparison with pollutant buildup, washoff is usually assumed to occur over much shorter periods that correspond to storm event runoff (e.g., minutes to hours). A first-order decay function was used in the model to represent pollutant washoff:

POFF	=	PSHED0 * (1.0 – EXP(-RCOEF (r*WASHPO)*t)
Where:		
POFF	=	cumulative pollutant load washed off at time t, lbs/ac
K	=	first-order decay rate = RCOEF * r
RCOEF	=	washoff coefficient, in-1
WASHPO	=	power exponent for runoff rate
PSHED0	=	pollutant mass available for washoff, lbs/ac
R	=	runoff rate during time interval, in/hr
T	=	time interval, hr

Based on previous calibration studies with this stormwater pollutant washoff equation (CDM, 1992; Hartigan, et. al., 1983; NVPDC, 1983) and information provided in the SWMM Users Manual (Huber and Dickinson, 1988), WASHPO was initially set at 1.0 and COEF at 4.6 in-1 (based on the assumption that a runoff rate of 0.5 in/hr will wash off 90 percent of the accumulated pollutant load over one hour.)

Table 5-4 lists the EMCs used for this study. In most cases, these values are based on the analysis of local NPDES stormwater sampling data provided by ARC. Keep in mind, however, that these values represent only an "average" value. Modeled surface runoff concentrations for a given storm will depend upon the calibrated buildup and washoff parameters, antecedent rainfall conditions, and runoff rate. Thus, the model should account for the variability in storm EMCs that was observed in the monitoring data.

5.3.3 Subbasin Approach

Due to the size of the Big Creek watershed and the number of subbasins used to characterize the watershed, the overall model was executed by developing and running several submodels, using discharges from one or more submodels as input to

Table 5-4
Recommended Event Mean Concentrations for Big Creek Watershed Study

Land Use	% Impervious	Oxygen Demand and Sediment (mg/l)				Nutrients (mg/l)				Heavy Metals (mg/l)				Fecal Coliform [3]	Source
		BOD	COD	TSS	TDS	TP	DP	TKN	NO23N	Lead	Copper	Zinc	Cadmium	(#/100 ml)	
Open/Forest	0.5%	4	27	222	47	0.16	0.02	0.7	0.49	0.016	0.008	0.047	0.001	2,436	A,B
Ag/Pasture and Cropland	0.5%	4	27	444	47	0.33	0.02	1.41	0.49	0.016	0.008	0.047	0.001	2,436	D
Single Family Residential:															
2.1 - 5.0 ac lot size [1]	10%	6	33	237	66	0.20	0.04	0.90	0.58	0.017	0.012	0.061	0.002	2,837	C,D
1.1 - 2.0 ac lot size [2]	12%	8	41	257	90	0.26	0.06	1.18	0.70	0.017	0.018	0.080	0.003	3,372	C,D
0.5 - 1.0 ac lot size	21%	9	47	272	109	0.30	0.08	1.38	0.79	0.018	0.022	0.094	0.004	3,773	C,D
0.25 - 0.4 ac lot size	26%	9	47	272	109	0.30	0.08	1.38	0.79	0.018	0.022	0.094	0.004	3,773	C,D
Townhouse/Garden Apartment	48%	10	60	121	53	0.22	0.13	1.06	0.66	0.015	0.013	0.141	0.005	2,306	C,D
Office/Light Industrial	70%	12	65	121	74	0.25	0.13	1.59	0.56	0.014	0.016	0.172	0.005	1,403	C,D
Heavy Industrial	80%	12	65	121	74	0.25	0.13	1.59	0.56	0.014	0.016	0.172	0.005	1,403	C,D
Commercial	85%	10	60	121	53	0.22	0.13	1.06	0.66	0.015	0.013	0.141	0.005	2,306	C,D
Major Roads	90%	10	60	121	53	0.22	0.13	1.06	0.66	0.015	0.013	0.141	0.005	2,306	C,D
Waterbodies	100%	3	22	26	100	0.03	0.01	0.60	0.60	0	0	0.11	0	100	A

SOURCES:
A: Nationwide Urban Runoff Program (1983)
B: "Chesapeake Bay Basin Model: Final Report," January 1983.
C: Atlanta Region Storm Water Characterization Study, 1993.
D: Atlanta Region Storm Water Sampling Program Annual Report, 1998.

NOTES:
[1] Recommended EMCs were based on 70% open/forest and 30% of 0.5 - 1.0 acre lot size
[2] Recommended EMCs were based on 30% open/forest and 70% of 0.5 - 1.0 acre lot size
[3] Fecal coliform EMCs are geometric means

a downstream submodel. The objective of this approach is to keep model and output file sizes manageable.

Figure 5-1 illustrates the subbasins that comprise the watershed model, which are as follows:

- Upper Big Creek: Headwaters to Georgia Highway 400
- Middle Big Creek: Georgia Highway 400 to USGS gage (Kimball Bridge Road)
- Lower Big Creek: USGS gage to watershed outlet (Roswell water intake)

Discharges at the Upper Big Creek outlet are used as input to the Middle Big Creek model. Similarly, the Middle Big Creek discharges are used as input to the Lower Big Creek model.

Each of the three major subwatersheds also has several subwatersheds contributing discharges. Kelley Mill Branch/Sawmill Branch, Cheatam Creek, and Bentley Creek are each simulated separately before the outflows from these watersheds are used as input to the Upper Big Creek submodel. Similarly, the Middle Big Creek submodel uses results from the Bagley Creek and Camp Creek/Caney Creek submodels as input, and the Lower Big Creek submodel uses results from the Foe Killer Creek and Long Indian Creek submodels as input.

5.3.4 Water Quality Model Limitations

SWMM is considered one of the state-of-the-art nonpoint pollution loading models. However, the buildup and washoff algorithms are probably best viewed as empirical functions, which can provide a reasonable approximation of the nonpoint pollution loading potential of a land use. There are physical, chemical, and biological processes, which are not explicitly represented in the SWMM framework. These processes are included in several of the model parameters but are not modeled as separate state variables.

5.4 Calibration of Water Quality Model

Calibration to individual storm events monitored at specific sites is not feasible for this study because the monitoring data reflect local considerations such as uneven spatial and temporal distribution of rainfall. This results in short-term fluctuations in flow and concentrations that are not predictable within the scope of these water quality evaluations. Since management programs involving BMPs will focus on reduction of long-term pollutant loadings, the model calibration efforts for the Big Creek will focus on matching the storm event EMCs presented in **Table 5-4**..

Based on the modeling results, it appears that the Big Creek watershed water quality model provides a reasonable representation of the water quality response during wet weather and dry weather periods under existing conditions. The modeled wet

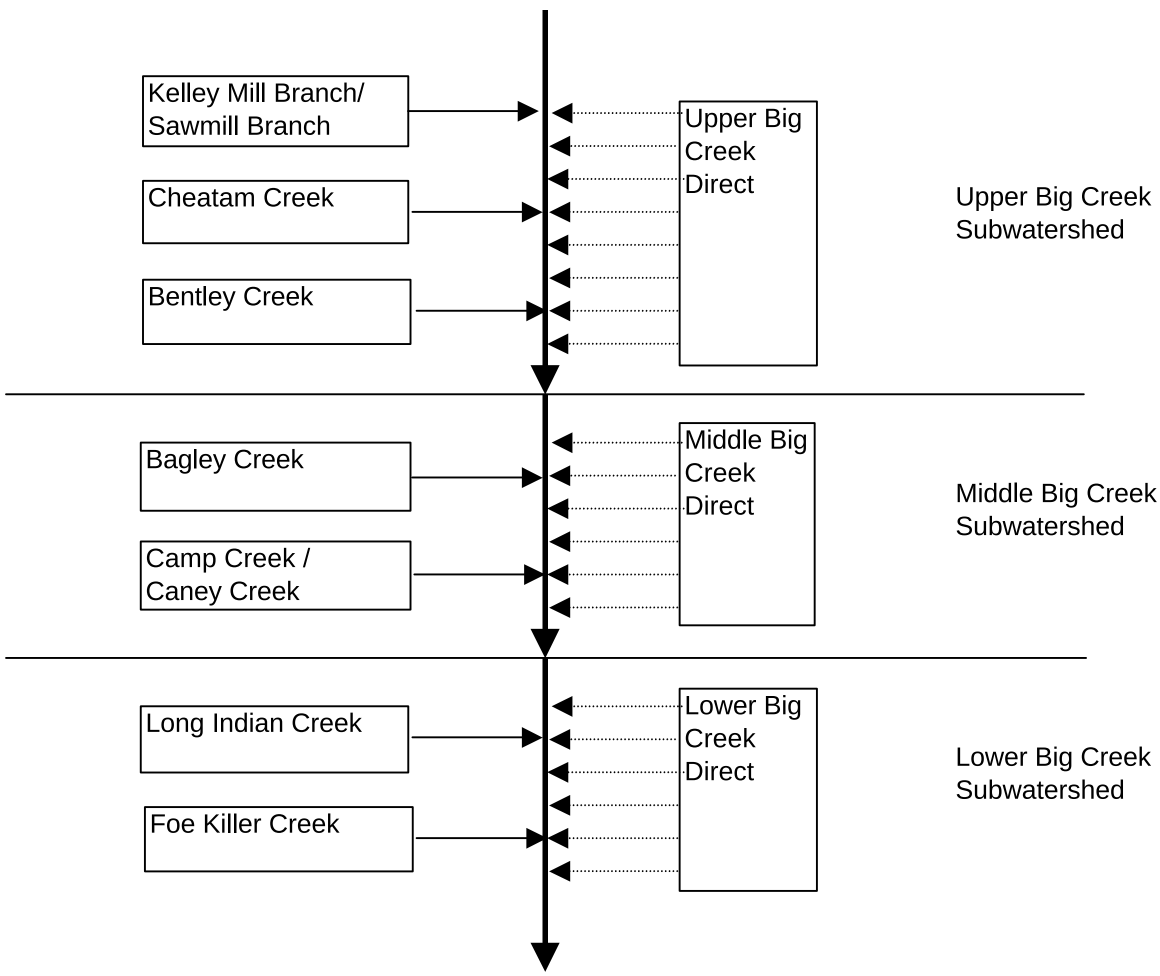


Figure 5-1
Structure of Big Creek Watershed Quality Model

weather concentrations, based on calibration of model buildup and washoff rates to an extensive NPDES stormwater runoff monitoring database, are representative of the wet weather grab sample concentrations collected during 1995. Modeled dry weather concentrations are generally close to the measured values, with the exception of total P and total N during the months of August through October. For these constituents, the difference between modeled and measured values is not critical to the calculation of annual loads, because this period is characterized by very low dry weather streamflows.

Overall, the distribution of modeled and measured instream concentrations over the 1995 monitoring period is similar. For fecal coliform bacteria, however, the modeled values are generally lower than the measured values, except at the extreme high and low values. This is probably due to the highly variable nature of bacteria sources, which is impossible to incorporate into a model.

When applied to future (year 2020) conditions, the model generally predicted increases in annual constituent loads as a result of increased wet weather loads. This is due to increases in runoff as watershed imperviousness increases, and generally higher runoff concentrations for developed land uses. The future condition also assumed changes in point source discharges, including the expansion of the City of Cumming plant and a lower total P permit limit for Tyson Foods, as well as removal of septic tanks in Forsyth County. The net result of these changes is lower total P and bacteria concentrations during dry weather conditions. In the case of bacteria, this results in better compliance with the instream standard of 200/100 ml.

This model is considered suitable for the evaluation of future conditions with alternative control measures. These control measures may include a combination of structural controls (e.g., wet detention ponds) and nonstructural measures (e.g., alternative future development/preservation of open space).

5.4.1 Model Results: Water Quality Impacts under Existing (1995) Conditions.

The RUNOFF and TRANSPORT models were run for 1995 land cover conditions, using the 1995 Duluth hourly rainfall data. The year 1995 was selected for several reasons. Analysis of long-term records indicated that the 1995 rainfall at Duluth was typical of long-term annual average rainfall, based on 50 years of record at Hartsfield Airport. In addition, the Georgia EPD had conducted a special sampling study in 1994-1996, generally collecting weekly samples during the months of May through October in Big Creek between the Roswell intake and the confluence with the Chattahoochee. The measured data could be compared to model results to validate the model.

A comparison of modeled and measured daily streamflow at the Big Creek USGS gage is shown in **Figure 5-2.** This figure plots the daily stream flows against the

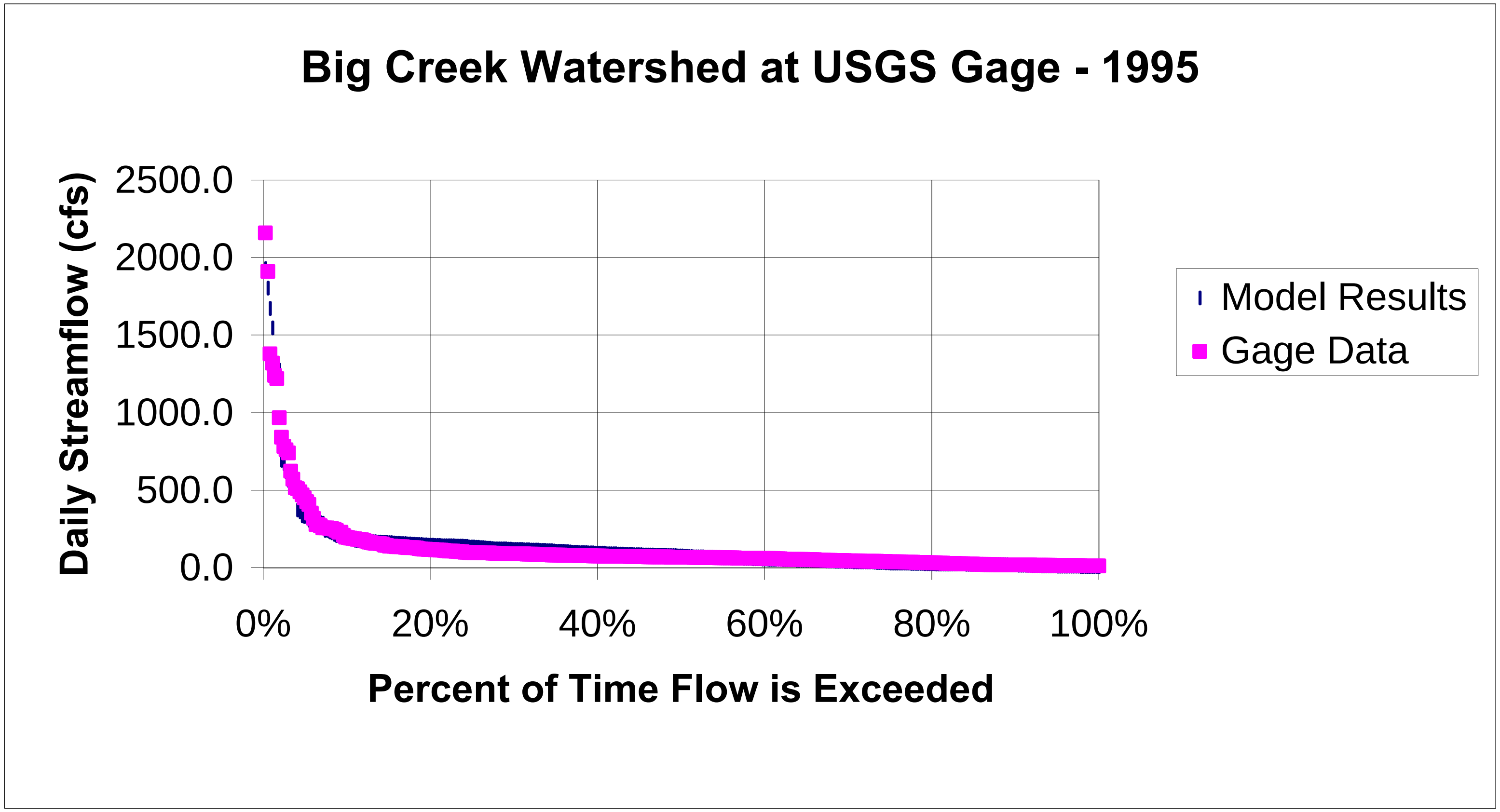


Figure 5-2
Comparison of Measured and Modeled Daily Streamflows at Big Creek USGS Gage

percent of time that the flow was exceeded. The figure indicates that the modeled flow distribution in very similar to that measured at the gage.

Table 5-5 summarizes modeled annual load data for the major subwatersheds, and at several locations along the Big Creek main stem. For each location, the table summarizes the drainage area, percent imperviousness, streamflow volume, and loads for selected constituents. Though the model includes 13 constituents (the 12 NPDES constituents plus fecal coliforms), the tabulated values have been limited to those constituents for which EPD monitoring data were available. In the case of metals, no EPD data were available; zinc data are presented because measurements for the other metals (lead, zinc, cadmium) are often below detection limit in surface runoff and groundwater.

A comparison of measured and modeled Big Creek instream concentrations is presented in **Table 5-6**. The table shows the distributions of measured values (based on 35 grab sample values) during the months of May through October, as well as the distributions of hourly-modeled values for the entire year, and for the period corresponding to the sampling period. The modeled and measured distributions should be similar if the model accurately represents watershed conditions. However, one can expect some difference between the measured and modeled values, particularly at the extremes (i.e, 100% or 0%) because the limited number of measured data is not likely to measure the true range of concentrations. Quite often, data covering multiple years and multiple conditions are required to achieve a statistically sound correlation between measured values and modeling results. Nonetheless, the results for this study indicate that the modeled and measured concentrations have distributions that are similar and appear that, for most constituents, model results match measured data closely.

Some concern was raised by the Project Team regarding the comparison of measured and modeled fecal coliform bacteria values. In particular, there was concern that the measured values at the 50th, 75th and 90th percentiles were high in comparison with the modeled values. Additional model runs were conducted, alternatively raising the dry weather and wet weather loads to see if either adjustment, or a combination of adjustments, would result in a better match between measured and modeled values. These load adjustments did not result in a better overall match. Considering the extreme variability of bacteria concentrations and the difficulty in quantifying bacteria loads from various sources, it is believed that the modeled values in Table 5-6 are adequate, particularly because they match well with measured values near the instream standard of 200/100 ml.

Time series plots of instream concentrations are presented in **Figures 5-3** through **5-8** for the constituents discussed above. The modeled values presented here reflect flow-weighted average daily concentrations. On days that sampling data were collected by the Georgia EPD, the measured values are also presented. Daily rainfall data from the

Table 5-5
Annual Load Data for Big Creek Watershed - 1995 Conditions

Location	Area (SQ MI)	% IMP	Flow (CU FT)	BOD (LB/YR)	TSS (LB/YR)	Total P (LB/YR)	Total N (LB/YR)	Zinc (LB/YR)	F. COLI. (#/YR)
Major Subwatersheds									
Kelley Mill Branch	3.8	17.7	2.14E+08	4.79E+04	1.35E+06	1.87E+03	1.54E+04	1.07E+03	3.23E+14
Sawmill Branch	2.8	15.1	1.54E+08	2.50E+04	9.12E+05	1.15E+03	9.49E+03	6.38E+02	1.30E+14
Cheatam Creek	9.2	6.4	4.57E+08	8.91E+04	3.85E+06	4.51E+03	3.42E+04	2.43E+03	6.34E+14
Bentley Creek	10.8	4.3	5.24E+08	7.07E+04	3.36E+06	4.16E+03	3.28E+04	2.65E+03	3.18E+14
Bagley Creek	6.0	8.7	3.05E+08	5.54E+04	2.56E+06	2.83E+03	2.13E+04	1.59E+03	3.76E+14
Camp Creek/Caney Creek	10.7	16.3	5.78E+08	9.56E+04	2.76E+06	4.06E+03	3.59E+04	2.43E+03	3.65E+14
Long Indian Creek	3.1	21.5	2.09E+08	4.84E+04	1.21E+06	1.95E+03	1.50E+04	1.12E+03	2.98E+14
Foe Killer Creek	12.7	23.8	7.05E+08	1.86E+05	4.56E+06	6.82E+03	5.31E+04	4.09E+03	1.01E+15
Mainstem Locations									
Big Creek at GA HWY 400	42.5	9.0	2.23E+09	4.00E+05	1.52E+07	3.40E+04	1.66E+05	1.13E+04	2.02E+15
Big Creek at USGS GAGE	73.5	11.3	3.88E+09	7.13E+05	2.68E+07	4.81E+04	2.80E+05	1.95E+04	2.93E+15
Big Creek at Roswell Intake	99.2	15.2	5.41E+09	1.19E+06	3.96E+07	6.56E+04	4.16E+05	2.90E+04	5.37E+15

Table 5-6
Instream Concentration Statistics at Watershed Outlet for 1995 Conditions

Percentile	BOD (mg/l)	TSS (mg/l)	TOTAL P (mg/l)	TOTAL N (mg/l)	ZINC (mg/l)	F. COLI. (#/100 ML)
MODEL RESULTS - JANUARY 1, 1995 - DECEMBER 31, 1995						
100%	19.9	646.0	0.95	4.22	0.242	42,300
90%	2.4	63.7	0.45	1.44	0.095	1,480
75%	1.3	9.5	0.29	1.03	0.094	800
50%	0.9	9.0	0.16	0.78	0.094	408
25%	0.8	9.0	0.12	0.71	0.089	285
10%	0.7	8.9	0.11	0.68	0.068	243
0%	0.5	6.6	0.05	0.41	0.027	136
MODEL RESULTS - MAY 1, 1995 - NOVEMBER 1, 1995						
100%	19.9	646.0	0.95	4.22	0.242	42,300
90%	2.4	58.6	0.62	1.61	0.095	1,760
75%	1.5	9.7	0.41	1.20	0.094	1,050
50%	1.1	9.1	0.29	0.98	0.093	703
25%	0.9	9.0	0.19	0.82	0.087	480
10%	0.8	8.9	0.15	0.76	0.065	367
0%	0.8	6.6	0.06	0.41	0.027	159
AMBIENT SAMPLING 0.5 MILES ABOVE CHATTAHOOCHEE RIVER						
MAY 1- NOVEMBER 1, 1995						
100%	7.9	233.3	0.56	2.20	No data	23,833
90%	2.1	69.2	0.43	1.64	No data	4,900
75%	1.3	23.7	0.33	1.19	No data	2,300
50%	1.0	11.3	0.25	0.94	No data	1,253
25%	1.0	7.2	0.23	0.85	No data	468
10%	1.0	5.6	0.20	0.75	No data	239
0%	1.0	4.0	0.12	0.40	No data	130

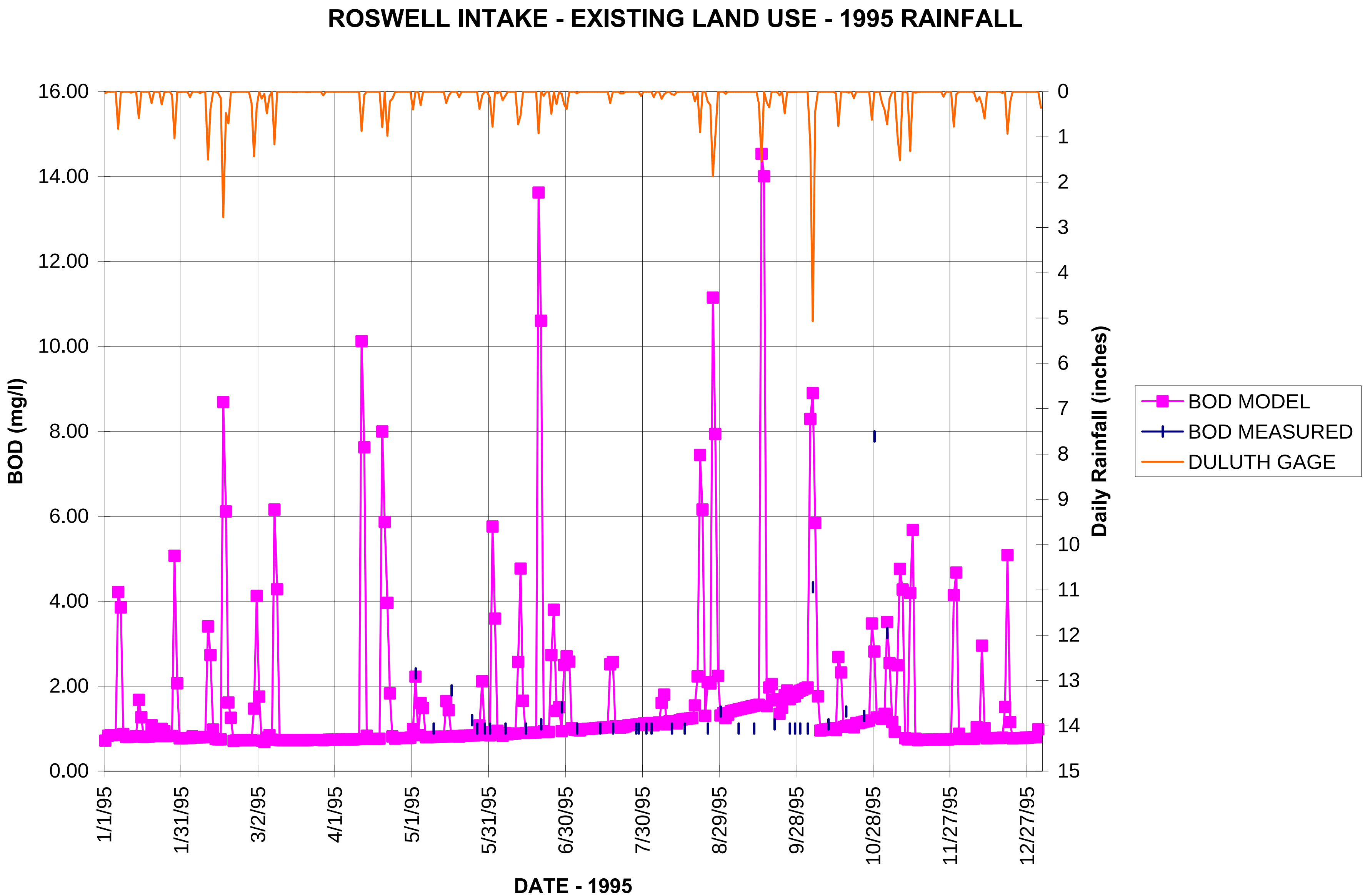


Figure 5-3 Daily BOD Concentrations at Roswell Intake - 1995 Conditions

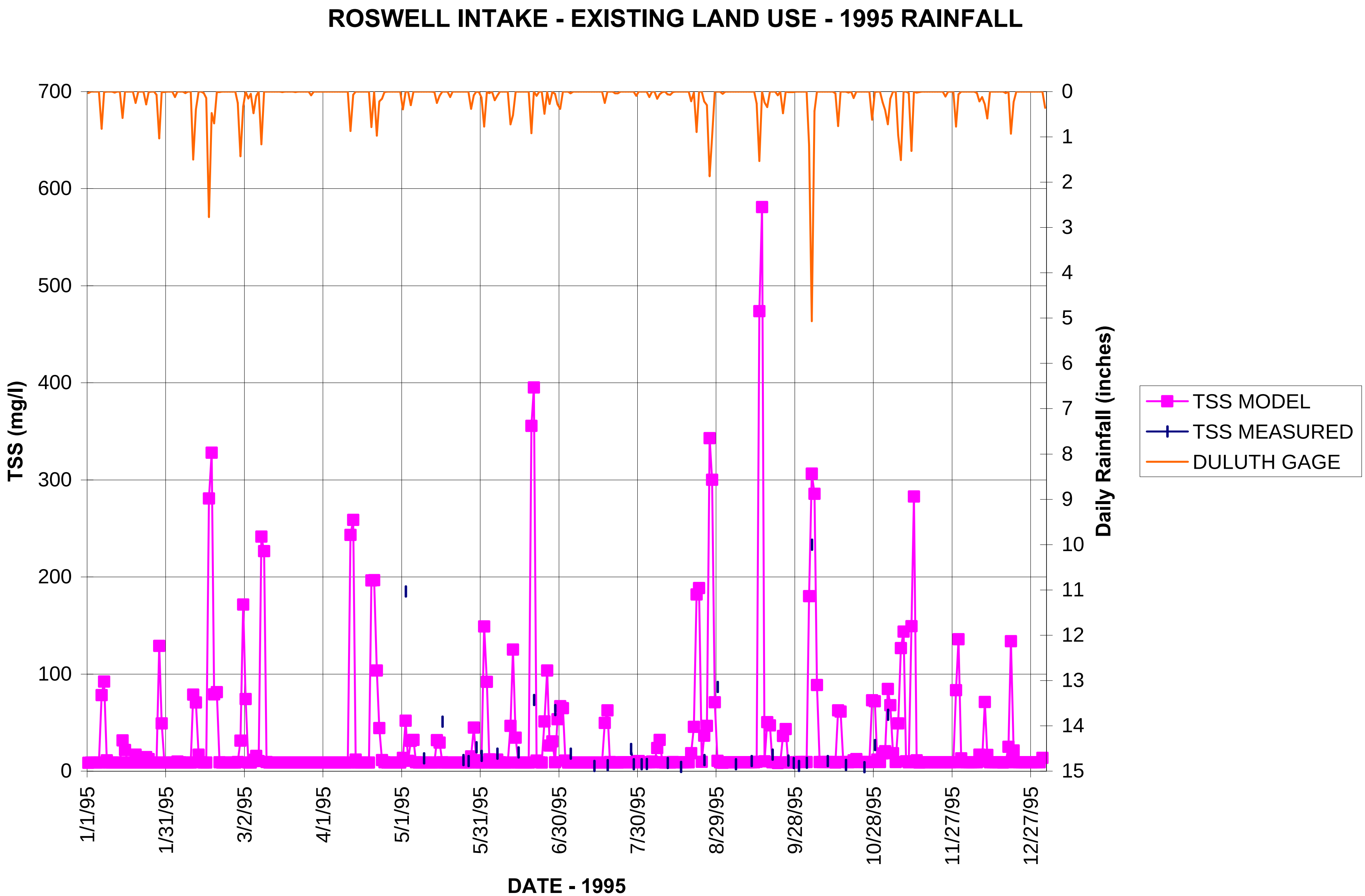


Figure 5-4 Daily TSS Concentration at Roswell Intake - 1995 Conditions

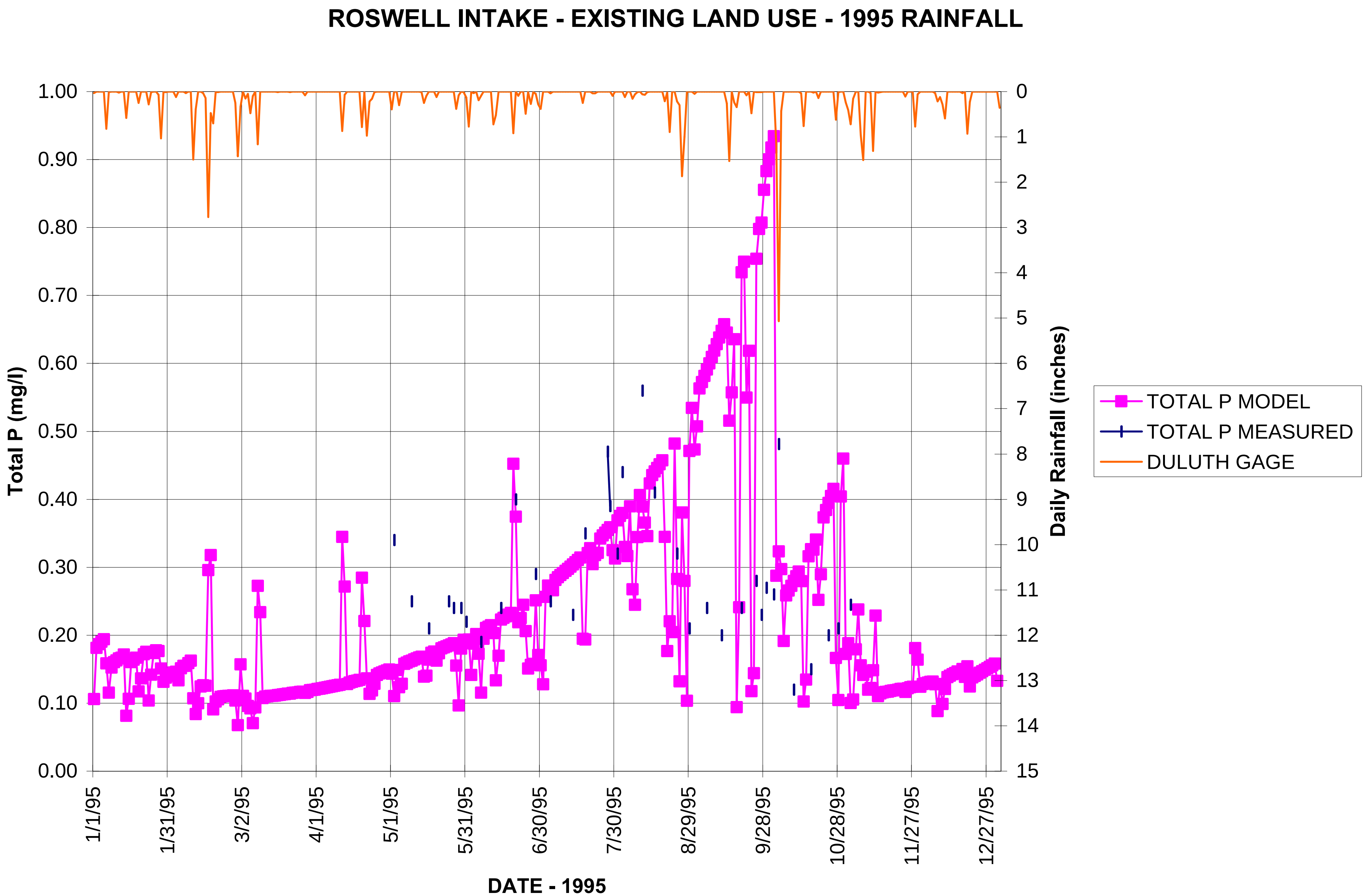


Figure 5-5 Daily Total P Concentration at Roswell Intake - 1995 Conditions

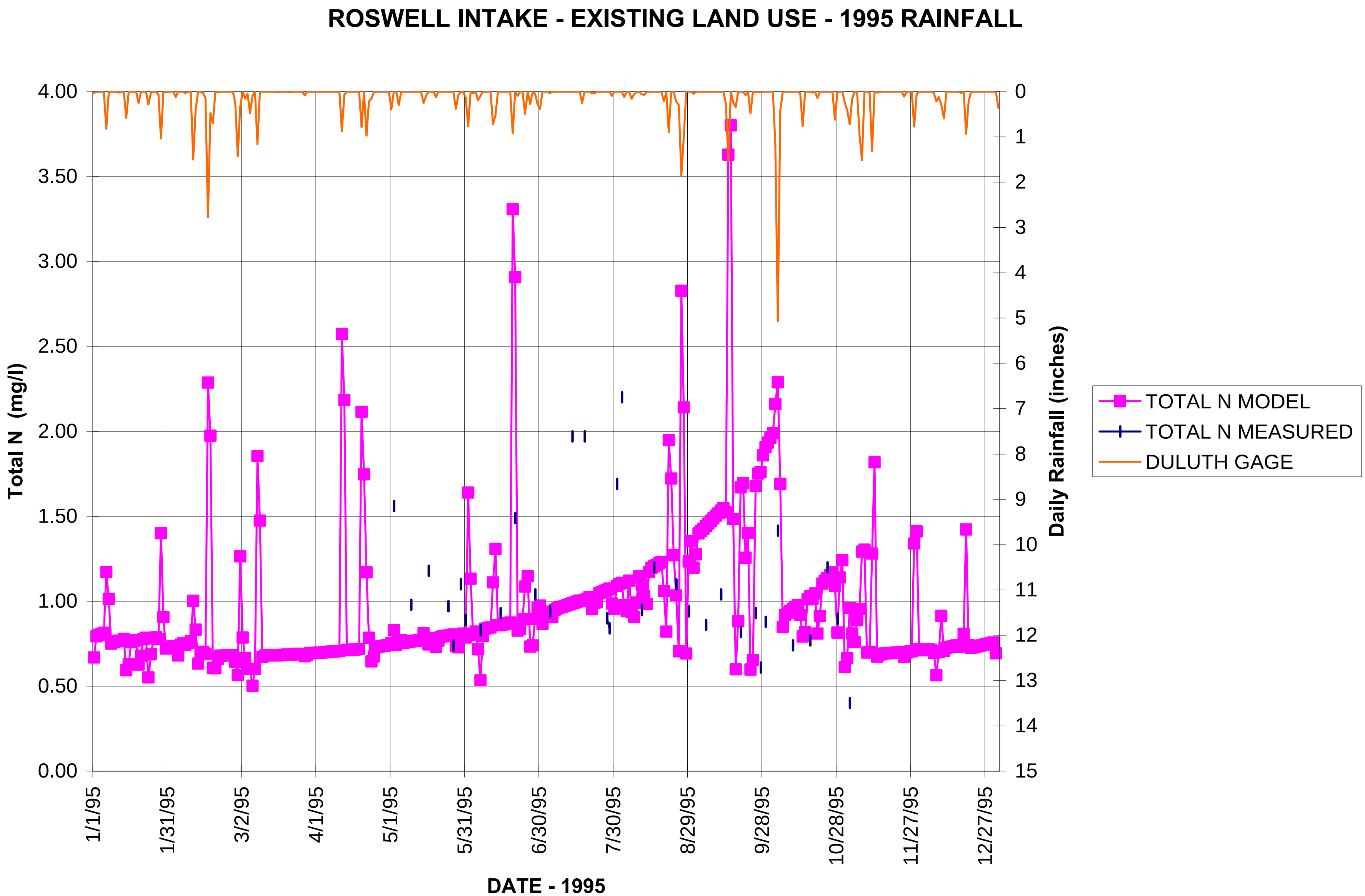


Figure 5-6 Daily Total N Concentrations at Roswell Intake - 1995 Conditions

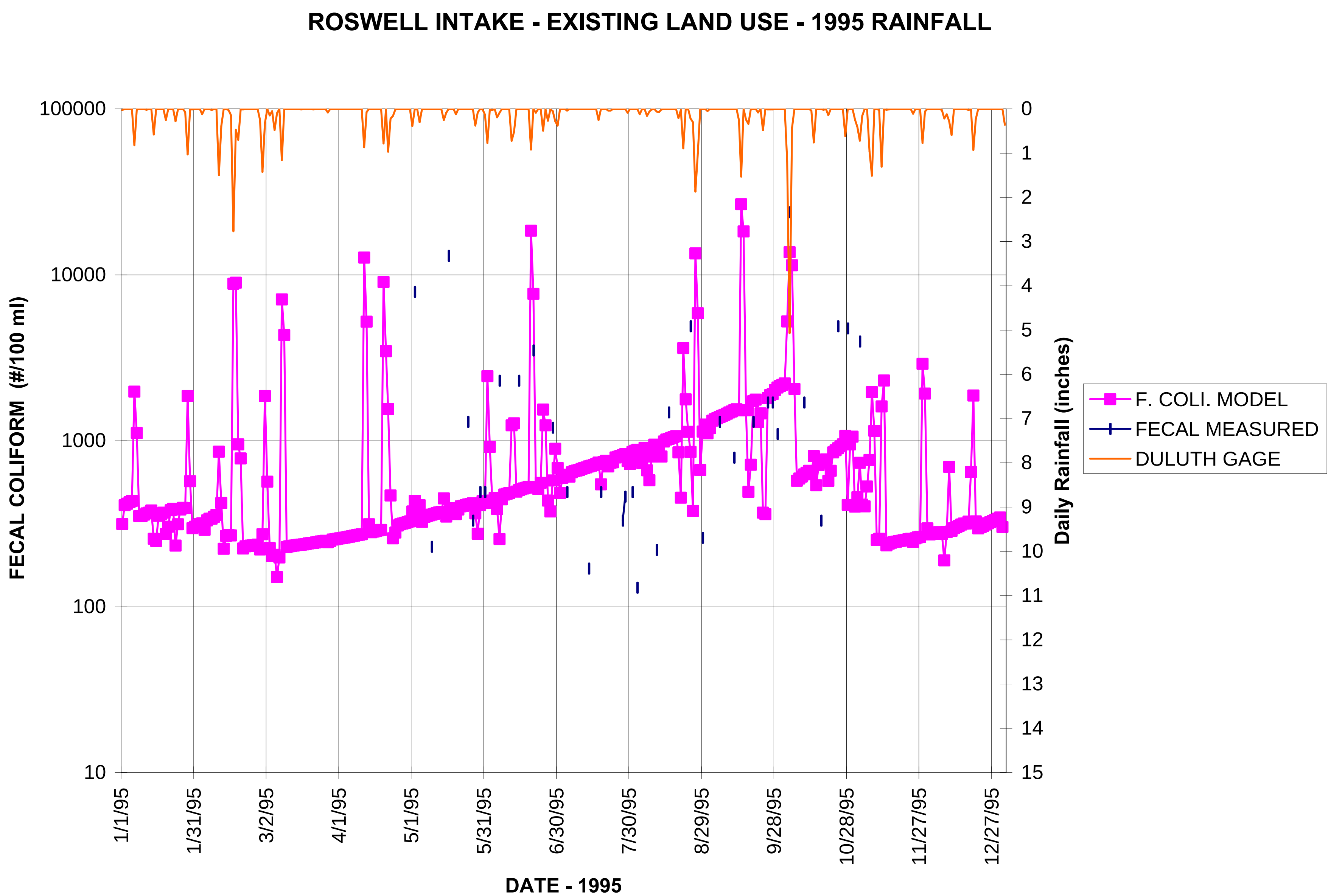


Figure 5-7 Daily Bacteria Concentrations at Roswell Intake - 1995 Conditions

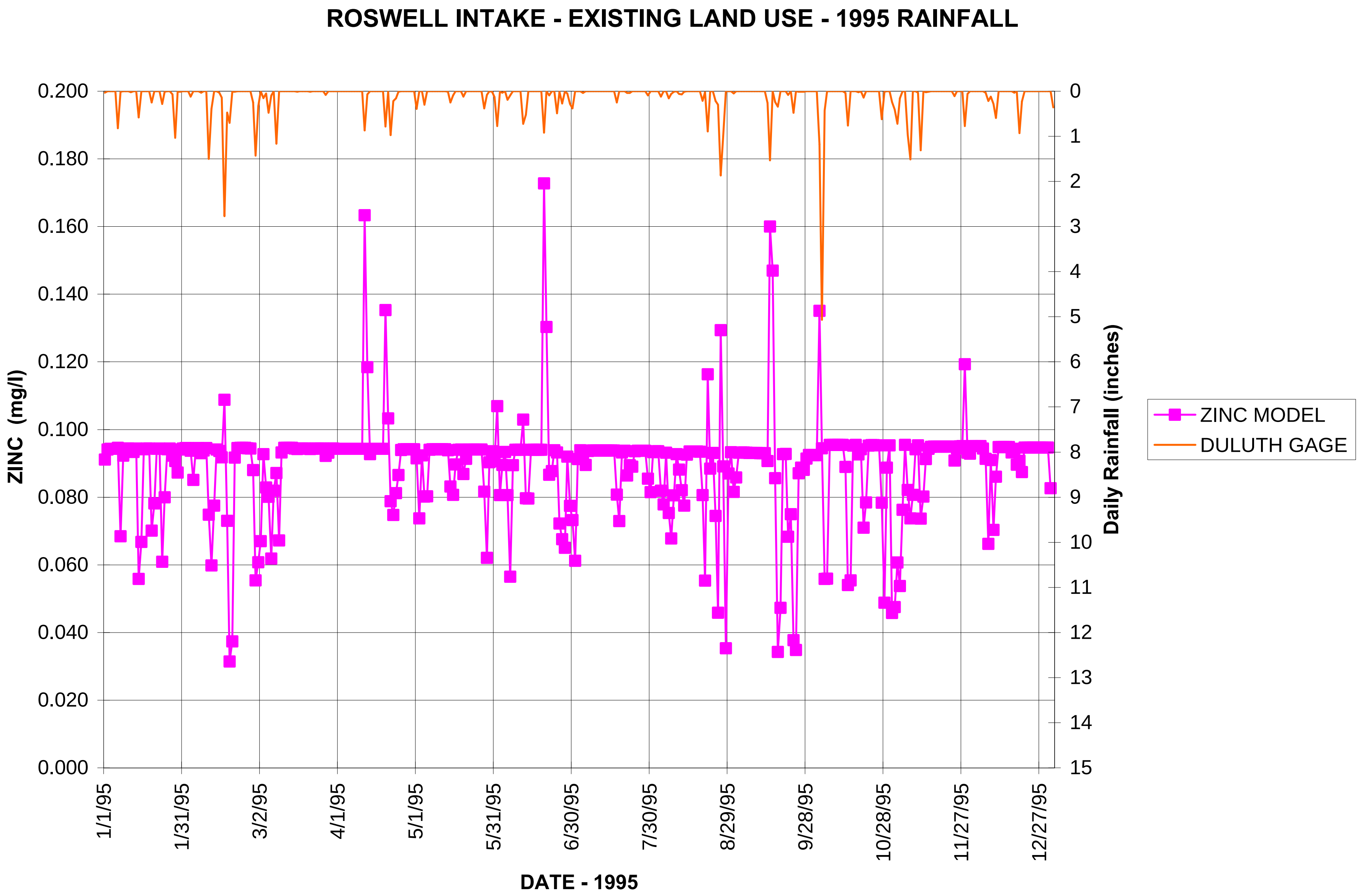


Figure 5-8 Daily Zinc Concentrations at Roswell Intake - 1995 Conditions

Duluth gage are also plotted at the top of the graphs, to show how the modeled instream concentrations are affected during wet and dry weather periods.

In general, the comparison of modeled and measured values shows that the modeled values during wet and dry weather periods are consistent with the measured values. While comparisons of measured and modeled values on a particular day may not always match, the model captures the trends occurring in the watershed, and is expected to provide a representative calculation of total constituent load and frequency-exceedance for instream concentrations.

One apparent difference between the modeled and measured results is in the total P and total N results during the months of August through October. During dry weather conditions, the model predicts concentrations that are greater than the measured values. Reasons for this difference include the following:

- The model predicts dry weather flows that are somewhat lower than the measured instream flows. Consequently, the dilution of the point source loads from Tyson Foods and the City of Cumming is not as great in the model as it actually was in the watershed.

- The loads of nitrogen and phosphorus from the Tyson Foods and Cumming plants may have been lower than average for that period. In contrast, the model assumes a constant flow rate and discharge concentration for the plants.

- The failure rate of septic tanks may be lower during this period, due to lower water table levels. Again, the model assumed a constant failure rate throughout the year.

Though the factors discussed above result in apparent differences between modeled and measured instream concentrations, the differences have little impact on the overall calculation of annual loads of total N and total P. These differences are limited to dry weather conditions during the months of August through October. For both modeled and measured values, the total quantity of dry weather flow during this period is much less than the dry weather flows during the rest of the year, and is a very small percentage of the total flow (wet weather plus dry weather) for the year. Consequently, the differences described above have almost no effect on the annual loads calculated for total N and total P.

5.4.2 Model Results: Water Quality Impacts under Future (2020) Conditions

The RUNOFF and TRANSPORT models were run for future (year 2020) conditions, again using the 1995 Duluth hourly rainfall data. Differences between the existing conditions model and future conditions model include the following:

- Land use data was updated to reflect anticipated development between the present and the year 2020. ARC developed the future land use data through consultation with the local jurisdictions. The results indicated that the imperviousness of the watershed will increase from 15% (1995) to 35% (2020). Increased imperviousness will result in increased surface runoff flows and loads.

- The Cumming treatment plant flow rate was increased to 8 mgd, based on available planning information. Discharge concentrations were assumed to be the same. It is noted that Cumming's recently reissued NPDES permit to discharge treated effluent does not allow for pollutant load increases with increases in permitted flow. Subsequently, instream pollutant concentrations during low flow periods of dry weather would be lower than modeling results show.

- The Tyson Foods discharge concentration of total phosphorus was reduced to 0.75 mg/l, based on recent changes to their existing permit. The flow rate was assumed to be the same.

- It was assumed that all of Forsyth County would be sewered by the year 2020, based on discussion between ARC and Forsyth County staff; therefore, the load due to failing septic tanks was eliminated from the model for future conditions.

Table 5-7 summarizes modeled annual load data for the major subwatersheds, and at several locations along the Big Creek main stem, for the future condition. Modeled Big Creek instream concentrations for the future condition are presented in **Table 5-8**. Time series plots of instream concentrations for future land use conditions are presented in **Figures 5-9** through **5-14** for the constituents discussed above. The modeled values presented here reflect flow-weighted average daily concentrations. Daily rainfall data from the Duluth gage are also plotted at the top of the graphs, to show how the modeled instream concentrations are affected during wet and dry weather periods.

Again, under the provisions of Cumming's recently reissued NPDES permit, with an increase in permitted flow to 8 mgd, effluent concentrations would be reduced by a factor of four. Although not reflected in the future conditions modeled, additional water quality benefits in Big Creek would be realized, in particular during dry weather low flow periods. The percentage of time fecal coliform concentrations are met would likely increase. Furthermore, any estimated increase in total nitrogen concentrations would be negated with no increase in loading associated with the City of Cumming's discharge.

5.4.3 Comparison of Existing and Future Water Quality Impacts

A direct comparison of existing (1995) and future (2020) flows and loads is presented in **Table 5-9**. As a result of increased urbanization, the total streamflow increased 25% at the watershed outlet, and 10 to 30% in the major subwatersheds. The total loads for all water quality constituents also increased as a result of increased urbanization. The increased constituent loads at the watershed outlet ranged from 25% (TSS) to 140% (fecal coliform bacteria). Load increases varied widely between the

Table 5-7
Annual Load Data for Big Creek Watershed - 2020 Conditions

Location	AREA (SQ MI)	% IMP	FLOW (CU FT)	BOD (LB/YR)	TSS (LB/YR)	TOTAL P (LB/YR)	TOTAL N (LB/YR)	ZINC (LB/YR)	F. COLI. (#/YR)
MAJOR SUBWATERSHEDS									
KELLEY MILL BRANCH	3.8	32.4	2.42E+08	8.38E+04	1.61E+06	2.64E+03	2.16E+04	1.39E+03	6.80E+14
SAWMILL BRANCH	2.8	45.5	1.98E+08	7.30E+04	1.13E+06	1.89E+03	1.63E+04	1.07E+03	4.63E+14
CHEATAM CREEK	9.2	23.0	4.50E+08	1.22E+05	6.40E+06	6.51E+03	4.21E+04	2.29E+03	1.67E+15
BENTLEY CREEK	10.8	20.7	6.24E+08	1.31E+05	3.25E+06	5.28E+03	4.21E+04	3.30E+03	7.48E+14
BAGLEY CREEK	6.0	30.0	3.70E+08	1.36E+05	2.99E+06	4.47E+03	3.39E+04	2.38E+03	1.08E+15
CAMP CREEK/CANEY CREEK	10.7	39.1	7.03E+08	2.44E+05	3.13E+06	6.51E+03	5.71E+04	3.91E+03	1.10E+15
LONG INDIAN CREEK	3.1	32.7	2.32E+08	7.82E+04	1.99E+06	2.91E+03	2.18E+04	1.39E+03	7.58E+14
FOE KILLER CREEK	12.7	35.8	7.76E+08	2.91E+05	5.16E+06	8.75E+03	7.00E+04	5.06E+03	1.62E+15
MAINSTEM LOCATIONS									
BIG CREEK AT GA HWY 400	42.5	27.6	2.92E+09	8.10E+05	1.92E+07	3.34E+04	3.03E+05	1.63E+04	5.17E+15
BIG CREEK AT USGS GAGE	73.5	33.5	4.99E+09	1.68E+06	3.36E+07	5.79E+04	5.03E+05	3.03E+04	8.44E+15
BIG CREEK AT ROSWELL INTAKE	99.2	35.2	6.69E+09	2.56E+06	4.99E+07	8.35E+04	7.07E+05	4.41E+04	1.28E+16

Table 5-8
Instream Concentration Statistics at Watershed Outlet for 2020 Conditions

PERCENTILE	BOD (MG/L)	TSS (MG/L)	TDS (MG/L)	TOTAL P (MG/L)	TOTAL N (MG/L)	ZINC (MG/L)	F. COLI. (#/100 ML)
MODEL RESULTS - JANUARY - DECEMBER							
100%	30.2	685.0	224.0	0.77	5.64	0.337	61,100
90%	3.0	47.8	38.8	0.17	2.30	0.094	688
75%	1.8	9.7	38.4	0.14	1.66	0.094	135
50%	1.1	9.1	38.1	0.11	1.16	0.093	120
25%	1.0	9.0	37.4	0.09	0.95	0.089	95
10%	0.9	8.9	30.2	0.08	0.82	0.068	66
0%	0.5	4.7	12.3	0.03	0.37	0.023	16
MODEL RESULTS - MAY - OCTOBER							
100%	30.2	685.0	224.0	0.77	5.64	0.314	61,100
90%	2.9	45.0	38.3	0.18	2.47	0.094	539
75%	2.0	9.7	38.2	0.16	2.14	0.093	123
50%	1.5	9.3	37.9	0.13	1.54	0.092	102
25%	1.2	9.1	36.5	0.10	1.16	0.085	73
10%	1.0	8.9	29.5	0.09	0.99	0.066	59
0%	0.6	4.7	12.3	0.03	0.38	0.023	16

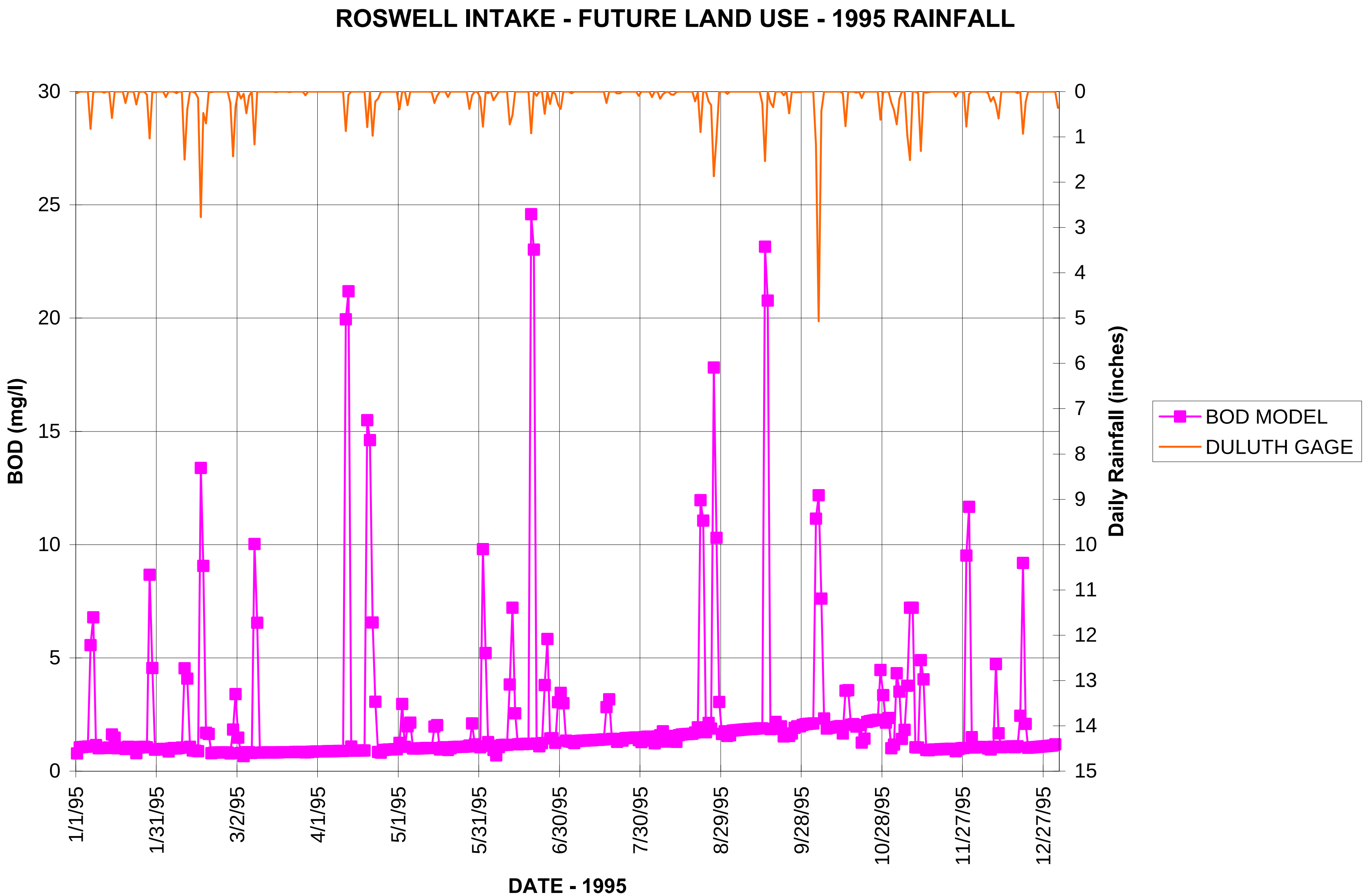


Figure 5-9 Daily BOD Concentrations at Roswell Intake - 2020 Conditions

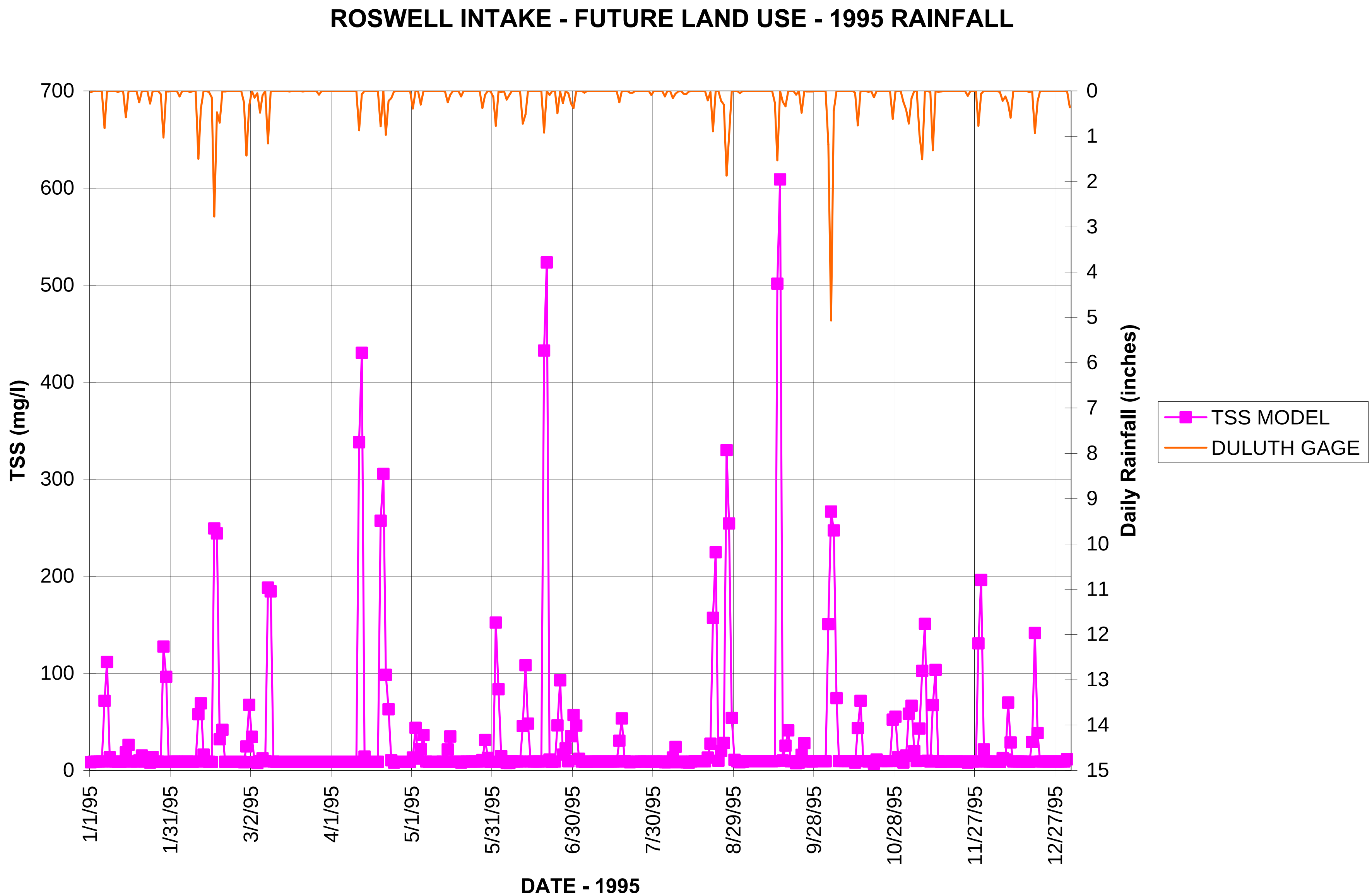


Figure 5-10 Daily TSS Concentrations at Roswell Intake - 2020 Conditions

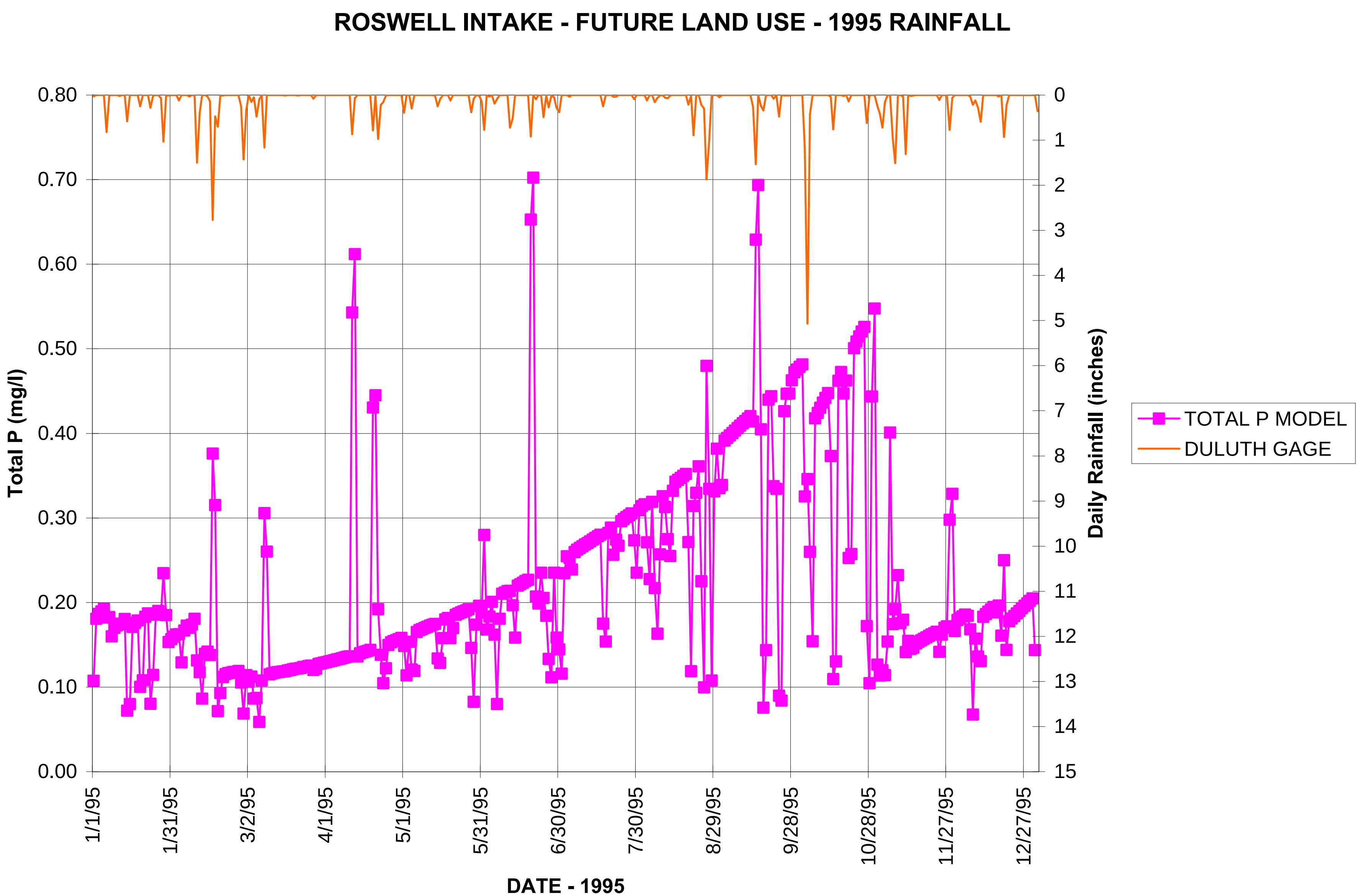


Figure 5-11 Daily Total N Concentrations at Roswell Intake - 2020 Conditions

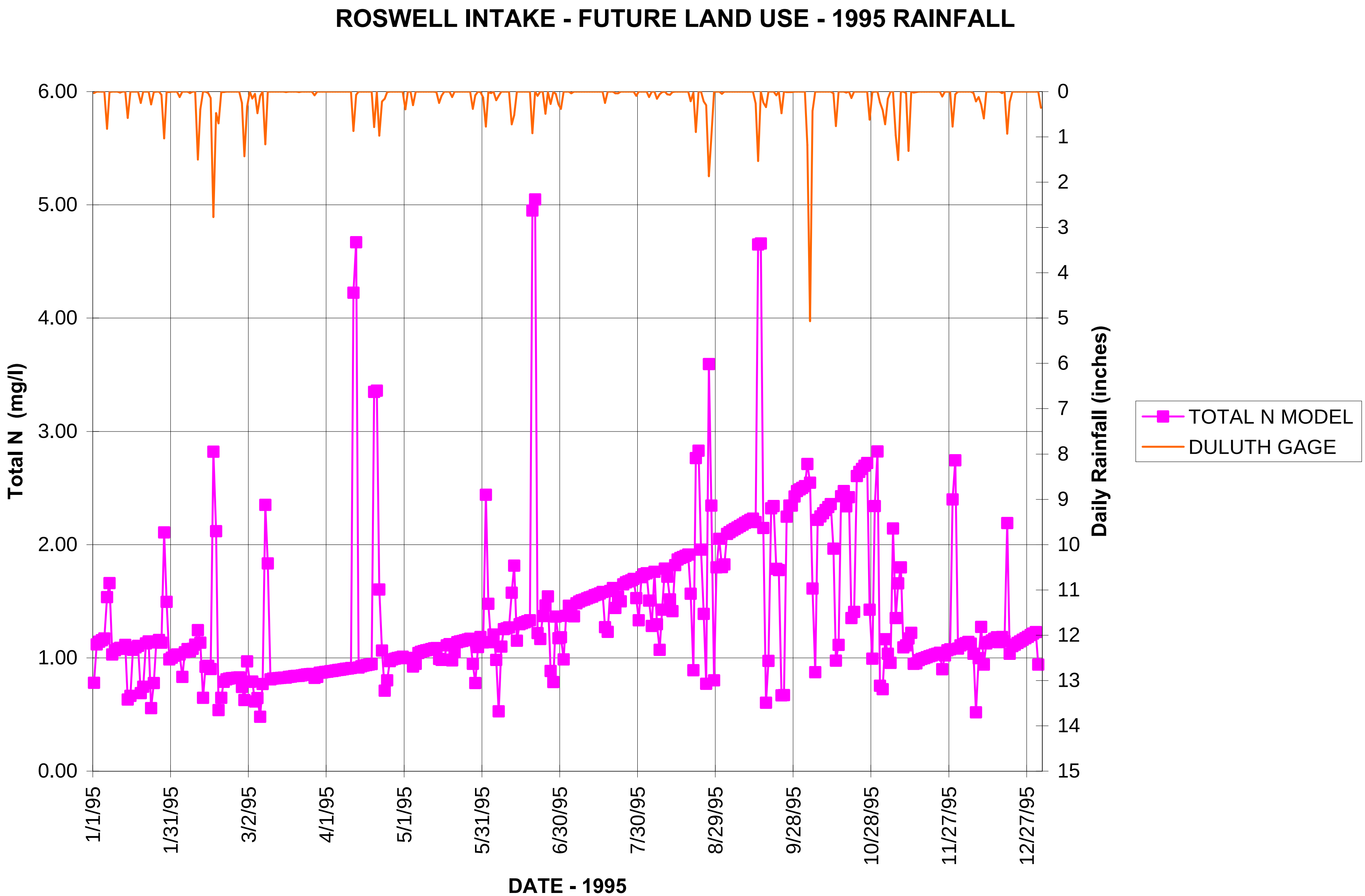


Figure 5-12 Daily Bacteria Concentrations at Roswell Intake - 2020 Conditions

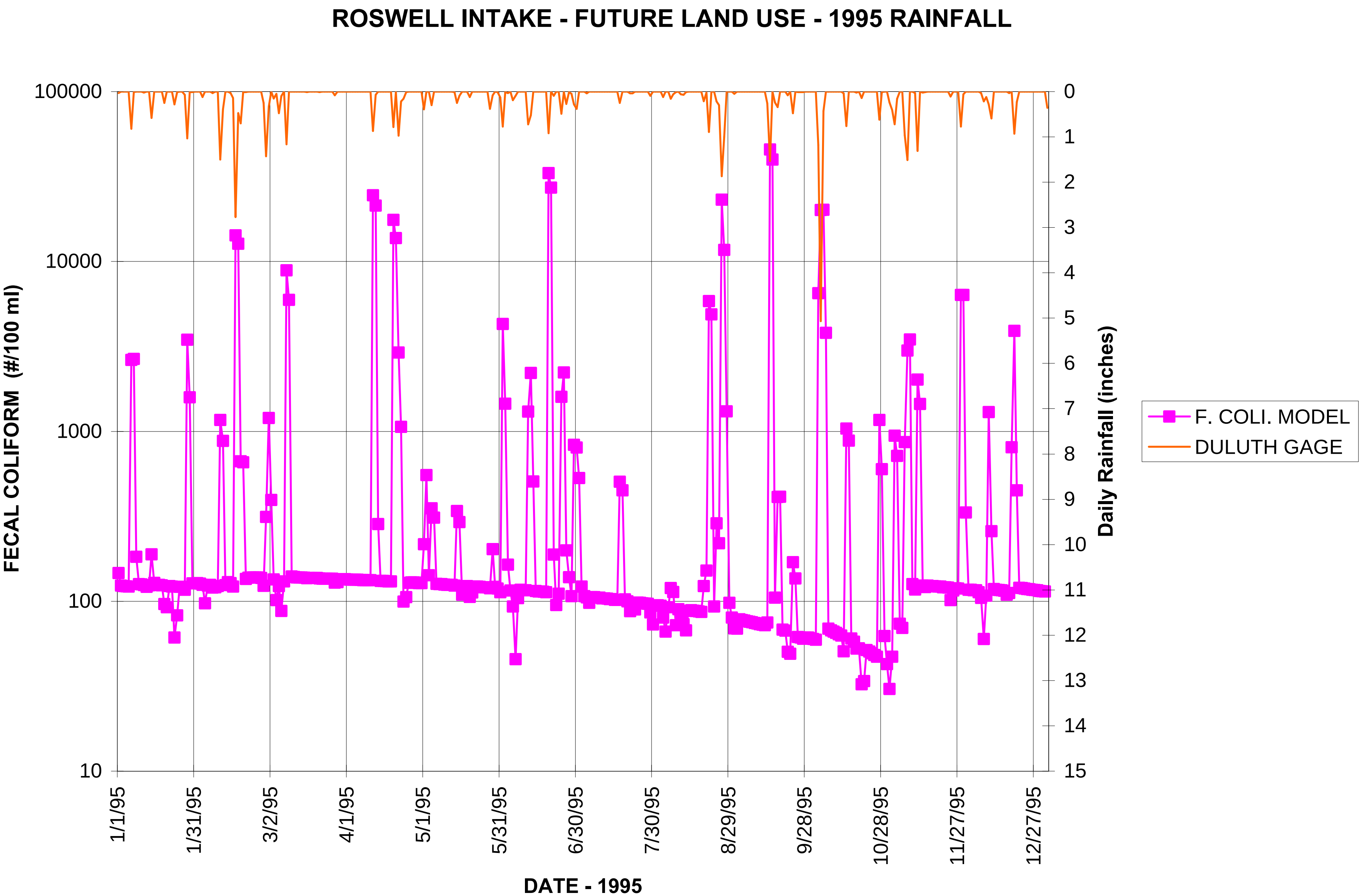


Figure 5-13 Daily Fecal Coliform Concentrations at Roswell Intake - 2020 Conditions

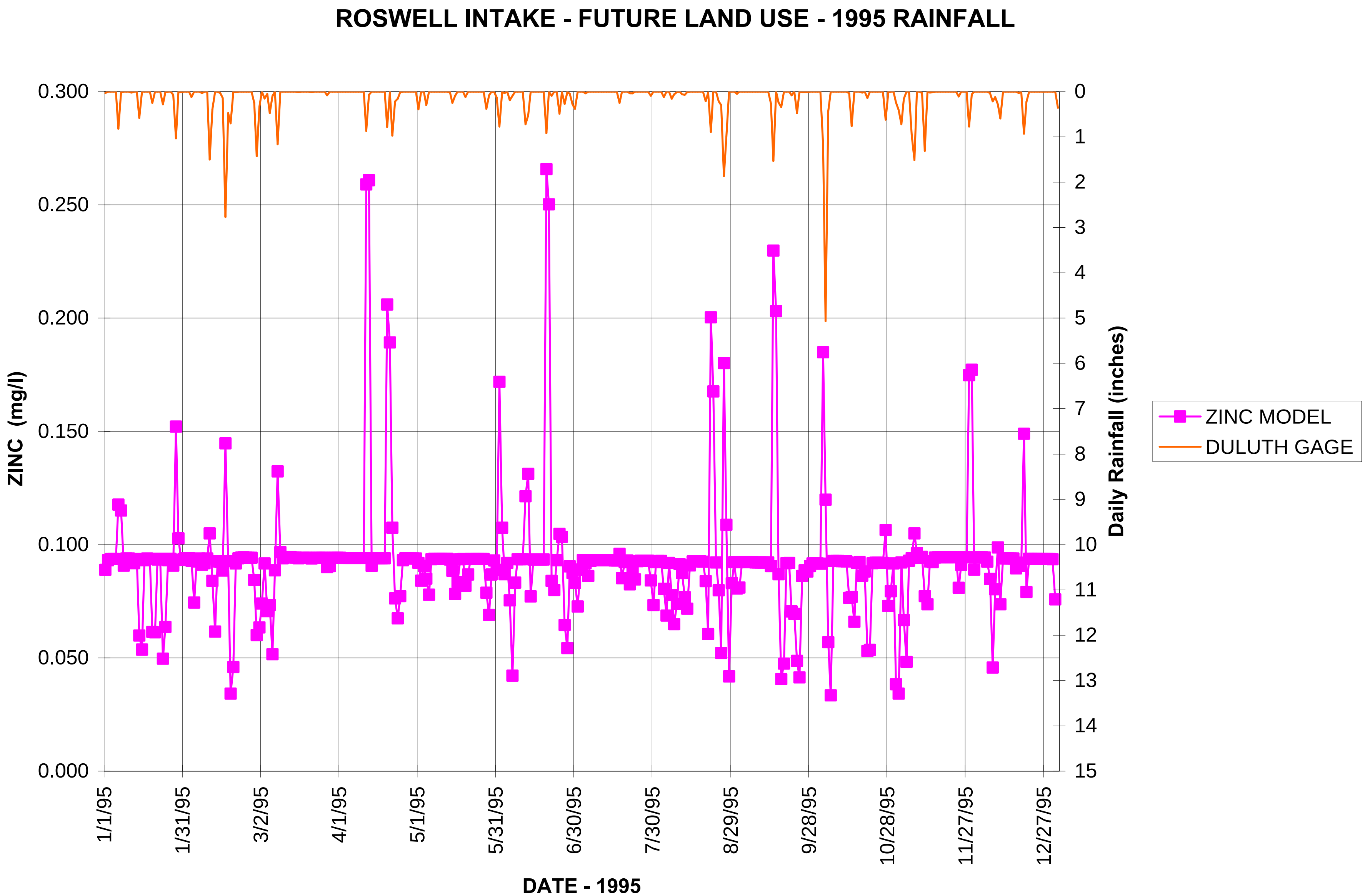


Figure 5-14 Daily Zinc Concentrations at Roswell Intake - 2020 Conditions

major subwatersheds. The largest percentage increases in constituent loads occurred in subwatersheds such as Sawmill Branch and Camp Creek/Caney Creek, which also had the largest changes in percent imperviousness. In contrast, subwatersheds with the smallest changes in percent imperviousness (e.g., Foe Killer Creek) had the smallest percent increases in constituent loads.

A comparison of (existing and future conditions) reveals several interesting findings as illustrated in **Table 5-9**. For example, fecal coliform concentrations for the future condition are generally much lower than for the existing conditions. There are two reasons for this: (1) elimination of the failing septic tanks as a bacteria source and (2) a greater discharge of low-bacteria flow from the Cumming plant. According to the model, the standard of 200/100 ml should be met more than 75% of the time under the assumed future conditions. Future total phosphorus concentrations are also generally lower than existing values, for the same reasons, and because the Tyson Foods discharge now has a total phosphorus discharge limit. On the other hand, total nitrogen concentrations tend to be higher in the future condition because treatment plant discharges of total nitrogen are typically greater than concentrations from other sources such as surface runoff or groundwater.

The impact on future development on instream constituent concentrations varies by constituent. For most constituents, the wet weather concentrations tend to be higher for future conditions than for existing conditions. The exception is TSS, for which future wet weather concentrations appear to be about the same as for existing conditions. As discussed earlier, dry weather concentrations of total P, total N and fecal coliform bacteria also differ from existing to future conditions. The concentrations of total P and bacteria will generally be lower, because of increased discharges of relatively low total P and bacteria from the City of Cumming plant, removal of septic tanks in Forsyth County, and a lower total P permit limit for the Tyson Foods discharge. Dry weather total N concentrations tend to increase in the future due to the increased discharge from the Cumming plant, assuming the same discharge concentration as for existing conditions.

5.4.4 Travel Time Analysis

Travel time denotes the length of time it takes water to flow from one part of the watershed to a designated point. This would ideally be determined by analyzing a range of storm events which occur over the course of one or more years. However the limited scope of this project requires an assessment of travel time from several points in the watershed to the Roswell intake over average wet weather conditions. Based upon statistics on the mean duration and mean volume for regional rainfall events, travel time contours were developed for the Big Creek watersheds and are shown in **Figure 5-15.**

Table 5-9
Comparison of Existing and Future Flows and Constituent Loads in Big Creek Watershed

% INCREASE IN ANNUAL LOAD		
CONSTITUENT	**MAJOR SUBWATERSHEDS**	**WATERSHED OUTLET**
Flow	10 - 30	25
BOD	60 - 190	120
TSS	0 - 90	25
Total P	30 - 70	25 *
Total N	30 - 70	70
Zinc	10 - 70	50
Fecal Coliform	60 - 260	140

* For Total P, major load reduction occurs at Tyson Foods, which is located in the Upper Big Creek Direct area. Direct drainage areas to the Big Creek mainstem are not included in the major subwatershed load increase values presented above. This explains why the % increase at the watershed outlet (which includes the Tyson Foods total P reduction) is less than the lowest percent increase calculated at any of the major subwatersheds.

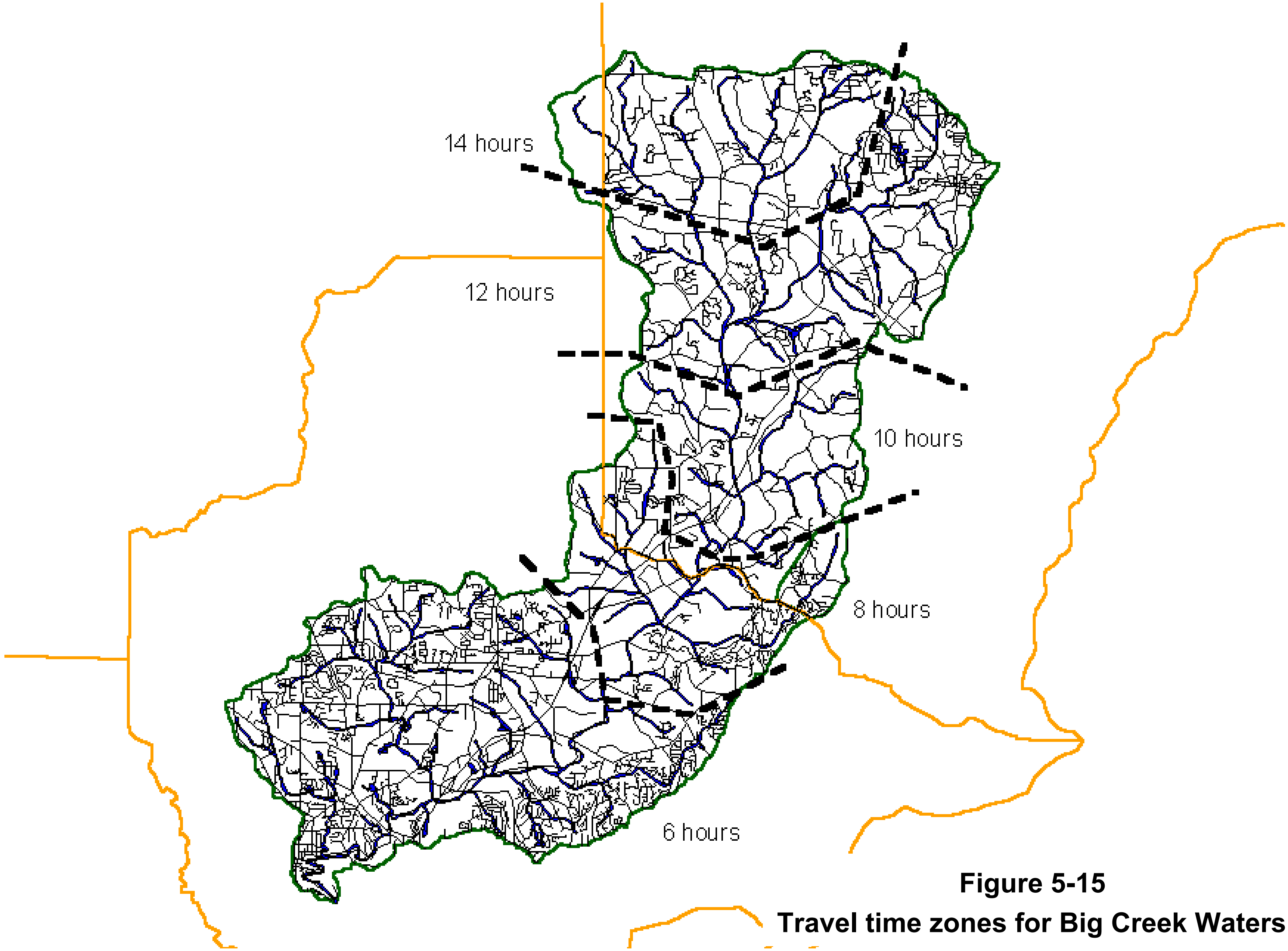


Figure 5-15

Travel time zones for Big Creek Watershed

Section 6
Overview of Water Quality Control Measures for Watershed Protection

6.1 Introduction

This section provides a description and comparison of the various Best Management Practices (BMPs) that can be applied within the Big Creek Watershed to reduce nonpoint source pollution loads.

Best Management Practices (BMPs) are required to cost-effectively minimize the impact of urbanization on local water resources. Numerous studies (including several in the Atlanta region) have demonstrated that the water quality impacts of urbanization are certain and that mitigating this impact after development has occurred is difficult and costly. However, when BMPs are properly integrated into drainage infrastructure during development, the protection of water quality, coupled with benefits received from decreased erosion, habitat protection, and improved waterway aesthetics, result in a net benefit for the community.

In the past, urban BMPs were divided into two classes: non-structural and structural. Non-structural controls minimized the opportunity for pollutants to come in contact with rainfall and runoff, while structural controls were constructed facilities for treating runoff.

More recently, BMPs have been grouped into the following three categories:

- Pollution Prevention - These practices keep chemicals from coming into contact with rainfall and runoff so that they never pose a pollution threat to receiving waters (examples are anti-dumping programs).

- Source Controls - Source controls are placed near the runoff point of origin so the amount of runoff and the subsequent quantity of pollutants that must be dealt with are small and manageable (examples are reducing impervious area and encouraging infiltration of storm water). Typical applications for source controls are drainage from roads and parking lots, residential lots and internal drainage in industrial estates. The tributary area to these devices is generally less that one acre.

- Treatment Controls - Treatment controls usually drain areas five acres or larger, and are designed to remove or treat pollution (examples are detention ponds and constructed wetlands). Treatment control concepts, sizing, and general layout are based on scientific principles first. However, the physical environment of the facility guides application of these principles, so that the facility achieves harmony with the surrounding environment. These facilities return the most value to the community when they are integrated into the surrounding environment, such as within park or greenbelt areas.

6.2 Pollution Prevention Practices

Many of the practices considered to be pollution prevention controls revolve around public education since the majority of activities that generate pollutants that enter runoff are man-induced or behavioral activities. Therefore, public education is used to encourage a net behavioral change in society resulting in the reduction of pollutant-generating activities. Examples of public education activities include anti-dumping campaigns and programs to encourage proper application of pesticides and fertilizers.

Other pollution prevention activities center on using less polluting materials in day-to-day activities or removing polluting materials from areas where they can interact with rainfall. The benefit of pollution prevention practices is intuitive as most people recognize that it is far less costly to prevent pollution than remediate it.

All pollution prevention controls are potentially applicable within the Big Creek watershed. The most important practices are:

- Public education – reduces polluting activities, but also reinforces importance of community programs for watershed management with citizens;
- Illicit connection detection and removal – programs to keep sanitary flows in the sanitary sewer system (or septic system) and storm water confined to surface drainage infrastructure;
- Management of construction and industrial activities – encouraging owner/operators of these facilities to comply with NPDES storm water permit requirements; and
- Drainage system operation and maintenance -- encouraging owner/operators of these facilities to comply with NPDES storm water permit, requiring drainage infrastructure, including treatment controls must be operated and maintain in a manner that is conducive to long-term water quality management. Improperly operated and maintained infrastructure can exacerbate problems. The condition of the drainage system should be known and maintenance decisions should be proactively made on the basis of inspections and known need rather than solely on the basis of complaints of flooding, erosion, or observed pollution.

6.3 Source Controls

Source controls are designed to limit the amount of runoff and by doing so reduce pollutant loads to waterways. All source controls have essentially the same function: reduce runoff by encouraging a greater percent of rainfall to infiltrate into the ground. Source controls can further be described as either passive or active with regards to infiltration. Passive infiltration practices seek to take advantage of the soil's natural ability to infiltrate rainfall and runoff, while active infiltration devices are designed to enhance infiltration through engineering means (such as infiltration ponds & trenches).

6.3.1 Density Restrictions

Density restrictions are the most popular type of land use control for watershed management. Selection of the most appropriate density restriction should be based upon comparisons with structural controls and evaluations of the marginal benefits achieved by incremental increases in residential lot sizes (i.e., incremental reductions in density).

An acceptable alternative to larger lot subdivisions is the use of clustered development, where development is concentrated on a small portion of a tract, leaving the remainder as permanent open space. To provide watershed protection benefits, cluster development should be associated with a nonpoint pollution-loading target.

A critical requirement of the clustered development approach is that the required onsite open space must be permanently preserved. Development of the open space areas at some point in the future would result in nonpoint pollution loading increases, which would violate the performance standard used to design the clustered development approach. Options for permanently restricting development of the open space preserve of clustered sites include deed restrictions, common ownership by the homeowner's association, and dedication of the land to the county. If a local government chooses to rely upon the clustered development approach, it is very important that effective provisions, which restrict development of the open space areas, are implemented. Economic considerations naturally limit the degree to which this can be applied.

6.3.2 Locational Restrictions

Sections of the watershed, which are adjacent to creeks and streams, are generally considered more critical than upland sections. Ideally, this critical zone should be restricted to the optimum land use controls (i.e., undeveloped buffer areas, or large lot residential zoning) for watershed protection. This is because development adjoining the rivers and creeks can result in relatively undiluted "slug" loadings from paved areas being delivered directly to the receiving waters. Where feasible, stringent nonpoint pollution controls might be considered for new development in these areas.

Locational restrictions are primarily applicable to undeveloped areas and are therefore largely infeasible, especially in the lower portion of Big Creek.

6.3.3 Land Acquisition

In some areas, water quality protection is achieved by public ownership of the entire watershed or a significant portion of the watershed. This approach is primarily used in critical drinking water supply watersheds. For example, New York City has an active land acquisition program to increase public ownership of the city's water supply reservoirs. By keeping large areas of the watershed in an undeveloped, pristine condition, water quality problems due to nonpoint pollution discharges can be minimized. In order to be effective in reducing pollution discharges, a land acquisition program must include a large percentage of the watershed areas. Given the existing levels of development within the Big Creek watershed reliance on a land acquisition program would likely be prohibitively expensive and unpractical.

Limited land acquisition may be applicable in conjunction with other jurisdictional programs such as expansion of a park facility. Targeted land acquisitions could be prioritized along waterways or stream valley areas. The areas would probably be small and primarily intended for recreational usage. While useful for addressing localized problems especially along degraded streams, land acquisition is not feasible on a large enough scale to improve water quality throughout the watershed.

6.3.4 Buffer Zones

Buffer zones can be an important part of the overall water quality management package that constitutes a watershed plan. If located in areas that receive sheet flow from adjoining urban development, buffer zones can achieve reduction in suspended nonpoint pollution loadings. Buffer zones can also help protect natural stream banks by keeping development away from the channel, thereby contributing to the prevention of streambank erosion and sedimentation. Further, buffer zones keep streams shaded, maintaining lower water temperatures, which can support fish habitats.

Nonpoint pollution monitoring studies over the past 10 to 15 years have demonstrated that maintaining buffer zones along streams alone does not provide sufficient water quality protection. Unless continuous buffers are in place throughout a watershed, drainage ways (storm sewers, swales) may bypass buffer zones and discharge polluted runoff directly to streams. Also, monitoring studies have shown that upland areas can contribute significant nonpoint pollution loadings to local receiving waters, meaning that an effective watershed management program should not be restricted to stream corridor areas immediately adjacent to the creeks and streams.

6.3.5 Landscape/Grass Swales

Due to the less permeable/infiltrative soils found in the Big Creek watershed, active infiltration BMPs are NOT recommended for application in the watershed. Only after extensive piloting should these be considered. In all likelihood, active infiltration devices would have very short life cycles in the watershed, making them quite expensive to maintain. CDM recommends passive source controls such as swales, buffers, and filter strips.

Swales are typically grassed or vegetated shallow channels with a relatively mild slope. Besides encouraging infiltration, swales also provide pollutant removal via the filtering capacity of the swale’s vegetation. This BMP will not treat the entire "treatment volume", but rather should be used in combination with other treatment controls. Grass swales are used to replace curb and gutter in residential, low-density commercial/industrial, and highway areas. They are cost competitive with curb and gutter systems.

6.3.6 Filter Strips

Filter strips or buffer strips perform similarly to swales, they are used as buffers for runoff from pervious surfaces (such as parking lots), slow down the velocity of the water, and encourage infiltration as well as provide filtering capacity. Filter strips are mildly sloping vegetated surfaces located along impervious surfaces. Similar to grassed swales, this BMP should be used in combination with other treatment controls as it will not treat the entire "treatment volume".

6.4 Treatment Controls

6.4.1 Treatment Control Alternatives

Treatment controls can be broadly categorized as either treatment devices (such as sand filters and oil/water separators) or as detention/retention devices designed to pool water for a certain period and remove either suspended or dissolved pollutants. For detention devices, the goal is to detain the water quality volume (determined through analysis of rainfall records) for a period of 24 to 48 hours. This allows approximately 90 percent of suspended solids (and most objectionable pollutants) to be captured in the device. For retention devices, the water quality volume is retained on the order of 7 to 14 days in order for biological uptake of dissolved constituents to occur. There are numerous variations of BMPs based on these principles. Assessing, selecting, and designing an urban runoff management program using BMPs is, in many ways, as much an art as engineering is a science. Experience nationwide with BMPs (i.e., what works and in what context) is less than desired, but expanding rapidly. Nevertheless, there is sufficient experience to indicate what BMPs are likely to be effective. BMPs were screened for applicability and appropriateness for the Big Creek watershed based on the following knowledge sources:

- Input from each of the affected jurisdictions in the Big Creek watershed (Fulton County, Forsyth County, Cherokee County and the Cities of Roswell, Alpharetta, and Cumming) on current BMP use and preferences;

- WEF/ASCE Urban Runoff Water Quality Management manual of practice (ASCE/WEF 1998);

- Draft material produced for the State of Georgia BMP Manual (ARC 1999) currently in development;

- ASCE/WERF nationwide study on BMP performance (ASCE/WEF 1999);

- Other regional BMP guidance efforts (California Statewide Handbooks, Texas Nonpoint SourceBook, North Central Texas BMP Manuals, etc.); and

- Camp Dresser & McKee experience.

It is important to recognize that there are numerous variations in the design of treatment controls, including the hybridization of one or more specific type of control. Furthermore, design of treatment controls must address more than just water quality concerns. Channel protection, overbank flood protection, and extreme storm performance must be addressed as well. This information will be provided in the recommended design in the Watershed Management Plan report.

For the purposes of this consideration however, five basic types of treatment controls seem the most applicable to the Big Creek watershed: extended detention, retention, detention with filtration, constructed wetlands, and retrofitting.

6.4.1.1 Extended detention

Extended detention ponds provide from 24 to 48 hours of detention for the water quality volume and the entire water quality volume is drained from the pond to prepare for the next event. The pollutant removal is primarily through solids settling. Extended detention ponds may be dry between events or may have a permanent pool of water for aesthetic purposes. They may also exist as a series of multiple ponds or micro-pools. This method of treatment should not be used in flat areas, and if standing water occurs in the basin, it will become a nuisance due to mosquito breeding.

Extended detention can be easily integrated with water quantity management needs and it is anticipa ted that extended detention will be one of the most cost-effective means to meet the water quality needs in the Big Creek watershed. They are usually less expensive than other pond options, but the cost is influenced mainly by the type of outlet, and the landscaping used in the basin. **Figure 6-1** presents a schematic of a typical extended detention pond.

6.4.1.2 Retention

Retention ponds provide detention of runoff for several more days than the extended detention pond to allow for uptake of nutrients and other dissolved constituents. As

such, retention ponds (often called wet ponds) maintains a permanent pool of water and generally have areas where aquatic plants thrive (a littoral zone). Retention can also be easily integrated with quantity management goals.

It is doubtful that existing or future water quality needs in the Big Creek watershed will necessitate widespread application of retention. However, because it lends itself to the development of aesthetically pleasing water features, jurisdictions may find numerous opportunities where it is beneficial to apply retention devices. Retention may not be a feasible solution for dense urban areas due to space constraints. Care should also be taken with locating retention ponds so that a loss of wetlands or forest does not occur. If the pond has the potential to impact wetlands, permitting costs may be substantial. Cost may vary considerable, depending on the design of the

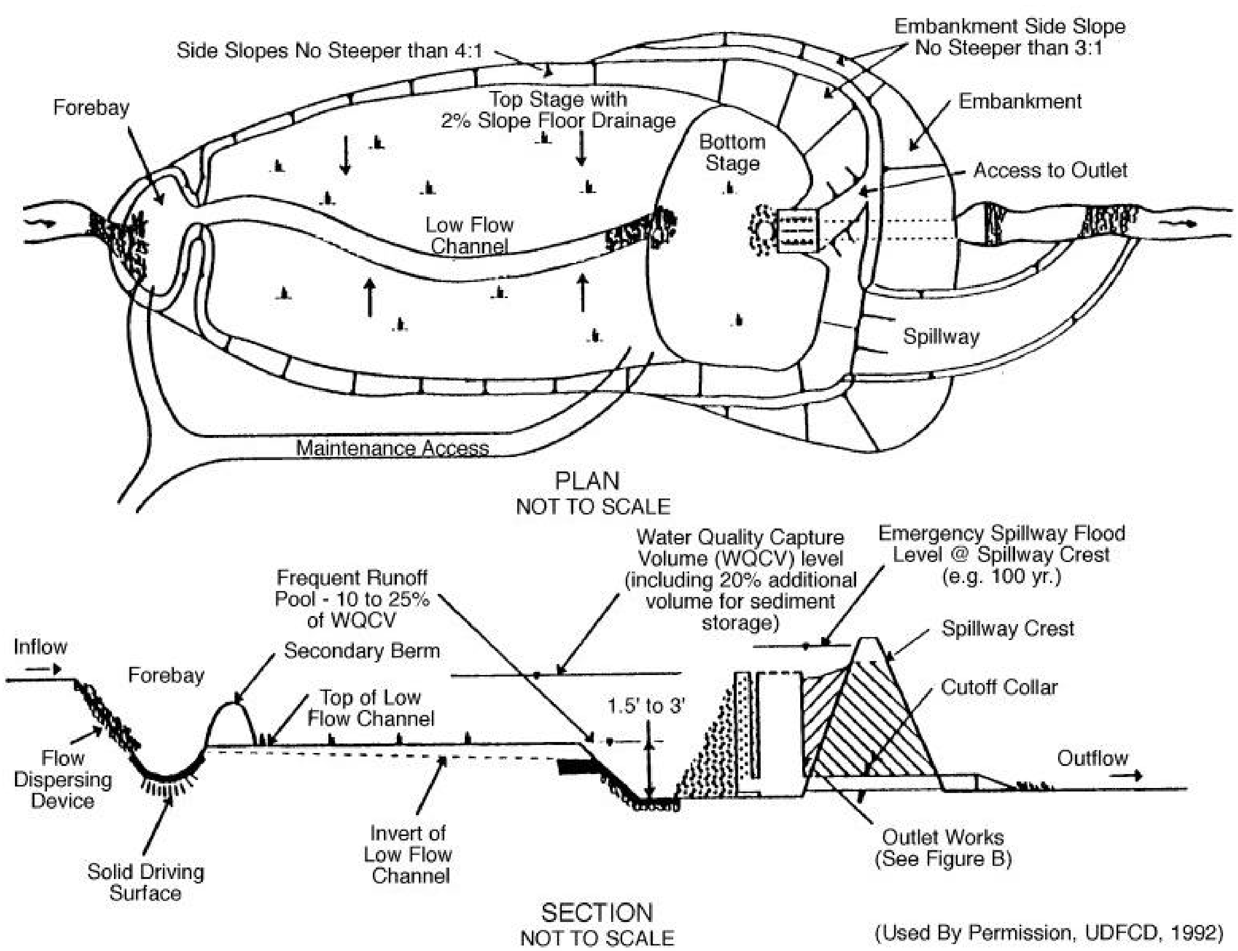


Figure 6-1
Schematic of Extended Detention Pond

pond. If wetland vegetation is provided, it may need to be replanted in subsequent seasons. **Figure 6-2** presents a schematic of a typical retention pond.

6.4.1.3 Constructed Wetlands

In a sense, constructed wetlands are retention devices with increased littoral zones. Constructed wetlands will have less open water surface and will have increased pollutant removal capability (for the same hydrologic capacity of a retention basin) because of the increased amount of aquatic plants. As with retention devices, widespread application of constructed wetlands is not seen as necessary for the Big Creek watershed, but opportunities to use constructed wetlands for habitat enhancement and replacement will be found in the watershed.

Constructed wetlands are inappropriate in dense urban areas outside of floodplains due to space concerns. Since they consume more space than any other BMP, the cost of land may substantially increase the construction cost, depending on the location. The cost of replanting vegetation may also be substantial.

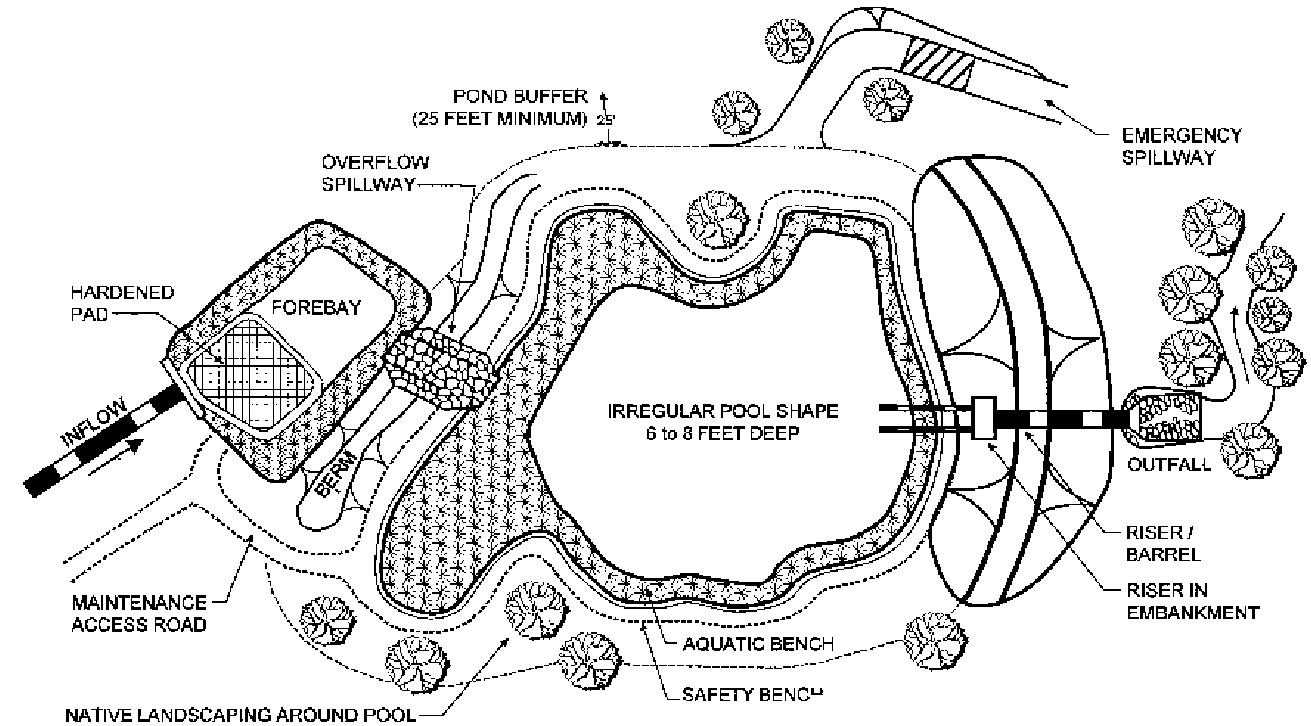
6.4.1.4 Detention with filtration

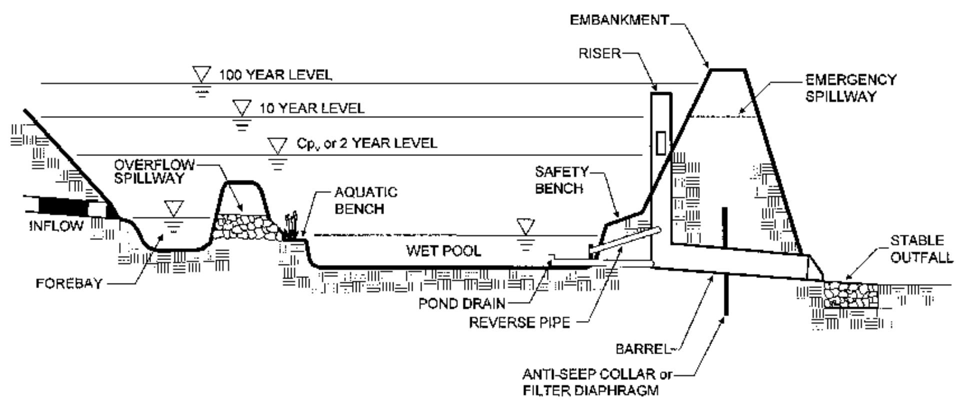
Detention with filtration combines the detention of the water quality volume with an enhanced means to remove suspended solids (through a sand filter) making this device well suited for commercial or industrial applications where space is limited. Once filtered, runoff is released to waterways. Soluble pollutants are not removed by this control. Filtration devices cannot generally be cost-effectively integrated with quantity management concerns and are best applied on a development-by-development basis. **Figure 6-3** presents a schematic of a typical detention with filtration device.

Experience with this application is that, if not designed with a vegetative surface (grass, etc.), plugging of the filter occurs rapidly without yearly maintenance. No active construction can be allowed upstream of the device or it will plug. Filters with vegetative covers may not need to be maintained annually, but if not maintained properly the facilities will fail (as opposed to being reduced in efficiency). Maintenance costs are significantly higher for this type of control than for other controls (e.g. Extended Detention). However the land requirements for these controls are significantly less than for other controls.

6.4.1.5 Retrofits

All existing detention facilities in the watershed should be inventoried and assessed for their water quality and quantity benefits. Furthermore, each facility should be assessed for opportunities to improve water quality performance while maintaining (and certainly not worsening) any quantity management requirements of the facility. For example, inlet and outlet structures can be reconfigured to improved water quality performance during smaller storms. Retrofits are often the most cost-effective means of addressing water quality from already developed areas. The City of





PROFILE

Figure 6-2
Schematic of Typical Retention Pond

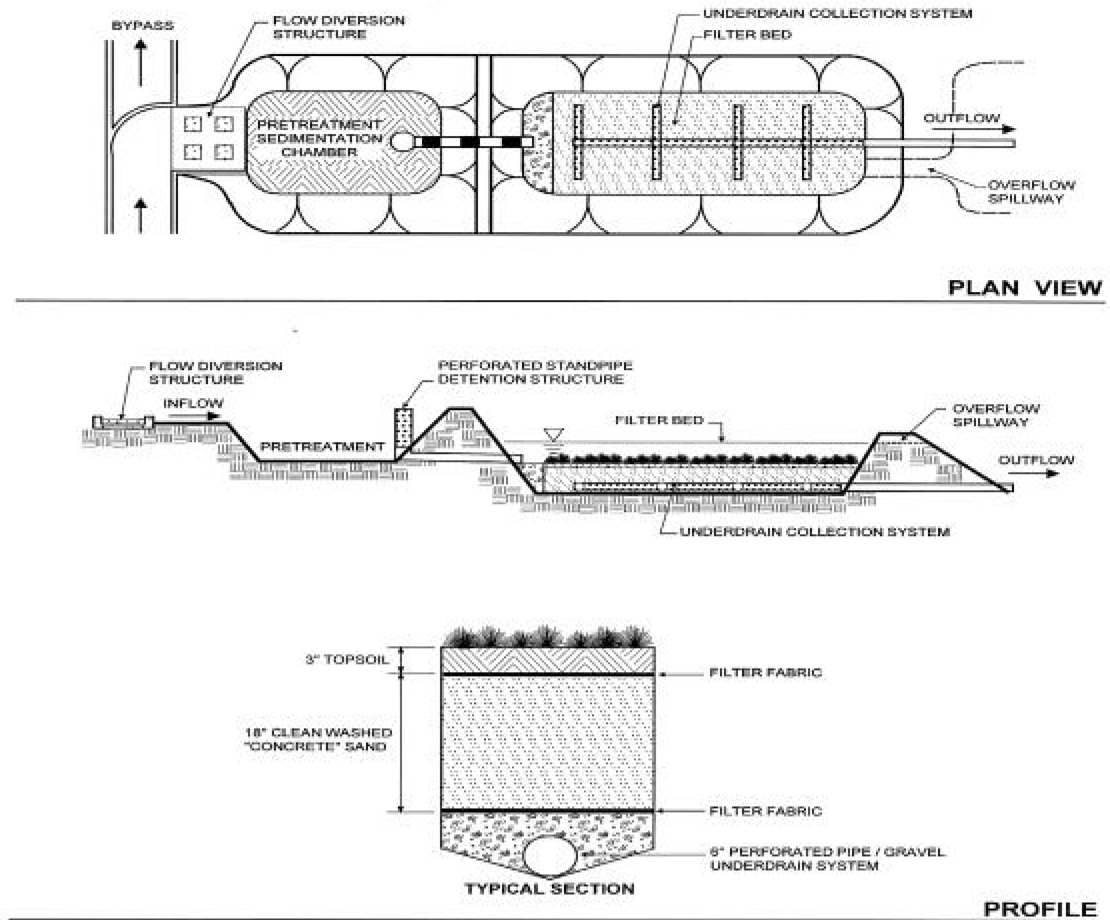


Figure 6-3
Schematic of Typical Detention with Filtration

Roswell Lakes and Parks and Demonstration Programs are examples of retrofit alternatives.

6.5 Pollutant Removal Efficiencies

The removal efficiencies used in this project for the various BMPs are detailed in **Table 6-1.** These are mid ranged values obtained from a literature review and CDM's professional experience. Some variation in the performance can be expected due to individual site conditions, design variations, and maintenance procedures.

Table 6-1
Source and Treatment Control Removal Efficiencies (%)

Control Type	TSS	Total Nitrogen	Total Phosphorus	Metals	Bacteria
Limiting Impervious Area	NA	NA	NA	NA	NA
Swales	10	10	10*	10	10*
Filter Strips	10	10	10*	10	10*
Extended Detention	70	30	10	30	70
Retention	70	40	50	50	70
Wetlands	90	50	60	60	70
Filtration	90	50	50	30	50

* unknown, estimated

6.6 Design Criteria and O&M Requirements for Selected Treatment Controls

It is quite important to recognize that source and treatment controls are only as effective as their design and construction. Particularly important to treatment devices are the inlet and outlet structures. It is highly recommended that any jurisdiction-employing source and/or treatment controls develop detailed design guidance or, better yet, detailed design criteria to insure that infrastructure performs as expected. Numerous communities have found that infrastructure installed without robust design and construction requirements quite often does not provide the expected water quality benefit and becomes an operation and maintenance burden for the community.

Design of BMPs centers on "sizing" the BMP for water quality and quantity purposes for determining the water quality capture volume, the methodology presented in the WEF Manual of Practice No. 23 was used. This is consistent with the methodology used in the ARC Stormwater Design Manual. The capture volume varies according to the percent impervious area. For details, refer to the ARC Stormwater Design Manual.

For water quantity control, the BMPs are typically designed for the 25-year design storm. BMPs designed to control larger storm events are generally not cost effective. The same thing holds true for channel protection and overbank flood protection. However, for the extreme storm sizing criteria, the design storm used will vary on a case-by-case basis up to a 100-yr storm. Once again, the ARC Stormwater Design Manual should be consulted for details on the sizing.

Proper operation and maintenance of treatment controls has a large impact on long-term effectiveness. The condition treatment controls should be tracked and operation and maintenance decisions should be proactively made on the basis of known need rather than solely on the basis of complaints of flooding, erosion, or pollution. **Table 6-2** details the annual operation and maintenance requirements and the cost associated with them. For example, grass swales have a life cycle of 50 years and the annual operation and maintenance consists of approximately $0.75 / linear foot in order to maintain the grass cover by reseeding or applying additional sod. Expected useful life is also presented and is used to determine the present worth cost of each of the BMPs.

Table 6-2
Level of Annual Operation and Maintenance Requirements and Associated Costs*

Control Type	O&M Requirements	Annual Cost	Units
Limiting Impervious Area	None	0	NA
Swales	Low	1.10	$/linear foot
Filter Strips	Low	.90	$/liner feet
Extended Detention	70	3 - 5	percent of capital cost
Retention	70	3 - 5	percent of capital cost
Wetlands	90	3 - 5	percent of capital cost
Filtration	90	7	percent of capital cost

*Cost estimates from EPA -840-B-92-002,Coastal Zone Guidance Manual , January 1993 and adjusted for inflation

Below is a summary of the design criteria and O&M requirements associated with each of the requirement source and treatment controls.

6.6.1 Swales

Key Design Criteria: The following design criteria apply to swales:

- The minimum width for a swale is determined by Manning's Equation.
- The longitudinal slope must not be exceed 5%.
- Use a flow spreader and energy dissipator at the entrance of a swale.

- Use check dams to control velocity and reduce channeling.
- Maximum velocity - 1 foot per second for water quality management.
- Maximum velocity - 3 feet per second for erosion control.
- Maximum flow depth - 6 inches.

Inspection/Maintenance Considerations: Swales should be inspected annually for erosion.

6.6.2 Filter Strips

Key Design Criteria: They should be designed for sheet flow and provides dense vegetation so that erosion does not occur.

Inspection/Maintenance Considerations: Filter strips should also be inspected semi-annually for signs of erosion.

6.6.3 Extended Detention Ponds

Key Design Criteria: Basin size (for water quality) is computed using the "treatment volume" computed by the Maximized Water Quality Volume Approach (ASCE/WEF 1998). Add 2 to 3 feet of freeboard for safety. Design the pond with a length to width ratio of at least 2:1. Side slopes should be relatively flat (3:1 to 5:1). Provide a low flow channel to convey trickle flow and the last of the captured volume to the outlet. Provide a sediment forebay to trap incoming sediment and make maintenance easier. A vertical rock filter is a useful option to create a forebay to presettle heavier solids. Make certain that the inflow does not short circuit through the basin. A sediment forebay with rock filter will prevent short-circuiting. Baffles can be installed at the inlet, but this is not commonly done. Use a non-clogging outlet such as a reverse slope pipe, perforated riser, or v-notch weir. If necessary provide a trash rack or gravel pack to keep the outlet from becoming clogged. Design the embankment so it will not fail during large storms. Provide an emergency spillway that will pass the 100-yr flood. Stabilize the outfall of the basin to prevent channel erosion.

Inspection/Maintenance Considerations: Inspect after construction to ensure that sediment has not reduced the treatment capacity. Thereafter inspect monthly for trash, debris and organic matter, and remove if necessary. Inspect vegetation monthly and mow when necessary (grass at 3"-6") to prevent woody vegetation from developing (unless designed as such). Inspect inlet and outlet annually and repair when necessary. Remove sediment from thepond or forebay approximately every seven years, or when half of the forebay depth is filled with sediment. Dredge the entire pond when necessary.

6.6.4 Retention Ponds

Key Design Criteria: Basin size (for water quality) is computed using the lake eutrophication theory, or a professional should be consulted for proper sizing. Provide a sediment forebay to trap incoming sediment and make maintenance easier. Provide maintenance access to the forebay. Conduct a water balance to ensure that a sufficient inflow is available to maintain the permanent pool. Design the pond with a length to width ratio of at least 2:1. Design the pond so that runoff has a long flow path through the system. Design the pond with relatively flat (3:1 to 5:1) side slopes. Consider using multiple ponds in series, or using a pond with another BMP as part of a "treatment train" approach to pollutant removal. Consider a larger water quality volume to achieve greater phosphorous removal. Use a non-clogging outlet such as a reverse slope pipe. Stabilize the outfall of the pond to prevent channel erosion. Provide an aquatic bench of plantings along the shore of the pond. Preserve a vegetated buffer around the pond. Provide a pond drain to draw down the pond for maintenance.

Inspection/Maintenance Considerations: Inspect permanent pool monthly for trash, debris and floating organic matter, and remove if necessary. Inspect after construction to ensure that sediment has not reduced the treatment capacity. Inspect inlet and outlet annually and repair when necessary. Remove sediment from the forebay approximately every seven years, or when half of the forebay depth is filled with sediment. Dredge the entire pond once every twenty years.

6.6.5 Detention with Filtration

Key Design Criteria: A sand filter should not be installed by itself. A sedimentation basin is required for settling of gross solids and capture of floatables. Design the filter to be off-line of the main drainage system, so that flows in excess of the water quality design storm bypass the basin. Where possible direct runoff across filter strips and through swales on its way to this control in order to provide an opportunity for solids to be removed by these source controls. Do not use this BMP if there is active construction upstream, unless there are excellent site controls for capturing sediment from construction runoff. See ASCE/WEF 1998 reference for sizing and design guidance.

Inspection/Maintenance Considerations: Inspect monthly for trash and remove if necessary. Frequent maintenance is required to remove sediment that accumulates on the filter and to keep the control operational. Filter surfaces with vegetative cover have significantly longer maintenance intervals.

6.6.6 Constructed Wetlands

Key Design Criteria: The guidelines of the retention pond apply to the shallow marsh as well. Because of the complexity of these systems, professional design assistance should be sought. Design with a deep forebay at the inlet and "micropool" at the outlet. Use "complex microtopography" in the wetland. In other words, design the wetland so that zones of both very shallow (<6") and moderately shallow (<18") wetlands are incorporated. This design will provide a longer flow path through the wetland to encourage settling. It also provides two depth zones to encourage plant diversity. Provide shallow marsh areas using structures such as coconut rolls, fascines and straw bales. Wetland vegetation can be established using "wetland mulch" with seeds. Provide maintenance access to the forebay, and on-site sediment disposal. Preserve a vegetated buffer around the wetland. Provide a variety of wetland plant species to encourage plant diversity. Provide a detailed "pondscaping" plan. Only plant wetland species during the optimal planting season (usually during the spring). It is preferable to stock wetlands with native species.

Inspection/Maintenance Considerations: Inspect monthly for trash, debris and floating matter, and remove if necessary. Provide "reinforcement plantings" in subsequent years if there is significant wetland plant die-off. Inspect after construction to ensure that sediment has not reduced the treatment capacity. Inspect inlet and outlet annually and repair when necessary. Remove sediment from the forebay approximately every seven years, or when half of the forebay depth is filled with sediment. Remove invasive vegetation when necessary.

6.7 Deployment of Treatment Controls

Figure 6-4 illustrates the two different approaches that can be taken for deployment of structural BMPs for watershed protection. Storage can be provided as on-site or regional. For on-site facilities local developers will have the responsibility for building and maintaining the BMPs. The jurisdiction will review the constructed facility to ensure conformance with the destine, and ensure that a maintenance plan is implemented. For the regional approach, BMPs will be strategically sited to control nonpoint pollution loadings from multiple development projects. BMP capital cost would be recovered from upstream developers as a “pro-rata” basis as development occurs. The local jurisdiction will maintain the facility. Generally, individual facilities will be phased in as development occurs rather than constructed at one time.

The regional facilities provide equal water quality benefits and are provided at a lower cost. Most of the advantages of the regional approach over the onsite approach can be attributed to the need for fewer structural facilities, which are strategically located throughout the watershed. The specific advantages of the regional approach are summarized below.

- ***Reduction in capital costs*** for structural BMPs: A single stormwater detention facility controls runoff from 5 to 15 development sites within a larger (typically 100 - 300 acre) subwatershed. This permits the local government to take advantage of economies-of-scale in designing and constructing the regional facility. In other words, the total capital cost (i.e., land acquisition, engineering design, construction) of several small, onsite detention BMPs is greater than the cost of a single, regional detention basin BMP which provides the same total storage volume.

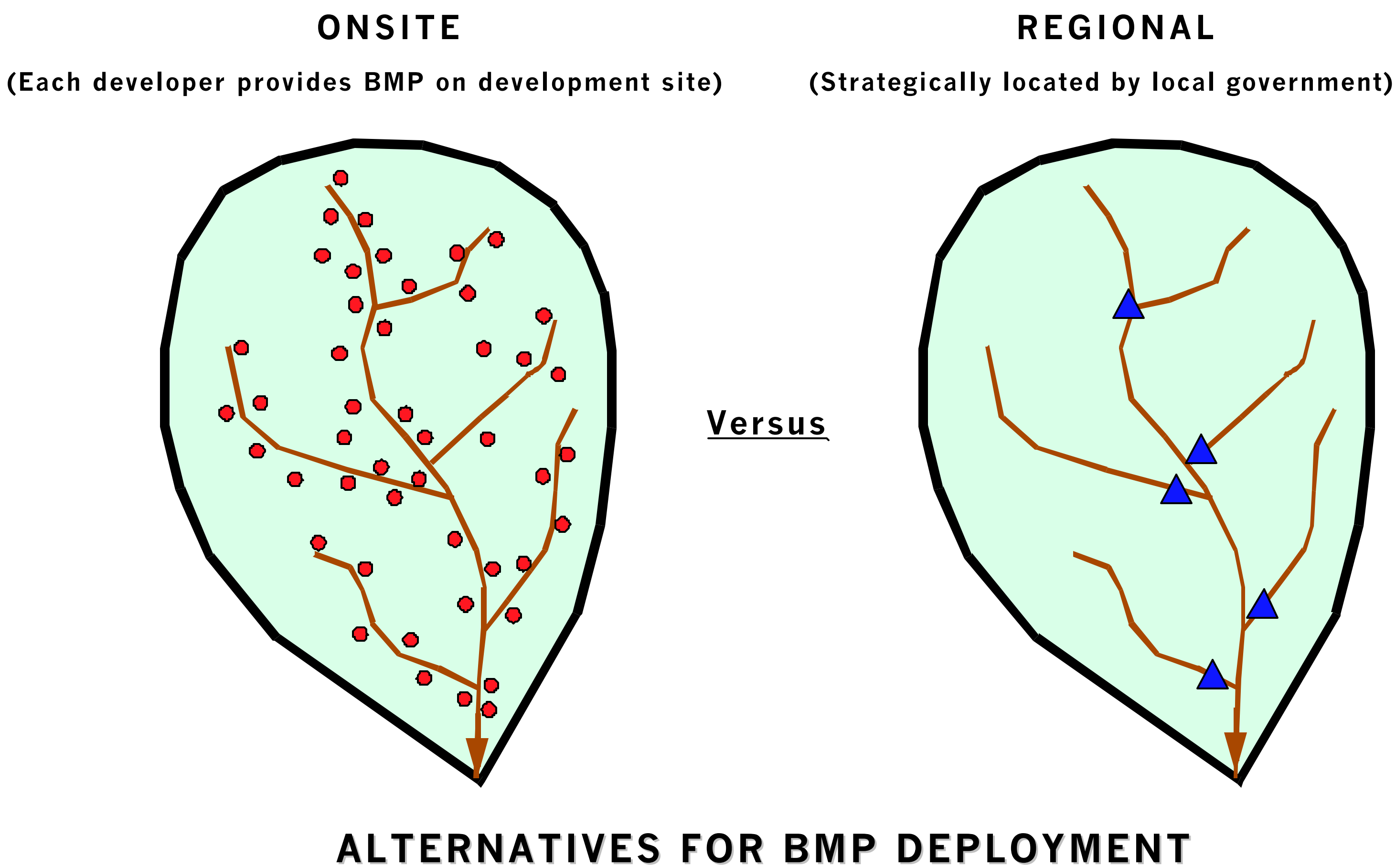


Figure 6-4
Regional vs Onsite BMPs

- ***Reduction in maintenance costs***: Fewer stormwater detention facilities significantly lower the annual cost of maintenance programs. Regional detention facilities designed to facilitate maintenance activities further reduce annual maintenance costs in comparison with onsite facilities.

- ***Greater reliability***: A regional BMP system will be more reliable than an onsite BMP system because it will be more likely to be maintained. With fewer facilities to maintain and design features which reduce maintenance costs, the regional BMP approach is much more likely to result in an effective long-term maintenance program. Due to the greater number of facilities, the onsite BMP approach tends to result in a large number of facilities that are not adequately maintained and therefore soon cease to function as designed.

- ***Opportunities to manage existing nonpoint pollution loadings***: Nonpoint pollution loadings from existing developed areas can be affordably controlled at the same regional facilities, which are sited to control future urban development. The costs of retrofitting existing development sites with onsite detention BMPs to control existing nonpoint pollution loadings would be more expensive.

- ***Popularity among land developers***: Land developers recognize that economies-of-scale available at a single regional BMP facility should produce lower capital costs in comparison with several onsite detention facilities. They also tend to prefer the regional BMP approach, because it eliminates the need to set aside acreage for an onsite facility, and often allows them to construct an increased number of dwelling units.

The major disadvantages of the regional BMP approach include the requirement of up front planning. Local governments must perform planning studies to locate and develop preliminary designs for regional BMP facilities. They may be required to finance, design, and construct the regional BMP facilities before the majority of future urban development occurs, with reimbursement by developers over a build-out period that can be 15-25 years in duration. In some cases, local governments may be required to carry out extraordinary maintenance activities for regional BMPs that are perceived by the public to be primarily recreational facilities that merit water quality protection.

6.8 Other Watershed Practices

6.8.1 Streambank Stabilization

Streambank stabilization applies bioengineering techniques to stabilize eroding channel banks while maintaining the existing overall channel alignment. Soil bioengineering uses woody vegetation installed in specific configurations that offer immediate erosion protection, reinforcement of soils, and over time provide streambanks with a woody vegetative surface cover (e.g., scrubs and trees) and extensive root network. Soil bioengineering can be implemented in combination with other stabilization techniques. Other stabilization techniques include revegetation with grasses or woody vegetation using erosion control fabrics, and use of rockwork in conjunction with vegetation. In contrast with conventional riprap or channel armoring, this technique employs limited use of rock such that the streambank eventually appears and functions more naturally. The advantage of this type of streambank stabilization is that the stream can be restored to a more natural aesthetically pleasing condition that provides environmental benefits such as improved habitat for fish and wildlife. Streambank stabilization is only a temporary solution for stream channel systems that are actively adjusting to a new flow regime. Unstable channel reaches downstream of recently developed areas are not good candidates for streambank stabilization projects. Costs for streambank stabilization range from $25 to $75 per linear foot of stream depending on the streambank height, access to the site, necessary grading, and balance of cut and fill.

6.8.2 Stream Restoration

Stream restoration applies physical and geomorphological principles to redesign stream channel geometry so that the channel stability and habitat quality are maintained while the stream system is able to convey flows and sediments discharged from the upstream watershed. This alternative is a more permanent solution to address stream degradation problems than streambank stabilization alone. The design objective of stream restoration is often expressed in terms of Rosgen class. For example the objective of a certain project might be to restore a Class F channel back to a more stable Class C. Stream restoration requires preliminary and final design, hydrologic and hydraulic analyses, permitting, construction drawings and specifications, construction and construction management. Immediately after construction, the restored stream channel will be vulnerable to damage until vegetation has had an opportunity to root and mature. A minimum of two years of monitoring and maintenance are recommended to periodically identify damage and perform repairs after completion of a stream restoration project. Costs for stream restoration to achieve a more stable Rosgen class range from $75 to $200 per linear foot depending on site-specific conditions including bank heights, required grading and site access.

Section 7
Analysis of
Watershed Management Scenarios

7.1 Description of Scenarios

This section presents a set of alternative watershed management scenarios and summarizes the water quantity, water quality, habitat and social impacts of each. These scenarios serve to illustrate the benefits of different management approaches and to determine whether they adequately met water quality goals. Each watershed management scenario is comprised of a collection of source controls and/or treatment control Best Management Practices. The objective of this analysis was to identify the most appropriate management option based on the relative comparison of alternatives. A more robust analysis of impacts and costs of the recommended management approach are included in Section 8 – Recommended Watershed Management Plan.

There are also a number of pollution prevention controls that are applicable to the watershed. Pollution prevention controls are considered to be common sense elements of a watershed management plan. This, coupled with the fact that it is very difficult (if not impossible) to directly measure and model the effectiveness of these practices (ASCE/WEF 1998), dictates that these practices will not be directly assessed in the management scenarios. Pollution prevention controls include:

- Public education – reduces polluting activities, but also reinforces importance of community programs for watershed management with citizens;

- Illicit connection detection and removal – programs to keep sanitary flows in the sanitary sewer system (or septic system) and storm water confined to surface drainage infrastructure; and

- Management of construction and industrial activities – encouraging owner/operators of these facilities to comply with NPDES storm water permit requirements.

- Drainage system operation and maintenance -- encouraging owner/operators of these facilities to comply with NPDES storm water permit requiring drainage infrastructure, including treatment controls must be operated and maintain in a manner that is conducive to long-term water quality management. Improperly operated and maintained infrastructure can exacerbate problems.

- The effectiveness of the source controls recommended (swales, filter strips, and impervious area limitations) is generally understood and will be a part of the management scenario evaluations. The recommended treatment controls (extended detention, detention with filtration, retention, constructed wetlands, and retrofits of existing infrastructure) are the most understood practices and will also be assessed in the management scenarios.

7.1.1 Scenario 1: Status Quo - Future Land Use with Existing Controls

This alternative will assess where the watershed will be in the year 2020 if there are no additional requirements put in place. It is the analysis of future land use conditions accounting for existing policies, ordinances, and regulations. The local guidelines considered in this and subsequent scenarios were detailed in Section 3.

7.1.2 Scenario 2: Limit Impervious Area to Achieve Water Quality Goals

This scenario will identify the maximum amount of watershed impervious area that could occur before source water quality is impaired based on water quality targets set for this study. The State requirement is 25 percent. Other studies, such as the Big Haynes Creek Study, suggest the limit might be less than the State requirement. Water quality targets were established for lead, zinc and fecal coliform to evaluate this scenario and are presented in **Table 7-1** along with the State of Georgia current water quality standards. Lead and zinc are two parameters that are relatively well understood. Because of the variability inherent in watersheds and because of Total Maximum Daily Load requirements, it is important to include a margin of safety in the watershed water quality targets. Therefore the reduced concentrations shown in Table 7-1 are the recommended water quality goals. Pathogens targets are more problematic due to the deficiency of fecal coliform as an indicator parameter in the watershed. However, relative performance of the scenarios can be gauged against the current water quality standard. No margin of safety is recommended.

Management of nutrients, toxics, and pathogens are desired in the watershed. While euthrophication from excessive amounts of nutrient is not an issue watershed-wide, it can be problematic for smaller impoundments. Management strategies that address the water quality goals below will also drive nutrient management.

7.1.3 Scenario 3: Jurisdictions at 25% or Existing Impervious Area (whichever is greater)

This scenario assessed limiting all five jurisdictions to 25 percent impervious coverage each, but recognized exceedances that currently exist. **Tables 7-2** and **7-3** illustrate the land use characteristics associated with the years 1995 and 2020 respectively. **Table 7-4** illustrates the land use characteristics associated with this scenario and **Table 7-6** summarizes the differences in developed and undeveloped lands between different scenarios.

Table 7-1
Recommended Water Quality Goals for Big Creek

Goals/Consideration	Dissolved Mean Concentration		Fecal Coliform (MPN/100ml)
	Lead (ug/L)	Zinc (ug/L)	
State of Georgia Water Quality Standards [a]	1.2	58	200
Recommended Water Quality Goal – Based on State Standards with Margin of Safety[b]	**1.0**	**30**	**200**

Notes:
[a] Based on State of Georgia receiving water quality chronic toxicity standards for lead and zinc (assumes hardness levels less than 100 mg/L).

[b] No margin of safety is recommended for fecal coliform.

7.1.4 Scenario 4: Watershed at 25% Impervious

This scenario assessed limiting the total watershed impervious area to 25%. This scenario consisted of limiting jurisdictions exceeding 25% impervious to their 1995 impervious area and increasing the impervious area of the remaining jurisdictions to an equivalent percent impervious area, such that impervious area watershed-wide is 25 percent. **Table 7-5** shows the area associated with each land use for the individual jurisdictions used for this analysis.

Table 7-6 summarizes the differences in developed and undeveloped lands between different scenarios.

7.1.5 Scenario 5: Future Land Use with Source Controls Only

This scenario assessed the benefits of applying source controls to areas of new development based on the future (2020) land use projections for the watershed. Source controls were presented because they help reduce the pollutant load before it enters the stream. Unless otherwise indicated in a jurisdiction, a minimum buffer of 100 feet was applied. Swales were applied to all new residential development and filter strips were applied to all new commercial and industrial development. **Table 7-7** summarizes the pollution reduction for the various source controls.

Table 7-2
Land Use and Impervious Area Percentages in the Big Creek Watershed
Year 1995

JURISDICTION	DESCRIPTION	Total Acres	Impervious Percent	Total Impervious Area
City of Alpharetta	Ag/Pasture and Cropland	1,122	0.5%	5.61
	Commercial	923	85.0%	784.55
	Heavy Industrial	145	80.0%	116.00
	Major Roads	408	90.0%	367.20
	Office/Light Industrial	385	70.0%	269.50
	Open/Forest	4,132	0.5%	20.66
	SF Res (0.25 - 0.4 ac lot size)	1,194	26.0%	310.44
	SF Res (0.5 - 1.0 ac lot size)	1,764	21.0%	370.44
	SF Res (1.1 - 2.0 ac lot size)	690	12.0%	82.80
	SF Res (2.1 - 5.0 ac lot size)	607	10.0%	60.70
	Townhome/Apartment	432	48.0%	207.36
	Water Bodies	224	0.0%	0.00
Alpharetta Total		**12,026**	**21.6%**	**2,595**
Cherokee County	Ag/Pasture and Cropland	699	0.5%	3.50
	Commercial	37	85.0%	31.45
	Heavy Industrial	12	80.0%	9.60
	Open/Forest	179	0.5%	0.90
	SF Res (0.5 - 1.0 ac lot size)	31	21.0%	6.51
	SF Res (1.1 - 2.0 ac lot size)	17	12.0%	2.04
	SF Res (2.1 - 5.0 ac lot size)	170	10.0%	17.00
	Water Bodies	2	0.0%	0.00
Cherokee Total		**1,147**	**6.2%**	**71**
City of Cumming	Ag/Pasture and Cropland	285	0.5%	1.43
	Commercial	535	85.0%	454.75
	Office/Light Industrial	0	70.0%	0.00
	Open/Forest	631	0.5%	3.16
	SF Res (0.25 - 0.4 ac lot size)	120	26.0%	31.20
	SF Res (0.5 - 1.0 ac lot size)	28	21.0%	5.88
	SF Res (1.1 - 2.0 ac lot size)	204	12.0%	24.48
	SF Res (2.1 - 5.0 ac lot size)	85	10.0%	8.50
	Townhome/Apartment	0	48.0%	0.00
Cumming Total		**1,888**	**28.0%**	**529**
Forsyth County	Ag/Pasture and Cropland	10,272	0.5%	103.86
	Commercial	1,459	85.0%	1,241.92
	Heavy Industrial	24	80.0%	19.46
	Major Roads	505	90.0%	454.53
	Office/Light Industrial	110	70.0%	76.77
	Open/Forest	13,258	0.5%	133.66
	SF Res (0.25 - 0.4 ac lot size)	175	26.0%	46.64
	SF Res (0.5 - 1.0 ac lot size)	1,449	21.0%	310.11
	SF Res (1.1 - 2.0 ac lot size)	3,151	12.0%	378.16
	SF Res (2.1 - 5.0 ac lot size)	3,134	10.0%	314.22
	Townhome/Apartment	0	48.0%	0.00
	Water Bodies	47	0.0%	46.81
Forsyth Total		**33,584**	**9.3%**	**3,126**
Fulton County	Ag/Pasture and Cropland	997	0.5%	9.97
	Commercial	297	85.0%	252.51
	Heavy Industrial	51	80.0%	41.07
	Major Roads	82	90.0%	73.50
	Office/Light Industrial	37	70.0%	25.89
	Open/Forest	2,358	0.5%	23.58
	SF Res (0.25 - 0.4 ac lot size)	2,486	26.0%	646.23
	SF Res (0.5 - 1.0 ac lot size)	430	21.0%	90.37
	SF Res (1.1 - 2.0 ac lot size)	511	12.0%	61.29
	SF Res (2.1 - 5.0 ac lot size)	984	10.0%	98.41
	Townhome/Apartment	201	48.0%	96.61
Fulton Total		**8,434**	**16.8%**	**1,419**
City of Roswell	Ag/Pasture and Cropland	467	0.5%	2.34
	Commercial	1,175	85.0%	998.75
	Heavy Industrial	163	80.0%	130.40
	Major Roads	77	90.0%	69.30
	Office/Light Industrial	533	70.0%	373.10
	Open/Forest	1,825	0.5%	9.13
	SF Res (0.25 - 0.4 ac lot size)	892	26.0%	231.92
	SF Res (0.5 - 1.0 ac lot size)	2,730	21.0%	573.30
	SF Res (1.1 - 2.0 ac lot size)	334	12.0%	40.08
	SF Res (2.1 - 5.0 ac lot size)	439	10.0%	43.90
	Townhome/Apartment	753	48.0%	361.44
	Water Bodies	46	0.0%	0.00
Roswell Total		**9,434**	**30.0%**	**2,834**
Grand Total		**66,513**	**15.9%**	**10,575**

Table 7-3
Land Use and Impervious Area Percentages in the Big Creek Watershed
Year 2020

JURISDICTION	DESCRIPTION	Total acres	Percent Impervious	Total Impervious Area
City of	Ag/Pasture and Cropland	0	0.5%	0.00
	Commercial	1,319	85.0%	1,121.10
Alpharetta	Heavy Industrial	7	80.0%	5.60
	Major Roads	325	90.0%	292.50
	Office/Light Industrial	3,918	70.0%	2,742.60
	Open/Forest	684	0.5%	3.42
	SF Res (0.25 - 0.4 ac lot size)	3,361	26.0%	873.86
	SF Res (0.5 - 1.0 ac lot size)	760	21.0%	159.60
	SF Res (1.1 - 2.0 ac lot size)	117	12.0%	14.04
	SF Res (2.1 - 5.0 ac lot size)	636	10.0%	63.60
	Townhome/Apartment	675	48.0%	324.00
	Water Bodies	224	0.0%	0.00
Alpharetta Total		**12,026**	**46.6%**	**5,600**
Cherokee County	Ag/Pasture and Cropland	599	0.5%	3.00
	Commercial	47	85.0%	39.95
	Heavy Industrial	12	80.0%	9.60
	Open/Forest	170	0.5%	0.85
	SF Res (0.5 - 1.0 ac lot size)	32	21.0%	6.72
	SF Res (1.1 - 2.0 ac lot size)	115	12.0%	13.80
	SF Res (2.1 - 5.0 ac lot size)	170	10.0%	17.00
	Water Bodies	2	0.0%	0.00
Cherokee Total		**1,147**	**7.9%**	**91**
City of	Ag/Pasture and Cropland	56	0.5%	0.28
Cumming	Commercial	782	85.0%	664.70
	Office/Light Industrial	168	70.0%	117.60
	Open/Forest	88	0.5%	0.44
	SF Res (0.25 - 0.4 ac lot size)	177	26.0%	46.02
	SF Res (0.5 - 1.0 ac lot size)	376	21.0%	78.96
	SF Res (1.1 - 2.0 ac lot size)	102	12.0%	12.24
	Townhome/Apartment	139	48.0%	66.72
Cumming Total		**1,888**	**52.3%**	**987**
Forsyth County	Ag/Pasture and Cropland	4	0.5%	0.02
	Commercial	2,830	85.0%	2,405.50
	Heavy Industrial	0	80.0%	0.00
	Major Roads	1,001	90.0%	900.90
	Office/Light Industrial	2,193	70.0%	1,535.10
	Open/Forest	5,740	0.5%	28.70
	SF Res (0.25 - 0.4 ac lot size)	17	26.0%	4.42
	SF Res (0.5 - 1.0 ac lot size)	20,122	21.0%	4,225.62
	SF Res (1.1 - 2.0 ac lot size)	4	12.0%	0.48
	SF Res (2.1 - 5.0 ac lot size)	0	10.0%	0.00
	Townhome/Apartment	1,627	48.0%	780.96
	Water Bodies	47	0.0%	0.00
Forsyth Total		**33,585**	**29.4%**	**9,882**
Fulton County	Ag/Pasture and Cropland	0	0.5%	0.00
	Commercial	797	85.0%	677.45
	Heavy Industrial	37	80.0%	29.60
	Major Roads	59	90.0%	53.10
	Office/Light Industrial	633	70.0%	443.10
	Open/Forest	486	0.5%	2.43
	SF Res (0.25 - 0.4 ac lot size)	4,261	26.0%	1,107.86
	SF Res (0.5 - 1.0 ac lot size)	1,057	21.0%	221.97
	SF Res (1.1 - 2.0 ac lot size)	46	12.0%	5.52
	SF Res (2.1 - 5.0 ac lot size)	360	10.0%	36.00
	Townhome/Apartment	698	48.0%	335.04
Fulton Total		**8,434**	**34.5%**	**2,912**
City of	Ag/Pasture and Cropland	0	0.5%	0.00
Roswell	Commercial	1,769	85.0%	1,503.65
	Heavy Industrial	0	80.0%	0.00
	Major Roads	52	90.0%	46.80
	Office/Light Industrial	883	70.0%	618.10
	Open/Forest	875	0.5%	4.38
	SF Res (0.25 - 0.4 ac lot size)	2,152	26.0%	559.52
	SF Res (0.5 - 1.0 ac lot size)	3,026	21.0%	635.46
	SF Res (1.1 - 2.0 ac lot size)	58	12.0%	6.96
	SF Res (2.1 - 5.0 ac lot size)	30	10.0%	3.00
	Townhome/Apartment	543	48.0%	260.64
	Water Bodies	46	0.0%	0.00
Roswell Total		**9,434**	**38.6%**	**3,639**
Grand Total		**66,514**	**34.7%**	**23,110**

Table 7-4
Land Use and Impervious Area Percentages in the Big Creek Watershed
25% or Existing Impervious Area

JURISDICTION	DESCRIPTION	Total acres	Percent Impervious	Total Impervious Area	Percent Change in Projected 2020 Land Use	Percent Change in 1995 Land Use
City of Alpharetta	Ag/Pasture and Cropland	0	0.5%	0.00	0%	-100%
	Commercial	702	85.0%	596.45	-47%	-24%
	Heavy Industrial	4	80.0%	2.98	-47%	-97%
	Major Roads	173	90.0%	155.61	-47%	-58%
	Office/Light Industrial	2,084	70.0%	1,459.06	-47%	441%
	Open/Forest	5,887	0.5%	29.44	761%	42%
	SF Res (0.25 - 0.4 ac lot size)	1,788	26.0%	464.89	-47%	50%
	SF Res (0.5 - 1.0 ac lot size)	404	21.0%	84.91	-47%	-77%
	SF Res (1.1 - 2.0 ac lot size)	62	12.0%	7.47	-47%	-91%
	SF Res (2.1 - 5.0 ac lot size)	338	10.0%	33.84	-47%	-44%
	Townhome/Apartment	359	48.0%	172.37	-47%	-17%
	Water Bodies	224	0.0%	0.00	0%	0%
Alpharetta Total		**12,026**	**25.0%**	**3,007**		
Cherokee County	Ag/Pasture and Cropland	0	0.5%	0.00	0%	-100%
	Commercial	186	85.0%	158.10	296%	403%
	Heavy Industrial	13	80.0%	10.40	8%	8%
	Open/Forest	259	0.5%	1.30	52%	45%
	SF Res (0.5 - 1.0 ac lot size)	270	26.0%	70.20	744%	771%
	SF Res (1.1 - 2.0 ac lot size)	247	12.0%	29.64	115%	1353%
	SF Res (2.1 - 5.0 ac lot size)	170	10.0%	17.00	0%	0%
	Water Bodies	2	0.0%	0.00	0%	0%
Cherokee Total		**1,147**	**25.0%**	**287**		
City of Cumming	Ag/Pasture and Cropland	285	0.5%	1.43	409%	0%
	Commercial	535	85.0%	454.75	-32%	0%
	Office/Light Industrial	0	70.0%	0.00	0%	0%
	Open/Forest	631	0.5%	3.16	617%	0%
	SF Res (0.25 - 0.4 ac lot size)	120	26.0%	31.20	-32%	329%
	SF Res (0.5 - 1.0 ac lot size)	28	21.0%	5.88	-93%	-86%
	SF Res (1.1 - 2.0 ac lot size)	204	12.0%	24.48	100%	140%
	SF Res (2.1 - 5.0 ac lot size)	85	10.0%	8.50	-39%	0%
	Townhome/Apartment	0	48.0%	0.00	0%	0%
Cumming Total		**1,888**	**28.0%**	**529**		
Forsyth County	Ag/Pasture and Cropland	4	0.5%	0.02	0%	-100%
	Commercial	2,450	85.0%	2,082.50	-13%	68%
	Heavy Industrial	0	80.0%	0.00	0%	-100%
	Major Roads	1,001	90.0%	900.90	0%	98%
	Office/Light Industrial	1,400	70.0%	980.00	-36%	1173%
	Open/Forest	9,850	0.5%	49.25	72%	-26%
	SF Res (0.25 - 0.4 ac lot size)	17	26.0%	4.42	0%	-90%
	SF Res (0.5 - 1.0 ac lot size)	17,184	21.0%	3,608.64	-15%	1086%
	SF Res (1.1 - 2.0 ac lot size)	4	12.0%	0.48	0%	-100%
	SF Res (2.1 - 5.0 ac lot size)	0	10.0%	0.00	0%	-100%
	Townhome/Apartment	1,627	48.0%	780.96	0%	0%
	Water Bodies	47	0.0%	0.00	0%	0%
Forsyth Total		**33,584**	**25.0%**	**8,407**		
Fulton County	Ag/Pasture and Cropland	0	0.5%	0.00	0%	-100%
	Commercial	575	85.0%	488.38	-28%	93%
	Heavy Industrial	27	80.0%	21.31	-28%	-48%
	Major Roads	42	90.0%	38.23	-28%	-48%
	Office/Light Industrial	456	70.0%	319.03	-28%	1132%
	Open/Forest	2,712	0.5%	13.56	458%	15%
	SF Res (0.25 - 0.4 ac lot size)	3,068	26.0%	797.66	-28%	23%
	SF Res (0.5 - 1.0 ac lot size)	761	21.0%	159.82	-28%	77%
	SF Res (1.1 - 2.0 ac lot size)	33	12.0%	3.97	-28%	-94%
	SF Res (2.1 - 5.0 ac lot size)	259	10.0%	25.92	-28%	-74%
	Townhome/Apartment	503	48.0%	241.23	-28%	150%
Fulton Total		**8,434**	**25.0%**	**2,109**		
City of Roswell	Ag/Pasture and Cropland	0	0.5%	0.00	0%	-100%
	Commercial	1,371	85.0%	1,165.35	-22%	17%
	Heavy Industrial	0	80.0%	0.00	0%	-100%
	Major Roads	40	90.0%	36.27	-23%	-48%
	Office/Light Industrial	684	70.0%	479.03	-23%	28%
	Open/Forest	2,790	0.5%	13.95	219%	53%
	SF Res (0.25 - 0.4 ac lot size)	1,668	26.0%	433.63	-23%	87%
	SF Res (0.5 - 1.0 ac lot size)	2,345	21.0%	492.48	-23%	-14%
	SF Res (1.1 - 2.0 ac lot size)	45	12.0%	5.39	-23%	-87%
	SF Res (2.1 - 5.0 ac lot size)	23	10.0%	2.33	-23%	-95%
	Townhome/Apartment	421	48.0%	202.00	-23%	-44%
	Water Bodies	46	0.0%	0.00	0%	0%
Roswell Total		**9,434**	**30.0%**	**2,830**		
Grand Total		**66,513**	**25.8%**	**17,170**		

Table 7-5
Land Use and Impervious Area Percentages in the Big Creek Watershed
(Watershed @ 25%)

JURISDICTION	DESCRIPTION	Total acres	Percent Impervious	Total Impervious Area	Percent Change in Projected 2020 Land Use	Percent Change in 1995 Land Use
City of Alpharetta	Ag/Pasture and Cropland	0	0.5%	0.00	0%	-100%
	Commercial	671	85.0%	570.67	-49%	-27%
	Heavy Industrial	4	80.0%	2.85	-49%	-98%
	Major Roads	165	90.0%	148.88	-49%	-59%
	Office/Light Industrial	1,994	70.0%	1,395.98	-49%	418%
	Open/Forest	6,143	0.5%	30.71	798%	49%
	SF Res (0.25 - 0.4 ac lot size)	1,711	26.0%	444.79	-49%	43%
	SF Res (0.5 - 1.0 ac lot size)	387	21.0%	81.24	-49%	-78%
	SF Res (1.1 - 2.0 ac lot size)	60	12.0%	7.15	-49%	-91%
	SF Res (2.1 - 5.0 ac lot size)	324	10.0%	32.37	-49%	-47%
	Townhome/Apartment	344	48.0%	164.92	-49%	-20%
	Water Bodies	224	0.0%	0.00	0%	0%
Alpharetta Total		**12,026**	**23.9%**	**2,880**		
Cherokee County	Ag/Pasture and Cropland	0	0.5%	0.00	0%	-100%
	Commercial	176	85.0%	149.92	275%	377%
	Heavy Industrial	12	80.0%	9.92	3%	3%
	Open/Forest	301	1.0%	3.01	77%	68%
	SF Res (0.5 - 1.0 ac lot size)	257	21.0%	54.06	704%	730%
	SF Res (1.1 - 2.0 ac lot size)	235	12.0%	28.26	105%	1285%
	SF Res (2.1 - 5.0 ac lot size)	162	10.0%	16.21	-5%	-5%
	Water Bodies	2	0.0%	0.00	0%	0%
Cherokee Total		**1,147**	**22.8%**	**261**		
City of Cumming	Ag/Pasture and Cropland	285	0.5%	1.43	409%	0%
	Commercial	535	85.0%	454.75	-32%	0%
	Office/Light Industrial	0	70.0%	0.00	0%	0%
	Open/Forest	631	0.5%	3.16	617%	0%
	SF Res (0.25 - 0.4 ac lot size)	120	26.0%	31.20	-32%	329%
	SF Res (0.5 - 1.0 ac lot size)	28	21.0%	5.88	-93%	-86%
	SF Res (1.1 - 2.0 ac lot size)	204	12.0%	24.48	100%	140%
	SF Res (2.1 - 5.0 ac lot size)	85	10.0%	8.50	-39%	0%
	Townhome/Apartment	0	48.0%	0.00	0%	0%
Cumming Total		**1,888**	**28.0%**	**529**		
Forsyth County	Ag/Pasture and Cropland	4	0.5%	0.02	0%	-100%
	Commercial	2,334	85.0%	1,983.90	-18%	60%
	Heavy Industrial	0	80.0%	0.00	0%	-100%
	Major Roads	1,001	90.0%	900.90	0%	98%
	Office/Light Industrial	1,400	70.0%	980.00	-36%	1173%
	Open/Forest	11,150	0.5%	55.75	94%	-16%
	SF Res (0.25 - 0.4 ac lot size)	17	26.0%	4.42	0%	-90%
	SF Res (0.5 - 1.0 ac lot size)	16,000	21.0%	3,360.00	-20%	1004%
	SF Res (1.1 - 2.0 ac lot size)	4	12.0%	0.48	0%	-100%
	SF Res (2.1 - 5.0 ac lot size)	0	10.0%	0.00	0%	-100%
	Townhome/Apartment	1,627	48.0%	780.96	0%	0%
	Water Bodies	47	0.0%	0.00	0%	0%
Forsyth Total		**33,584**	**24.0%**	**8,066**		
Fulton County	Ag/Pasture and Cropland	0	0.5%	0.00	0%	-100%
	Commercial	548	85.0%	465.60	-31%	84%
	Heavy Industrial	25	80.0%	20.32	-31%	-50%
	Major Roads	40	90.0%	36.45	-31%	-51%
	Office/Light Industrial	435	70.0%	304.16	-31%	1074%
	Open/Forest	2,972	0.5%	14.86	512%	26%
	SF Res (0.25 - 0.4 ac lot size)	2,925	26.0%	760.46	-31%	18%
	SF Res (0.5 - 1.0 ac lot size)	726	21.0%	152.37	-31%	69%
	SF Res (1.1 - 2.0 ac lot size)	32	12.0%	3.79	-31%	-94%
	SF Res (2.1 - 5.0 ac lot size)	247	10.0%	24.71	-31%	-75%
	Townhome/Apartment	484	48.0%	232.30	-31%	141%
Fulton Total		**8,434**	**23.9%**	**2,015**		
City of Roswell	Ag/Pasture and Cropland	0	0.5%	0.00	0%	-100%
	Commercial	1,396	85.0%	1,186.60	-21%	19%
	Heavy Industrial	0	80.0%	0.00	0%	-100%
	Major Roads	40	90.0%	36.00	-23%	-48%
	Office/Light Industrial	672	70.0%	470.40	-24%	26%
	Open/Forest	2,800	1.0%	28.00	220%	53%
	SF Res (0.25 - 0.4 ac lot size)	1,638	26.0%	425.88	-24%	84%
	SF Res (0.5 - 1.0 ac lot size)	2,303	21.0%	483.63	-24%	-16%
	SF Res (1.1 - 2.0 ac lot size)	103	12.0%	12.36	78%	-69%
	SF Res (2.1 - 5.0 ac lot size)	23	10.0%	2.30	-23%	-95%
	Townhome/Apartment	413	48.0%	198.24	-24%	-45%
	Water Bodies	46	0.0%	0.00	0%	0%
Roswell Total		**9,434**	**30.1%**	**2,843**		
Grand Total		**66,513**	**25.0%**	**16,595**		

Table 7-6
Developed and Undeveloped Areas for Different Scenarios

Jurisdiction	Developed Land 1995 (acres)	Open Space 1995 (acres)	Developed Land 2020 (acres)	Open Space 2020 (acres)	Developed Land 2020 Under Scenario 3 (acres)	Open Space 2020 Under Scenario 3 (acres)	Developed Land 2020 Under Scenario 4 (acres)	Open Space 2020 Under Scenario 4 (acres)
City of Alpharetta	6,548	5,478	11,118	908	5,915	6,111	5,659	6,367
City of Cumming	972	916	1,744	144	972	916	972	916
City of Roswell	7,096	2,338	8,513	921	6,598	2,836	6,588	2,846
Cherokee County	267	880	376	771	886	261	844	303
Forsyth County	10,007	23,577	27,794	5,791	23,683	9,901	22,383	11,201
Fulton County	7,096	2,338	8,513	921	6,598	2,836	6,588	2,846
City of Alpharetta	54%	46%	92%	8%	49%	51%	47%	53%
City of Cumming	51%	49%	92%	8%	51%	49%	51%	49%
City of Roswell	75%	25%	90%	10%	70%	30%	70%	30%
Cherokee County	23%	77%	33%	67%	77%	23%	74%	26%
Forsyth County	30%	70%	83%	17%	71%	29%	67%	33%
Fulton County	75%	25%	90%	10%	70%	30%	70%	30%

Table 7-7
Removal Efficiencies (percent) of Source Control BMPs

Pollutant	**Swales**	**Filter Strips**
BOD	40	30
COD	40	30
TSS	80	60
TDS	10	10
TP	40	30
DP	10	10
TKN	40	30
NO2/3	40	30
Pb	75	60
Cu	50	30
Zn	50	30
Cd	65	30
Fecal	30	20

7.1.6 Scenario 6: Future Land Use with Treatment Controls Only

This scenario assessed the benefits associated with the application of treatment controls to meet water quality goals.

For the purposes of this scenario extended detention (with wet pool) was applied to all new residential and industrial land uses and detention with filtration was applied to commercial land uses. These controls were presented in Section 6 and are assumed to be designed to include a water quality volume as specified in the Georgia Best Management Practices Manual. Based on to Hartsfield Airport historical rainfall, this method will result in the capture of about 90 percent of the average annual rainfall and is the most cost-effective treatment level. The removal efficiencies for the treatment controls evaluated for this project is summarized below in **Table 7-8**.

Retrofitting of existing structures was included in the analysis. Based on previous experience, it was assumed that a combination of existing and retrofitted detention facilities would perform water quality treatment at one-half the efficiency of a detention facility designed for water quality treatment.

Table 7-8 Treatment Control Removal Efficiencies (Percent)

Treatment Control	**BOD**	**Cd**	**Cu**	**DP**	**FC**	**NO23**	**Pb**	**TKN**	**TP**	**TSS**	**Zn**
Detention	30	80	70	70	0	30	80	30	50	90	50
Det w/ Filtration	30	85	80	90	10	40	85	40	40	90	55
Retention	90	90	90	90	80	90	90	90	90	90	90
Retrofitting	25	80	60	65	0	0	80	25	45	85	50
Wetlands	70	70	70	0	0	0	70	30	30	90	70

7.1.7 Scenario 7: Future Land Use with Source and Treatment Controls

This scenario involved the analysis of impacts resulting from what appears to be to the most cost-effective balance of source and treatment controls using future 2020 land use projections. For the purposes of this scenario, extended detention (with wet pool) was applied to residential and industrial land uses and detention with filtration was applied to commercial land use. Swales were applied to residential land use and filters strips to commercial and industrial land use.

As with Scenario 6, retrofitting of existing structures was included in the analysis under the same assumptions. In addition, 100-foot stream buffers were applied throughout the watershed.

7.2 Scenario Analysis Methodology and Results

Intuitively, citizens understand that water quality and environmental protection are good, but citizens are also ever more diligent about how public funds are spent and will not blindly accept restrictions on the use of their land or increases in taxes or fees for watershed management. Therefore, the analysis procedures included evaluation of water quantity and water quality impacts and costs as well as habitat and social benefits.

A STELLA model was developed to represent the watershed relationships. STELLA is a modeling tool that functions, in essence as a visual spreadsheet, capable of integrating numerous relationships. A model specific to Big Creek was developed and used to evaluate each scenario with respect to water quantity, quality, habitat and social impacts/benefits.

7.2.1 Quantity

The water quantity factors analyzed were flooding potential and erosion potential. The floodplain maps and the erosion potential maps created for the water quantity assessment (Section 4) was used to determine the increase in flooding and erosion from existing conditions. In Fulton County, footprints of the buildings were available in GIS format and the number of buildings inside the existing and future floodplains was estimated. Electronic data on building locations for Forsyth County was not available and without this data it was assumed that no buildings were in the floodplain in Forsyth County. It was also assumed that no additional buildings would be built inside the floodplain throughout the watershed. The overall flooding effect was based on a scale of –3 to 3, where a major increase in flooding would rank a negative 3.

The erosion potential was based on the peak velocities along the stream for a 2-year 24-hour design storm. Where the peak velocity exceeded 5 ft/s, it was assumed that the stream would erode. For evaluating the alternatives, the velocities were determined for the future land use and how implementing the various best management practices would lower those velocities. The overall erosion potential was also based on a scale of –3 to 3, where –3 would represent a major increase in erosion.

Figure 7-1 shows the results of the flooding comparison. Each of the scenarios reduces flooding. Even the Status Quo scenario does since several jurisdictions have implemented detention since the 1995 land use was developed. Treatment controls (detention) are required to achieve the greatest reduction in flooding.

Figure 7-2 shows the erosion potential ranking for each scenario. As with flooding, all scenarios provide some reduction in streambank erosion. And, as with flooding, treatment controls are required to achieve the most benefit. It is interesting to note that source controls provide more reduction in streambank erosion that in flooding. This is because source controls reduce the total runoff from small storms (which still have big impact on erosion) significantly but reduce a relatively small amount of runoff from larger storm that cause flooding.

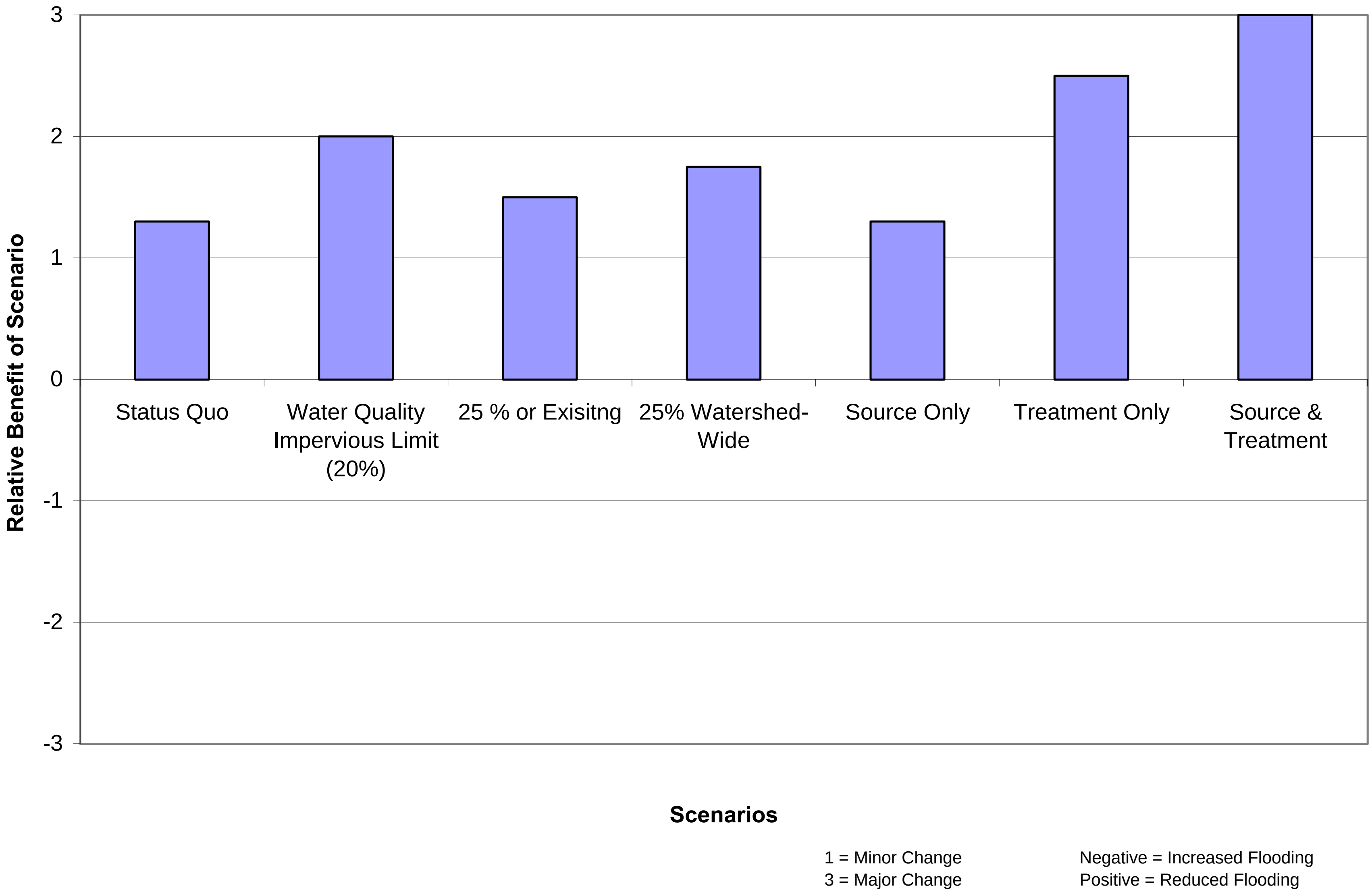
7.2.2 Quality

The Watershed Management Model (WMM) was integrated with STELLA to estimate the concentrations of lead, zinc and fecal coliform at the Roswell Intake. WMM is a model capable of estimating annual runoff pollution loads and concentrations and illustrating changes in nonpoint pollution due to land use or implementation of BMPs. The WMM results were then compared to the water quality goals presented in Table 7-1.

Typically, between 30 and 60 percent of metals are dissolved. Assuming 50 percent is dissolved, **Figure 7-3** presents lead concentrations for each scenario and **Figure 7-4** presents the zinc concentrations. Although not a water quality target parameter, TSS concentrations are presented in **Figure 7-5**.

Relative rankings were assigned to each scenario to evaluate the impact on fecal coliform concentrations and are presented in **Figure 7-6.** Relative rankings were used in the case of fecal coliforms due to the difficulty in quantifying the actual removal rate for a given scenario, given the level of data available and because current fecal concentrations are well in excess of the state water quality standard and it is unlikely that any scenario could reduce concentrations to the water quality standard. Actual concentrations were used to evaluate each scenario's effectiveness in reducing lead and zinc concentrations.

Lead becomes the limiting factor in the Big Creek watershed as the percent of impervious area in the watershed need only increase to 20 percent (Scenario 2) before



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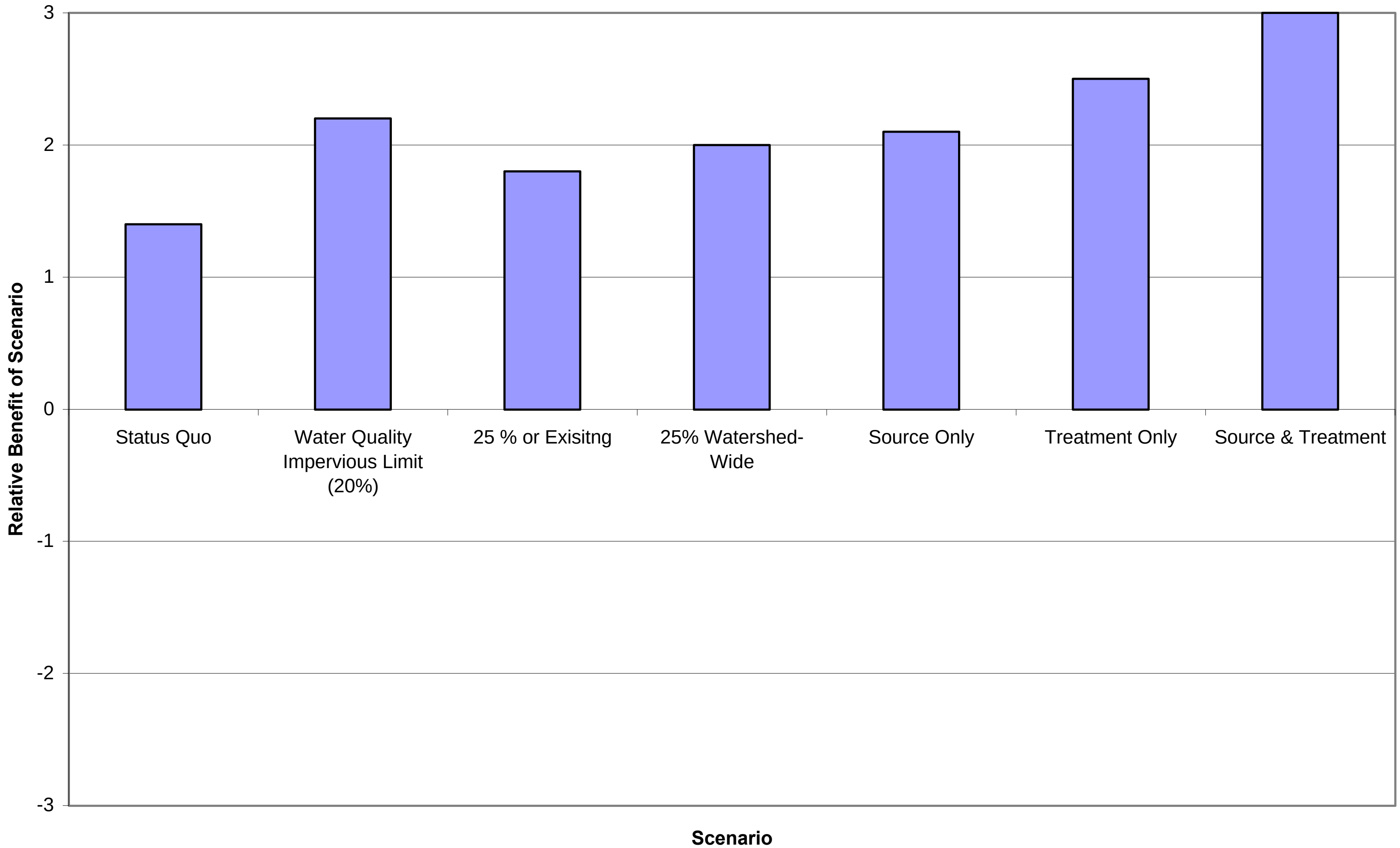
SECT7 TABLES A-fd.XLS

Figure 7-1
Benefit of Scenarios on Flooding



1 = Minor Change
3 = Major Change

Negative = Increased Erosion
Positive = Reduced Erosion

CDM Camp Dresser & McKee Inc.
SECT7 TABLES A-fd.XLS

Figure 7- 2
Benefit of Scenario on Eronsion Potential

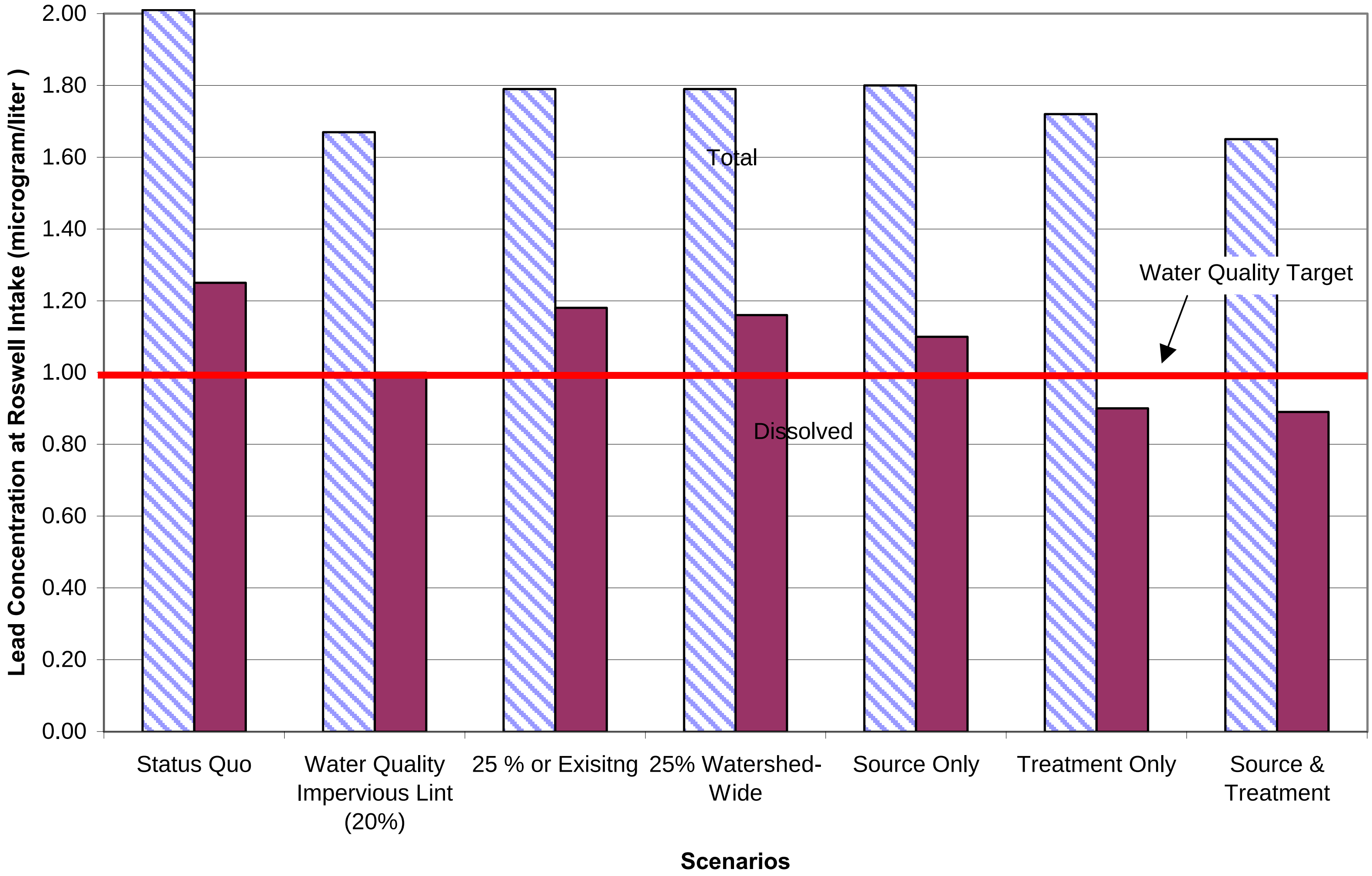


Figure 7- 3
Lead Comparison for Various Scenarios

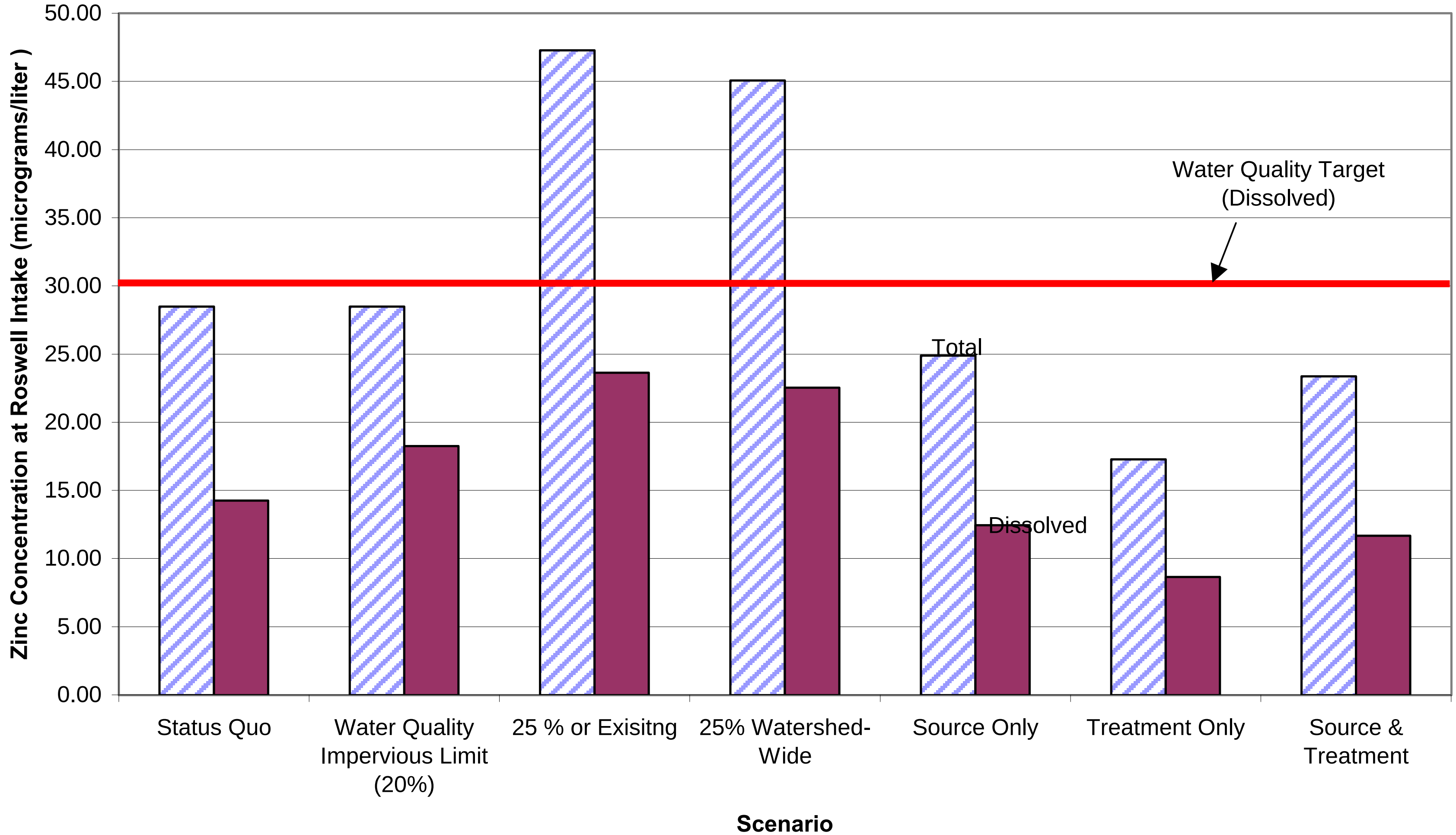


Figure 7- 4
Zinc Concentration for Various Scenarios

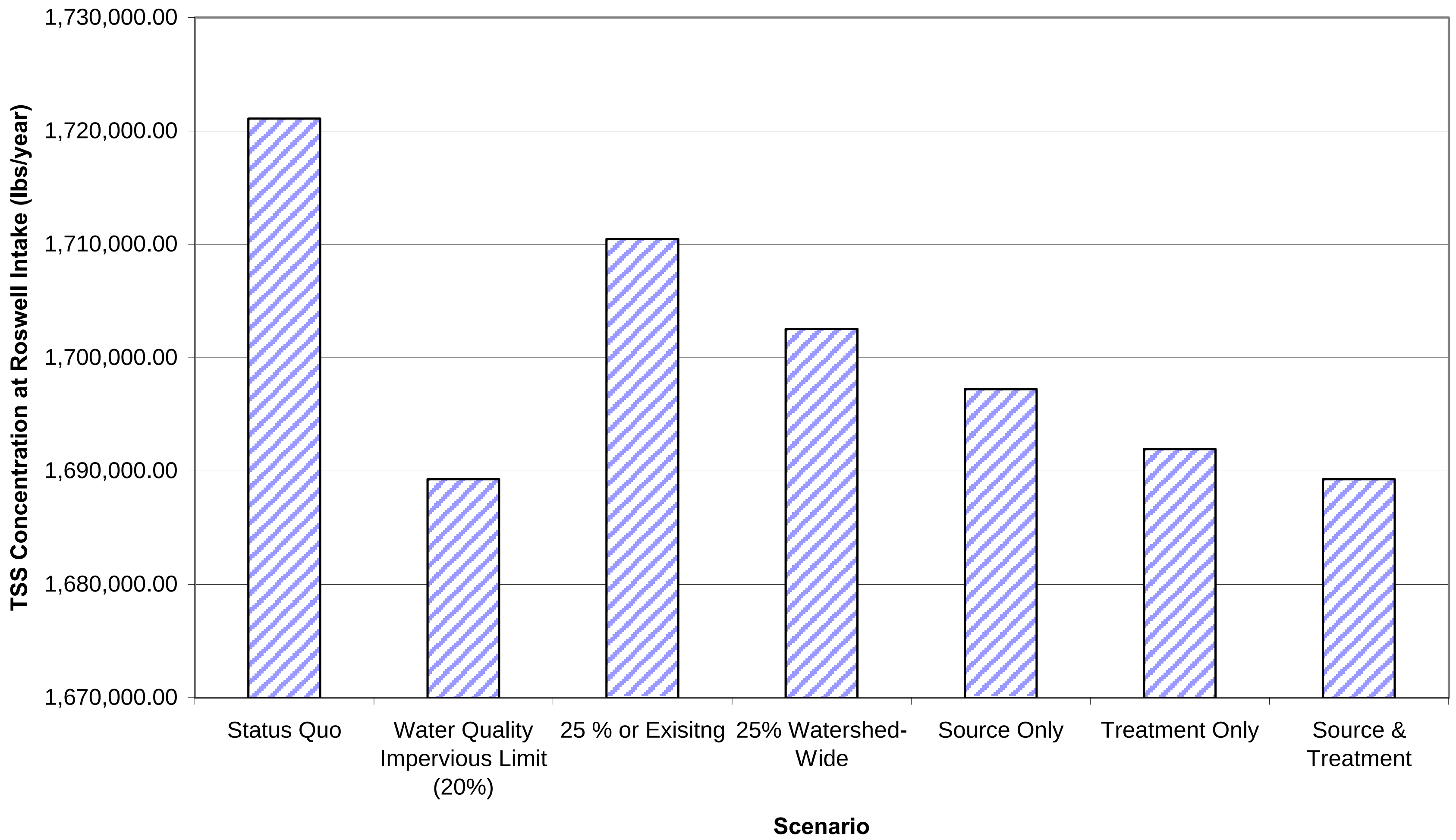


Figure 7-5
TSS Concentration for Various Scenarios

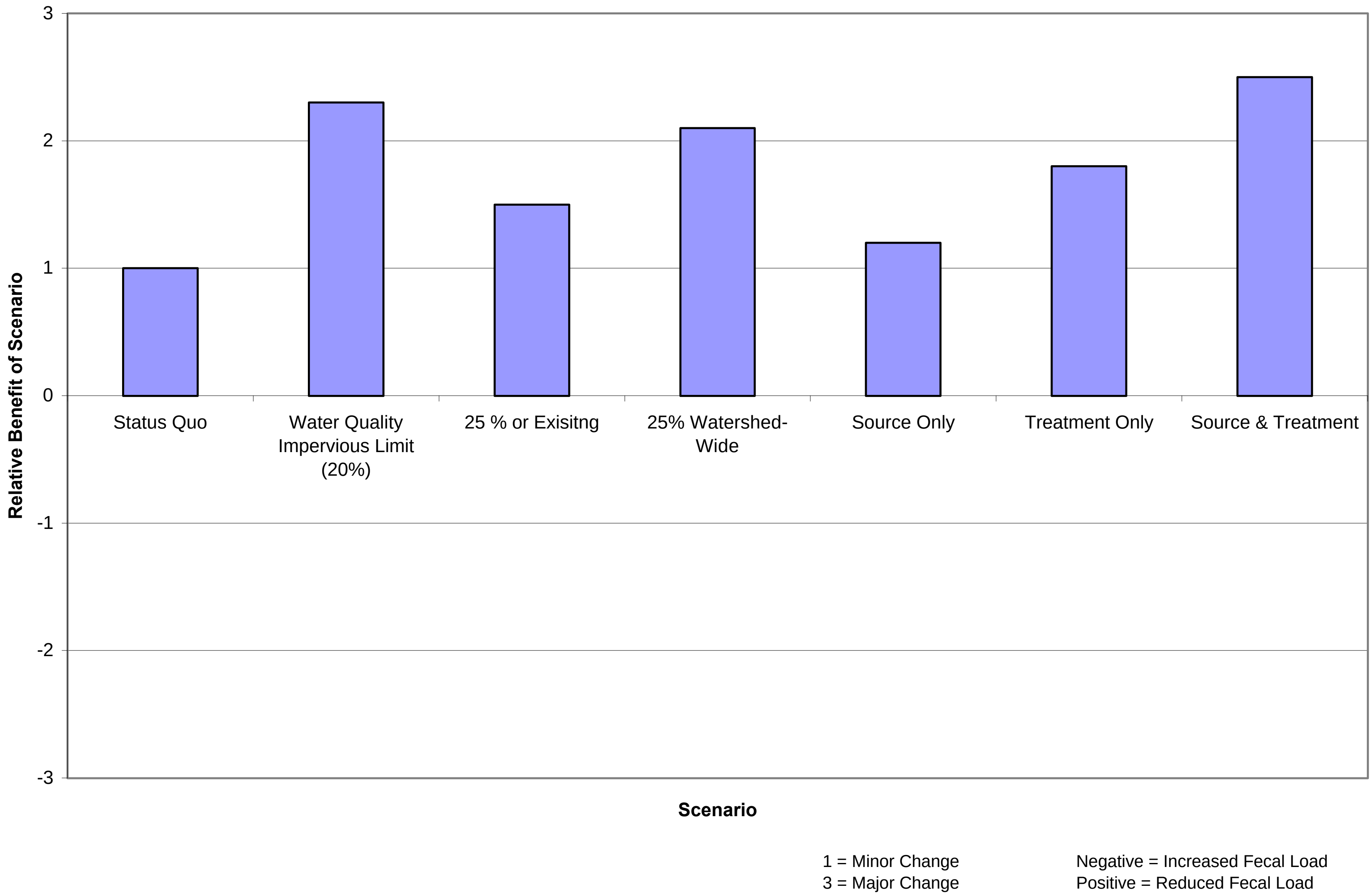


Figure 7-6
Benefit of Scenarios on Fecal Loadings

the water quality goal of 1.0 ug/L of lead is exceeded on the basis of dissolved concentrations. If total lead concentration is used, lead remains the limiting factor since the status quo concentration has already exceeded the water quality goal.

Combination source and treatment controls have the most benefit in reducing fecal coliform levels. Limiting impervious area also has significant benefit.

7.2.3 Habitat

The effects of each best management practice on the upland, riparian, and aquatic habitat was ranked. **Table 7-9** shows the effects that the various BMPs have on each of the habitat category. For the habitat and social components a value from –3 to 3 was chosen for characterizing the effect of each management decision. The –3 is the more negative effect on habitat where the +3 is the most positive effect on habitat. Each habitat category was treated equally and added together for the overall habitat result. The percent of the watershed that each BMP is applied to is taken into consideration when ranking these scenarios.

Table 7-9
Ranking of Habitat Components

Factor	Upland Habitat	Riparian Habitat	Aquatic Habitat
Stream Restoration	0	2	2
Stream Stabilization	0	2	2
Erosion	0	-2	-1

Figure 7-7 compares the overall habitat results of each scenario. Each of the scenarios, with the exception of the Maximum Impervious Area scenario, has a negative impact on habitat. Limiting the imperious area to a maximum amount based on water quality goals has a slight benefit. Of those scenarios that cause impacts to habitat, the combination source and treatment controls options has the least impact.

7.2.4 Social

Social impacts of each scenario were evaluated on the basis of the associated risk of flooding, perceived recreation benefit, environmental quality, and the quality of the drinking water. Best management practices were assigned a value for each. Once again, -3 to 3 was the range chosen to evaluate the effects on the social components, where –3 is the most adverse effect and +3 is the most positive effect. For each particular BMP, its effect on the different social components was ranked and all social components were weighted equally for determining the overall social effect of the management scenarios. **Table 7-10** shows the effects that the BMPs have on the social categories.

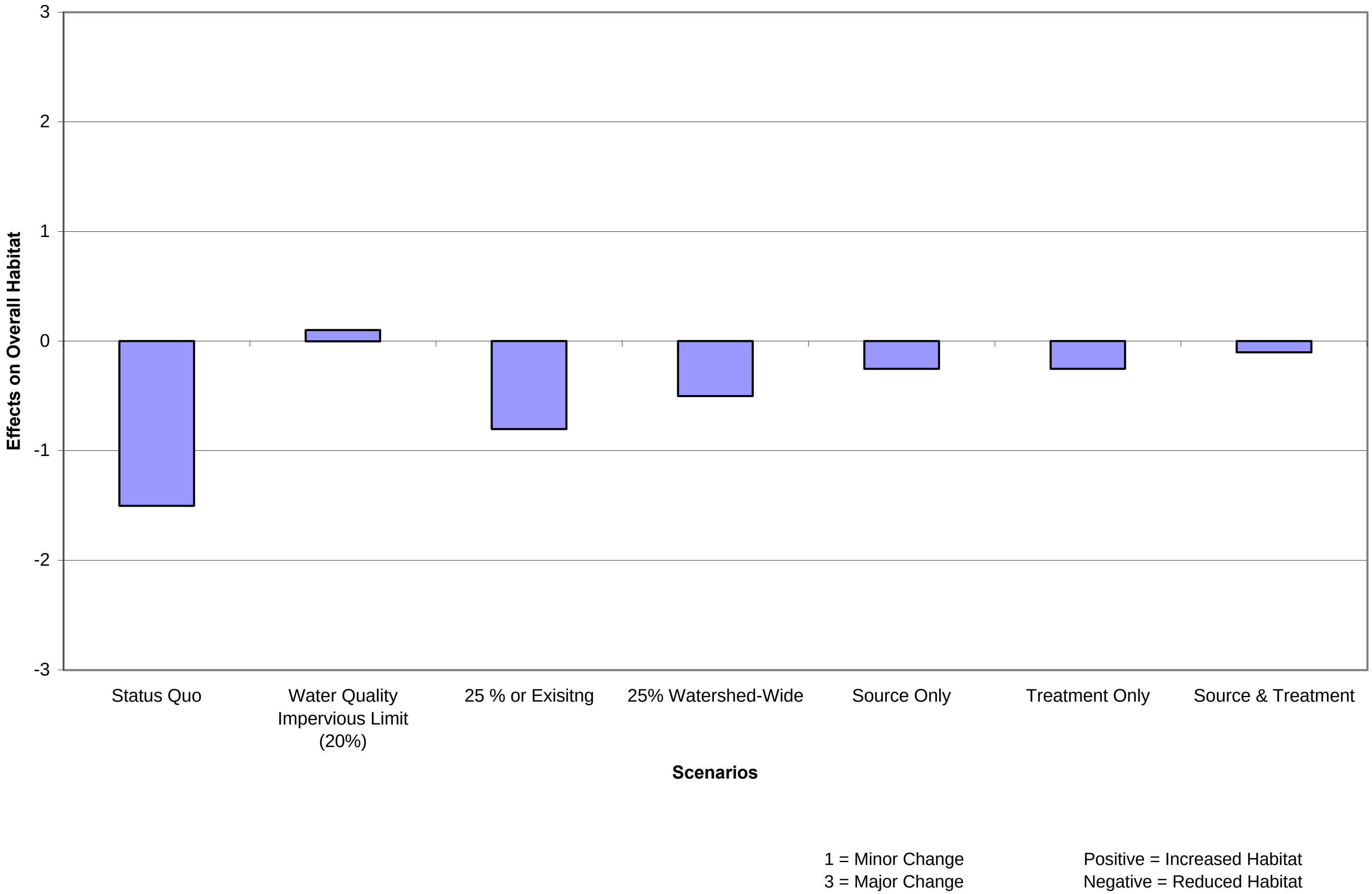


Figure 7-7
Habitat Rankings for Management Scenarios

Table 7-10
Ranking of Social Components

Factor	Water Supply	Recreation	Env. Quality	Risk of Flooding
Total Treatment Controls	1	2	2	3
Total Source Controls	2	0	2	0
Erosion	0	-1	-2	0
Common Sense Programs	0	0	2	0
Flooded Structures	0	0	-2	-3

Figure 7-8 compares the overall social results of the scenarios. Estimating the social impact of watershed management is a difficult enterprise. Watershed management approaches can have far-reaching social implications. However, the goal for this effort is to quickly assess broad social indicators. Conversion of land from open space to development impacts the social aspects of watershed negatively. Loss of open space and aesthetics are the main drivers and, as such, scenarios without treatment controls exhibit a negative social impact. Scenarios with treatment controls offset this somewhat by providing recreational facilities as well as improved aesthetics.

7.2.5 Economic

The estimated present worth of the BMPs chosen for the management plan will be determined based on local and national cost data. However, a ranking of the cost associated with each scenario is sufficient in narrowing down alternatives. In the case of scenarios 2, 3, and 4, relative cost differences were developed to reflect the impact of the proposed limitations on impervious areas. **Figure 7-9** illustrates the relative cost difference from status quo of each scenario. The highest cost would be that of the maximum impervious limit because of the impact this scenario would have on the economy by limiting future growth. The amount of revenue lost by limiting future growth is out of this project scope, therefore an economic analysis was only performed on Scenarios 5, 6, and 7.

This analysis was based on local unit costs for various BMPs developed for the Fulton County Watershed Management Program. For these scenarios, BMPs were applied to new development as described in Section 7.1. The estimated capital cost of new development BMPs for Scenarios 5, 6, and 7 are presented in **Table 7-11**. As shown, the source and treatment cost is the highest of the three. Source control only would be a reduction in cost from current regulations, however the source control only alternative has been eliminated due to the results of the water quality analysis, water quantity, habitat, and social components that were analyzed.

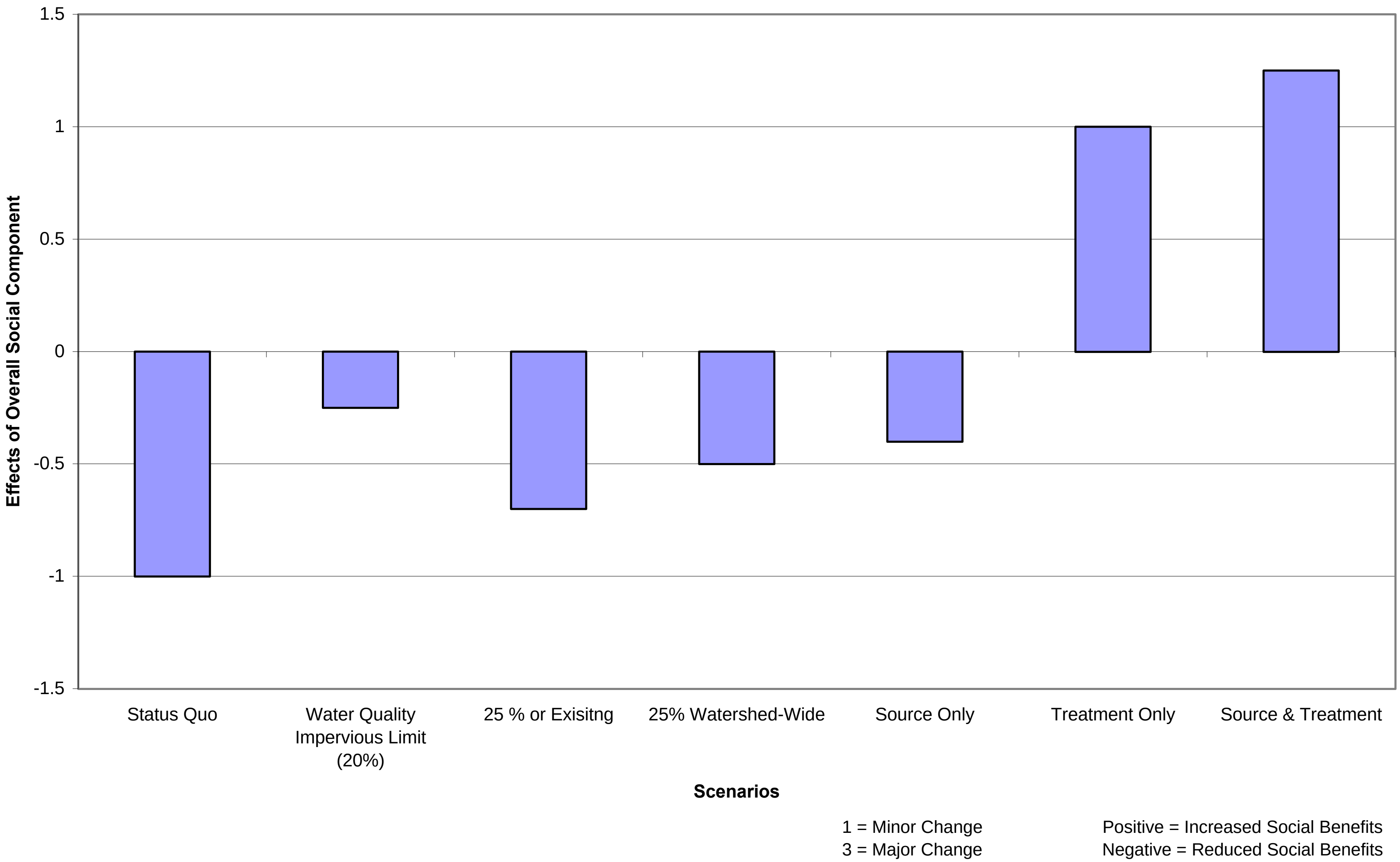
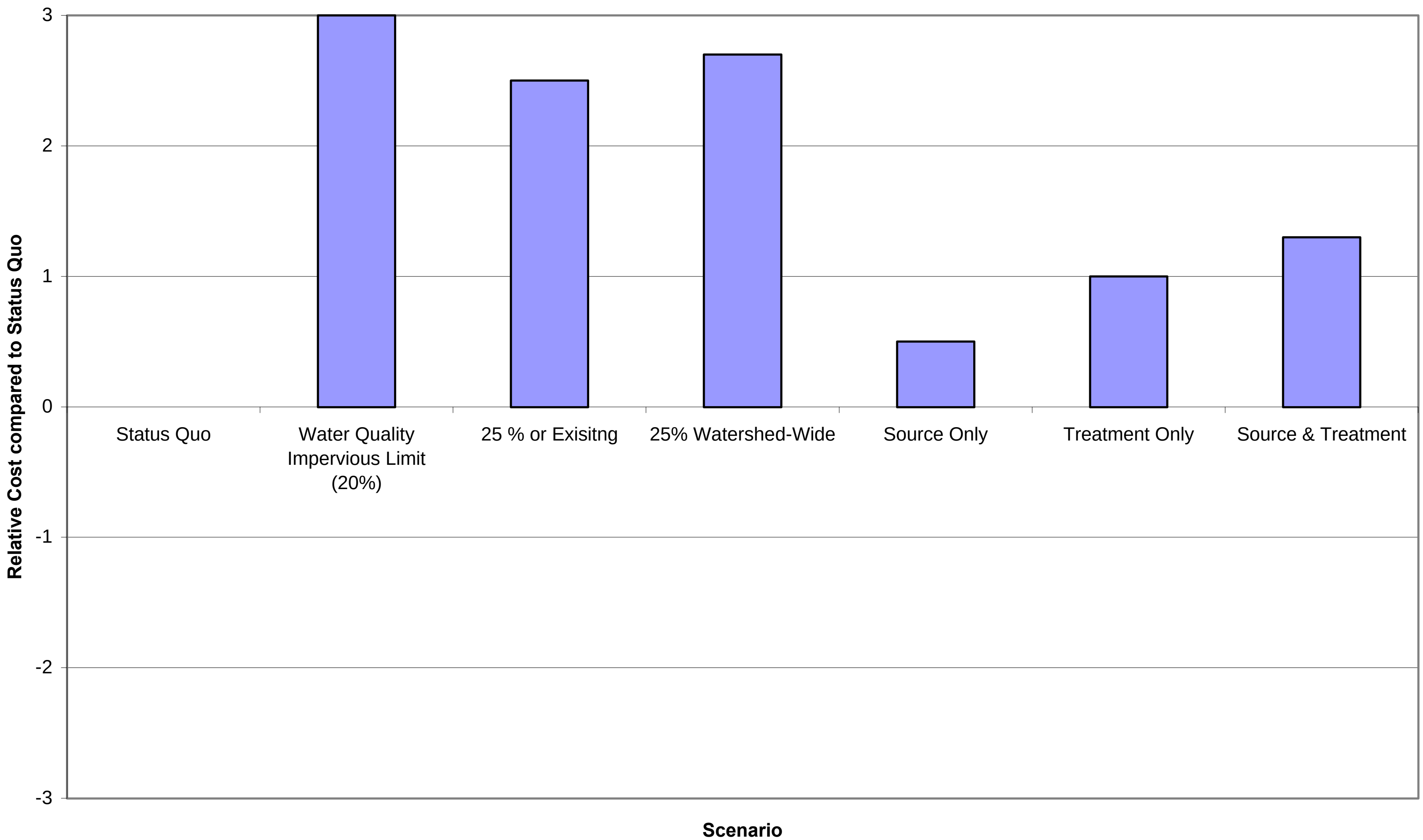


Figure 7-8
Social Ranking for Management Scenarios



1 = Minor Change
3 = Major Change

Positivee = Increased Economic Cost
Negative = Reduced Economic Cost

Figure 7-9
Relative Cost Comparison of Scenarios

Table 7-11
Capital Cost Estimates for Source Control Only, Treatment Control Only and Source and Treatment Control Management Scenarios

Future Land Use w/Source Controls

LU	New Development (ac)	Equivalent Annual Unit Cost $ / ac serv/yr	Equivalent Annual Cost $ / yr
SF Residential	24,088	713	17,170,000
Townhome	2,289	713	1,630,000
Light Ind / Office	6,740	713	4,810,000
Commercial	3,110	713	2,220,000
Total Cost			**$ 25,830,000**

* cost based on grassed swale (< 5% slope with check dam)

Future Land Use w/Treatment Controls

LU	New Development (ac)	Equivalent Annual Unit Cost $ / ac serv/yr	Equivalent Annual Cost $ / yr
SF Residential	24,088	1,115	26,860,000
Townhome	2,289	942	2,160,000
Light Ind / Office	6,740	2,227	15,010,000
Commercial	3,110	2,227	6,920,000
Total Cost - Scenario 6			**$ 50,950,000**

* cost based on extended wet detention pond

Future Land Use w/Source and Treatment Controls

LU	New Development (ac)	Equivalent Annual Unit Cost $ / ac serv/yr	Equivalent Annual Cost $ / yr
SF Residential	24,088	1,828	44,030,000
Townhome	2,289	1,655	3,790,000
Light Ind / Office	6,740	1,880	12,670,000
Commercial	3,110	1,880	5,850,000
Total Cost - Scenario 7			**$ 66,340,000**

* cost based on using BMPs as outlined in Section 7.1.7

7.3 Recommended Scenario

Scenario 7, the application of source and treatment controls throughout the undeveloped portion of the watershed, provides the best opportunity to achieve water quantity, water quality, and community goals. Besides allowing water quality targets to be met, the scenario also enhances and protects habitat and enhances social components such as recreation and overall environmental quality. While this scenario will require the application of Best Management Practices to new residential, commercial, and industrial development, that can be accomplished with minimal impact to economic growth in the watershed. Furthermore, the improvements to water management and environmental quality actually will accrue more benefits than the long-term cost.

Recognizing that water quality targets must be obtained, many of the scenarios became too costly in meeting that goal. For instance, the application of source controls only would seriously hinder the economic viability of the watershed.

Section 8
Recommended
Watershed Management Plan

8.1 Introduction

This section summarizes the recommended watershed management plan for the Big Creek watershed including stream restoration and water quality management options. The primary goals of the Big Creek Watershed Management Plan are to:

- Improve/maintain water quality of Big Creek and its tributaries;
- Maximize recreation potential/value;
- Minimize flooding, property damage, and stream impacts due to storm water;
- Educate the watershed's users about the resource; and,
- Consider a process for intergovernmental cooperation in protecting the watershed.

As discussed in Section 7, seven scenarios were analyzed to determine the relative habitat, social, water quality, and water quantity impacts. The scenarios were then ranked, providing the team with an overview of the level of improvements that can be achieved from several different management options. The ranking resulted in the selection of both source and treatment controls applied to all new development as the recommended scenario.

Source and treatment controls were then applied to the watershed in the SWMM models to determine the effect on water quality and water quantity at a greater level of detail. The results of which are presented herein.

Minimum environmental planning criteria have been developed by the Georgia Department of Natural Resources (DNR) as mandated in Part V of the Georgia Planning Act in the Mountains and River Corridors Protection Act to protect water supply watersheds. The criteria that apply to small water supply watersheds address buffers, setbacks, impervious areas, sanitary landfills and hazardous waste sites. Under Part V criteria for water supply watersheds, alternative criteria can be presented by all of the local governments in the watershed. The DNR can approve alternative criteria if deemed to provide an equivalent level of protection and at least as much stream corridor buffer and set back area as provided for under the minimum criteria.

The purpose of this study was to develop alternative criteria for the Big Creek Watershed, a small water supply watershed, which would protect the watershed and be acceptable to the Georgia Department of Natural Resources.

8.2 Analysis of the Recommended Scenario

8.2.1 Source and Treatment Controls

- A watershed management plan is recommended for the Big Creek watershed to control stormwater flows and pollutant loads under 2020 land use conditions. The assessment of watershed management options (Section 7) showed that treatment controls in the form of runoff detention must be applied for new development throughout the watershed in order to meet water quality goals. The recommended plan involves applying source and treatment controls across the watershed, which includes the following:

- Source controls consisting of swales for new residential land uses.

- Source controls consisting of filter strips for new commercial and industrial land uses where appropriate.

- Treatment controls consisting of on-site or regional detention for all new development.

- Retrofitting of existing structures where appropriate.

Building on the analysis performed in Section 7, the general type of treatment controls and the extent of coverage by each were determined based on a review of existing and future land use, topography, and other factors. BMP efficiencies were then applied to determine the fraction of the future load from each subbasin that would be removed by the BMP controls. This load reduction was applied in the model to calculate future loads with controls. Each subbasin in the watershed was assigned one of the following types of BMP control:

- Regional detention was assigned to subbasins that discharge to existing lakes capable of water quality treatment (e.g., Lake Windward) or discharge to areas and waterways where construction of a regional BMP appears possible based on existing land use and topography. In general, the tributary area to a regional BMP was limited to one square mile or less, to avoid problems that can occur in larger ponds (e.g., thermal stratification, increased dam safety requirements). Regional ponds were not located in areas of existing wetlands as portrayed on National Wetlands Inventory maps. Because of the relatively large tributary areas, the regional BMPs are assumed to be wet detention ponds with a permanent pool of water. The regional BMPs will treat runoff and baseflow from both existing and new development.

- Retrofitting was assigned to subbasins that appeared to have some opportunity for modification of existing structures (e.g., SCS ponds) to provide some control of existing development. Under this classification, it is presumed that BMPs will treat runoff from all new development, plus 50 percent of existing development. The assumed BMPs are a mix of wet detention and extended dry detention BMPs. The feasibility of BMP retrofits in some subbasin areas may be limited. In a highly urbanized area, a pragmatic approach for implementation of BMP retrofits is recommended. This approach would consider the priorities presented in this plan, but would focus primarily on areas where actual implementation of retrofit projects is highly feasible. One approach would be to link redevelopment or rezoning requests to an analysis of the feasibility of BMP retrofit projects.

- Local detention was assigned to subbasins that did not appear to have opportunity for regional detention or retrofitting. Under this classification, it is presumed that BMPs will only treat runoff from all new development. The assumed BMPs are a mix of wet detention and extended dry detention BMPs.

- Existing Controls was assigned to subbasins that are already completely developed, and appear to have no opportunity for regional detention or retrofitting.

Based on total watershed area, about 38 percent of the watershed is served by regional BMPs in the proposed control alternative as illustrated in **Figure 8-1**. Of the 38 percent, about one-third is tributary to existing lakes or ponds, and two-thirds would be tributary to future regional ponds. Retrofitting applies to 13 percent of the watershed, and local detention applies to 45 percent of the watershed. The remaining 4 percent is assumed to be fully built-out with no controls.

8.2.2 Buffers and Impervious Area Setbacks

It is recommended that a buffer width of perennial streams within the Big Creek watershed be equal to 100 feet or the 100-year floodplain whichever is greater. This is more stringent than the state's criteria. Within the 7-mile radius of the water supply intake, consistent with the State's criteria, it is recommended no impervious surface be constructed within a 150-foot setback area of perennial streams. Outside of the 7-mile radius of the water supply intake, it is recommended that no impervious surface be constructed within a 100-foot setback area of streams. It is further recommended that buffer averaging not be allowed (i.e., where less than 100 feet could be allowed for other areas with greater than 100 feet) as this tends to defeat the benefits of maintaining contiguous buffer zones.

Buffers help to maintain a stream's hydrology through the storage and extended discharge of floodwaters as well as through the interception and transpiration of precipitation. In addition, buffers serve to remove a portion of the sediments and other pollutants that might otherwise enter the stream. Buffer areas with high functional values are those areas on the natural floodplains or the low elevation areas adjacent to Big Creek and its tributaries. Buffers in the upper portions of the basin,

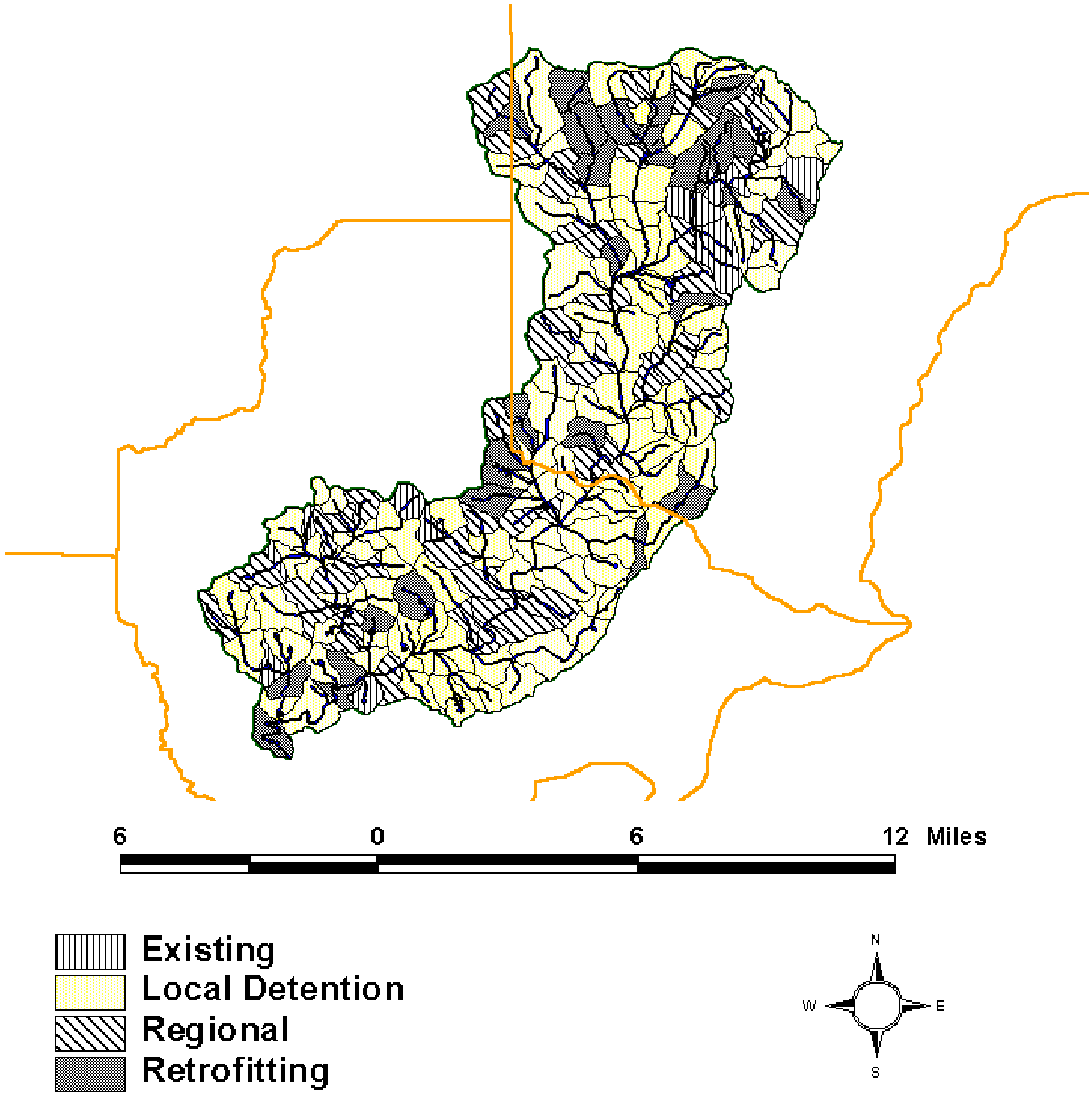


Figure 8-1
Recommended Detention Types by Subbasin

near headwaters, are more valuable for hydrologic control than those lower in the basin. However, floodplains on the main-stem middle reaches are best suited to reduce flood peaks in developed areas downstream. Buffers also serve to protect and preserve wetland areas.

Upland buffers function to reduce impacts to Big Creek water quality by controlling the severity of soil erosion and removing pollutants from stormwater runoff. Parameters such as phosphorus and fecal coliform are reduced by maintaining healthy native vegetation and preventing erosion on steep and unstable slopes. Protection of high-value buffers and riparian resources could be attained primarily through a voluntary conservation easement program along Big Creek and its tributaries.

8.2.3 Analysis of Recommended Scenario

The future (year 2020) conditions were evaluated with proposed controls using the calibrated SWMM model of the Big Creek watershed. The BMP efficiencies assigned to each subbasin category are presented in **Table 8-1**. All regional BMPs were assigned the same efficiencies applied to the existing ponds and lakes represented in the models for existing (1995) and future (2020) land use. For the retrofitting and local detention categories, the efficiencies are typical of a mixture of wet detention and extended dry detention BMPs.

Table 8-1
Assigned BMP Efficiencies for Subbasin Categories

	Removal Efficiency (%) for Subbasin BMP Classifications			
Constituent	Regional	Local Detention	Retrofitting	Existing
BOD	30%	25%	25%	0%
COD	30%	25%	25%	0%
TSS	90%	80%	80%	0%
TDS	30%	20%	20%	0%
Total P	50%	40%	40%	0%
Dissolved P	65%	45%	45%	0%
TKN	25%	20%	20%	0%
NO23N	35%	25%	25%	0%
Zinc	45%	45%	45%	0%
Fecal Coliform	75%	65%	65%	0%
Lead	80%	75%	75%	0%
Copper	65%	60%	60%	0%
Cadmium	80%	75%	75%	0%

NOTES:
1. Effficiencies for regional BMPs assume wet detention with a permanent pool.
2. Efficiencies for local detention and retrofitting assume a mixture of wet detention and extended dry detention BMPs.

For the local detention and the retrofitting categories, the subbasin load removal was a function of the BMP removal efficiency and the BMP coverage within the subbasin. For example, in a "local detention" subbasin that will be fully developed in the future, but is already 30 percent developed, the BMPs will only treat the runoff from 70 percent of the developed area within the subbasin. In this case, a BMP with 50 percent pollutant removal efficiency would remove 35 percent of the runoff load from the developed area.

BMP projects should be phased in by the local jurisdictions based upon an annual funding allocation and a priority system. The priority for facility construction should be based upon the rankings of subbasin loading reductions and on public/private funding agreements and other demonstration opportunities. A detailed monitoring plan is presented in Section 8.7 as a method of tracking the progress of the management plan.

8.2.4 Modeling Results

The percent reduction achieved by the proposed controls is listed in **Table 8-2**. The results of the model evaluation of future conditions with proposed controls are presented in **Table 8-3**. The table lists the annual load for each pollutant at the outlet of each major subwatershed, and at several points along the Big Creek main stem.

In some cases, the model calculates a net reduction in annual load for the future condition with controls, for parameters such as TSS and total P. The effectiveness of TSS reduction is due to the high efficiencies associated with removal in wet and extended dry detention ponds. In the case of total P, the effectiveness of load reduction is due to the improvement of the Tyson Foods discharge as well as the relatively high efficiencies associated with wet and extended dry detention ponds. Constituents such as BOD and total N, who have lower BMP removal efficiencies, exhibit the largest increase in total load from existing conditions to future conditions with proposed controls due to the change in land use.

Table 8-2
Reduction In Future Loads Due To Proposed Controls for the "Average Year"

Constituent	Percent Decrease in Annual Load	
	Major Subwatersheds	Watershed Outlet
Flow	0	0
BOD	10 - 20	20
TSS	25 - 70	60
Total P	10 - 35	30
Total N	5 - 20	15
Zinc	10 - 60	30
Fecal coliform	15 - 60	25

Table 8-3
Flows and Loads for "Average Year" Under 2020 Conditions

Watershed Location	Flow (cu ft)	BOD (lb/yr)	(lb/yr)	TSS (lb/yr)	(lb/yr)	Total P (lb/yr)	Total N (lb/yr)	(lb/yr)	(lb/yr)	(lb/yr)	Zinc (lb/yr)	Fecal Coliform (#/yr)
Major Subwatersheds												
Kelley Mill Branch	2.43E+08	5.98E+04	3.41E+05	5.70E+05	7.45E+05	1.65E+03	1.61E+04	4.35E+02	9.53E+03	6.57E+03	6.56E+02	2.84E+14
Sawmill Branch	1.97E+08	5.65E+04	3.30E+05	3.44E+05	5.58E+05	1.29E+03	1.33E+04	3.88E+02	7.89E+03	5.38E+03	6.06E+02	1.63E+14
Cheatam Creek	5.45E+08	9.74E+04	5.21E+05	2.13E+06	1.53E+06	4.40E+03	3.56E+04	6.21E+02	2.09E+04	1.47E+04	9.31E+02	6.10E+14
Bentley Creek	6.23E+08	1.02E+05	5.81E+05	9.48E+05	1.70E+06	3.48E+03	3.40E+04	7.45E+02	1.85E+04	1.55E+04	1.09E+03	2.97E+14
Bagley Creek	3.70E+08	8.64E+04	4.97E+05	6.75E+05	1.12E+06	2.47E+03	2.38E+04	6.66E+02	1.35E+04	1.02E+04	9.52E+02	2.88E+14
Camp Creek/Caney Creek	6.97E+08	1.74E+05	9.92E+05	7.37E+05	1.97E+06	4.04E+03	4.39E+04	1.09E+03	2.70E+04	1.68E+04	1.87E+03	3.39E+14
Long Indian Creek	2.32E+08	6.13E+04	3.50E+05	1.17E+06	8.75E+05	2.24E+03	1.81E+04	6.02E+02	1.04E+04	7.76E+03	7.11E+02	4.49E+14
Foe Killer Creek	7.80E+08	2.13E+05	1.20E+06	1.66E+06	2.42E+06	5.66E+03	5.42E+04	1.76E+03	3.29E+04	2.13E+04	2.44E+03	5.95E+14
Main Stem Locations												
Big Creek at GA Highway 400	3.02E+09	6.13E+05	3.46E+06	6.18E+06	9.30E+06	2.31E+04	2.58E+05	8.78E+03	1.21E+05	1.36E+05	8.09E+03	1.85E+15
Big Creek at USGS Gage	5.02E+09	1.18E+06	6.70E+06	9.78E+06	1.54E+07	3.69E+04	3.97E+05	1.29E+04	2.08E+05	1.89E+05	1.44E+04	2.79E+15
Big Creek at Roswell Intake	6.73E+09	1.71E+06	9.70E+06	1.52E+07	2.10E+07	5.10E+04	5.27E+05	1.74E+04	2.87E+05	2.40E+05	2.06E+04	4.46E+15

Table 8-4 displays a comparison of annual loads for existing land use versus future land use with the proposed controls. With controls, future loads of TSS and total P are less than the existing loads, due to the relatively high BMP removal efficiencies for these constituents and the improvement of the Tyson Foods discharge. For the other constituents, there is a net increase in annual load, even with the proposed controls.

Table 8-4
Comparison Of Existing Loads And Future Loads With Proposed Controls for the "Average Year"

Constituent	Percent increase in Annual Load	
	Major Subwatersheds	Watershed Outlet
Flow	0	0
BOD	30 - 110	75
TSS	(-75) - 10	(-50)
Total P	(-20) - 25	(-10)
Total N	5 - 30	45
Zinc	20 - 100	75
Fecal coliform	(-30) - 80	15

The reduction of pollutant loads associated with the application of these practices will, as demonstrated in Section 7, result in the attainment of water quality standards over the planning period and as the watershed develops fully. Section 7 showed that the watershed and Big Creek were most sensitive to lead and zinc and it is on the basis of these two constituents that attainment with water quality standards was assessed.

8.2.5 Cost Analysis

Unit cost estimates for the detention facilities, retrofitting, swales, and filter strips are shown in **Table 8-5** and were developed during the Fulton County Watershed Study. These unit costs were applied to the scenario to develop an overall present worth as seen in **Table 8-6**. The table summarizes the costs for each of the jurisdictions within

The capital costs include the estimated land cost, estimated base construction cost, plus 45 percent contingency for engineering, permits, and other considerations. Because the land cost is highly variable in this area, these costs may be refined for the draft master plan.

Overall, the new development net present worth of BMP improvements is estimated at over $500 million most of which will be borne by the private sector as a cost of development. In addition to that, a retrofitting cost of $73 million is estimated which public resources will likely fund. The BMPs were assumed to have a life cycle of 50 years.

the watershed, plus an overall cost.

Table 8-5
Unit Costs for Best Management Practices

BMP	Capital & Land Cost ($/acre served)	Operating Cost ($/acre served/year)	Equivalent Annual Cost ($/acre served/year)	Net Present Worth ($/acre served)
Detention Pond - Residential	$8,000	$360	$8,000	$11,800
Detention Pond - Commercial	$17,500	$575	$17,600	$23,600
Detention Pond - Mixed Use	$7,000	$320	$7,000	$10,500
Detention Pond - Regional	$4,750	$195	$4,800	$6,700
Retrofitting Regional Ponds	$7,500	$195	$7,500	$9,400
Vegetated Filter Strip	$5,750	$108	$653	$6,900
Grassed Swale (<5% slope w/check dam)	$5,900	$156	$713	$7,600

Note: Assumed BMP life-cycle of 50 years and annual interest rate of 7 percent

8.3 Stream Restoration / Stabilization Projects

Growth in the Big Creek watershed has resulted in significant degradation to Big Creek and many of its tributaries. Impacts observed during the field reconnaissance include stream channel degradation; loss of riparian zones; loss of fish and wildlife; flooding; water quality degradation; aesthetic degradation and economic loss. With the prospect of continued urbanization, further significant negative impacts to the Big Creek resources can be expected to rapidly occur. Increased flooding and channel erosion with the associated damage to infrastructure such as buildings, roads, bridges and pipeline crossings will present a significant drain to local funding resources.

Urbanization of the Big Creek basin has resulted in greater, more frequent, and longer-duration stream peak flows. These changes will test the resilience of its present channel morphology and the riparian systems it supports. Past disturbance and the changes in hydrology, channel morphology, and riparian zone function have already resulted in large areas of degraded aquatic habitat, which in turn offer limited fish, wildlife, and recreational values to society. Stormwater management and buffer development alone will not overcome existing degradation or fully prevent additional damage.

A high priority problem in the watershed is streambank instability and excessive streambank erosion due to increased runoff from growing urban areas. Streambank instability problems are pervasive throughout the watershed, particularly in the more intensely urbanized tributary areas characterized by steeper slopes.

Within the Big Creek watershed, channels that are in Stage 2 or, in some cases, Stage 3 of the Channel Evolution Model (CEM) are subject to degradation of the bed that diminishes stream stability and habitat quality. These stages of the stream evolution are where the streambed is lowering and the stream is widening due to increase changes in sediment load, flow regime, and boundary conditions. The stream undergoes rapid morphologic changes and channel incision occurs. Over time, the stream will move toward a new equilibrium and incision will cease. This degradation

Table 8-6: Present Worth of Detention Facilities

	Watershed Percentage	Area Served	Equivalent Annual Cost ($/acre served/year)	Equivalent Annual Cost ($)	Net Present Worth ($/acre served)	Net Present Worth ($)
Regional facilities	0.25	16086	$4,800	$77,210,000	$6,700	$107,780,000
Retrofitting	0.13	8255	$7,500	$61,910,000	$9,400	$77,600,000
Local detention	0.45	28575	$10,867	$310,510,000	$15,300	$437,190,000
Total Estimated Cost				$449,630,000		$622,570,000
City of Alpharetta						
Regional facilities	0.05	3047		$14,623,616		$20,412,131
Retrofitting	0.02	1563		$11,725,350		$14,695,772
Local detention	0.09	5412		$58,807,140		$82,799,010
City of Cumming						
Regional facilities	0.01	411		$1,974,784		$2,756,469
Retrofitting	0.00	211		$1,583,400		$1,984,528
Local detention	0.01	731		$7,941,360		$11,181,240
City of Roswell						
Regional facilities	0.03	1626		$7,806,720		$10,896,880
Retrofitting	0.01	835		$6,259,500		$7,845,240
Local detention	0.05	2889		$31,393,800		$44,201,700
Unicorporated Cherokee County						
Regional facilities	0.00	291		$1,394,752		$1,946,841
Retrofitting	0.00	149		$1,118,325		$1,401,634
Local detention	0.01	516		$5,608,830		$7,897,095
Unicorporated Forsyth County						
Regional facilities	0.14	8575		$41,159,168		$57,451,339
Retrofitting	0.07	4400		$33,001,800		$41,362,256
Local detention	0.24	15232		$165,516,720		$233,043,480
Unicorporated Fulton County						
Regional facilities	0.03	2137		$10,255,744		$14,315,309
Retrofitting	0.02	1096		$8,223,150		$10,306,348
Local detention	0.06	3795		$41,242,260		$58,068,090

must be arrested to prevent the adverse impacts discussed previously. The restoration procedure best suited to halting channel incision is the employment of grade control structures at key locations along the stream channel.

Grade control structures have long been used by engineers to stabilize streams. However, many traditional grade control structures are incompatible with stream restoration objectives. They can adversely impact fish passage, substrate composition, recreation, and other environmental functions. Low-head stone weirs (LHSW) can not only provide the same stabilization benefits of traditional grade control structures, but can also provide riffle and pool habitat, reoxygenate water, establish desired substrate characteristics, improve local bank stability, and enhance diversity and visual appeal.

The design of LHSW typically consists of a double row of stones angled in a V shape with the vortex of the V pointed upstream. The interior angle should be approximately 120 degrees. A wide stream (> 50 feet) may necessitate a W shape or flattened U shape to the weir in order to minimize the channel length of the structure. A narrow stream (<6 feet) may prohibit any shape other than a line of weir stones perpendicular to the channel. The angle of the stones will deflect flows from the banks and thus provide some measure of local bank protection. However, if local bank protection is an issue, the stones in the LHSW should be of a diameter about equal to the baseflow depth. In addition, it can not be assured that bank protection will be provided for flows that have depths that are significantly (> 5 times) the size of the stones. The weir does not necessarily need to be symmetrical and may be shaped to align the flow through a bend or for aesthetic reasons.

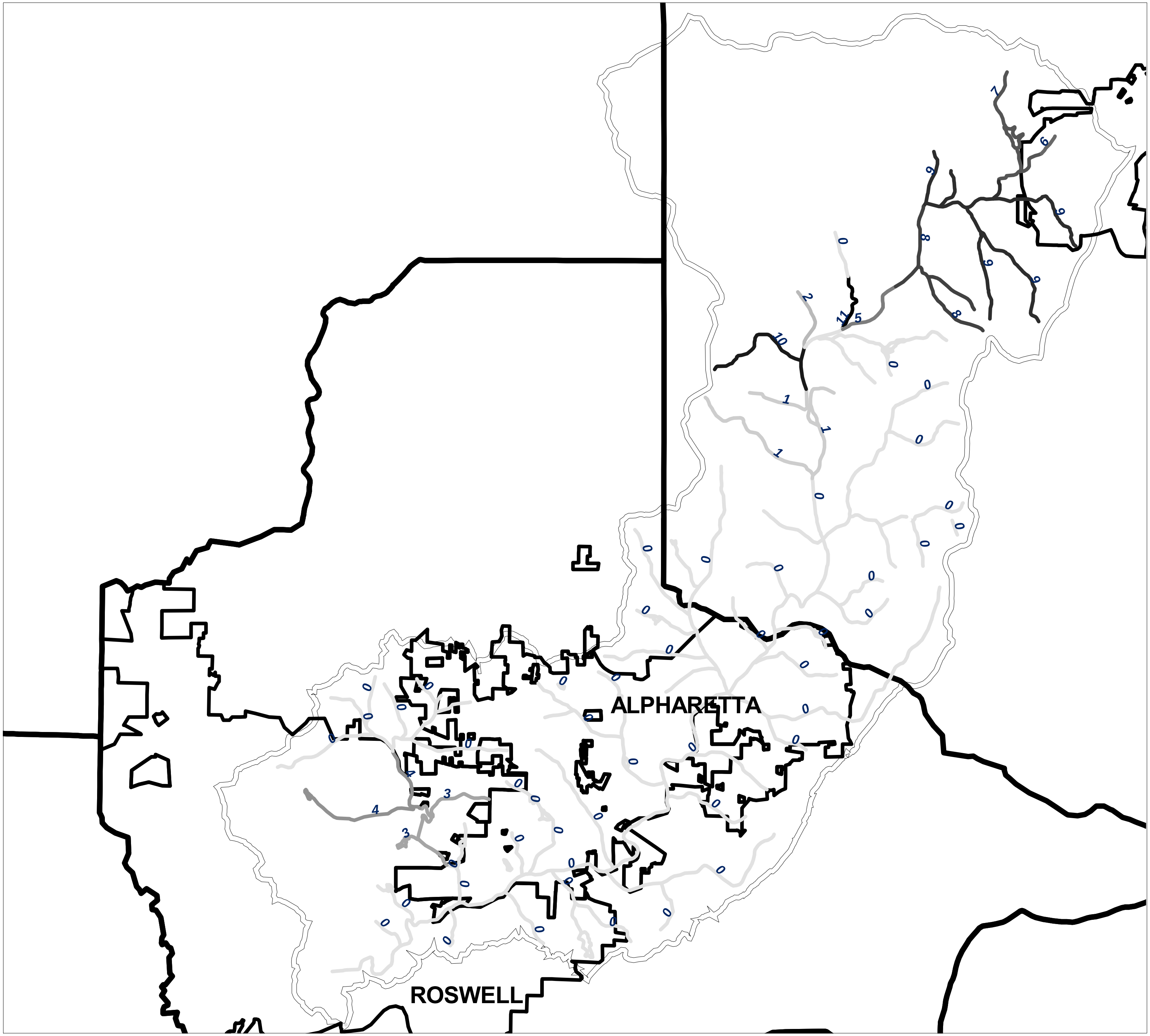
The crest of the stones of the upstream end of the weir should be lower than the stones that are keyed into the bank. In a typical placement on a 20-foot wide stream, the stones on the upstream portion of the vortex would be 0.5 feet above the existing stream grade and stones at the end of the V would be one foot above the existing grade. Modifications can include a notch at the vortex of the V. To reduce the possibility of flanking; the entire structure should be keyed into a stone toe protection on the banks.

After arresting degradation, the next step is to accelerate the recovery of habitats that were impacted by destabilization of the channel. This includes the use of structures to create pool habitat, planting to reestablish riparian vegetation, developing a new floodplain within the incised channel or reconnecting the stream to its original floodplain, and stabilizing actively eroding banks with soil bioengineering techniques.

Table 8-7 and **Figure 8-2** presents a summary of the recommended preservation and demonstration projects for the Big Creek watershed. The projects are prioritized based upon need, cost, and environmental benefit. Listed with each reach is a corresponding set of recommended management actions. Areas recommended for preservation are prioritized by environmental benefit only.

Table 8-7 Big Creek Reconnaissance

Sub-Watershed	Reach	Name	Demonstration Recommendation	Preservation Priority Number	Demonstration Priority Number
A	29	Big Creek	Stabilize banks, particularly on the first two outside bends, where meandering sections follow straightened sections (#13). Also stabilize banks just below Haynes Bridge Rd. bridge crossing (#4), where narrow abutments are causing turbulent flow directed at the near-bank regions during high water.		13 & 4
A	13	Foe Killer Creek, Below Hembree Rd.	Restore natural meanders in a small section accessible to the public (#11).	4	11
A	14	Foe Killer Creek	Enhance canopy cover by planting native streamside shade trees. Enhance the riparian zone by converting it to bottomland hardwoods.	3	9
A	30	Big Creek	Stabilize badly eroding bluffs at outer bends downstream of the channelized section. These areas have apartments perched on the edge of the bluffs. Bank hardening techniques (engineered structures) will probably have to be used.		20
A	31	Big Creek	Stabilize banks using soil bioengineering. This reach has outstanding channel features and pattern, but needs more vegetative cover on the banks.		14
B	6	Camp Creek	Restore the native streamside community by replacing the Chinese privet, which has achieved near-total dominance in the shrub layer, with native shrubs.		17
B	7	Camp Creek	Allow the stream to stabilize itself by re-establishing its meanders (#3). This approach would necessitate localized adjustments to land use. Replace the Chinese privet in the section between the golf course and Windward Parkway, next to the office complex (#16).		3 & 16
B	27	Big Creek	Stabilize the banks at the Ocee Greenway crossing with soil bioengineering techniques.		1
C	20	Big Creek	Enhance canopy cover in the snagged section.	10	8
C	21	Big Creek	Enhance bank cover in an accessible section by planting native shade-tolerant streamside shrubs.	1	5
C	24	Big Creek	Stabilize the north/western bank at the pasture using soil bioengineering techniques.		10
D	3	Cheatham Creek	Restore stream segment, add in-channel habitat features and stabilize banks with bioengineering.		19
D	4	Cheatham Creek	Restore in-channel habitat features.	11	18
D	19	Big Creek	Allow the stream to stabilize itself by re-establishing its meanders.		2
D	5	Bentley Creek	Enhance bank cover in an accessible section.	2	6
E	1	Kelly Mill Branch	Stabilize banks at outside bends in accessible areas using bioengineering; replace riprap with bioengineering where feasible and accessible.	6	15
E	2	Kelly Mill Branch		7	15
E	16	Big Creek	Speed the evolution of this channel in an accessible part of the agricultural section. Use restoration techniques and soil bioengineering to create a new floodplain and a stable bench within the existing channel.	9	12
E	17	Big Creek		8	12
E	18	Big Creek		5	12



ARC Big Creek Watershed Study

Figure 8-2 Demonstration Priorities

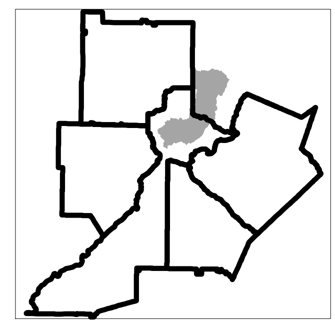
LEGEND

Study Reaches

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Big Creek Watershed

Jurisdictional Boundaries



Area of Detail

Data Sources:
1. Atlanta Regional Commission, Economic Development Information System, 1997
2. Fulton County, Department of Water and Wastewater, 2/1999

File Location: Q;\\ARCBC\STREAMREACH.APR

Date Produced: April 2, 2001

Produced by CDM Camp Dresser & McKee Inc.

N W E S

0.5 0 0.5 Miles

8.4 Wetland Protection Strategies

8.4.1 Introduction

The adverse impacts of development and urbanization on such resources as wetlands and riparian corridors are well documented. Development and urbanization can lead to profound changes in aquatic systems, wetlands, and riparian systems (Schueler 1995, Center for Watershed Protection 1998, Marsh 1991). It has been demonstrated that stream quality tends to decrease with increasing urbanization, and that more than any other factor, the amount of impervious surface in urban watersheds has been shown to have the greatest effect on the volume of runoff. Urbanization also leads to decreases in the magnitude of baseflows, greater, more frequent peak storm flows, and a greater tendency towards flash flooding.

All of these factors have serious impacts upon the hydrologic regime and water quality of wetlands associated with stream corridors. This includes increased magnitude and frequency of inundation, higher influxes of sediments and pollutants, and subsequent alterations to habitat quality. Alterations to habitat have further impacts such as reduced diversity and populations of amphibians, aquatic insects, and fish (CWP 1998, Marsh 1991).

Another threat to wetlands due to development and urbanization is the greater potential for large contiguous wetlands to be segmented or divided. Wetlands that have been divided into smaller pieces face the threat of even greater segmentation and loss. In addition, the ability of a wetland to function effectively as a pollutant filter or as sites for sedimentation is greatly impaired as they are cut into smaller and smaller segments.

8.4.2 Wetland Protection Assessment Criteria

In order to assess the wetland resources in the Big Creek Watershed, we have divided the watershed into six smaller subwatersheds. These are roughly the same subwatersheds used by Sotir & Associates in their study, plus an additional one in the northern section of the watershed. The criteria for delineation of the subwatershed are generally based upon topography and the area that serve the main tributaries of Big Creek. For the subwatersheds in the south of the watershed (A, B, and C), jurisdictional lines were also taken into consideration.

We have primarily relied on National Wetland Inventory (NWI) maps created by the U.S. Fish and Wildlife Service to identify the wetland resources. These maps, created between 1971 and 1992 from high altitude photographs, were intended to map the larger wetlands and wetland types in the United States. They were not designed to map all wetlands and deepwater habitats, nor to define jurisdictional wetlands as defined by the Corps of Engineers. This is chiefly because the methods for identifying jurisdictional wetlands differ from the methods used to prepare NWI maps. Studies have shown that NWI maps are very accurate with respect to the location of wetlands and generally accurate with respect to wetland size, but are relatively inaccurate with respect to classification (EDAW 2000, Tiner 1997, Holland et al. 1995). Thus, they are useful as a preliminary planning tool to identify significant wetland resources but would benefit from field surveys to verify wetland type and size, or to make a jurisdictional determination.

Brief field surveys were conducted of stream corridor wetlands in the southern parts of the Big Creek Watershed to assess type and quality. However, given budget and time constraints, these surveys were very limited.

Other important data that we have considered in assessing the threats and opportunities for wetland protection and preservation include the following:

- The presence of threatened and endangered species as listed by the Georgia Natural Heritage Program
- A system of proposed greenways for the watershed
- Potential for erosion of stream banks.
- Analysis of stream reaches and recommendations for preservation as completed by Sotir & Associates
- List of stream reaches that do meet water quality standards
- Future land use plan for 2020
- Percent change in impervious surface between now and 2020

Using this data, we have identified and prioritized the opportunities for wetland protection, preservation and restoration in the Big Creek Watershed by assessing the vulnerability of the wetlands to development and urbanization, their relative quality or value and the opportunities for preservation (**Table 8-8**)

8.4.2.1 Development Vunerability

The single greatest impact to wetland quality and function is development up to and including wetlands and activities such as direct dredging and filling within wetlands. These should be avoided or minimized as much as possible. We have also considered proposed future land uses adjacent to wetlands. Greater amounts of impervious surface may adversely impact wetland quality as more runoff containing pollutants and sediments drains into the wetland. In addition, development that requires construction of new roads or improvements to existing roads such as widening and straightening places wetland resources under greater risk of segmentation as well as the impacts associated with higher runoff. In light of this, the size, width, and contiguousness of a wetland are important qualitative features.

Table 8-8. Criteria for Prioritizing Wetlands and Identifying Preservation and Restoration Opportunities

Development Vulnerability	Future land use adjacent to wetland Potential for wetland to be segmented, divided or made non-contiguous Size and width of wetland Future impervious surface change in subwatershed draining to wetland Erosion potential in associated stream segment
Uniqueness, Quality, Management Importance	Habitat protection areas stream reach priorities of Sotir & Associates study, tream segments not in compliance with water quality standards (303(d)) Size and type of wetland Diversity of wetland types Threatened and endangered species
Opportunities for Preservation	Land ownership/characteristics adjacent to wetland Future land use plan Greenway segments in/near wetland Existing parks and open space adjacent to wetland

< Source Staff analvsis ^

The potential for a stream segment associated with a wetland to erode is also an important factor to consider. We have mapped data calculated from stormwater models completed by CDM that predict the potential for streambanks to widen by 25% (Low), 25% - 50% (Medium), and greater than 50% (High). Stream segments that are under a medium or high risk of erosion would be the first priority sites for streambank reinforcement.

8.4.2.2 Uniqueness, Quality and Management Importance

The uniqueness of a wetland resource was considered in light of attributes such as its size, the type of wetland, the diversity of wetland types in a subwatershed, and the presence of threatened and endangered species. The stream corridor wetlands of greatest quality and uniqueness are those that are large and encompass several different types of wetlands. In addition, we have also considered the stream reach priorities as determined by a study by Sotir & Associates, and streams that do not meet water quality criteria as required under Section 303(d). These stream reaches (and their associated wetlands) are the higher priorities for restoration activities.

8.4.2.3 Opportunities for Preservation

To assess the stream corridor wetlands that are of highest priority for preservation, we considered the current and future adjacent land use, the existing park and open space adjacent to wetlands, and proposed greenway segments in or near wetlands. We looked for opportunities to use wetlands as connectors between nodes of interest (parks and open space) via greenways as well as enhance and enlarge the greenway system.

8.4.3 Observations

The majority of stream corridor wetlands in the Big Creek Watershed are palustrine forested or palustrine scrub-shrub. According to the U.S. Fish & Wildlife Service, which reports on the status and trends of wetlands and deepwater habitats in the U.S., this is the predominant wetland type in Georgia. In addition, in the period from the mid-1970s and the mid-1980s, nearly 500,000 acres of palustrine forested wetland; were converted to palustrine scrub-shrub or emergent wetland (Dahl and Johnson 1991).

Most of the wetland resources in the Big Creek watershed are found in Forsyth County (**Table 8-9**), with the largest and most contiguous tracts found in Subwatershed C. In terms of size and width, and thus a wetland's capacity to function well as a pollutant filter, the largest concentration of valuable stream corridor wetlands are in Subwatershed C. These wetlands may also be under the greatest threat to future development and indirect impacts such as increased runoff due to increases in impervious surface.

The stream corridor wetlands in Subwatersheds D, E, and F are generally the same type (palustrine forested or scrub-shrub) but tend to occur in smaller and more isolated patches than those in C. These wetlands lie in the headwaters of the Big Creek Watershed and thus play an important role in maintaining downstream water quality.

In Subwatersheds A and B, the predominant wetland types are again palustrine forested or scrub-shrub, and occur in fairly large and contiguous tracts. These two Subwatersheds are the most highly developed in the Big Creek watershed and presently show signs of degradation. For example, two stream segments. Foe Killer Creek and a segment of Big Creek, do not meet water quality criteria as required by 303(d) standards.

8.4.4 Recommendations for Wetland Protection

A range of measures could be utilized for protecting and managing the wetland resources in Big Creek Watershed. The best approach is a proactive wetlands management and protection plan that is also coordinated with other surface water and ground-water protection programs and with other resource management programs, such as flood control, water supply, protection of fish and wildlife, recreation, control of stormwater, and non-point source pollution.

The single best method of protecting the wetlands in the Big Creek Watershed is to prohibit all development or disturbance within the floodplains. Since the floodplain is very likely to encompass the stream corridor wetlands or act as a buffer for the wetlands, this prohibition provides the easiest and most efficient means of resource protection. The present and future floodplain boundary should be verified and mapped to ensure this protection. Existing ordinances, such as stream buffer ordinances, may be easily modified to include protective measures for wetlands

Table 8-9: Wetland Characteristics by Subwatershed

Sub-Watershed		% Impervious Area			Stream corridor wetlands			
Name	Total Area'	199 5	2015	% Change	Total Area'	Dominant Wetland Type	Area'	%of Total
A	24347 Acres	29%	41%	+12%	235 Acres	Palustrine forested/scrub-shrub. temporarily to semipermanently flooded Palustrine unconsolidated bottom, permanently flooded Other	194 Acres 26 Acres 15 Acres	83% 11% 6% /
B	5968 Acres	28%	42%	+14%	239 Acre*	Palustrine forested/scrub-shrub, temporarily to semipermanently flooded Other	220 Acres 19 Acres	92% 8%
C	13561 Acres	"25%"	"34%-	~+6%-	577 Acres	Palustrine forested/scrub-shrub, temporarily to semipermanently flooded Palustrine unconsolidated bottom, permanently flooded Other	549 Acres 13 Acres 15 Acres	95% 2% 3%
0	5894 Acre*	20%	20%	0%	177 ACT-	Palustrine forested/scrub-shrub, temporarily to semipermanently flooded Other	174 Acres 3 Acres	98% 2%
E	10821 Acres	22%	33%	+11%	200 Aow	Palustrine forested/scrub-shrub, temporarily to semipermanently flooded Other	172 Acres 28 Acres	86% 14%
F	6930 Acres	27%	25%	-2%	71 Acres	Palustrine forested/scrub-shrub, temporarily to semipermanently flooded Other	70 Acres 1Acre	99% 1%

Source: National Wetland Inventory (USFWS), Camp Dresser & McKee, and Staff analysis within stream buffers and or floodplains. Buffers of at least 100 feet from the top of bank are recommended to provide adequate resource protection.

The general goals for wetland protection, management and restoration may be guided by the general characteristics of each subwatershed. For example, the quality of wetlands and stream reaches in Subwatersheds A and B is currently somewhat degraded. The primary goal for these Subwatersheds would be to improve the conditions by restoring and reinforcing streambanks, assessing the quality and size of wetland and stream buffers, and where possible, providing additional means of wetland protection. There also is great opportunity to incorporate wetlands into the many greenways proposed in these Subwatersheds.

For Subwatershed C, the goals would be to provide adequate protective measures for wetlands such as buffers, incorporate greenways into existing wetland systems, and ensure that large and contiguous tracts of wetlands are not segmented or divided by road crossings, bridges, and utility lines and rights of way.

For the three Subwatersheds in the northern part of the Big Creek Basin, Subwatersheds D, E, and F, the overall goal would be to ensure adequate wetland buffers widths, especially in areas where the amount of impervious surface may increase. This may be the most effective means of maintaining water quality, especially for the reaches downstream.

An overall wetland management program for the entire watershed would typically include the following components:

- Defined goals and objectives
- Inventory and mapping
- Valuation and prioritization
- Protection and conservation
- Development of policies, ordinances, and development guidelines
- Restoration, creation, and enhancement
- Research and monitoring
- Education and interpretation
- Acquisition and incentive program
- Mitigation program
- Enforcement

In each jurisdiction, the wetland resources should be accurately mapped, inventoried, and surveyed. National Wetland Inventory maps would provide an initial base but do not provide complete or completely accurate information. This data could be enhanced by taking and interpreting infra-red aerial photographs to verify stream corridor wetlands mapped by NWI and capture stream corridor wetlands that the NWI maps may have missed. A field component would also be recommended for a select number of stream corridor wetlands to verify their type and condition.

Once a high-quality map of the wetland resources is created, the resources may be prioritized for protection and preservation. Wetlands determined as the highest quality should be the first to be incorporated into a greenway network in the watershed. This would satisfy the two goals of wetland protection and providing recreation resources.

Numerous federal agencies have programs related to wetlands. **Table 8-10** lists many of these through which jurisdictions may pursue funding.

Table 8-10
Federal Programs Related to Wetlands

Program Name	Administering Agency
Section 503 Watershed Management, Restoration, and Development	US Army Corps of Engineers
Aquatic Ecosystem Restoration	US Army Corps of Engineers
Everglades and South Florida Ecosystem Restoration	US Army Corps of Engineers
Conservation Reserve Program	Farm Service Agency
Wetlands Protection Development Grants	US Environmental Protection Agency
Clean Water Act State Revolving Loan Fund	US Environmental Protection Agency
Conservation Farm Option	Natural Resources Conservation Service
Wetlands Reserve Program	Natural Resources Conservation Service
Environmental Programs and Management (EPM)	US Environmental Protection Agency
State and Tribal Assistance Grants	US Environmental Protection Agency
Coastal Wetlands Planning, Protection, & Restoration Act	U.S. Fish and Wildlife Service
National Estuary Program	US Environmental Protection Agency
Consolidated Pesticide Enforcement Cooperative Agreements	US Environmental Protection Agency
Environmental Education and Training Program	US Environmental Protection Agency
Environmental Education Grants	US Environmental Protection Agency
Cooperative Endangered Species Conservation	U.S. Fish and Wildlife Service
Wildlife Conservation and Appreciation	U.S. Fish and Wildlife Service
Administrative Grants for Federal Aid in Sport Fish and Wildlife Restoration	U.S. Fish and Wildlife Service
Habitat Conservation	National Marine Fisheries Service
Watershed Surveys and Planning	Natural Resources Conservation Service
Forestry Incentives Program	Natural Resources Conservation Service
Soil and Water Conservation	Natural Resources Conservation Service
Great Plains Conservation	Natural Resources Conservation Service
Plant Materials for Conservation	Natural Resources Conservation Service
Emergency Conservation Program	Farm Service Agency
Water Bank Program	Natural Resources Conservation Service
Emergency Advance Measures for Flood Prevention	US Army Corps of Engineers
Rural Economic Development Loans and Grants	Rural Business-Cooperative Service, USDA

Program Name	Administering Agency
Urban Park and Recreation Recovery Program	National Parks Service
North American Wetlands Conservation Fund	U.S. Fish and Wildlife Service
Fish, Wildlife, and Parks Program on Indian Lands	Bureau of Indian Affairs
Aquatic Plant Control	US Army Corps of Engineers
Coastal Zone Management Administration	National Oceanic and Atmospheric Administration
Sea Grant Support	National Oceanic and Atmospheric Administration
Columbia River Fisheries Development Program	National Marine Fisheries Service
Flood Mitigation and Riverine Restoration Program (Section 212)	US Army Corps of Engineers
Farmland Protection Program	Natural Resources Conservation Service
Economic Adjustment Assistance	Economic Development Administration

8.5 Greenway Policy for the Big Creek Watershed

8.5.1 Introduction

The objectives in developing a greenway policy for the Big Creek watershed are as follows:

- Document the methodology and approach for developing a greenway policy that could be adopted for incorporation into the watershed plan for the Big Creek watershed;
- Develop a greenway policy that includes a vision statement and goals for a regional greenway system, its framework, and acceptable uses; and
- Recommend strategies for general implementation of greenways proposed by local jurisdictions.

8.5.2 Methodology and Approach

The identification of existing and proposed greenway facilities in the Big Creek Watershed were developed by conducting data collection for mapping and research regarding greenway approaches and policies both regionally and nationally. The following documents were reviewed for both policies and greenway projects in the study area:

- Georgia Trail Corridors and Greenways Plan
- Atlanta Region Bicycle Transportation and Pedestrian Walkways Plan
- The Fulton County Bicycle and Pedestrian Plan
- Atlanta Parks Open Space and Greenways Plan
- The Conceptual Greenways Plan: A Greenways Vision for Alpharetta
- Historic Roswell Trail System Master Plan for the Roswell Riverwalk

- The Big Creek Greenway (Alpharetta)

Other documents were reviewed for general information regarding greenway approaches and policies.

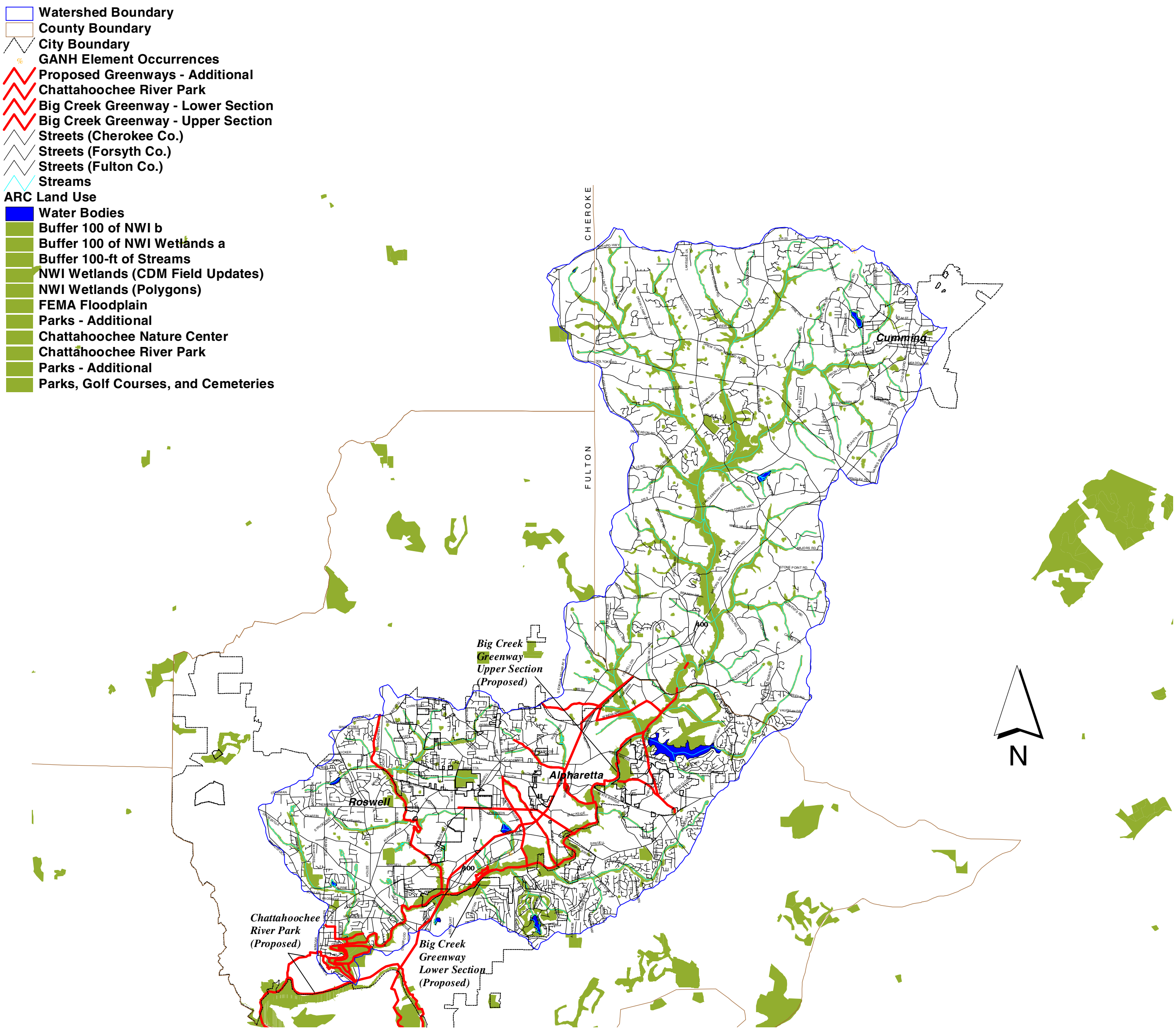
A GIS coverage of existing and conceptual greenways was developed for the study using projects found in the above documents is shown in **Figure 8-3**. Parks and open space mapped by ARC were also digitized to supplement parks and open space coverages and land use data which previously existed. Threatened and Endangered species element occurrences were obtained from the Georgia Department of Natural Resources Natural Heritage Program. Wetlands data was obtained from the U.S. Fish and Wildlife Service. It is important to note that the use of different scales and sources of data necessarily creates a margin of error in certain areas.

Charles Little, in his classic work, Greenways for America, defines greenways as follows:

> *A greenway is 1) a linear open space established along either a natural corridor, such as a riverfront, stream valley, or ridgeline, or overland along a railroad right-of-way converted to recreational use, a canal, a scenic road, or other route; 2) any natural or landscaped course for pedestrian or bicycle passage; 3) an open-space connector linking parks, nature reserves, cultural features, or historic sites with each other and with populated areas; or 4) locally, certain strip or linear parks designated as a parkway or greenbelt.*

He then categorizes greenways into five major project types:

- Urban riverside greenways, usually created as part of (or instead of) a redevelopment program along neglected, often run-down city water fronts.
- Recreational greenways, featuring paths and trails of various kinds, often of relatively long distance, based on natural corridors as well as canals, abandoned railbeds, and other public rights-of-way.
- Ecologically significant natural corridors, usually along rivers and streams and (less often) ridgelines, to provide for wildlife migration and "species interchange," nature study, and hiking.
- Scenic and historic routes, usually along a road or highway (or, less often, a waterway), the most representative of them making an effort to provide pedestrian access along the route or at least places to alight from the car.
- Comprehensive greenway systems or networks, usually based on natural landforms such as valleys and ridges but sometimes simply an opportunistic assemblage of greenways and open spaces of various kinds to create an alternative municipal or regional green infrastructure.



Atlanta Regional Commission
Big Creek Watershed Study

Figure 8-3
Proposed Greenway System

The greenway component of this study promotes the fifth project type, a regional greenway network for the Big Creek basin with emphasis placed upon ecological greenways protecting Big Creek and its tributaries. This approach allows the opportunistic integration of all proposed greenway types from local jurisdictions, which serve multiple purposes, with the objective of this study which is the protection of water quality in the Big Creek basin. Ecological greenways would serve the primary function of protecting streams but would be supplemented by other greenway types such as utility easements or roadside trails serving other purposes.

Ecological greenways have shown themselves to be immensely valuable as movement corridors for species, vegetative filters of sediment and nonpoint pollution from runoff along streams, and moderators of air pollution and temperature extremes in cities. All greenways need not provide recreational benefits and intensively developed greenways can conflict with the natural value of a greenway. In some cases, it may only be appropriate to have a narrow soft surface trail in a greenway and in certain cases, there may be reasons not to develop any recreational public access at all. The uses and functions of various greenway segments must be assigned based upon the suitability of a segment for a particular use or function. Most corridors will support multiple uses but each segment must be evaluated on a site-specific basis before uses are assigned. The potential uses and benefits of greenways are as follows:

- Preserve vital habitat and migration corridors
- Promote plant and animal species diversity
- Provide critical filtering zone for stormwater runoff
- Cleanse and replenish air
- Provide outdoor recreation areas for jogging, walking, hiking, fishing, and canoeing
- Provide safe, non-polluting transportation routes for commuters thus improving air quality and traffic congestion
- Provide access to historic and cultural sites
- Utilize public transportation and utility corridors for multiple uses
- Preserve rural character or safeguard visual interests
- Protect urban open space and forest
- Provide opportunities for environmental education and research
- Provide community amenities with economic implications for property values, revitalization, and tourism.

- Provide flood control by protecting floodplains and wetlands

The conceptual framework for a Big Creek Greenway system developed for this study is a regional network of greenways for both human and environmental benefit. Greenway segments will fulfill different purposes and uses as appropriate. The framework would be developed at a regional level, incorporate existing local plans and efforts and making connections across jurisdictional boundaries. A unified vision and goals would drive the development of the conceptual framework; however, individual greenway segments would be design, programmed and implemented by local jurisdictions based upon unified guidelines and principles.

The primary focus of a greenway system for the Big Creek basin would be an ecological one. Ecological functions which can be achieved in the Big Creek basin include floodplain, wetland, and stream protection; habitat and corridor preservation;

maintenance of species biodiversity; and air and water quality improvement. In addition, the system can provide many other community and economic benefits as described above.

The backbone of the system would be the riparian area surrounding Big Creek and its tributaries. The riparian greenway system would be complemented by cross-country linkages including utility easements and roadside trails as defined by local jurisdictions. Ideally, the primary greenway system would include all of the floodplain area around Big Creek and its tributaries plus appropriate undisturbed buffers around streams and large or significant stream corridor wetlands. The floodplain would remain undisturbed with the exception of certain minimal uses.

To complete the ecological greenway network, cross-county greenway linkages are recommended to tie the system together, particularly in headwater areas. One useful approach to establishing cross-country corridors is to connect existing open spaces, such as parks, golf courses, or cemeteries, which are located in upland areas. These can be connected with greenway corridors, both to each other and to the riparian based greenway network. This linking provides multiple avenues for species migration and habitat preservation. Critical network links must be established and maintained to ensure the ecological function of the greenway system. In developing areas, this means setting aside critical corridors, especially highway crossings. In already developed areas, links may have to be re-established, by restoring riparian buffers for example. One challenge, which must be met in the Big Creek basin, is the provision of greenway links across Georgia 400 and future transportation thoroughfares.

Once the ecological greenway framework has been established, it may be supplemented and overlain by trails and other uses serving human transportation and recreational needs. Criteria should be developed for the use of greenway segments based on environmental sensitivity. Some greenway segments may only be suitable to handle limited or no human use. For example, public access should be limited around threatened and endangered species habitat areas, sensitive stream segments and some wetlands. Guidelines and criteria could be developed for trail, recreational, and educational greenway uses.

A likely use for the Big Creek Greenway system is a regional trail network. Trails of varying magnitude are appropriate in some ecological greenways. In addition, trails can be located in cross-country greenways such as road corridors, utility easements, and rail rights-of-way. Trail networks are often designed to connect environmental education sites, historic and cultural sites, schools, recreational facilities, transit stops, major commercial and employment centers, and neighborhoods. When developing a regional trail system, it is important to address multiple users, age groups, and geographic areas. It is also important to tie the off-street greenway trail system to more urban pedestrian and on-street bicycle networks. If greenways cannot be carried into the heart of urban centers, they should be designed to link to the urban open space system of streets, sidewalks, and squares.

8.5.3 Draft Greenway Policy for the Big Creek Watershed

8.5.3.1 Vision Statement

A necessary component of any greenway policy is a multi-jurisdictional vision statement from which goals can be established. A vision statement for a greenway system should capture the multiple goals and priorities the community has for the system. Below is a recommended vision statement, which emphasizes water quality and natural resource protection as the primary goal of a greenway system with recreational benefits as a secondary goal.

> *The Big Creek Greenway system will be a multi-jurisdictional greenway system, which protects water quality and natural resources while providing community amenities such as parks, open space, and trails for recreation, education and transportation.*

8.5.3.2 Goals

Goals and objectives can be refined with public input and tailored to local needs and desires. Sample goals are offered for consideration below:

- ***Regional Greenway System***
  - Incorporate existing local plans and efforts into the regional greenway framework.
  - Make greenway connections across jurisdictional boundaries.
  - Develop and adopt unifying design guidelines and principles to guide the implementation of the greenway system across jurisdictions.

- Adopt the conceptual greenway plan into local comprehensive plans and show preservation areas and greenway corridors on local Comprehensive Land Use Maps.

- Incorporate greenway system implementation and preservation of conservation areas and corridors into local development codes and ordinances.

- Develop a management plan, which ensures the long-term maintenance and protection of the greenway system.

- Establish multi-jurisdictional agreements that protect and preserve the integrity of the greenway system.

- ***Physical Greenway Framework***

  - Design the riparian area surrounding Big Creek and its tributaries as the core of the regional greenway system.

    - Protect the floodplain of Big Creek and its tributaries from clearing, development, and other disturbance.

    - Establish 100 foot minimum undisturbed vegetative buffers around Big Creek, its tributaries, and stream corridor wetlands.

  - Supplement the core riparian greenway system with cross-county greenway linkages.

    - Connect existing open spaces, such as parks, golf courses, and cemeteries to each other and to the riparian greenway system.

    - Maintain greenway connections across major transportation thoroughfares for species migration and trail connections.

  - Restore greenway corridors in developed areas.

  - Restore fragmented riparian buffer zones and restore degraded streambanks..

    - Establish greenway links across Georgia 400 for both trail connections and species migration.

    - Link greenway corridors to urban open-space systems such as streets, squares, sidewalks, and on-street bikeways.

    - Adopt tree ordinances that allow tree mitigation banking in greenway corridors.

- ***Greenway Uses***

- Establish the primary purpose and role of each greenway segment.
- Determine appropriate uses in greenway segments based upon environmental considerations.
- Limit public access in areas surrounding threatened and endangered species habitats.
- Limit public access and uses in streams and wetlands, buffer areas, and floodplains.
- Develop and adopt guidelines for the development of trail, recreational, and educational greenway uses.
- Provide greenways for multiple users, age groups, and geographic areas.

- ***Regional Trail System***
  - Develop a comprehensive regional trail system that can serve a variety of users.
  - Connect the trail system across jurisdictional boundaries.
  - Avoid the location of trails in environmentally sensitive greenway segments.
  - Link the greenway trail system to on-street bicycle and sidewalk systems.
  - Trails located in wetland areas should be limited, should be linked with environmental education programs, and should be constructed of boardwalks and bridges.
  - Trails should not be located near the habitats of threatened or endanger species.
  - Adopt standards and guidelines for trial design and construction.
  - Adopt trail maintenance programs, which ensure the long-term upkeep of the trails.
  - Design limited and controlled access points to streams and waterbodies.
  - Design and plan the trail system to minimize conflicts among the different trail user groups.
  - Connect destination points throughout the study area including schools, recreation areas, major commercial and employment centers, neighborhoods, and historic and cultural sites.

8.5.4 Recommended Strategies for General Implementation

As described above, a regional greenway system should be developed for the Big Creek basin. The core of the system would consist of ecological greenways centered on Big Creek and its tributaries and the primary function of these greenways would be maintenance of water quality and stream integrity. The ecological greenways would be complimented by other greenways serving a variety of community needs and uses.

Following are some recommendations to local jurisdictions for prioritizing actions to implement the regional greenway system.

- Adopt a multi-jurisdictional greenway plan and policy to guide the development of greenway segments across jurisdictional boundaries.
- Map greenway corridors and adopt into local comprehensive plans and show on local comprehensive land use plan maps as protection areas.
- Protect floodplain and buffer areas through ordinances and regulations.
- Leave greenway properties which do not require public access in private ownership and protect through ordinances and conservation easements.
- Acquire fee simple ownership or public access easements for those greenway segments requiring public access.
- Require dedication of greenway corridors and linkage through the development review process. Provide developer incentives such as clustering, transfer of development rights, tax incentives, and waiver of impact fees.
- Publicize the multiple benefits of greenways including those documented in The Economic Benefits of Parks and Open Space published by The Trust For Public Land.
- Develop an acquisition plan, which prioritizes parcels for acquisition and identifies funding sources, time frames, and responsible parties.

8.6 Long-Term Monitoring Plan

8.6.1 Introduction

An ongoing watershed characterization / monitoring program is a necessary element of any watershed management program for two basic reasons. First, watersheds are constantly changing and characterizations must continue in order to measure these changes. Secondly, the effectiveness of watershed management activities should be periodically measured in order to assess the adequacy and cost-effectiveness of these activities.

The chief difficulty in monitoring watersheds is that they are highly variable systems with climatic, hydrologic, hydraulic, geomorphic, biological, and chemical characteristics. The basic goal of a continuing monitoring program is to collect sufficient data as is necessary to observe changes over the long-term, identify and address problems in the short-term, and to make management decisions and to demonstrate reasonable assurance.

There are several guiding principles used in the development of the recommended monitoring program for Big Creek:

- Because of the variability that is inherent in data collected on watersheds, it is imperative that statistical significance and confidence levels be recognized as a design tenet in crafting a monitoring program. It is in no one's interest to expend funds collecting data that provides insights that are, in essence, speculative.
- It is important to recognize that the water quality standards developed for Big Creek (and other US waterways) were developed for a specific flow regime (representative low flow conditions) and, as such, are an inadequate set of standards for indicating watershed health.
- It is important to recognize that public dollars are limited and that for every dollar spent on monitoring, fewer funds become available to assist in the implementation of management programs.
- A watershed-wide monitoring program needs to respect the existing monitoring programs of entities in the watershed to the maximum extent practicable. For example, Roswell is implementing a Long-Term Monitoring Plan, including Big Creek and major sub-watersheds, that is designed to measure restoration progress and provide drinking water protection. Roswell's system will include a compilation of chemical, biological and physical measurements of watershed health. Roswell intends to share the results and its experiences with the monitoring program with the other local jurisdictions. This, along with other regional and national experiences could lead to changes in the base program after review.

Using the guiding principles discussed previously in developing a long-term monitoring program, the following recommendations are made. This monitoring plan is recommended as a base minimum and may be expanded to meet other needs as identified by each community and the State.

8.6.2 Land Use Specific Monitoring

Because of the similarity in EMC values from specific land use types across the country and because of the significant cost associated with measuring EMCs, this type of monitoring is not seen as value-added for the Big Creek watershed. In addition, the overall value of this type of monitoring has been called into question in recent years (Torno 1994).

8.6.3 Ambient Water Quality Monitoring

Dry and wet weather ambient water quality monitoring data should be collected. These should be collected at least three times per year. For dry weather, samples should be collected after an antecedent dry period of at least 72 hours. For wet weather, grab sampling should be conducted within 24 hours of a rainfall of 3/4 –inch or greater as agreed on by the team. This depth of rainfall is targeted, as it will most likely generate sufficient flows to be representative of ambient conditions. Approximately 10 sampling locations should be distributed throughout the Big Creek watershed at which dry and wet weather monitoring occurs. These are best distributed at confluence points within the watershed so that should pollutants be found in significant amounts (particularly in dry weather), source investigations can ensue logically.

Parameters that should be measured include:

- In-Field Analyses:
  - Flow
  - Temperature and pH
  - Conductivity
  - Dissolved oxygen
  - Turbidity
- Laboratory Analyses:
  - Total suspended solids (TSS)
  - Total dissolved solids (TDS)
  - Total hardness (as $CaCO_3$)
  - BOD_5
  - Chemical oxygen demand (COD)
  - Total phosphorus (TP)
  - Orthophosphorus (PO_4)
  - NO_2, plus NO_3

- Ammonia
- Total kjeldahl nitrogen (TKN)
- Fecal coliform
- E. Coli
- Total and Dissolved Metals (Zinc, Lead, Copper, Chromium, Iron, Manganese).

E. Coli is suggested in addition to fecal coliform as E. Coli is generally thought to be more indicative of human waste if present. Recent studies have shown that the presence of fecal coliform in natural waterways may or may not be indicative of human waste.

Total Dissolved Solids may be correlated to conductivity, which requires only measurement with a probe and can be done in the field. Similarly, Total Suspended Solids may be correlated with turbidity. This is a spectrophotometric test and can also be done in the field. If jurisdictions choose to use these tests, data for TDS and TSS should be collected until the correlation can be established using statistical methods.

8.6.4 Flow-weighted Instream Water Quality

Because of its importance to water quality modeling calibration and verification, wet weather sampling of instream water quality is recommended. It should be done throughout the watershed at selected locations, which include the ambient monitoring locations. Five samples per year per season should be taken until a statistically significant database is developed.

The same parameters as those recommended for collection under ambient monitoring should be used.

8.6.5 Stream Channel Morphology

An assessment of stream geomorphology, based on the methodologies outlines by Rosgen is an integral part of the watershed plan. Rosgen developed a stream classification system used throughout the United States. It is frequently modified to meet specific needs and extend local capabilities. The process of performing a Rosgen Assessment is divided into four levels. Much of the Level I geomorphic characterization utilizes aerial photography and topographic maps. Riparian landforms are sorted into 11 valley types based upon the slope of the stream and topography of its valley. Rivers and streams are divided into 8 broad types on the basis of their channel and floodplain geometry. Individual Level I reach classifications are checked by field examination of the reaches.

The Level II morphological description provides a much more detailed description based upon stream measurements at selected locations. Streams are further subdivided into 94 subtypes based upon degree of entrenchment, width to depth ratio, water surface slope, streambed materials, and sinuosity. Of Level II criteria, the width-to-depth ratio is the most sensitive and positive indicator of trends in channel instability.

Stream form and structure, as defined by Level II criteria, describe a stream's basic pattern. The Level III assessment of stream condition:

- Describes the potential stability of a stream, as contrasted with its existing condition.
- Determines the variance of a stream's existing condition from a reference baseline.
- Provides guidelines for documenting and evaluating riparian vegetation, the pattern of channel deposits, channel obstructions, stream meander pattern, stream channel stability, and fish habitat.

Careful documentation of the observations obtained in the Level II and III classifications permit the development of informed conclusions about stream condition.

Level IV field data verification substantiates the extent and magnitude of stream channel adjustment processes indicated from collected stream and riparian area data. Such verification permits measurable extension of the stream classification technique to other areas having similar characteristics as determined from a Level III inventory. This approach blends both physical and biological function within a watershed context, providing a wide range of interpretations for natural resource management applications.

The Level IV analysis includes measurements of stream sediment, stream flow, and stream stability. Trends over time are also monitored. This analysis allows evaluation of sediment transport relationships, prediction of the response of tributaries to changes in land use, and development of effective stream restoration activities.

It is recommended that every five years, the Level I and II assessment should be conducted on all reaches and Level II and IV assessments in ten percent of the reaches.

8.6.6 Biological

As with stream morphology, biological indicators provide a much better long-term indicator of stream health. In conjunction with the assessment of stream channel morphology, biological assessment should be performed including stream habitat assessment, benthic macroinvertebrate community structure assessment, fish community structure assessment, and fish tissue analysis. These should also be conducted on a frequency of once every five years or less.

8.6.7 Ancillary Watershed Indicators

Monitoring of BMPs is recommended, as a more robust database of BMP performance is needed regionally and nationally. Protocols should follow those outlined by Oswald (1994) and ASCE/EPA (1999). At least three of each type of BMP (wet pond, regional pond, extended detention (dry), extended detention (wet), detentions with filtration, and retrofits) should be monitored. A greater number should be monitored if widely different designs are used among jurisdictions. This should occur over the next ten years and can taper off thereafter as sufficient understanding of BMP performance emerges.

CDM recommends that the "monitoring" of programmatic elements of the management programs (as proposed in the Forsyth County plan) be used as a tool to improve implementation methodologies under the management programs and not as a monitoring activity per se. These evaluation techniques are quite important but are highly specific to the institutions investigated and necessarily must be customized and continually adapted.

8.6.8 Monitoring Locations

CDM prioritized the recommended monitoring locations. **Table 8-11** provides a range of representative unit costs for monitoring activities. **Table 8-12** and **Figure 8-4** identify the monitoring location, which jurisdiction should maintain it, why the location was chosen, and which priority phase the monitoring should be installed.

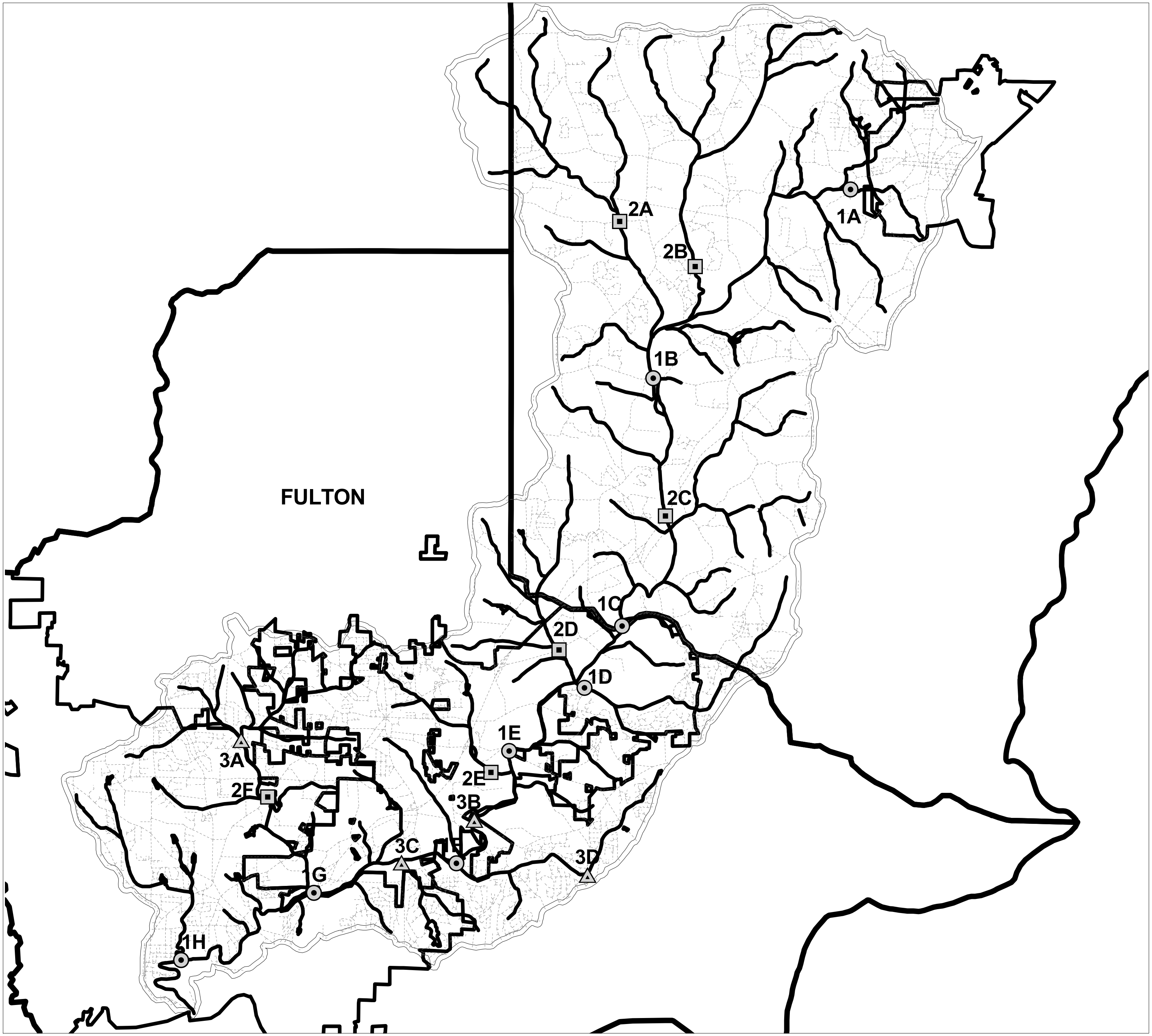
Table 8-11
Estimated Unit Costs for Monitoring Activities

Monitoring Activity	Unit Cost Range
Ambient Monitoring	$200-$1000 / sample
Wet Weather Flow -Weighted Monitoring	$750-$2000 / sample
Biological Assessment	$1500 - $7500 / location
Stream Morphology (Level 1 and 2)	$1250 - $10,000 / location
Stream Morphology (Level 3 and 4)	$4500 - $30,000 / location
BMP Monitoring	$200 - $2000 / sample

NOTE: Costs include sample acquisition and analysis

Table 8-12
Proposed Big Creek Monitoring Station Locations

RANKED MONITOR DESIGNATION	DISTRICT LOCATION	NEAREST ROADWAY	JURISDICTION RECOMMENDATION	GROSS DRAINAGE ACREAGE	LOCATION DESCRIPTION	JURISDICTIONAL RATIONALE
1A	FORSYTH	JASON DR	CUMMING	1,112	ROAD CROSSING 300 YDS UPSTREAM OF CONFLUENCE / DEVELOPED BY 1995	CUMMING: THIS MONITOR IS LOCATED IN FORSYTH, BUT SHOULD BE IN UNDER CUMMING JURISDICTION BECAUSE 1) THE MAJORITY OF THE FLOW PAST THIS STATION WILL DERIVE FROM CUMMING DRAINAGE. 2) OF THESE 13 MONITORING STATIONS, THIS IS THE ONLY ONE
1B	FORSYTH	ATLANTA HWY	FORSYTH	18,570	ROAD CROSSING / UNDEVELOPED IN 2020	FORSYTH: PRIMARY FLOW OBSERVED AT THIS STATION DERIVES FROM FORSYTH DRAINAGE BASINS
1C	FORSYTH 1 ALPHARETTA	CASTLEBERRY RD	FORSYTH	28,565	ROAD CROSSING 1 DEVELOPED BY 1995	FORSYTH: PRIMARY FLOW OBSERVED AT THIS STATION DERIVES FROM FORSYTH DRAINAGE BASINS
ID	ALPHARETTA	LAKE WINDWARD DR	ALPHARETTA	35,004	ROAD CROSSING 7 UNDEVELOPED BY 2020	FORSYTH: PRIMARY FLOW OBSERVED AT THIS STATION DERIVES FROM FORSYTH DRAINAGE BASINS
1E	ALPHARETTA	STATE BRIDGE RD	ALPHARETTA	37,420	ROAD CROSSING / DEVELOPED BY 2020	FORSYTH: PLOW DERIVES PRIMARILY FROM 1995 DEVELOPED ALPHARETTA DRAINAGE AREAS
IF	FULTON / ALPHARETTA	HILL CHASE	FORSYTH	2,336	NO ADJACENT ROADWAYS. CONFLUENCES. OR HIGHWAYS	FORSYTH. FLOW DERIVES EXCLUSIVELY FROM 1995 DEVELOPED FORSYTH DRAINAGE AREAS
1G	FULTON / ROSWELL / ALPHARETTA	GA HWY 400	ALPHARETTA	54,301	HIGHWAY CROSSING 200 YDS UPSTREAM OF CONFLUENCE / DEVELOPED BY 1995	ALPHARETTA: PRIMARY FLOW DERIVES FROM ALPHARETTA WITH SOME FLOW FROM ROSWELL
1H	ROSWELL	OXBO OR	ROSWELL	59,835	STREAM PARALLELS 30 YDS NORTH OF HWY / 20 YDS	ROSWELL: 1H TRACKS FLOW PRIMARILY FROM ROSWELL, AND NON-ROSWELL DERIVED FLOW IS GAUGED AT STATION 1G WHICH IS THE PREVIOUS UPSTREAM MONITOR
2A	FORSYTH	BENTLEY RD	FORSYTH	5,093	ROAD CROSSING 300 YDS DOWNSTREAM OF CONFLUENCE / UNDEVELOPED BY 2020	FORSYTH PRIMARY FLOW OBSERVED AT THIS STATION DERIVES FROM FORSYTH DRAINAGE BASINS
2B	FORSYTH	POLO DR	FORSYTH	760	ROAD CROSSING / DEVELOPED BY 1995	FORSYTH: PRIMARY FLOW OBSERVED AT THIS STATION DERIVES FROM FORSYTH DRAINAGE BASINS
2C	FORSYTH	SERVICE RT 400 NB	FORSYTH	21,736	ROAD CROSSING / DEVELOPED BY 1995	FORSYTH: FLOW DERIVES EXCLUSIVELY FROM 1995 DEVELOPED FORSYTH DRAINAGE AREAS
1D	ALPHARETTA	WINDWARD PKWY	FULTON	3,535	ROAD CROSSING / DEVELOPED BY 2020	FULTON: OF THE POTENTIAL JURISDICTIONS, FULTON HAS THE GREATEST AREA OF DEVELOPED DRAINAGE BASIN AREA.
2E	ALPHARETTA	MORRIS RD.	ALPHARETTA	2,118	NO CROSSING / DEVELOPED BY 2020	FORSYTH FLOW DERIVES EXCLUSIVELY FROM 1995 DEVELOPED ALPHARETTA DRAINAGE AREAS
2F	ROSWELL	ALPHARETTA ST	ROSWELL	6,069	ROAD CROSSING / DEVELOPED BY 1995	ROSWELL: THE FLOW IS PRIMARILY ROSWELL DERIVED, AND THE NON- ROSWELL DERIVED FLOW IS GAUGED AT AN UPSTREAM 2ND
3A	FULTON 1 ROSWELL	UPPER HEMBREE RD	FULTON	4,468	ROAD CROSSING 10 YDS DOWNSTREAM OF CONFLUENCE / DEVELOPED BY	FULTON: FULTON HAS THE LARGEST DEVELOPED AREA OF THE TWO POTENTIAL JURISDICTIONS FULTON AND ROSWELL
3B	FULTON / ALPHARETTA	KIMBALL BRIDGE RO	FORSYTH	41,280	ROAD CROSSING / DEVELOPED BY 1995	FORSYTH FLOW DERIVES EXCLUSIVELY FROM 1995 DEVELOPED FULTON DRAINAGE AREAS
3C	ALPHARETTA	HAYNES BRIDGE RD	ROSWELL	46,235	NO ADJACENT ROADWAYS OR CONFLUENCES / 220 YDS NW OF ROXBURGH LN/ UNDEVELOPED	ROSWELL: WHILE THIS MONITOR IS IN ALPHARETTA. THE PRIMARY FLOW PAST IT DERIVES FROM FROM DEVELOPED ROSWELL DRAINAGE BASINS
3D	FULTON	WILLOW MEADOW CIR	FULTON	762	ROAD CROSSING / DEVELOPED BY 1995	FULTON: 1) ALL EXISTING, ADJACENT 1995 DEVELOPMENT IS PULTON DEVELOPMENT. 2) THERE MUST BE A MONITOR HERE BECAUSE THE 2020 DEVELOPMENT IS PROJECTED TO BE

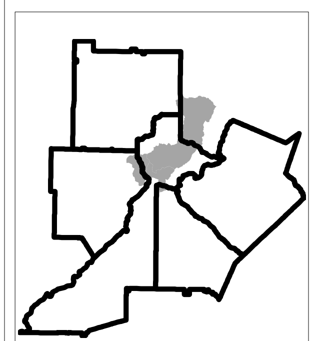


ARC Big Creek Watershed Study

Figure 8-4
Big Creek Watershed Flow Monitoring Stations

LEGEND

Monitor Locations
- Priority 1
- Priority 2
- Priority 3
- Big Creek Waterways
- Forsyth County Streets
- Fulton County Streets
- Big Creek Watershed
- Monitoring Jurisdictions



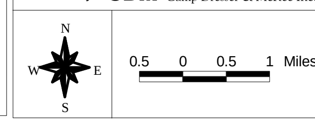
Area of Detail

Data Source:
1. Atlanta Regional Commission, Economic Development Information System, 1997

File Location: Q:\ARCBC\STATIONS.APR

Date Produced: April 2, 2001

Produced by: CDM Camp Dresser & McKee Inc.



8.7 Demonstration Projects

While scope of the project did not provide for a comprehensive assessment of where practices and policies should be implemented within the Big Creek watershed (this will be up to each jurisdiction to do), several opportunities were noted by the project team. The opportunities could be approached as "demonstration" projects – projects that will illustrate the benefits of different practices and policies and help refine implementation procedures.

These potential demonstration projects are:

- ***Long Indian Creek regional detention pond*** -- the proposed regional detention pond is located on an unnamed tributary of Long Indian Creek located between Timberstone Road and Waters Road. The pond will serve an area of approximately 90 acres. There have been complaints of flooding in this area in the past and flooding is expected to increase as future development increases the residential density of the area. Therefore, a regional pond is proposed to address both water quality and water quantity concerns.

- ***Wetland mitigation on Main Stem of Big Creek in Forsyth County*** - the majority of the existing wetlands in the Big Creek watershed are in Forsyth County. Therefore, preservation and enhancement of wetlands within the jurisdiction is critical.

- ***Roswell pond retrofitting*** - The City of Roswell currently has a Pond Partnership Program where the public and private sectors share the cost for improvements to enhance the stormwater capacity of its network of lakes and ponds in the City. There are over 100 ponds within the City limits, most of the ponds were built before water quality design requirements were developed. The City of Roswell has completed a study to assess the condition of these ponds. One pond has been modified and shown to exhibit water quality improvements. Others are in the evaluation stage.

- ***Greenways path in City of Alpharetta*** – The City of Alpharetta is developing along-term plan to acquire and develop a contiguous greenways path for their community. This effort should integrated with the watershed management practices and policies outlined in this study.

- ***Foe Killer Creek streambank restoration*** -- most of Foe Killer Creek has an outstanding value for in-channel and riparian habitat, channel pattern and bank vegetation. The area around new Upper Hembree Road is a meandering section and is experiencing severe erosion on the bends. This area is near a park and because it is highly visible would prove to be a good candidate for a demonstration project.

- ***Kelly Mill Branch stream stabilization*** -- is in the upland reaches of the Big Creek Watershed in the City of Cumming. This area has outstanding pattern and good substrate features and bank slope and should be protected. The canopy closure of this reach is 50-80 percent and has a significant input of large woody debris from undercut trees. The woody debris appears to be enhancing the habitat diversity and is providing substrate for invertebrates and cover for vertebrates. It is recommended that a buffer of 100 feet be enforced and banks stabilized at outside bends replacing riprap or combining riprap with soil bioengineering where feasible and accessible.

- ***Roswell Watershed Demonstration Program -*** Roswell is implementing a watershed demonstration program that includes a long-term monitoring network and performance testing of various stormwater control measures to attenuate flow and remove wet weather contaminants. Integral to the program is Roswell's Lakes and Ponds Ordinance, which encourages sustainable approaches to public/private projects for quality of life coupled with water quality improvements. The demonstration program includes retention facility enhancements, streambank stabilization, lake and pond retrofits, wetlands and riparian buffer protection, waterway optimization, monitoring and source management practices.

8.8 Summary of Watershed Management Recommendations

The recommended watershed management plan is based on the application of source and treatment control practices throughout the entire Big Creek watershed. Specifically, the application of detention-based treatment of urban runoff is required for the watershed to meet water quality goals. Without these practices, moratoriums on development become a distinct possibility. **Table 8-13** provides a recommended schedule for implementing components of the plan.

Table 8-13
Recommended Implementation Schedule for Watershed Management Program Elements

Element	Start	Finish
Long-Term Monitoring	2001	Ongoing
Develop Buffer Requirements	2001	2001
Implement Buffer Requirements	2002	Ongoing
Develop Wetland Requirements	2001	2001
Implement Wetland Requirements	2002	Ongoing
Develop Greenway Requirements	2001	2001
Implement Greenway Requirements	2002	Ongoing
Develop Criteria for BMP Application (Source and Treatment)	2001	2003
Implement BMP Requirements for All New Development	2002	Ongoing

Develop and Prioritize Stream Restoration and Stabilization Projects and Establish Funding	2001	2004
Execute Stream Restoration and Stabilization Projects	2004	Ongoing
Determine Program Costs to Jurisdictions and Establish Funding	2001	2004

These detention practices include extended detention, retention or wet ponds, and constructed or protected and enhanced wetlands. Detention with filtration is also included, though the practice centers on filtering runoff as opposed to detaining it for pollutant settling and/or uptake. Jurisdictions should work with their internal processes and the local development community to implement these detention practices. These may be employed at the local development level or on a broader regional basis. The plan identifies several subbasins within the Big Creek watershed where regional detention seems possible. Regional detention generally provides improved pollutant removal efficiencies compared to local detention and does so at a lower per acre cost. However, site or other restrictions may prevent the application of regional facilities. In such a case, a jurisdiction should rely on local detention on a development-by-development basis.

For existing development, opportunities to retrofit existing detention for water quality benefits should be pursued by each jurisdiction. It is quite important to stress that the application of detention should be done in a manner that provides both water quality and water quantity benefits. Detention facilities should be designed to not only to manage the small storms that make up the bulk of annual runoff for water quality purposes, but they should also be designed to simultaneously provide attenuation for larger storms to prevent flooding.

Source controls, those controls that limit the amount of runoff are recommended as well. Coupled with treatment controls, source controls provide increased infiltration of runoff and reduced flows to BMPs and waterways. These controls include swales and filter strips. Jurisdictions can apply these as each sees fit.

There are several other watershed management practices that are important considerations as they provide high returns on investment. While these practices are not mandatory to achieve water quality goals, they do provide important social and habitat benefits and are considered by many to be common-sense approaches to achieving sustainable urban water resources. Pollution prevention controls (those controls that limit the generation of stormwater pollution) should always be integrated into jurisdictional programs. These controls include anti-dumping, public education, and industrial management activities.

Protecting and restoring streams is another important effort that is strongly recommended. The overall health of waterways is a combination of water quality management (i.e., pollutant management) and habitat management. In order to management habitat effectively several things must occur:

- Existing habitat (e.g., wetlands) must be protected;
- Development should be kept away from waterways and floodplains (at least 100 feet),
- Flow must be controlled as the watershed develops to minimize streambank erosion; and
- Existing erosion problems must be mitigated either by standard stabilization techniques (e.g., channel lining) or by restoring natural channel conditions with bioengineering practices.

By using the required detention practices, source and pollution prevention practices, and other common-sense watershed management techniques, jurisdictions will find that they can meet water quality goals while enhancing the environmental quality of their communities while, at the same time, create the lowest life-cycle cost drainage infrastructure.

8.9 Administrative and Regulatory Needs

With the passage of the Clean Water Act and subsequent legislation, the focus on water quality has increased. As such, most communities have adopted ordinances in an effort to mitigate stormwater runoff impacts to water quality of State waters. The consensus watershed protection plan for the Big Creek watershed includes the implementation of source and treatment controls (engineered structural stormwater quantity and quality structural controls) and enforcement of a minimum stream buffer width of 100-foot or the 100-year floodplain (whichever is greater). Necessary watershed management plan implementation requirements are presented below.

8.9.1 Ordinance, Code and Criteria Revision

8.9.1.1 Source and Treatment Controls

The local jurisdictions should adopt and/or revise existing stormwater management ordinances requiring implementation of the selected source and treatment controls. Ordinances should also require the implementation of appropriate design criteria and establish maintenance requirements.

Application of the recommended controls to areas outside of the Big Creek watershed area will likely aid the local jurisdictions with regards to compliance with NPDES stormwater requirements, help meet water quality goals established as part of recent community watershed assessments, and may address some of the needs associated with TMDL implementation. Alternatively, a Big Creek watershed stormwater management district could be established whereby the management plan recommendations would only affect areas within the Big Creek watershed. However, as stated above, the management plan requirements would likely support water quality management programs outside the Big Creek watershed drainage area.

Additional recommended activities related to the implementation of source and treatment controls:

- Existing drainage infrastructure criteria should be modified to provide explicit requirements for BMP design and construction. This will lower the long-term cost of these structures and improve overall effectiveness.
- For those communities that prefer a regional facility approach, the adopted/revised ordinances should allow for and/or require the implementation of off-site facilities.
- For those facilities that are constructed onsite, the following BMP requirements should be included in the appropriate ordinance(s):
  - Submittal of a stormwater management plan, which provides required facility information; and
  - Submittal of a maintenance plan and agreement for onsite controls.

8.9.1.2 Minimum Buffer Requirements

Adopt and/or revise applicable local ordinances requiring that development in the watershed satisfy buffer zone requirements. For those communities currently exceeding the minimum buffer requirement, revision of ordinances is not necessary.

8.9.1.3 Variances

The project team feels the BMP requirements as well as the buffer requirements are critical to the health of the Big Creek Watershed. Variances should only be granted in cases where implementation of BMPs is not feasible. Applications for variances must be supported by scientific and engineering data which clearly demonstrates that BMPs cannot be implemented. If variances are granted, the applicants may be required to implement alternative measures in other areas of the watershed, such as contributions to the development of a regional facility, greenways, or wetlands.

8.9.1.4 Utility

If the jurisdictions elect to implement a stormwater utility to finance the capital and operation and maintenance of controls, the local governments will have to adopt a stormwater utility ordinance which establishes the utility and provides specifics of this fee structure (e.g., billing schedule and mechanism, record keeping, and provision for appeal).

8.10 Assessment of Funding and Financing Alternatives

Funding is required for both formation and operation of local stormwater management activities. In Georgia, local general funds from property taxes are typically the main funding source for stormwater management programs/activities. However, alternative funding mechanisms, such as the sale of bonds, the state revolving loan fund, development impact fees, the formation of a local special assessment/improvement/tax districts and the creation of stormwater user fee systems (also known as stormwater utilities) do exist. These mechanisms are discussed below and should be further assessed as to their potential revenue and public acceptance within the community as well as legality.

Beyond funding, financing is required to implement the stormwater program. Financing can be accomplished several ways, issuing bonds being the most common. Bonds and other options are discussed below as well.

8.10.1 Funding Options

Annual funding requirements of a local stormwater program include administrative, permitting, design, planning, operation, maintenance, and debt service. The following are the most common options for funding storm water programs. They can be used separately or together to develop the funds necessary.

8.10.1.1 Ad Valorem Taxes / General Funds

A jurisdiction's general fund may be its largest pool of money with a stable funding source (property taxes, miscellaneous revenue, etc.). General fund revenues are primarily derived from ad valorem-based levies on taxable properties. The significant advantage to citizens is that these costs are tax deductible. However, the stability of ongoing stormwater management activities, when funded by general funds, is subject to budget deliberations each fiscal year which may result in irregular funding in budget-short years unless tax increases can compensate. Therefore, stability is a genuine concern. Ad valorem taxes are also less equitable as tax-exempt property does not contribute and charges are based on property value rather than relative stormwater contribution.

8.10.1.2 Special Purpose Local Option Sales Tax

Additional sales tax, identified for a special purpose, such as stormwater management, can be used for funding. These typically require voter approval. Unlike ad valorem taxes, sales tax levies are not tax deductible for the consumer. However, nonresidents also pay the local sales tax, likely offsetting the cost of not having the tax deduction to the citizen. As with ad valorem taxes, sales taxes are less equitable as tax-exempt entities do not contribute and charges are not tied to relative stormwater contribution.

8.10.1.3 Special Assessment / Improvement Tax Districts

A local community may create special tax districts to develop stormwater control systems. The approach is good in cases where capital improvements, special studies and/or extraordinary maintenance benefits a specific area or number of properties within a jurisdiction. The result is that only those who benefit from the system pay for them. As a result, these districts have several funding options available: special taxes on property within the district area, debt financing, development fees and user fees. An alternative to creating districts is to establish basin-specific user fees through a stormwater utility.

8.10.1.4 User Fee/Stormwater Utilities

User fees present an alternative to increased taxes for support of stormwater management activities. Similar to water and wastewater rates, stormwater fees are assessed on "users" of the system based on average conditions for groups of customers with similar service requirements. This arrangement has been commonly called a stormwater utility.

Stormwater infrastructure and management programs can be considered a public service or utility similar to wastewater or water programs and be funded on a similar basis. Typically, fees are based on some measure of a property's impervious area. Rates may be assessed in charges per either equivalent dwelling unit (e.g., "\" dollars per unit per month) or unit area (e.g., "x" dollars per 100 square feet per month). Alternative methodologies include the use of a runoff factor or coefficient based on the type or category of land use, a flat rate per customer, or a combination of any of these methods. Depending on the size and administrative resources of the stormwater utility, customer bills may be assessed either alone or in conjunction with other utility bills.

Stormwater utilities have existed for a number of years in several states, but only recently have been created in Georgia. The chief concern is whether utility charges constitute a tax or a fee. In order to be legally valid, the service must be a fee and assessed equitably. Below are several features which can enhance the chances of a stormwater utility surviving any legal contests:

- Assessed equitably based on amount of service used (runoff generated, impervious area amount, etc.)
- Operation as a separate public utility
- Detailed findings explaining why the project is needed to protect the public health, safety and welfare
- Revenues from fees are segregated and managed as a separate fund
- Credits can be implemented

- Findings and resultant fees are based upon a profession analysis
- An appeal process is provided

While the creation of a stormwater utility is not free of legal risk, they have withstood legal challenges when properly established. Local governments in Georgia would be well advised to consider them for funding their stormwater management activities.

8.10.2 Financing Options

Significant capital expenditures are required in implementing stormwater management programs that include the installation of source and treatment controls. As such, some means of financing the expenditure is required. The most common options for financing are illustrated below. As with funding options, they may be used separately or in combination to achieve the necessary results.

8.10.2.1 Pay-As-You-Go

This approach seeks to establish a flow of revenue into a sinking fund. Expenditures are made (e.g., construction of a regional pond) after the fund contains enough funds to pay for the purchase.

8.10.2.2 Developer-Constructed Improvements

This method simply requires the construction of stormwater improvements as a condition of approving a proposed new development. This is typically restricted to on-site improvements, but in certain cases, off-site improvements have been negotiated.

8.10.2.3 In-Lieu-Of Charges/Development Fees

A development fee or "impact fee" is an assessment of a development's impact within a proposed watershed system area. The total share of the costs for the project is determined by the new facilities required and/or increased levels of service necessary. Rather than require developers to construct on-site a structural control at their expense, each development is assessed a fee up-front. These are generally one-time fees, the revenues of which are used specifically to finance new stormwater facilities or other system components.

Compatible with a regional facility approach, development fees provide an up-front source of cash to fund projects as they become necessary. However, unless fees are levied retroactively, they may not be appropriate for highly developed areas. Typically the fee covers only construction costs, meaning the maintenance costs must be covered through some other source. Moreover, the fee rate structure required must be designed carefully to withstand legal challenges.

8.10.2.4 General Obligation/Revenue Bonds

Debt financing of capital and operation and maintenance can be accomplished through issuing general obligation bonds, revenue bonds or a combination of the two.

Typically, however, bond revenue distributes the costs of capital improvements over several years, thereby lowering the initial annual cost, allowing for construction to occur sooner. A bond issue requires voter approval on a referendum ballot and is subject to local administrative policy in the form of "debt ceilings." Most stormwater project debt has been financed through issuance of 15-year term bonds. These bonds are repayable from service charge proceeds, general revenue and other sources such as development fees. If backed by user fee revenues, revenue bonds issued may not be an option until a government has established a user fee history, since these bonds would be retired through user fee revenues.

8.10.2.5 Georgia Environmental Facilities Authority (GEFA) - State Revolving Loan Fund

Stormwater related projects can be financed through the Clean Water State Revolving Loan Fund (CWSRF) of GEFA. Discussions with GEFA staff have indicated that they are trying to induce more nonpoint source pollution control projects, in particular projects addressing stormwater management. Activities eligible for funding include, but are not limited to construction of structural nonpoint source pollution controls and acquisition of buffer zones or wetlands adjacent to State waters. Other non-construction and non-acquisition related activities would be evaluated on a case-by-case basis.

Loans are available at a low interest rate for a maximum of twenty years. Because the funds originate as federal grants to the state, federal requirements are involved.

Appendix A
HEC-2 / HEC-RAS Input Files

C	Long Indian FEMA Study									
C	14									
C	725	X-SECTION-A								
C	3350	X-SECTION-B								
C	5520	X-SECTION-C								
C	6428	WATERS	ROAD							
C	6500	X-SECTION-D								
C	10700	X-SECTION-E								
C	12335	X-SECTION-F								
C	13964	WILLOW	MEADOW	CIRCLE						
C	15035	X-SECTION-G								
C	17240	BUICE	ROAD							
C	18177	INDIAN	VILLAGE	DRIVE						
C	18230	X-SECTION-H								
C	20500	STATE	BRIDGE	ROAD						
C	20585	X-SECTION-I								
C2	0.1	0.1	0.05	0.1	0.3					
*	FEMA X-SECTION	A								
C3	725	11	1268	1291						
C4	975	1000	966.2	1046	965.9	1082	964.5	1182	966.2	1268
C4	960.4	1271	959.7	1288	965.1	1291	966.5	1359	969.4	1382
C4	982.1	1482								
C2	0.15									
*	FEMA X-SECTIO	B								
C3	3350	11	1080	1106	2700	2400	2625			
C4	985.3	1000	978.4	1023	973.4	1080	968.9	1085	969.6	1097
C4	973.1	1100	975.9	1106	974.9	1200	974.6	1300	975.8	1349
C4	982.4	1375								
*	FEMA X-SECTION	C								
C3	5520	11	1085	1125	1900	2040	2170			
C4	1000.5	1000	986.8	1045	986.3	1085	979.4	1095	979.1	1113
C4	987.6	1125	986	1156	985.8	1200	987.3	1300	989.8	1350
C4	997.1	1380								
C2	0.15									
C3	6000	10	1153	1175	570	450	480			
C4	1000	1000	995	1015	990	1145	985	1153	981.1	1156
C4	981.1	1168	985	1175	990	1212	995	1268	1000	1290
C2	0.3	0.5								
C3	6400	22	1257.5	1272	400	400	400			
X3	10	995	995							
C4	1005	950	1000.4	1000	996	1009	993	1039	990.4	1100
C4	989.5	1200	989	1243	988.8	1251	988.8	1251.1	988.7	1257.5
C4	986.8	1257.6	982.8	1260	986.6	1271.9	987.8	1272	989.2	1281
C4	989.2	1281.1	992.2	1300	995	1385	996.6	1397	1000	1420
C4	1005	1445	1017	1590						
*	WATERS	ROAD								
SB	0.9	1.56	2.9	0	12.8	0.1	160.5	0.081	982.8	982.8
C3	6428	28	28	28						
X2	1	995.5	995.6							
X3	10	995.6	995.6							

BT	-13	1000	1006.8	0	1100	1000.5	0	1200	995.6	0
BT	1251	995.8	0	1251.1	997.8	0	1281	997.8	0	
BT	1281.1	995.8	0	1300	995.6	0	1385	996.4	0	
BT	1397	996.6	0	1420	1000	0	1445	1005	0	
BT	1590	1017	0							
*	FEMA X-SECTION	D								
C3	6500	15	1243	1271	72	72	72			
C4	1005	950	1000.4	1000	996	1009	993	1039	990.4	1100
C4	989.5	1200	989	1243	982.8	1252	982.7	1262	987.8	1271
C4	992.2	1300	995	1385	1000	1420	1005	1445	1017	1590
C2	0.1	0.3								
C3	7100	12	205	231	560	630	600			
C4	1010	0	1005	19	1000	40	995	68	990	205
C4	987.1	210	987.1	215	990	231	995	345	1000	365
C4	1005	385	1010	395						
C3	7600	12	130	160	480	500	500			
C4	1010	0	1005	15	1000	31	995	109	993	130
C4	989.8	138	989.8	147	993	160	995	262	1000	320
C4	1005	361	1010	400						
C3	8400	15	1160	1235	730	750	800			
C4	1025	1000	1020	1017	1015	1034	1010	1052	1005	1085
C4	1000	1160	998	1205	996.6	1207	996.6	1211	998	1212
C4	1000	1235	1005	1290	1010	1305	1015	1335	1020	1355
C3	9885	9	1050	1077	1330	1240	1485			
C4	1022.7	1000	1013.8	1022	1011	1050	1007.3	1059	1007.3	1074
C4	1011.9	1077	1011	1083	1016.6	1100	1019.7	1120		
*	FEMA X-SECTION	E								
C3	10700	9	1026	1052	670	950	815			
C4	1025.5	1000	1019	1026	1013.6	1033	1013.6	1044	1015.8	1052
C4	1017.4	1070	1018.3	1100	1020.2	1153	1025.5	1169		
*	FEMA X-SECTION	F								
C3	12335	13	1091	1113	1550	1515	1635			
C4	1037.4	1000	1028.6	1026	1027	1067	1024	1091	1020.5	1094
C4	1021.5	1103	1025.3	1113	1027.3	1150	1026.9	1200	1029.1	1300
C4	1030.9	1323	1034.8	1338	1036.5	1353				
C2	0.1	0.1								
C3	13500	10	195	227	1170	1050	1165			
C4	1045	0	1040	118	1035	147	1030	195	1027	215
C4	1027	223	1030	227	1035	435	1040	476	1045	530
C2	0.6	0.8								
C3	13900	12	1152	1195	380	340	400			
X3	10	1042.4	1043.7							
C4	1045.9	1000	1043.1	1100	1042.5	1139	1042	1140	1032	1152
C4	1031.9	1195	1036.5	1235	1036.7	1300	1035.8	1400	1037.1	1500
C4	1039.6	1555	1044.6	1587						
*	WILLOW	MEADOW	CIRCLE							
SC	4.012	0.4	2.9	0	10	10	64	8.1	1032.3	1031.9
C3	13964	12	1152	1195	64	64	64			
X2	2	1042.4								
X3	10	1042.4	1043.7							

BT	-8	1000	1046.3	0	1100	1043.5	0	1139	1042.9	0
BT	1140	1042.4	0	1152	1042.8	0	1195	1043.7	0	
BT	1300	1044.1	0	1587	1045	0				
C4	1046.3	1000	1043.5	1100	1042.9	1139	1042.4	1140	1032.4	1152
C4	1032.3	1195	1036.9	1235	1037.1	1300	1036.2	1400	1037.5	1500
C4	1040	1555	1045	1587						
C3	14030	11	1139	1235	66	66	66	0.4		
C4	1046.3	1000	1043.5	1100	1042.9	1139	1032.4	1152	1032.3	1196
C4	1036.9	1235	1037.1	1300	1036.2	1400	1037.5	1500	1040	1555
C4	1045	1587								
C2	0.08	0.08	0.1	0.3						
C3	14600	10	340	370	630	300	570			
C4	1050	0	1045	63	1040	182	1035	340	1033.5	345
C4	1033.5	360	1035	370	1040	415	1045	431	1050	446
*	FEMA X-SECTION	G								
C3	15035	13	1375	1400	440	385	435			
C4	1053	1000	1046.7	1100	1041.8	1178	1041.1	1200	1040.9	1300
C4	1039.8	1375	1034.7	1379	1035.9	1394	1039.7	1400	1039.6	1500
C4	1040.6	1513	1047.6	1528	1050.3	1543				
C3	16135	9	1053	1072	950	1100	1100			
C4	1054.6	1000	1048.7	1001	1045	1053	1043.5	1060	1042.9	1071
C4	1045.5	1072	1048.4	1095	1051.9	1110	1053.6	1146		
C3	16700	10	338	362	545	490	565			
C4	1060	0	1055	105	1050	230	1047	338	1045	345
C4	1045	352	1047	362	1050	440	1055	460	1060	550
C2	0.12	0.12	0.3	0.5						
C3	17160	7	1303	1335	380	490	460			
X3	10	1061.3	1061.8							
C4	1055.2	1000	1053.4	1303	1046.7	1303.1	1046.7	1334.9	1052.1	1335
C4	1058.4	1463	1060.3	1500						
*	BUICE	ROAD								
SC	3.012	0.4	2.9	0	8	10	80	8.1	1047.3	1046.7
C3	17240	7	1303	1335	80	80	80			
X2	2	1061.3								
X3	10	1061.3	1061.8							
BT	-4	1000	1061.3	0	1303	1062.1	0	1335	1062.1	0
BT	1500	1061.8	0							
C4	1055.8	1000	1054	1303	1047.3	1303.1	1047.3	1334.9	1052.6	1335
C4	1059	1463	1060.9	1500						
C2	0.1									
C3	17300	9	1306	1336	60	60	60			
C4	1060	1000	1057.5	1050	1055	1100	1054	1306	1046.1	1310
C4	1046.9	1326	1052.6	1336	1059	1463	1060.9	1500		
C2	0.15	0.6	0.8							
C3	17990	15	1065	1097	600	630	690			
X3	10	1057	1057							
C4	1071	645	1066	895	1062	1000	1060.3	1053	1056.6	1065
C4	1048.8	1065.1	1048.7	1075	1048.4	1085	1049	1096.9	1056.4	1097
C4	1056.1	1100	1060.8	1123	1064	1136	1066	1400	1071	1480
*	INDIAN	VILLAGE	DRIVE							

SC	2.012	0.5	2.9	0	5.5	0	187	1.2	1052.4	1048.4
C3	18177	15	1065	1097	187	187	187			
X2	2	1069.7								
X3	10	1069.9	1069.7							
BT	-4	645	1075	0	1000	1070.7	0	1100	1069.7	0
BT	1480	1075	0							
C4	1075	645	1070	895	1066	1000	1064.3	1053	1060.6	1065
C4	1052.8	1065.1	1052.7	1075	1052.4	1085	1053	1096.9	1060.4	1097
C4	1060.1	1100	1064.8	1123	1068	1136	1070	1400	1075	1480
*	FEMA X-SECTION	H								
C3	18230	13	1100	1117	70	30	53			
C4	1075	977	1068.6	1000	1065.2	1021	1060	1030	1059.3	1097
C4	1058.3	1100	1054.1	1105	1054	1112	1059.6	1117	1059.8	1125
C4	1066.3	1153	1070	1185	1073	1215				
C2	0.12	0.1	0.1	0.3						
C3	18640	13	1134	1151	340	430	410			
C4	1075	965	1069.8	1000	1062.7	1032	1060.1	1058	1061.3	1100
C4	1060	1134	1056.6	1137	1056.5	1145	1060.6	1151	1061.9	1200
C4	1064.3	1232	1071.6	1267	1075	1300				
C2	0.15	0.15	0.055							
C3	19260	10	75	100	585	640	620			
C4	1075	0	1070	35	1065	69	1063	75	1060	80
C4	1060	90	1063	100	1065	121	1070	255	1075	330
C3	20080	10	195	213	750	590	820			
C4	1080	0	1075	30	1070	173	1067	195	1064.5	200
C4	1064.5	207	1067	213	1070	227	1075	317	1080	432
C2	0.6	0.8								
C3	20472	13	1261	1273	370	380	392			
X3	10	1074	1074							
C4	1083.2	1000	1079.2	1042	1078.4	1051	1076.9	1100	1074.6	1200
C4	1071.8	1261	1066.7	1261.1	1066.9	1270	1067.4	1273	1067.4	1282
C4	1077	1296	1077.4	1297	1083	1400				
*	STATE	BRIDGE	ROAD							
SB	0.9	1.56	2.9	0	11.2	0.1	100	0.046	1066.7	1066.7
C3	20500	28	28	28						
X2	1	1075.3	1076.7							
X3	10	1076.7	1076.8							
BT	-10	1000	1083.2	0	1042	1079.2	0	1051	1079	0
BT	1100	1078	0	1200	1076.9	0	1261	1076.7	0	
BT	1273	1076.8	0	1296	1077	0	1297	1077.4	0	
BT	1400	1083	0							
*	FEMA X-SECTION	I								
C3	20585	9	1262	1297	100	80	85			
C4	1083.2	1000	1078.4	1051	1076.9	1100	1074.6	1200	1071.8	1262
C4	1067	1270	1067.1	1280	1077.4	1297	1083	1400		
C2	0.1	0.1	0.3							
C3	20800	10	210	228	250	175	215			
C4	1085	0	1080	82	1075	180	1073	210	1071	215
C4	1071	221	1073	228	1075	250	1080	313	1085	380
C3	21300	8	147	163	500	500	500			

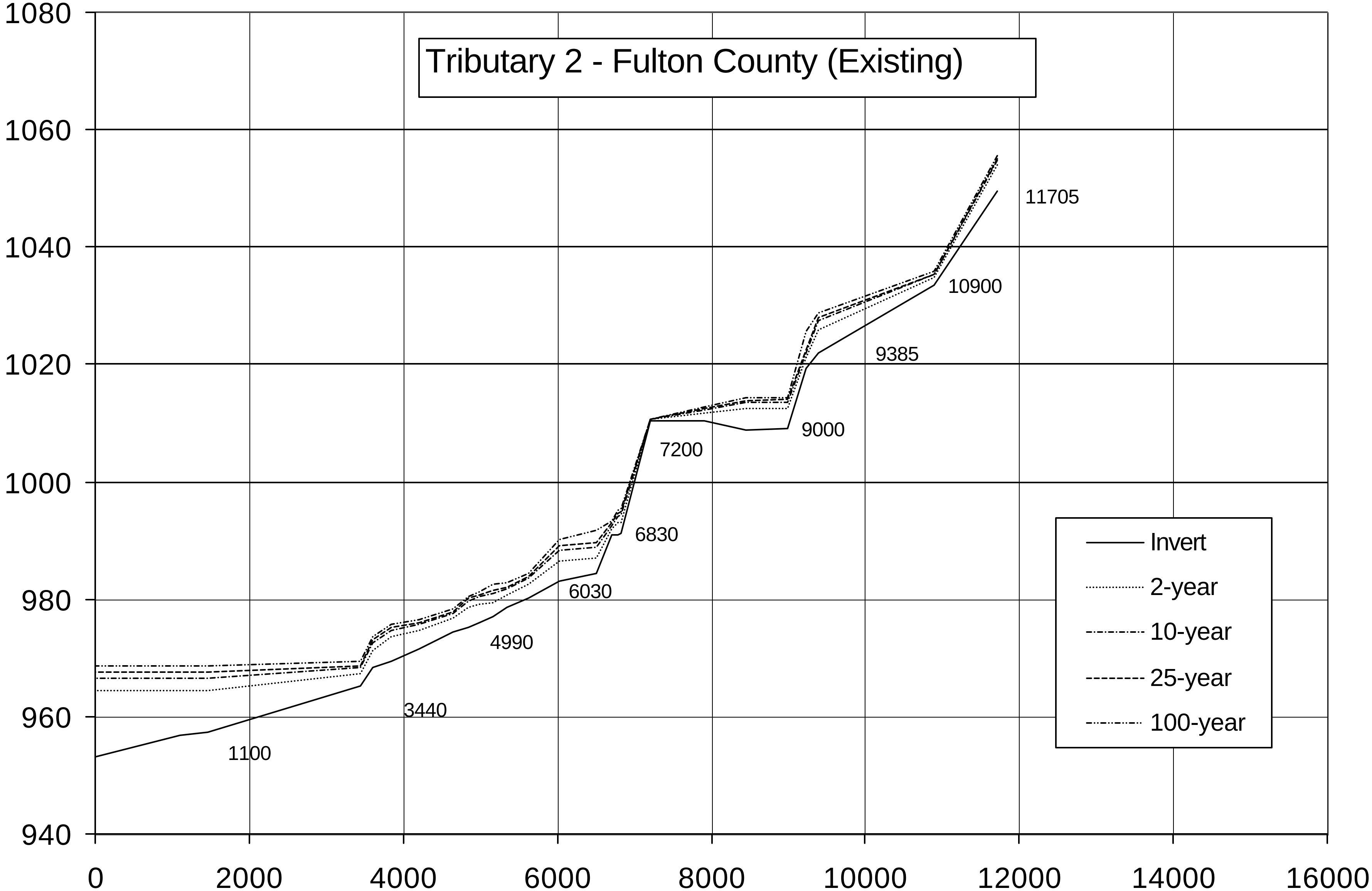
C4	1085	0	1080	111	1079	147	1075.5	150	1075.5	160
C4	1079	163	1080	171	1085	295				

C	Tributary 2 - Big Creek FEMA									
C	3440	CULVERT	UNDER	MALL	PARKING	LOT				
C	3600	X-SECTION	A							
C	5171	CULVERT	UNDER	ENTRANC	ROAD	TO	MALL			
C	5630	X-SECTION	B							
C	6515	GEORGIA	400							
C	6565	X-SECTION	C							
C	9240	MORRISON	PARKWAY							
C	9385	X-SECTION	D							
C	10900	X-SECTION	E							
C	11705	X-SECTION	F							
C2	0.15	0.15	0.04	0.1	0.3					
C3	1100	14	1450	1480						
C4	980	1000	980	1120	975	1160	970	1190	965	1240
C4	960	1450	956.7	1455	956.7	1460	960	1480	965	1810
C4	970	1860	975	1900	980	1940	985	1990		
C2	0.6	0.8								
*	8x8	CONCRETE	BOX	CULVERT	UNDER	SHOPPINGMALL				
C3	1455	13	1151	1168	355	355	355	-7.9		
X3	10	1003.6	1010.8							
C4	984.5		973.9	1025	972.1	1100	972.9	1123	967.7	1136
C4	966.2	1151	965.3	1151.1	965.3	1159	965.3	1168	966.7	1168.1
C4	968	1177	975.5	1190	981.7	1210				
SC	2.012	0.4	2.9	0	8	8	1985	8.1	965.3	957.4
C3	3440	13	1151	1168	1985	1985	1985			
X2	2	1003.6								
X3	10	1003.6	1010.8							
BT	-5	1000	1003.6	1100	1007.9	1151	1010			
BT	1168	1010.8	1210	1012.1						
C4	984.5	1000	973.9	1025	972.1	1100	972.9	1123	967.7	1136
C4	966.2	1151	965.3	1151.1	965.3	1159	965.3	1168	966.7	1168.1
C4	968	1177	975.5	1190	981.7	1210				
*	X-SECTIONA									
C3	3600	10	150	175	160	160	160			
C4	985	0	980	10	975	20	972	150	968.4	153
C4	968.4	173	972	175	975	180	980	192	985	206
C2	0.1	0.1	0.3							
C3	3850	10	285	306	335	200	250			
C4	985	0	980	113	975	230	972	285	969.3	288
C4	969.3	303	972	306	975	350	980	380	985	410
C3	4200	12	560	580	270	340	350			
C4	990	0	985	110	980	280	975	400	973.5	560
C4	971.5	562	971.5	577	973.5	580	975	586	980	602
C4	985	635	990	679						
C3	4650	10	575	595	330	400	450			
C4	990	0	985	274	980	350	975	575	974.5	578
C4	974.5	593	975	595	980	614	985	645	990	682
C3	4850	10	450	475	270	175	200			
C4	990	0	985	177	980	365	978	450	975.2	455
C4	975.2	470	978	475	980	485	985	535	990	598
*	8x8	CONCRETE	BOX	CULVERT	UNDER	MALL	ENTRANC	DRIVE		
C2	0.6	0.8								
C3	4990	12	1186	1203	100	170	140	-1		
X3	10	990.5	992.3							
C4	989.5	1000	987.1	1100	986.3	1121	982	1142	981.7	1175
C4	977.5	1183	977	1186	977	1203	981.1	1226	984.1	1293

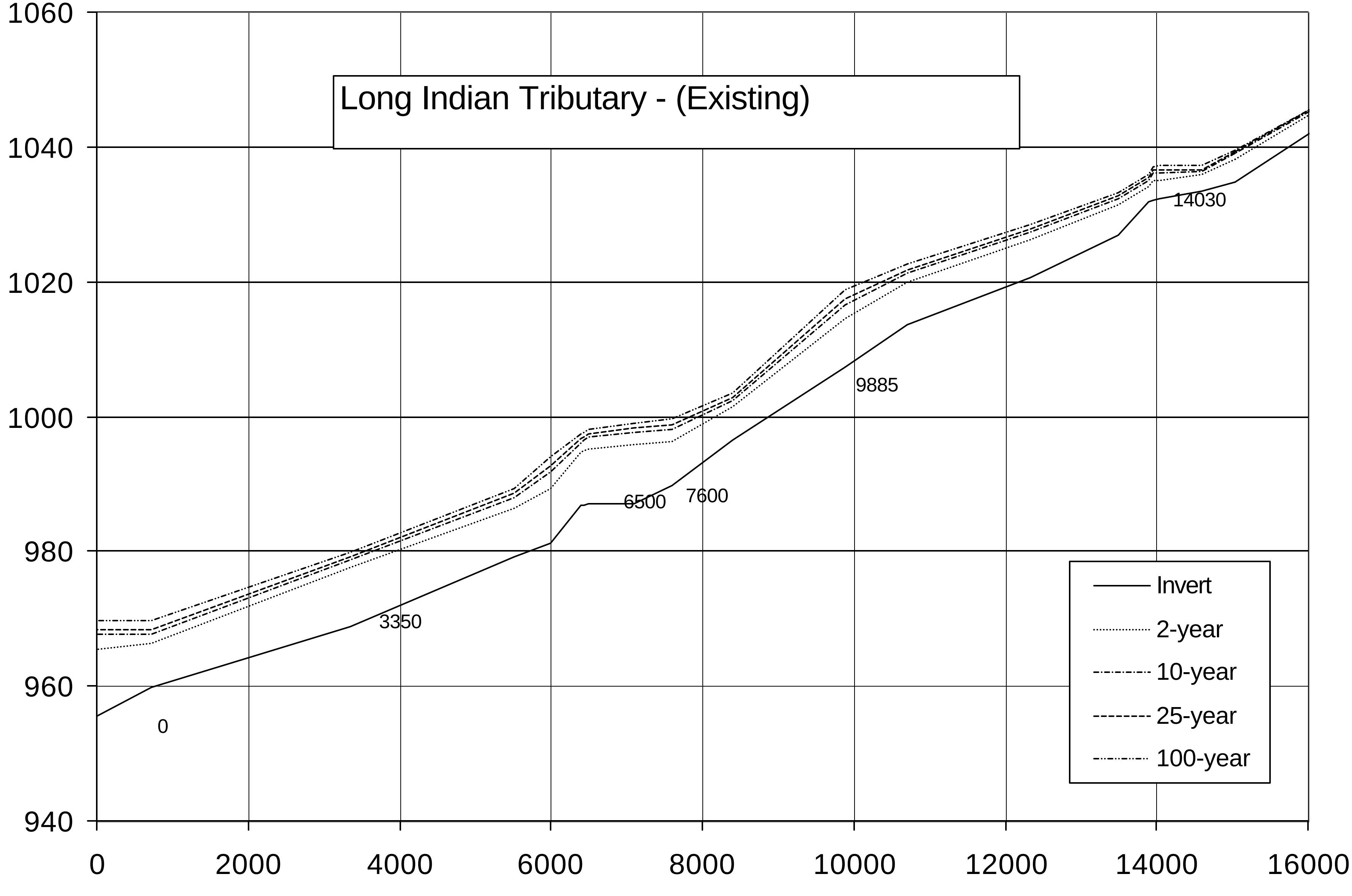
C4	987.4	1300	991.8	1310						
SC	2.012	0.4	2.9	0	8	8	181	8.1	977	976
C3	5171	12	1186	1203	181	181	181			
X2	2	990.5								
X3	10	990.5	992.3							
BT	-5	1000	990.5	0	1100	991	0	1186	992.1	0
BT	1203	992.3	0	1300	995.1	0				
C4	989.5	1000	987.1	1100	986.3	1121	982	1142	981.7	1175
C4	977.5	1183	977	1186	977	1203	981.1	1226	984.1	1293
C4	987.4	1300	991.8	1310						
C3	5350	14	980	1025	140	100	179			
C4	1000	570	992	730	990	829	988	920	986	945
C4	984	960	982	980	978.5	989	978.5	1011	982	1025
C4	984	1110	986	1145	990	1178	998	1230		
C2	0.15	0.05	0.1	0.3						
*	X-SECTION B									
C3	5630	11	985	1015	190	120	280			
C4	1000	575	986	820	984	968	982	985	980.3	989
C4	980.3	1011	982	1015	984	1030	988	1130	992	1175
C4	1000	1212								
C2	0.6	0.8								
C3	6030	12	1146	1163	175	180	400	-1.3		
X3	10	1035	1033.9							
C4	998.8	1000	995.1	1037	992.5	1100	990.8	1122	989.7	1146
C4	984.3	1146.1	984.3	1154	984.3	1162.9	988	1163	992.3	1187
C4	993.9	1200	999.5	1230						
*	GEORGIA	400	AND	ROCK	MILL	ROAD				
SC	2.012	0.4	2.9	0	6	8	485	8.1	984.3	983
C3	6515	12	1146	1163	485	485	485			
X2	2	1033.9								
X3	10	1035	1033.9							
BT	-6	1000	1036.9	0	1100	1036	0	1146	1035	0
BT	1163	1034.7	0	1200	1033.9	0	1230	1034.1	0	
C4	998.8	1000	995.1	1037	992.5	1100	990.8	1122	989.7	1146
C4	984.3	1146.1	984.3	1154	984.3	1162.9	988	1163	992.3	1187
C4	993.9	1200	999.5	1230						
*	X-SECTION C									
C3	6565	11	1147	1164	50	50	50			
C4	998.8	1000	995.1	1037	992.5	1100	990.8	1122	989.6	1147
C4	986	1152	986.4	1158	988	1164	992.3	1187	993.9	1200
C4	999.5	1230								
C2	0.1	0.3								
C3	6700	27	219	244	155	120	135			
C4	1025	0	1020	18	1015	25	1010	45	1005	65
C4	1000.2	85	1000.9	92	1000.3	106	999.8	118	994.4	129
C4	997	162	997.1	185	994.8	219	992.7	228	991.1	229
C4	991	244	993.6	250	994.7	261	997.2	285	996.6	292
C4	1001.2	305	1010	330	1011.6	350	1013.2	370	1014.4	385
C4	1016.4	395	1018.4	405						
C3	6770	80	70	70						
D	10	993	994.5							
*	TOP	OF	DAM							
SC	1.024	0.8	3.1	0	1.5	0	100	2.3	992	991
C3	6785	15	15	15						
X2	2	1010.5								
X3	10	1010.5	1013.9							

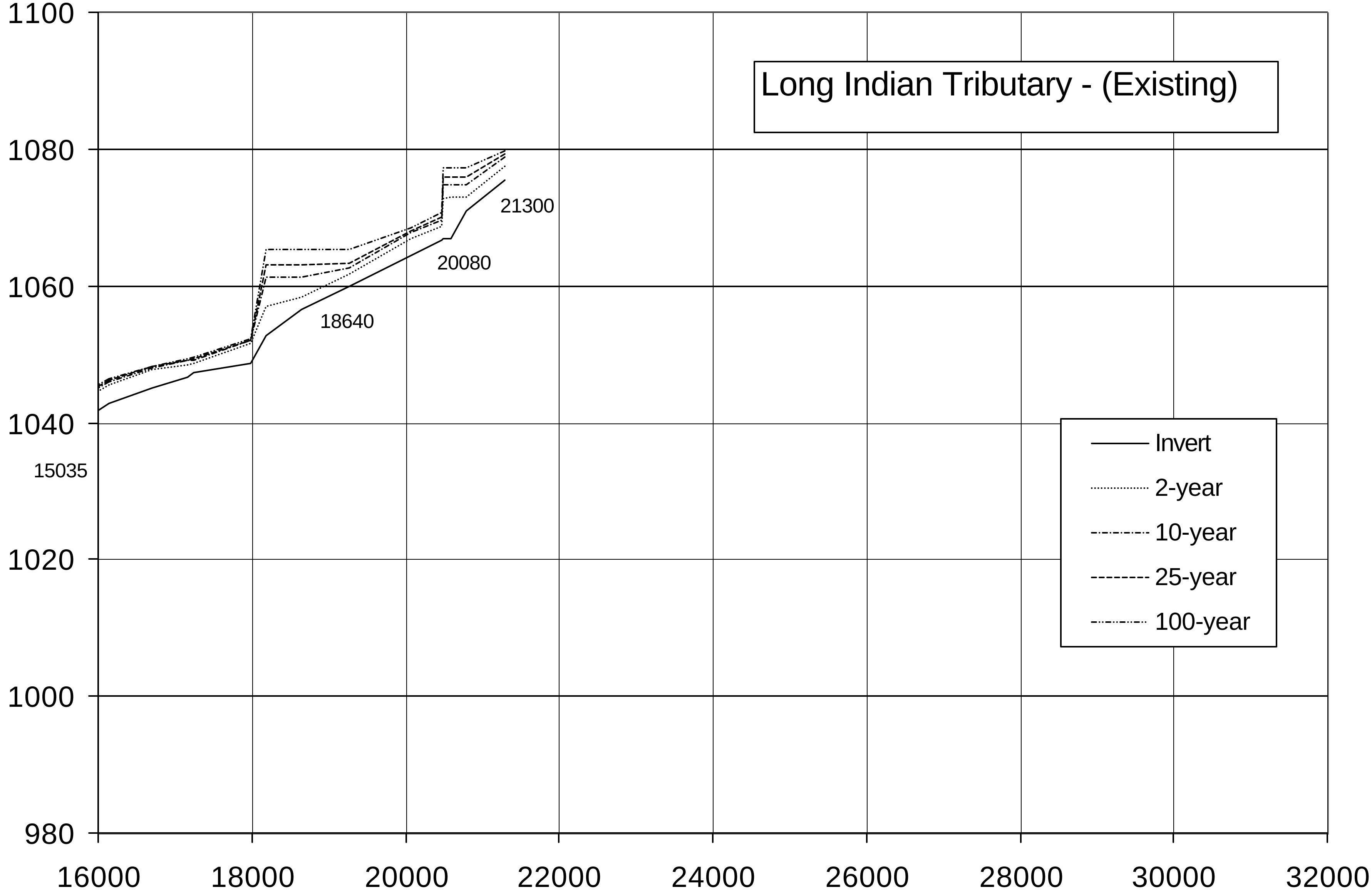
BT	-12	0	1025	0	65	1025	0	85	1014.1	0
BT	92	1011.1	0	106	1010.5	0	118	1012.8	0	
BT	129	1014	0	185	1013.6	0	261	1013.9	0	
BT	285	1013.9	0	385	1014.4	0	405	1018.4	0	
C3	6830	45	45	45	0.1					
C3	7200	8	105	760	345	510	370			
C4	1025	0	1020	45	1015	83	1010.5	105	1010.5	760
C4	1015	800	1020	840	1025	880				
C3	7900	8	307	495	650	700	800			
C4	1025	0	1020	128	1015	225	1010.5	307	1010.5	495
C4	1015	565	1020	630	1025	730				
C3	8445	9	1069	1133	570	490	545			
C4	1022.3	1000	1019.6	1046	1015.4	1069	1010.3	1091	1008.8	1110
C4	1010.5	1130	1013.4	1133	1015	1180	1023.8	1227		
C2	0.6	0.8								
C3	9000	8	360	775	555	555	555			
X3	10	1024.5	1030.5							
X5	5	1022.2	1023.8	1024.1	1025.4	1024.1				
C4	1030	0	1025	290	1020	360	1009	440	1009	457
C4	1020	775	1025	795	1030	825				
*	MORRISON PARKWAY									
SC	2.024	0.5	2.9	0	7	0	240	2.2	1019.2	1009
C3	9240	10	1032	1052	240	240	240			
X2	2	1030								
X3	10	1030	1030.5							
BT	-5	950	1032	0	1000	1030	0	1032	1030.2	0
BT	1052	1030.5	0	1100	1031	0				
C4	1032	950	1027.9	1000	1025.7	1026	1020.3	1032	1019.2	1032.1
C4	1019.2	1051.9	1021.9	1052	1022	1055	1026.3	1065	1031	1100
*	X-SECTION D									
C3	9385	9	1063	1080	310	110	145			
C4	1037.3	1000	1036.8	1020	1030.6	1041	1028.6	1063	1022	1067
C4	1021.9	1073	1027.9	1080	1034	1100	1034.7	1110		
C2	0.1	0.1	0.05	0.1	0.3					
*	X-SECTION E									
C3	10900	12	1149	1247	1440	1410	1515			
C4	1044.9	1000	1040.5	1043	1038.9	1100	1038.6	1109	1038.3	1116
C4	1038	1124	1037.9	1128	1037.1	1149	1034	1155	1033.5	1228
C4	1039.9	1247	1042.7	1295						
*	X-SECTION F									
C3	11705	9	1180	1189	805	805	805			
C4	1060.4	1000	1055.5	1100	1050.4	1180	1049.4	1184	1049.5	1188
C4	1052.1	1189	1052.1	1200	1054.8	1300	1059	1400		

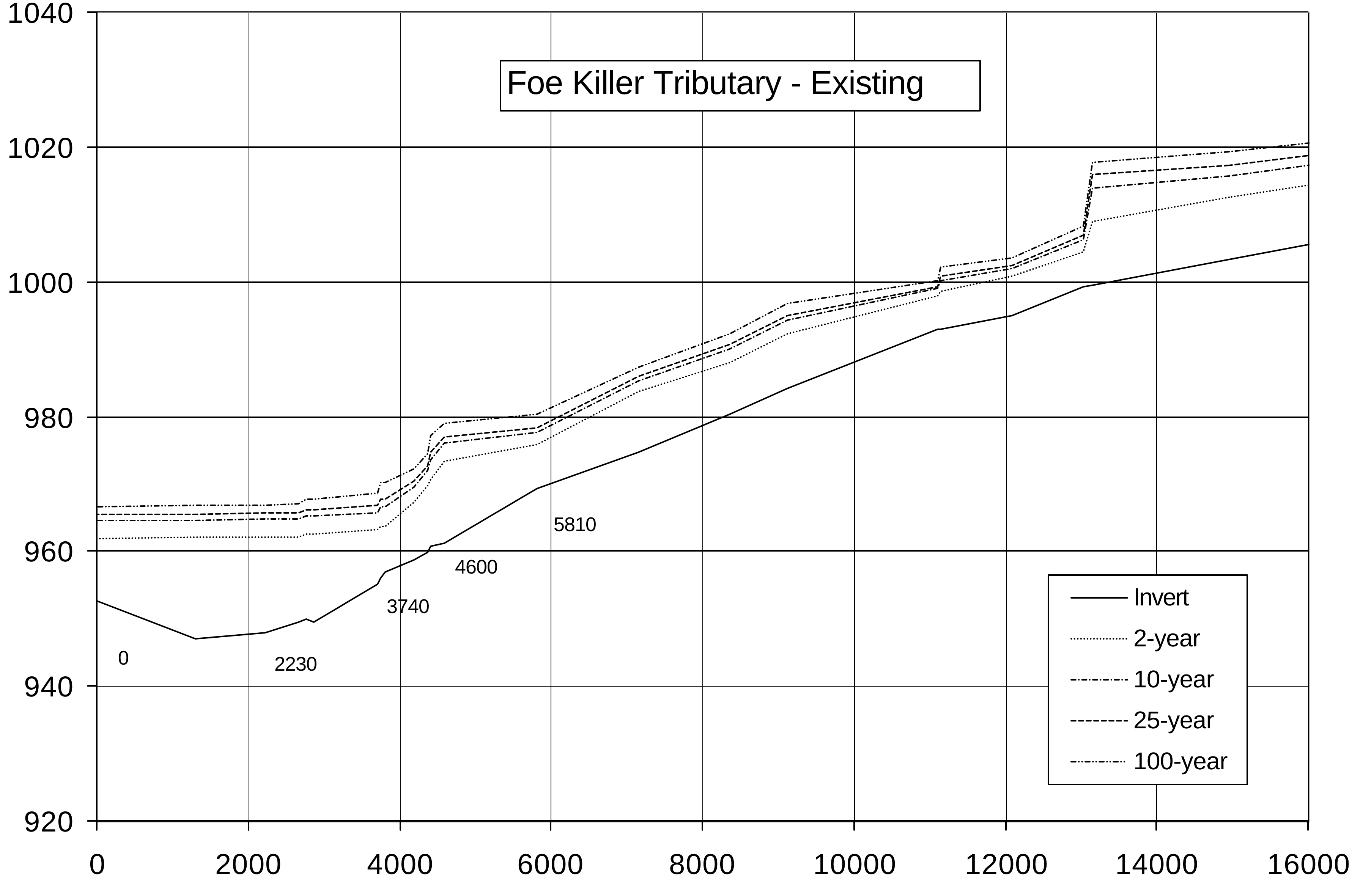
Appendix B
Flood Profiles for Selected Locations for Existing Conditions

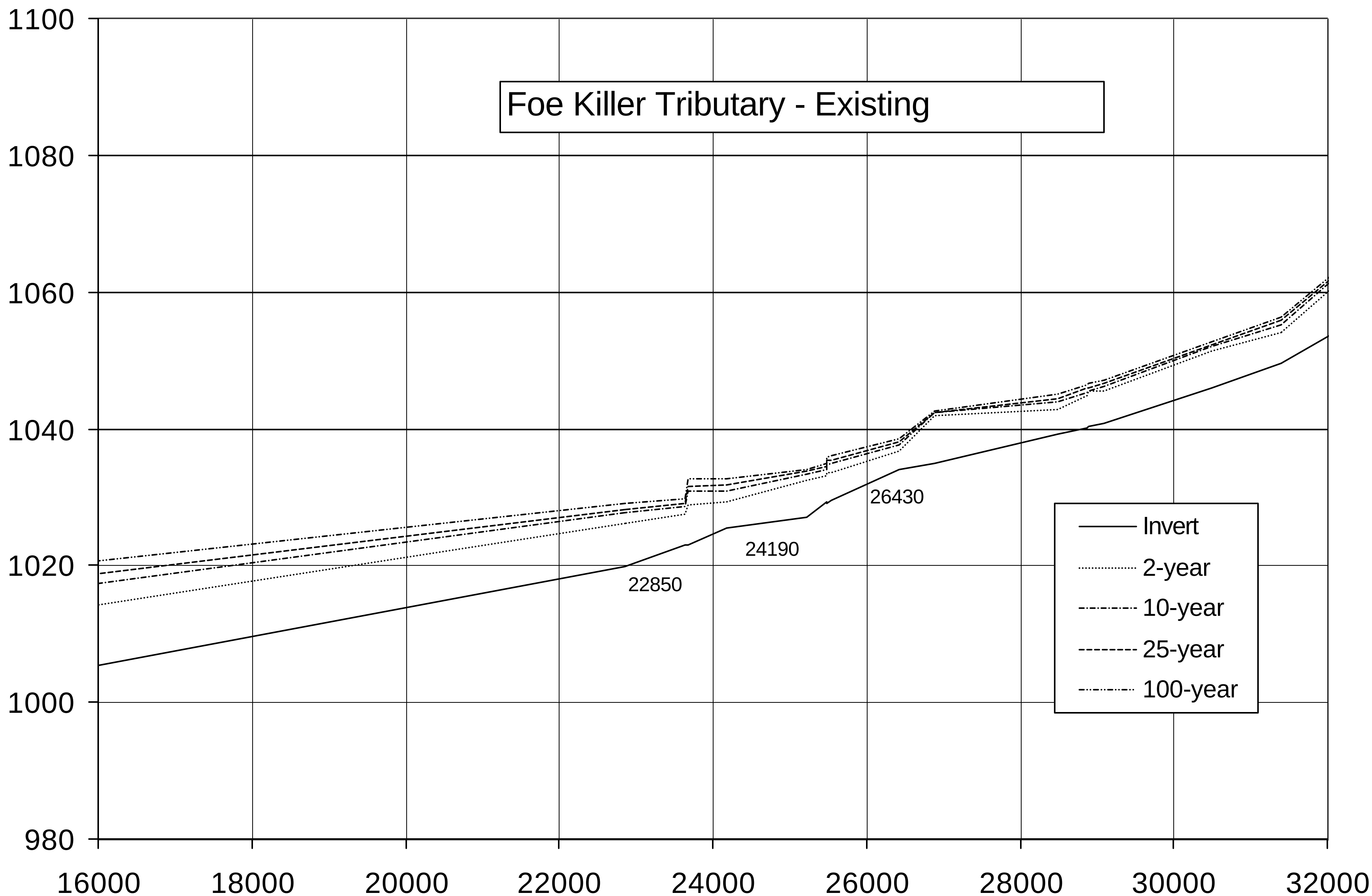


Tributary 2 - Fulton County (Existing)
1080
1060
1040
1020
1000
980
960
940
0
2000
4000
6000
8000
10000
12000
14000
16000
1100
3440
4990
6030
6830
7200
9000
9385
10900
11705
Invert
2-year
10-year
25-year
100-year

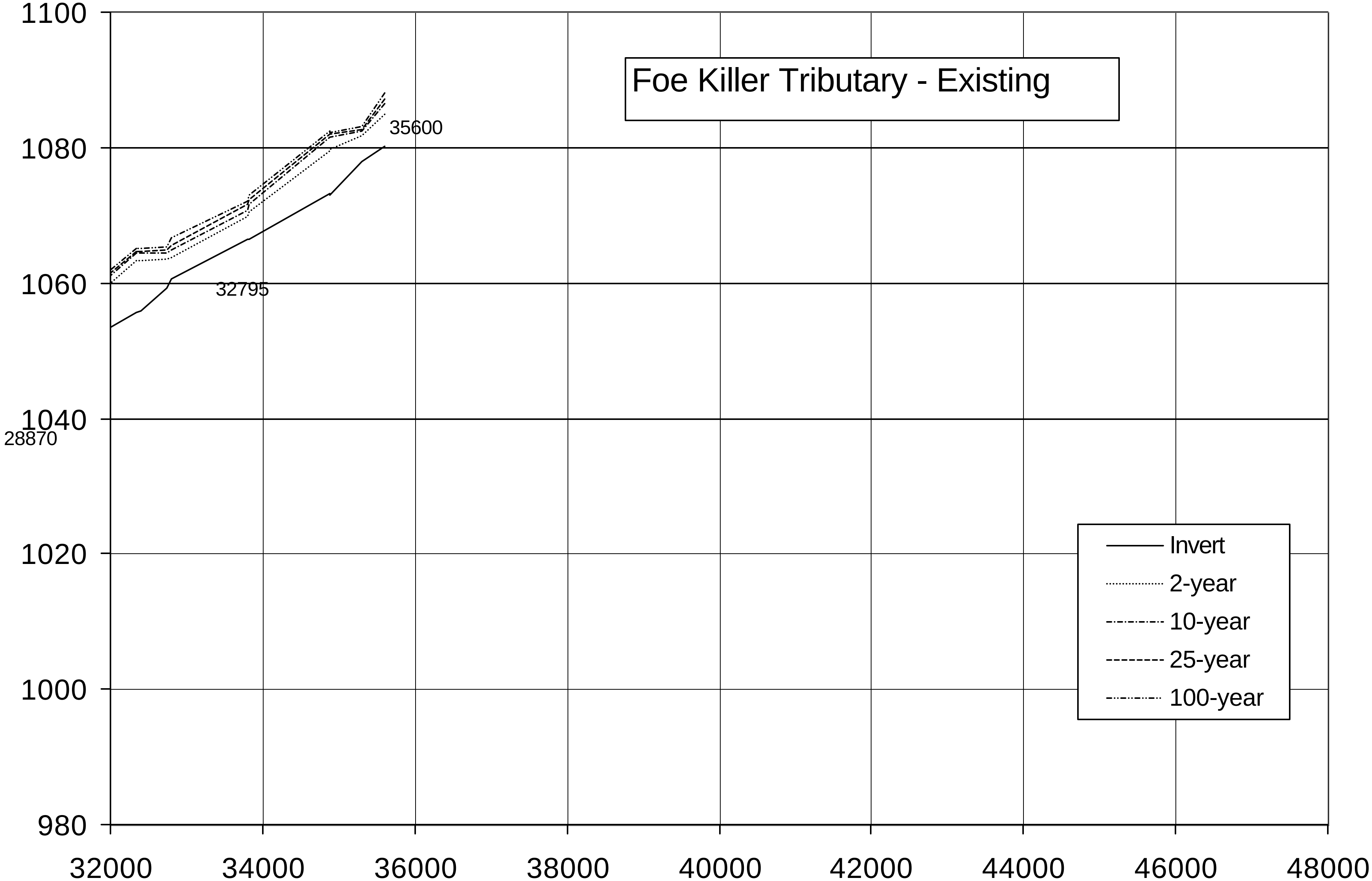

Long Indian Tributary - (Existing)
1060
1040
1020
1000
980
960
940
0
2000
4000
6000
8000
10000
12000
14000
16000
0
3350
6500
7600
9885
14030
Invert
2-year
10-year
25-year
100-year


Long Indian Tributary - (Existing)
1100
1080
1060
1040
1020
1000
980
16000
18000
20000
22000
24000
26000
28000
30000
32000
15035
18640
20080
21300
Invert
2-year
10-year
25-year
100-year

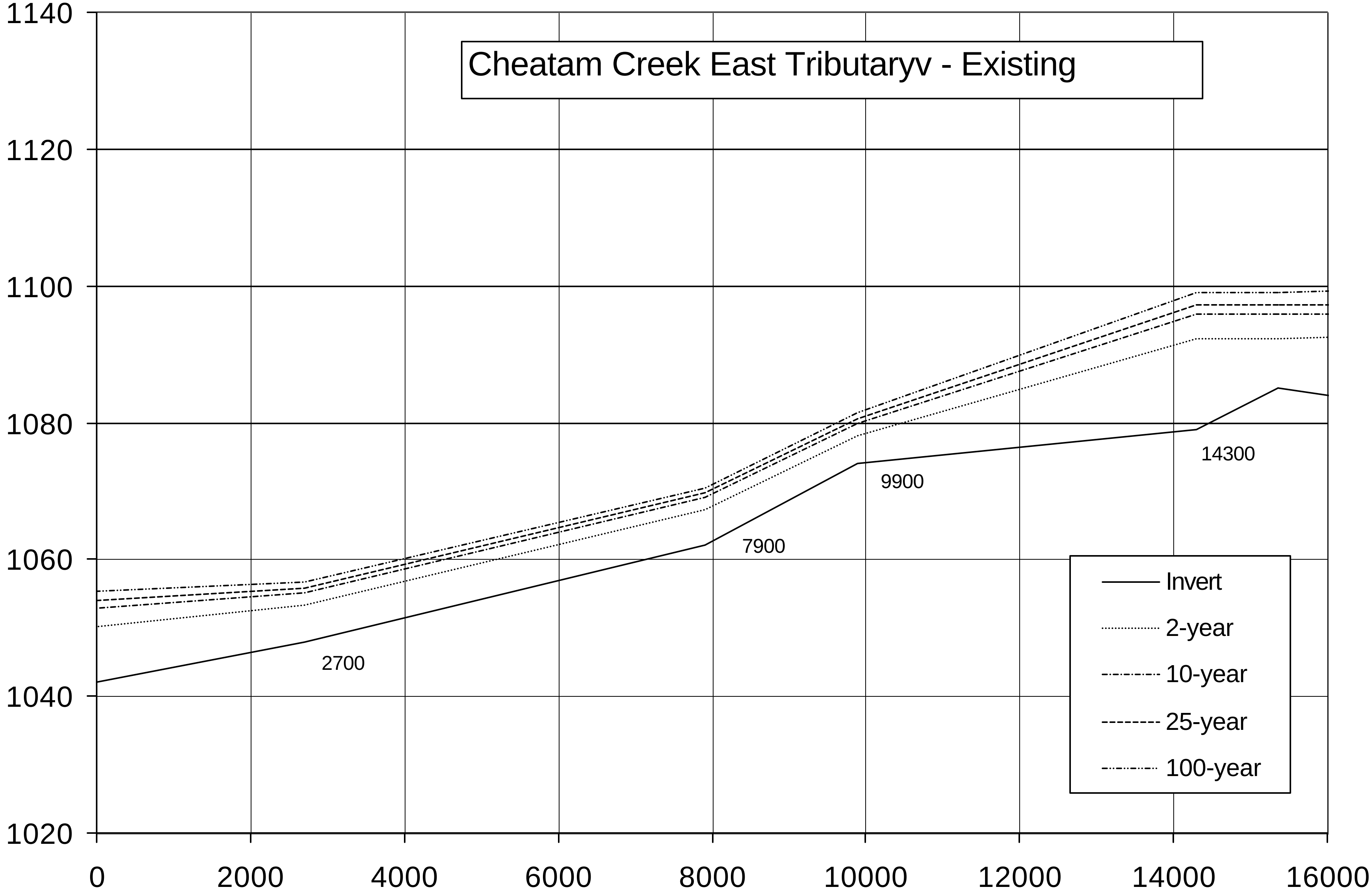

Foe Killer Tributary - Existing
1040
1020
1000
980
960
940
920
0
2000
4000
6000
8000
10000
12000
14000
16000
0
2230
3740
4600
5810
Invert
2-year
10-year
25-year
100-year

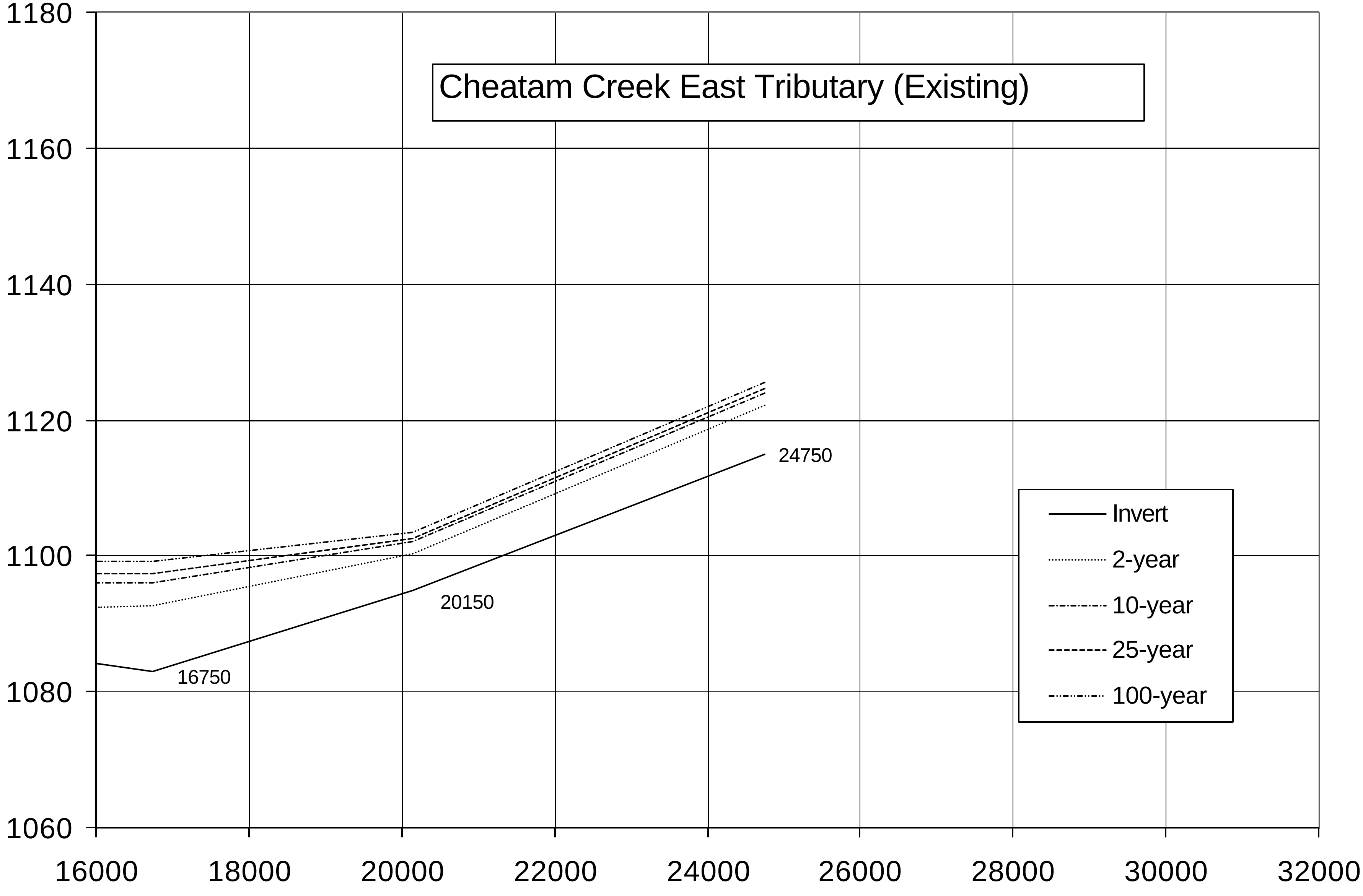

Foe Killer Tributary - Existing
1100
1080
1060
1040
1020
1000
980
16000
18000
20000
22000
24000
26000
28000
30000
32000
26430
24190
22850
Invert
2-year
10-year
25-year
100-year

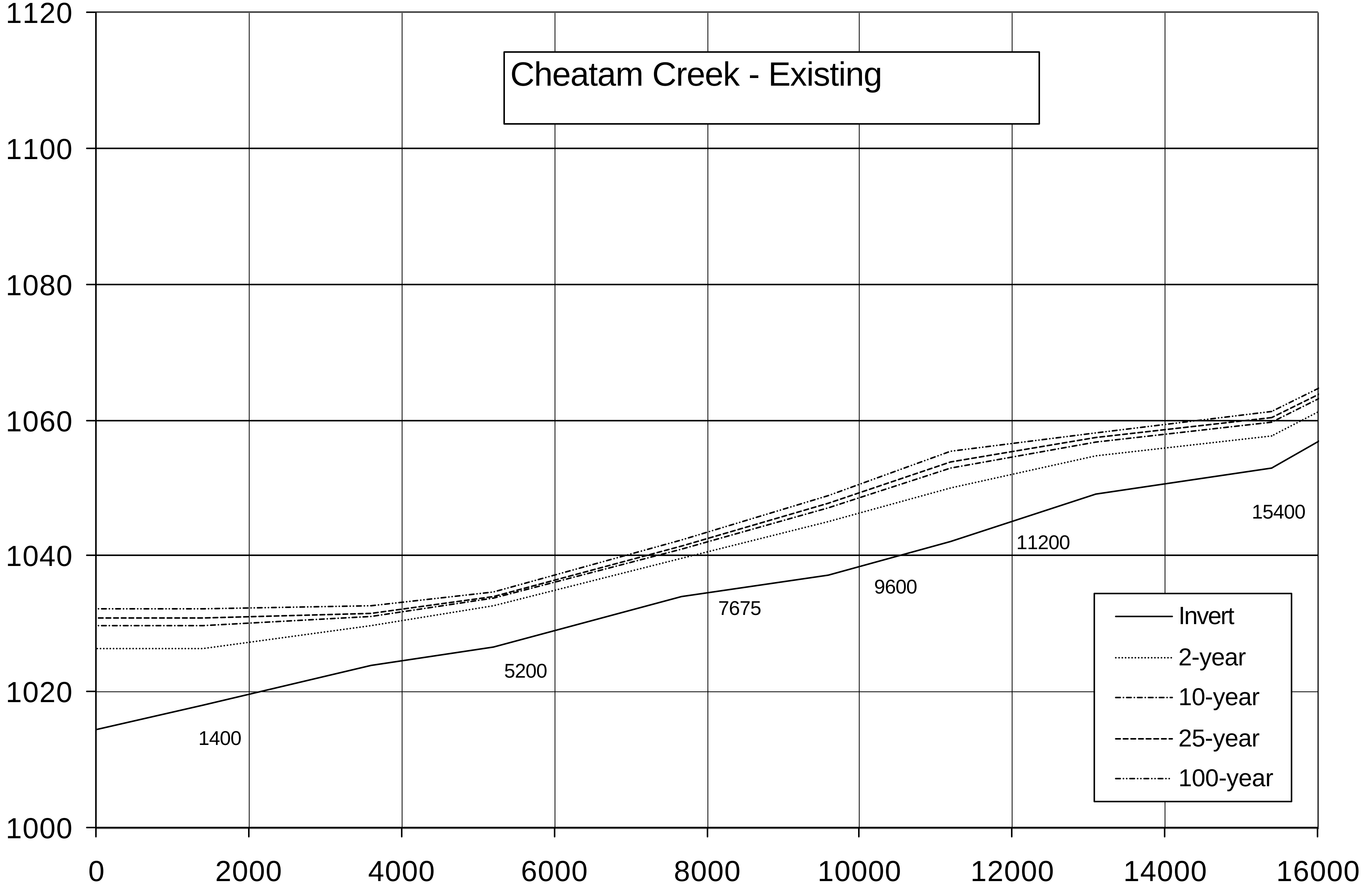
7160

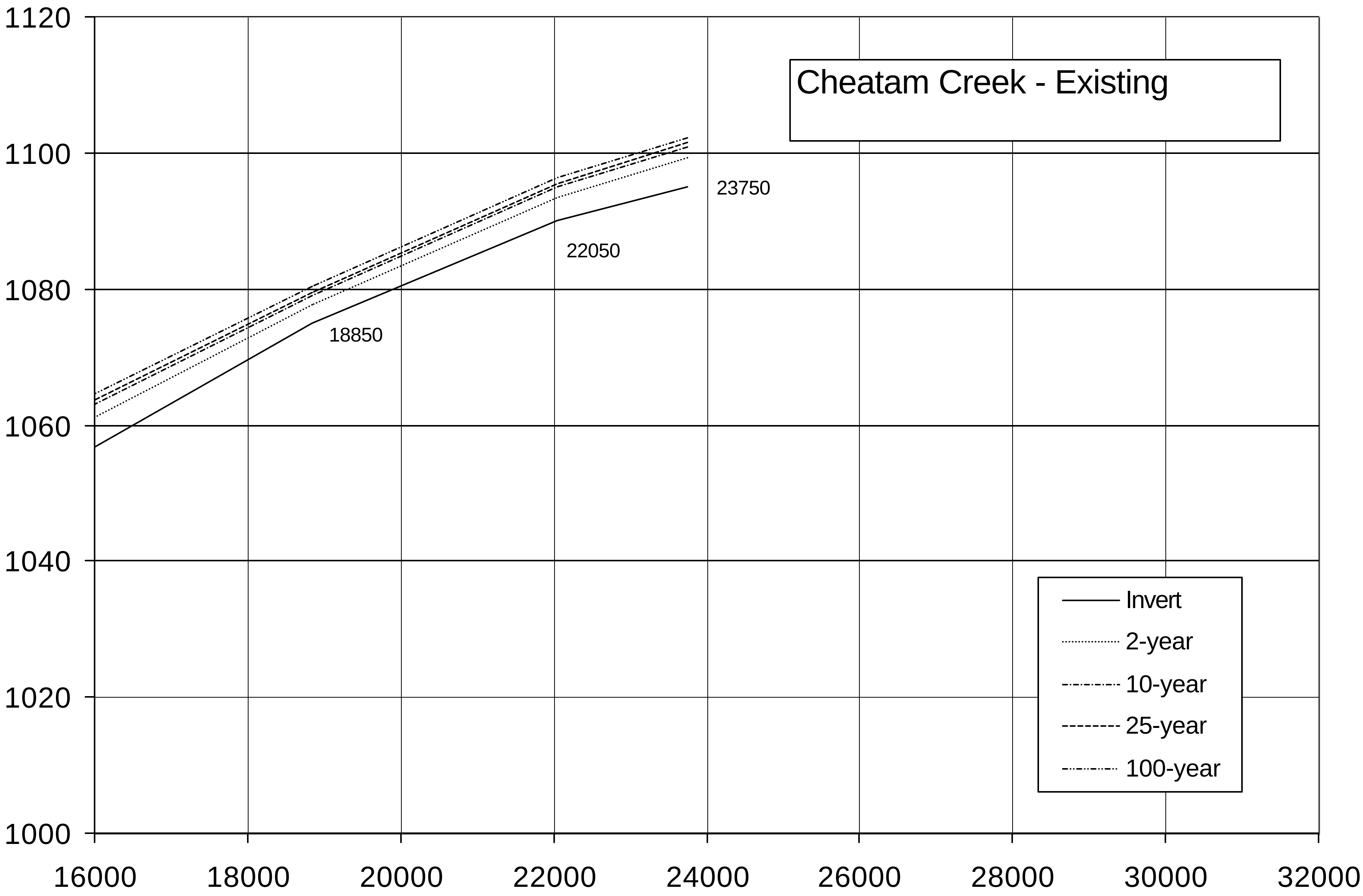


Foe Killer Tributary - Existing
1100
1080
1060
1040
1020
1000
980
32000
34000
36000
38000
40000
42000
44000
46000
48000
35600
32795
28870
Invert
2-year
10-year
25-year
100-year

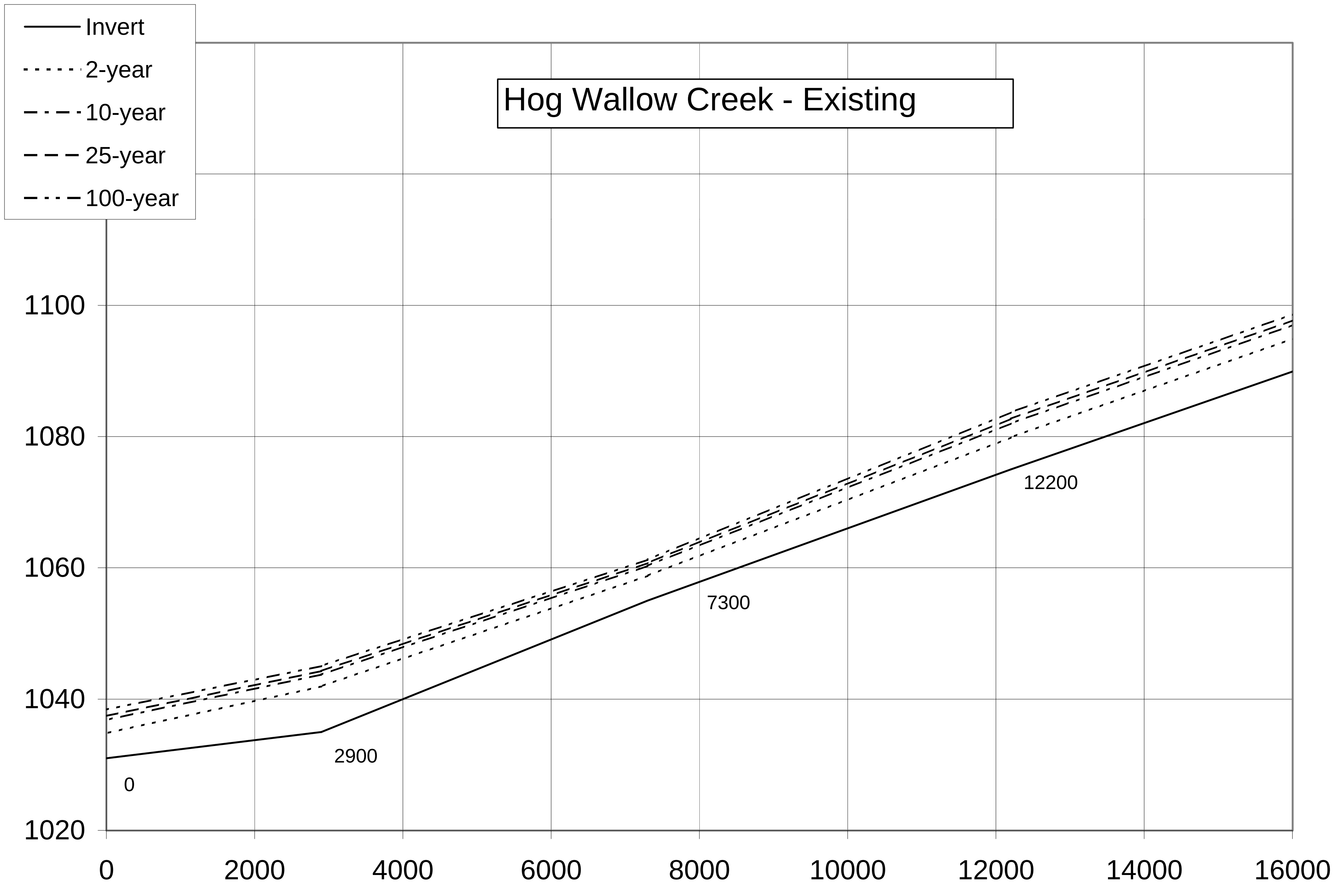

Cheatam Creek East Tributaryv - Existing
1140
1120
1100
1080
1060
1040
1020
0
2000
4000
6000
8000
10000
12000
14000
16000
2700
7900
9900
14300
Invert
2-year
10-year
25-year
100-year


Cheatam Creek East Tributary (Existing)
1180
1160
1140
1120
1100
1080
1060
16000
18000
20000
22000
24000
26000
28000
30000
32000
24750
20150
16750
Invert
2-year
10-year
25-year
100-year

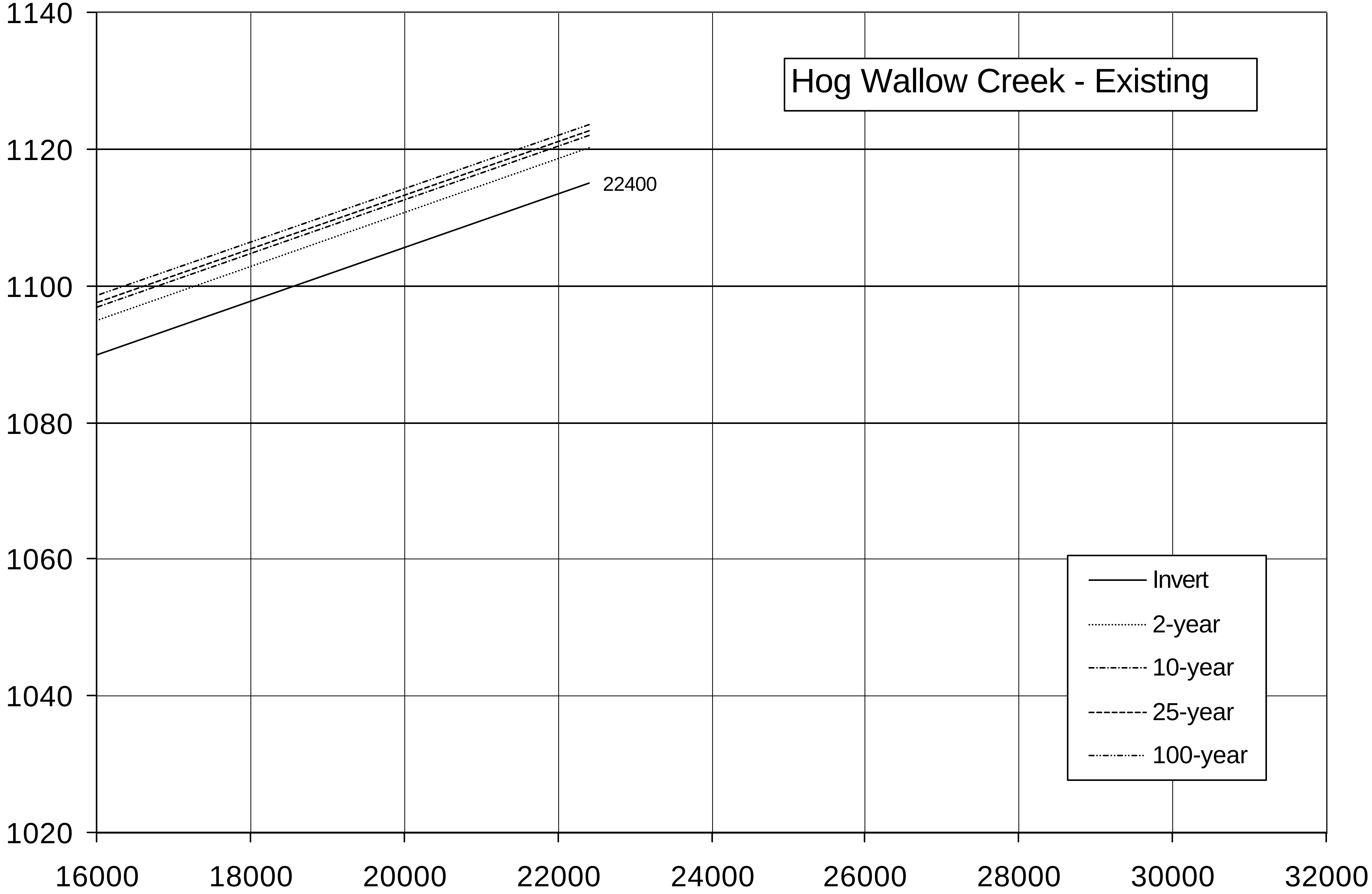

Cheatam Creek - Existing
1120
1100
1080
1060
1040
1020
1000
0
2000
4000
6000
8000
10000
12000
14000
16000
1400
5200
7675
9600
11200
15400
Invert
2-year
10-year
25-year
100-year



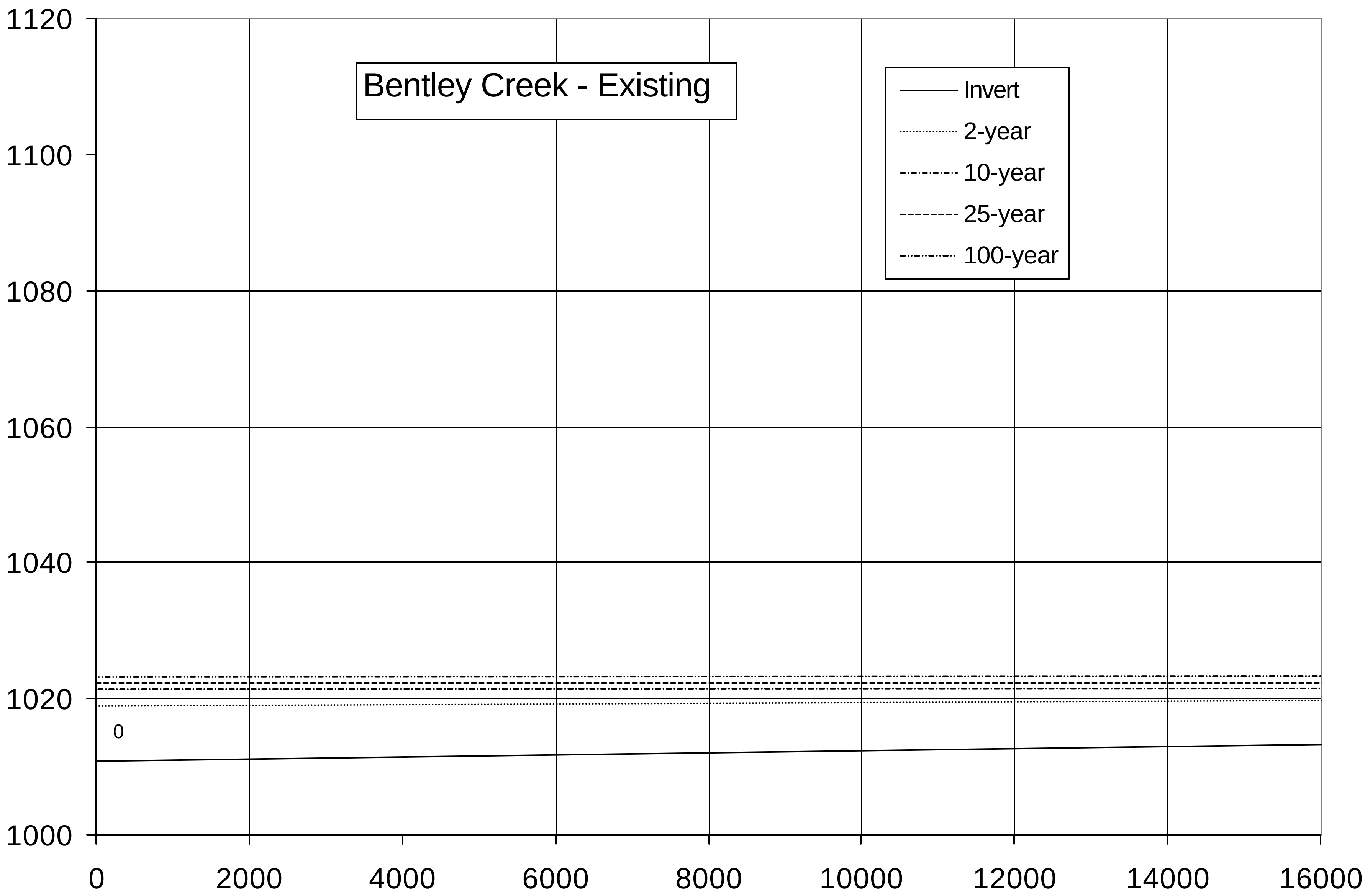
Cheatam Creek - Existing
1120
1100
1080
1060
1040
1020
1000
16000
18000
20000
22000
24000
26000
28000
30000
32000
23750
22050
18850
Invert
2-year
10-year
25-year
100-year



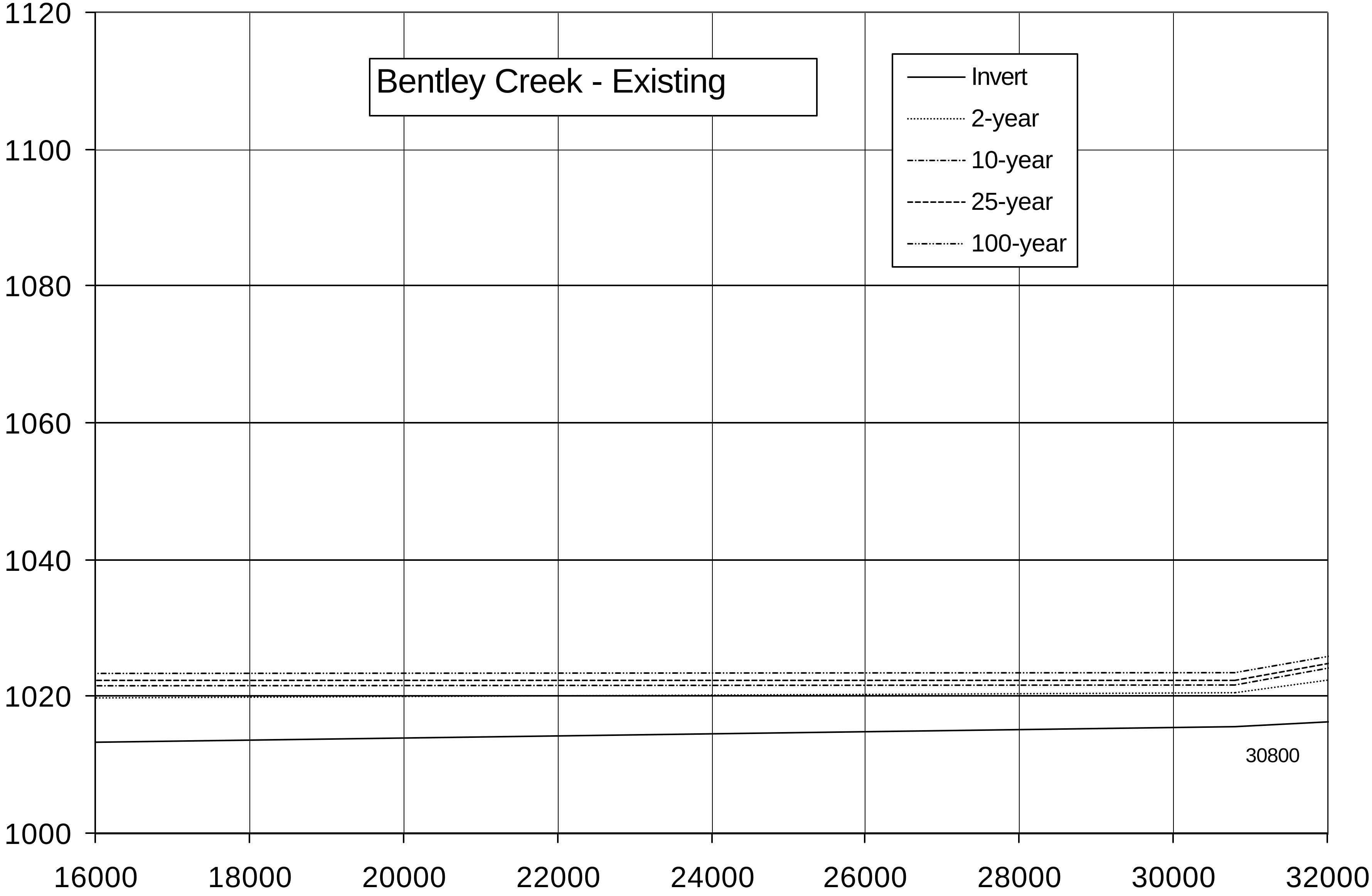
Hog Wallow Creek - Existing
Invert
2-year
10-year
25-year
100-year
1100
1080
1060
1040
1020
0
2000
4000
6000
8000
10000
12000
14000
16000
0
2900
7300
12200

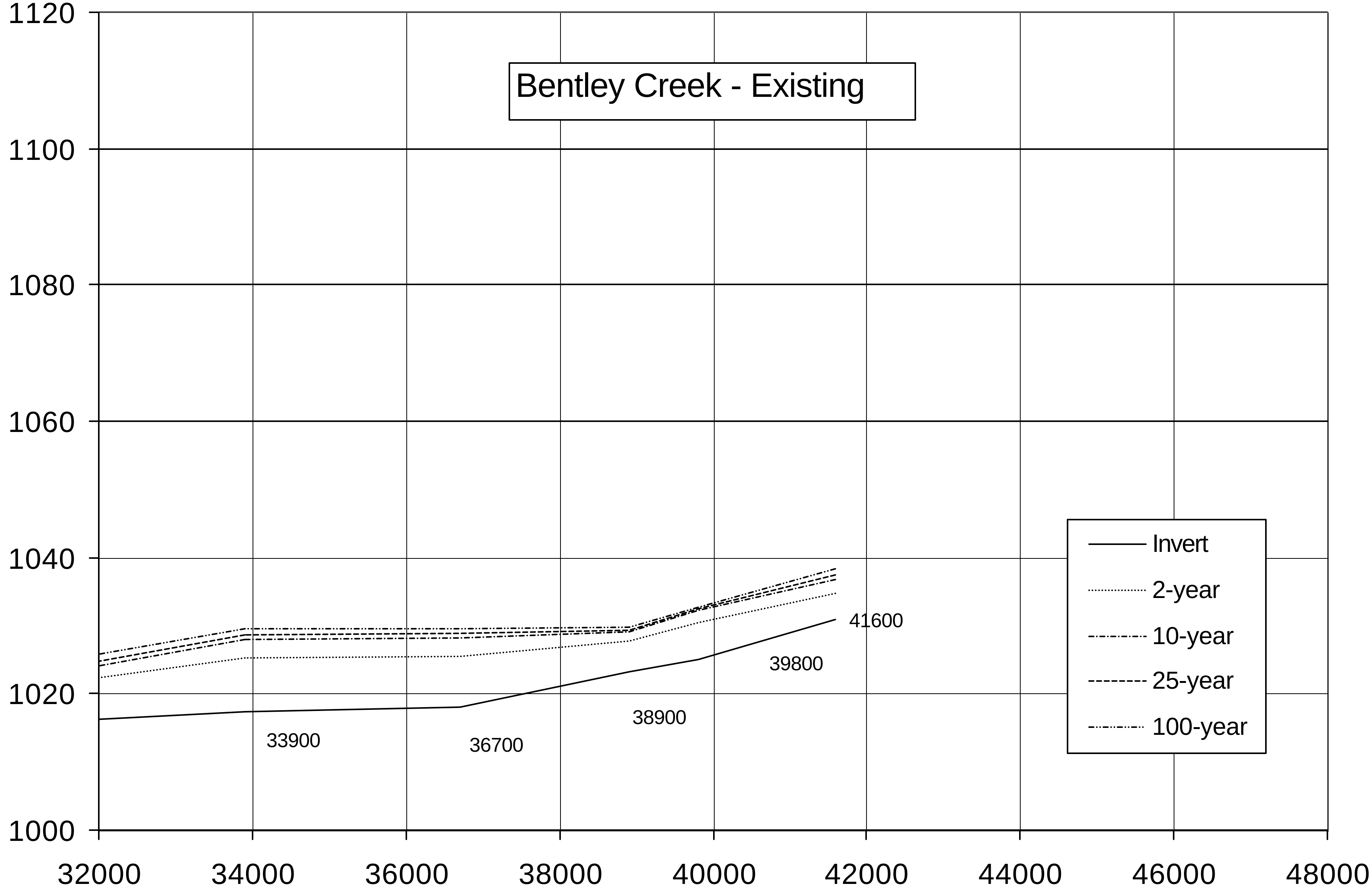


Hog Wallow Creek - Existing
22400
Invert
2-year
10-year
25-year
100-year
1140
1120
1100
1080
1060
1040
1020
16000
18000
20000
22000
24000
26000
28000
30000
32000

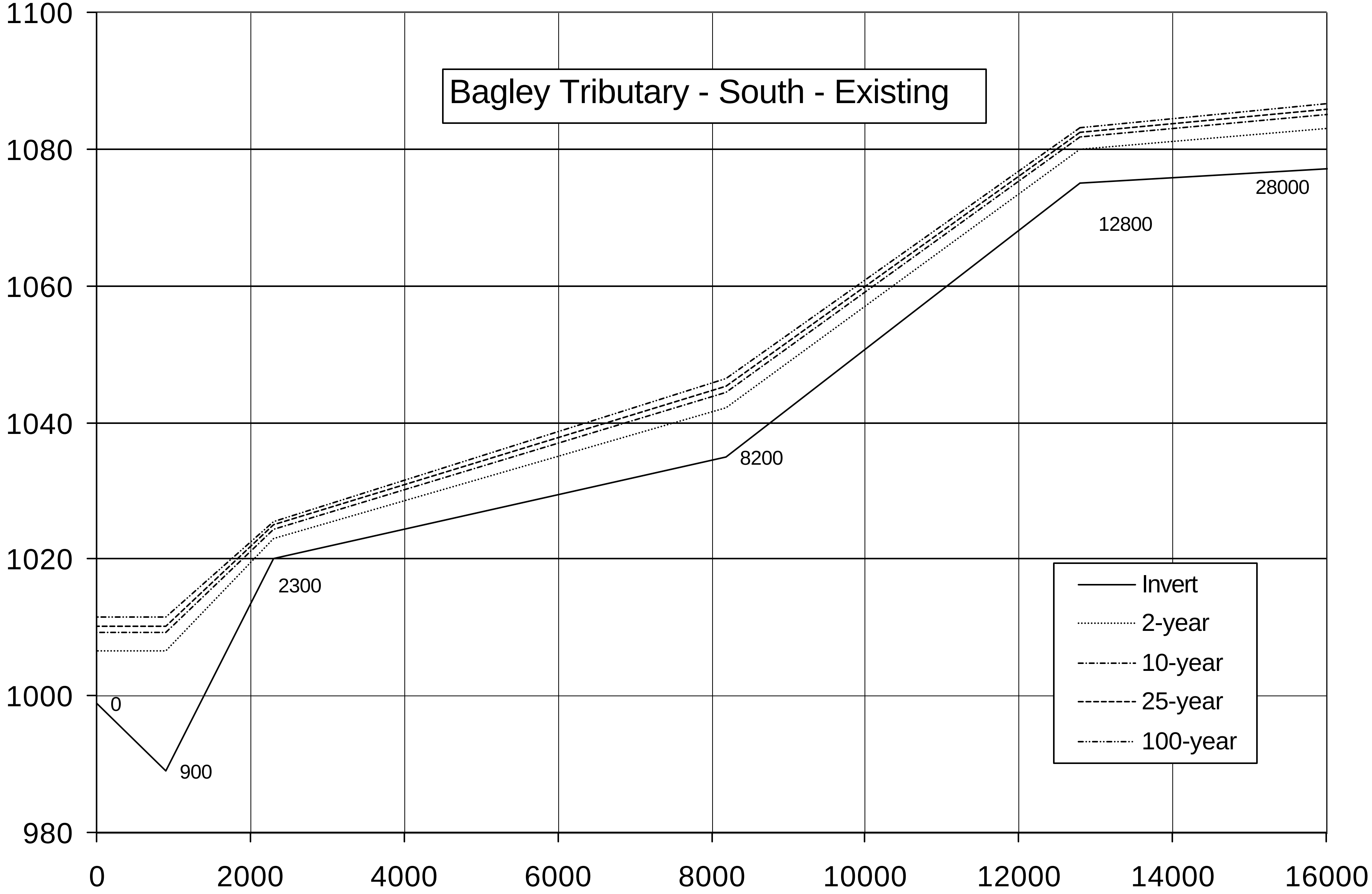


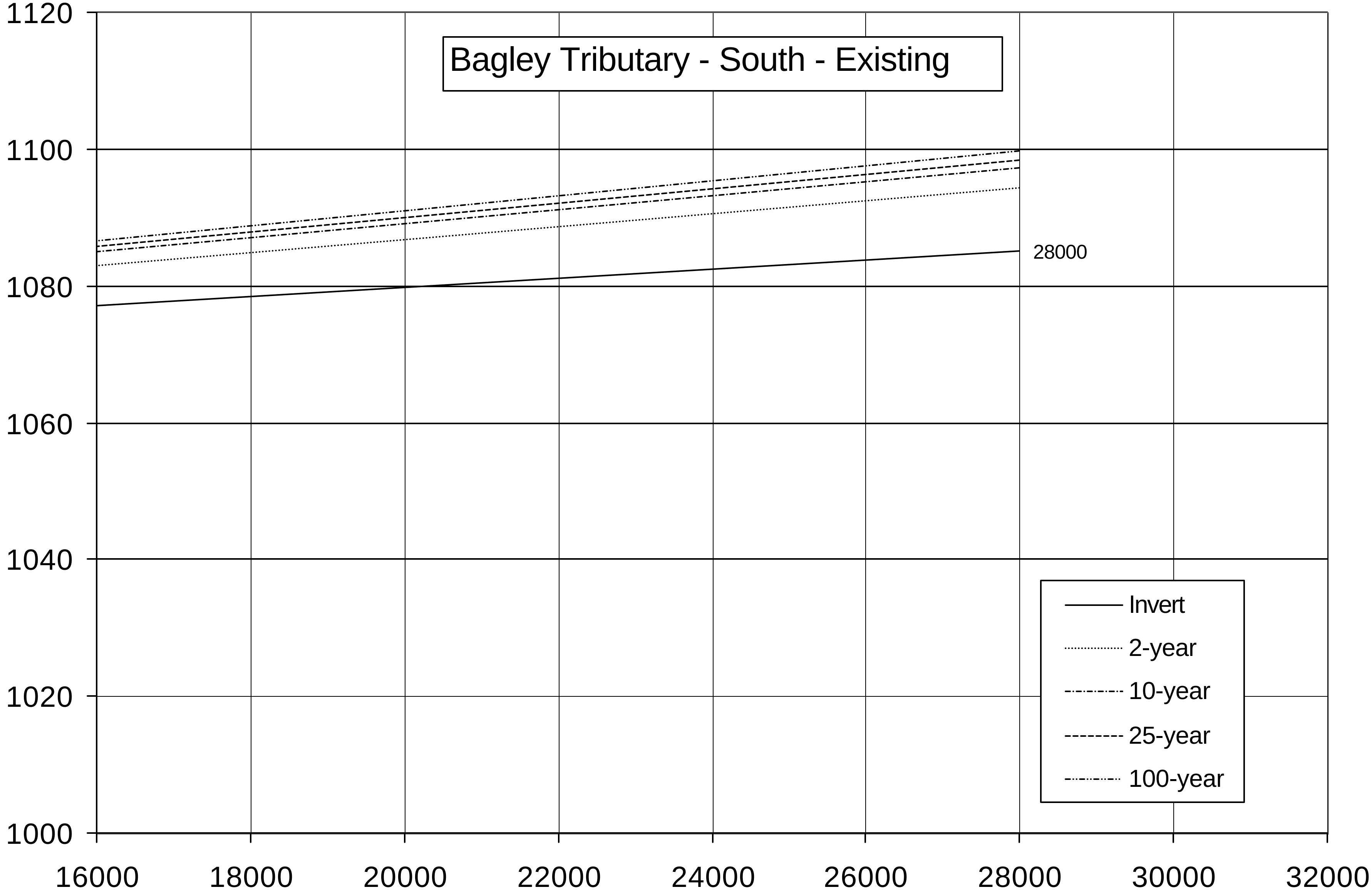
Bentley Creek - Existing
Invert
2-year
10-year
25-year
100-year
1120
1100
1080
1060
1040
1020
1000
0
0
2000
4000
6000
8000
10000
12000
14000
16000


Bentley Creek - Existing
Invert
2-year
10-year
25-year
100-year
1120
1100
1080
1060
1040
1020
1000
16000
18000
20000
22000
24000
26000
28000
30000
32000
30800

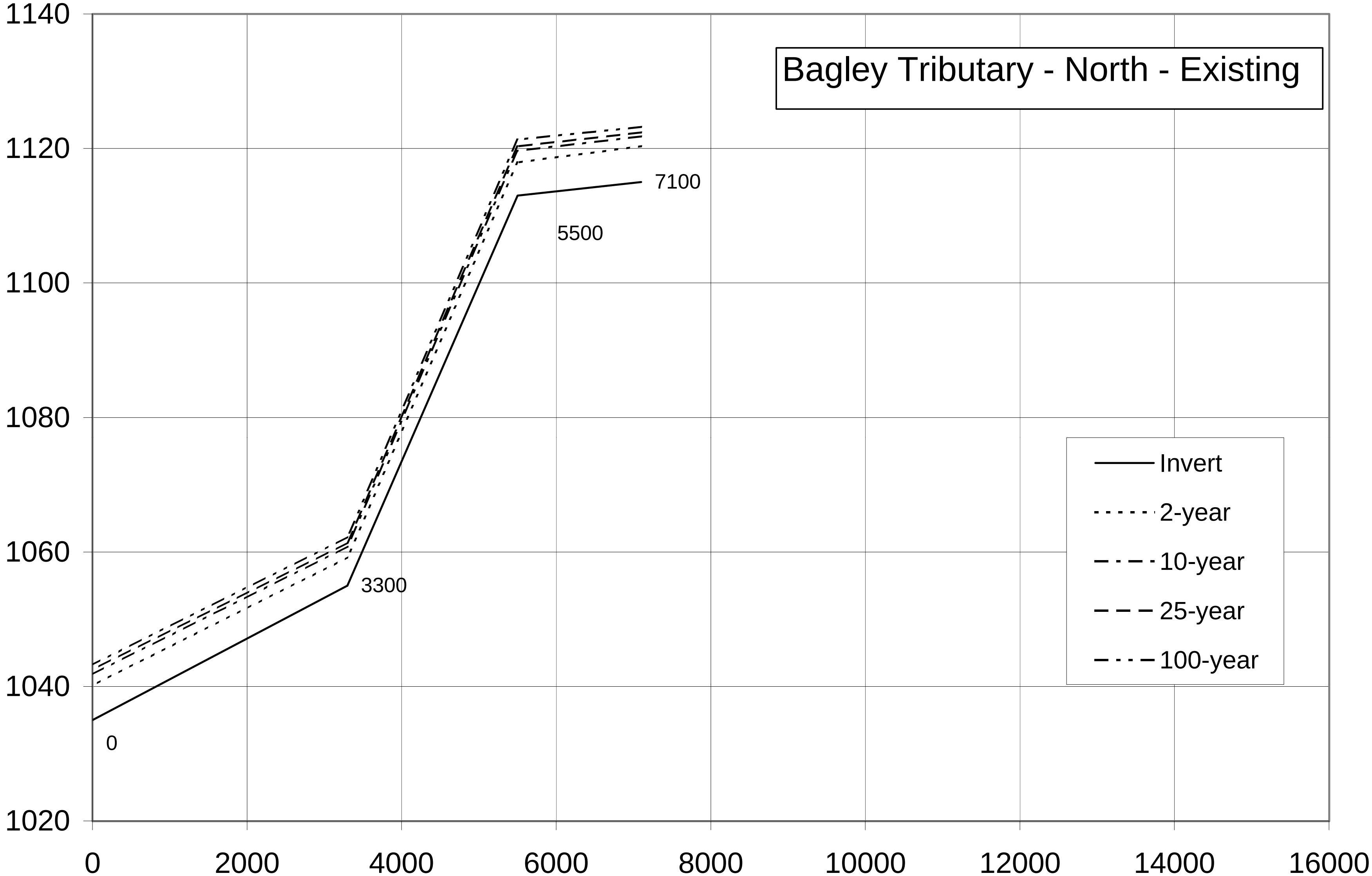


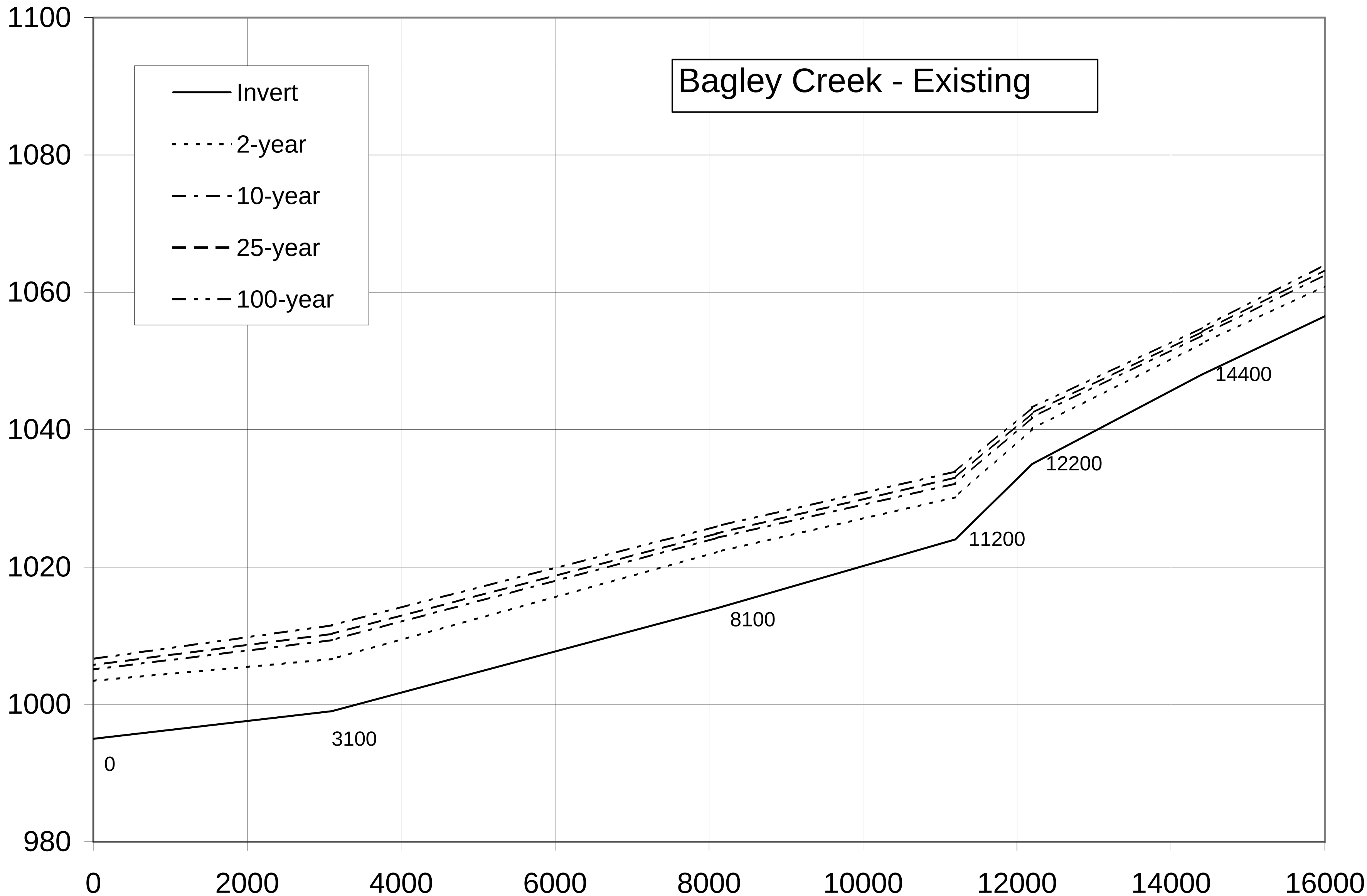
Bentley Creek - Existing
1120
1100
1080
1060
1040
1020
1000
32000
34000
36000
38000
40000
42000
44000
46000
48000
33900
36700
38900
39800
41600
Invert
2-year
10-year
25-year
100-year

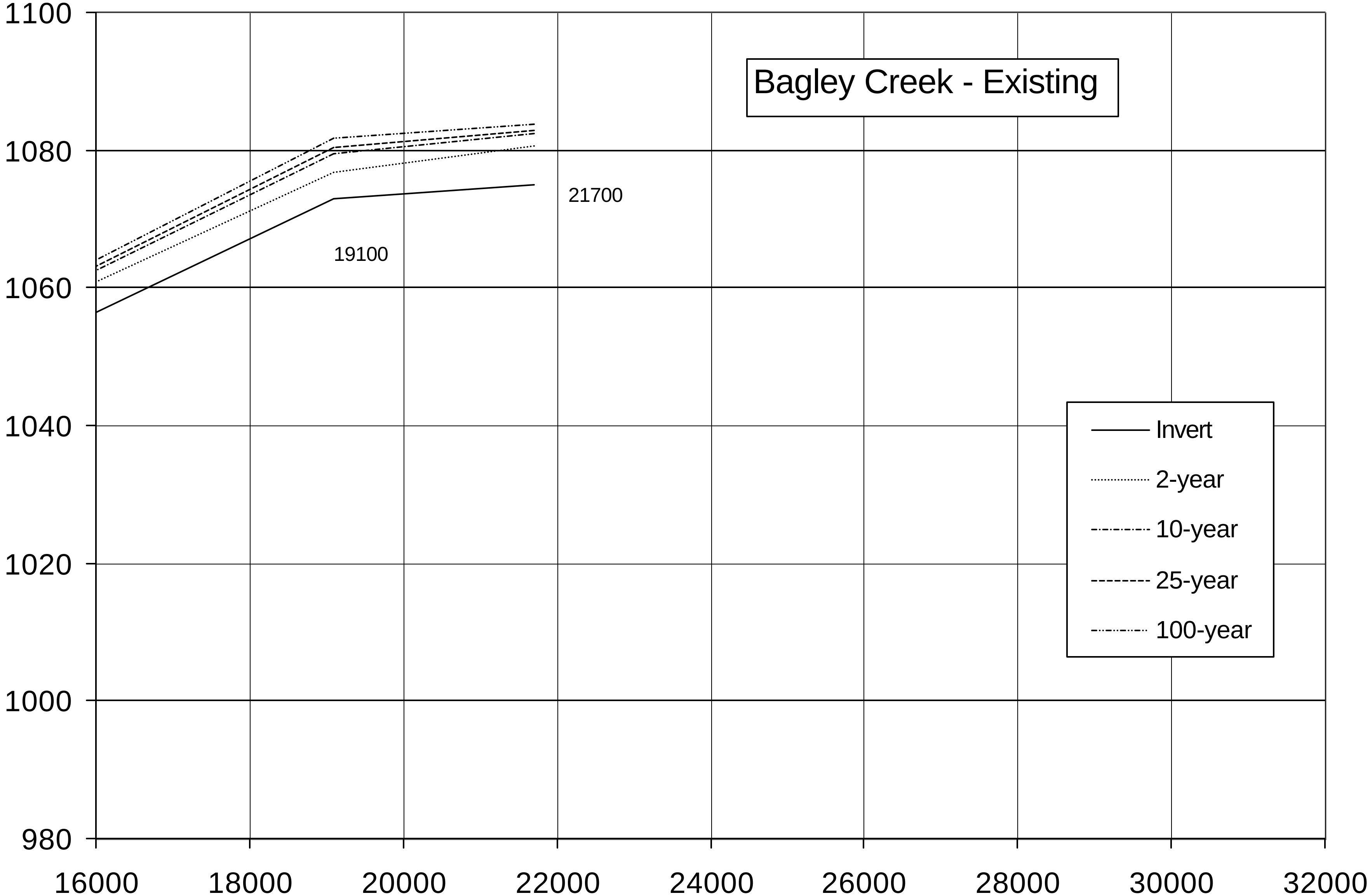

Bagley Tributary - South - Existing
1100
1080
1060
1040
1020
1000
980
0
2000
4000
6000
8000
10000
12000
14000
16000
0
900
2300
8200
12800
28000
Invert
2-year
10-year
25-year
100-year



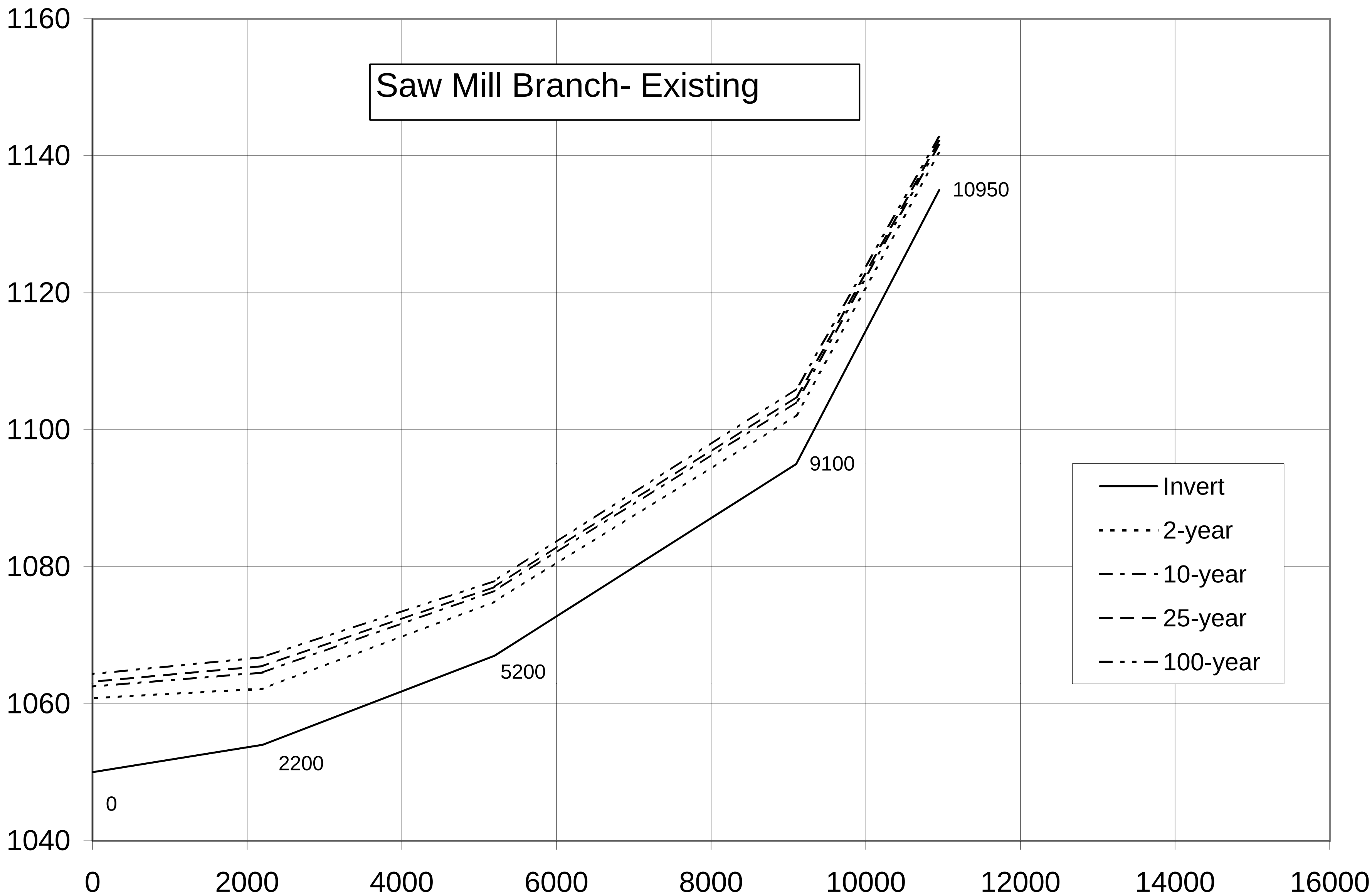
Bagley Tributary - South - Existing
1120
1100
1080
1060
1040
1020
1000
16000
18000
20000
22000
24000
26000
28000
30000
32000
28000
Invert
2-year
10-year
25-year
100-year


Bagley Tributary - North - Existing
1140
1120
1100
1080
1060
1040
1020
0
2000
4000
6000
8000
10000
12000
14000
16000
7100
5500
3300
0
Invert
2-year
10-year
25-year
100-year

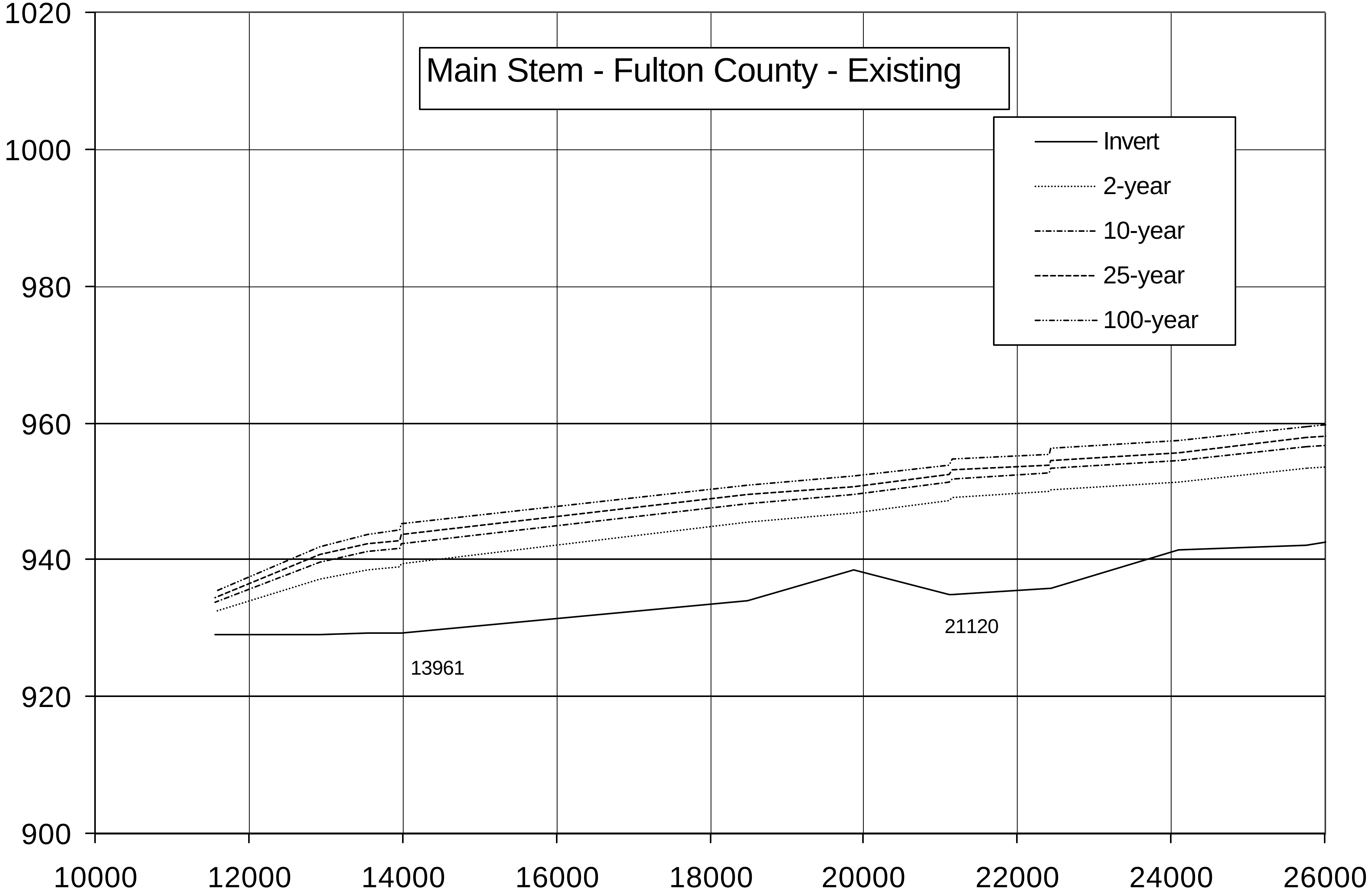

Bagley Creek - Existing
Invert
2-year
10-year
25-year
100-year
1100
1080
1060
1040
1020
1000
980
0
2000
4000
6000
8000
10000
12000
14000
16000
0
3100
8100
11200
12200
14400



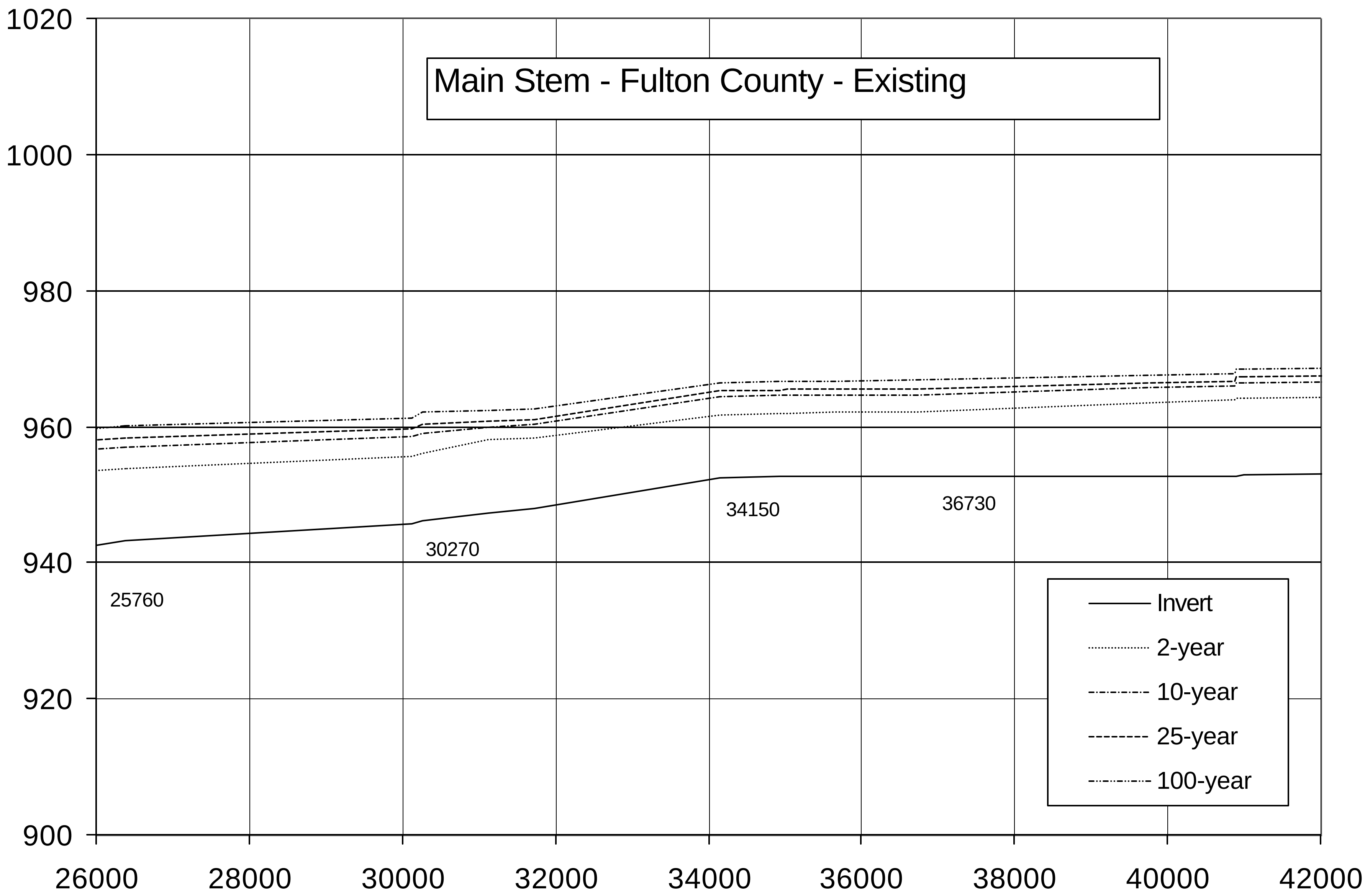
Bagley Creek - Existing
1100
1080
1060
1040
1020
1000
980
16000
18000
20000
22000
24000
26000
28000
30000
32000
19100
21700
Invert
2-year
10-year
25-year
100-year

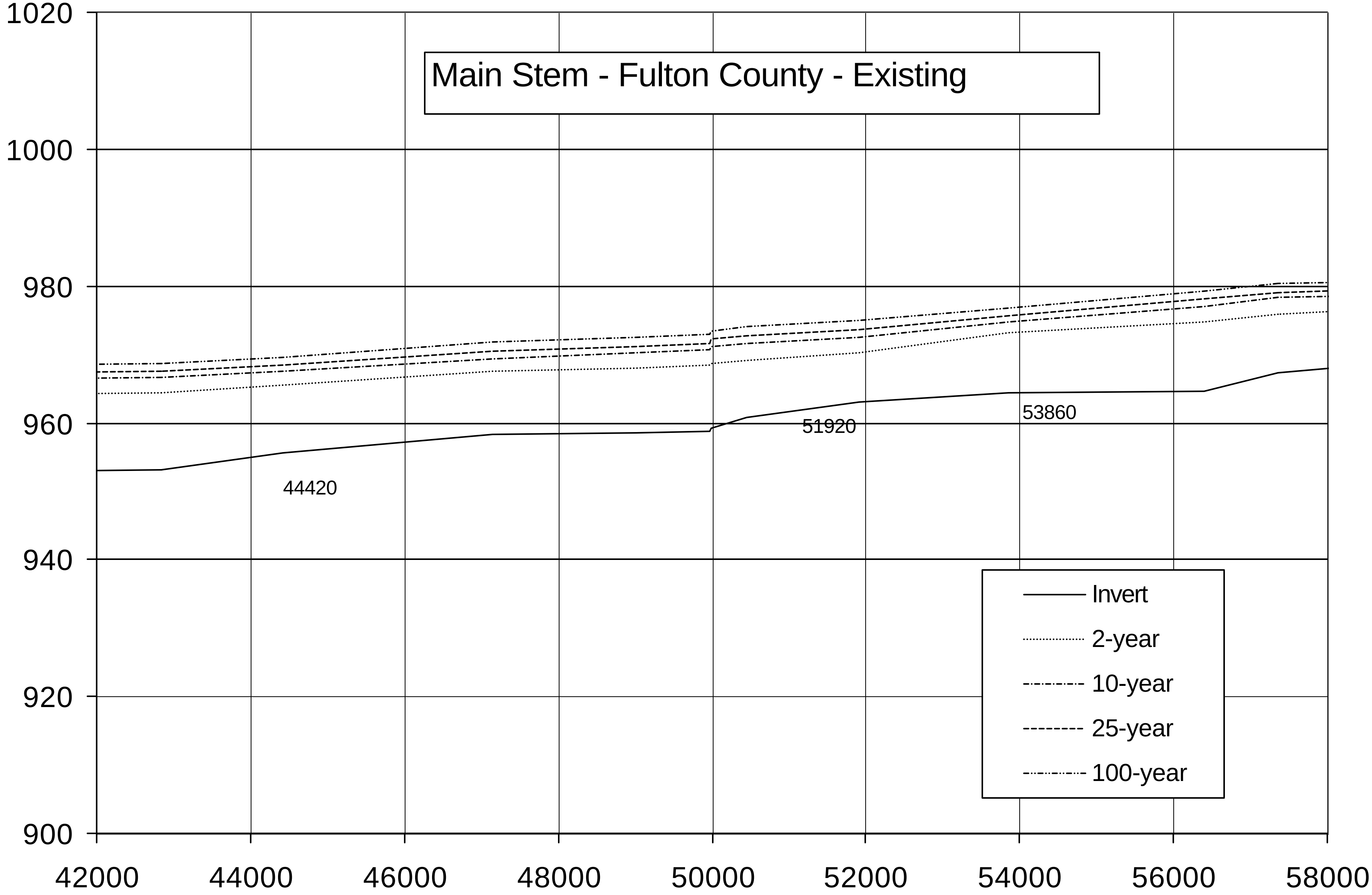


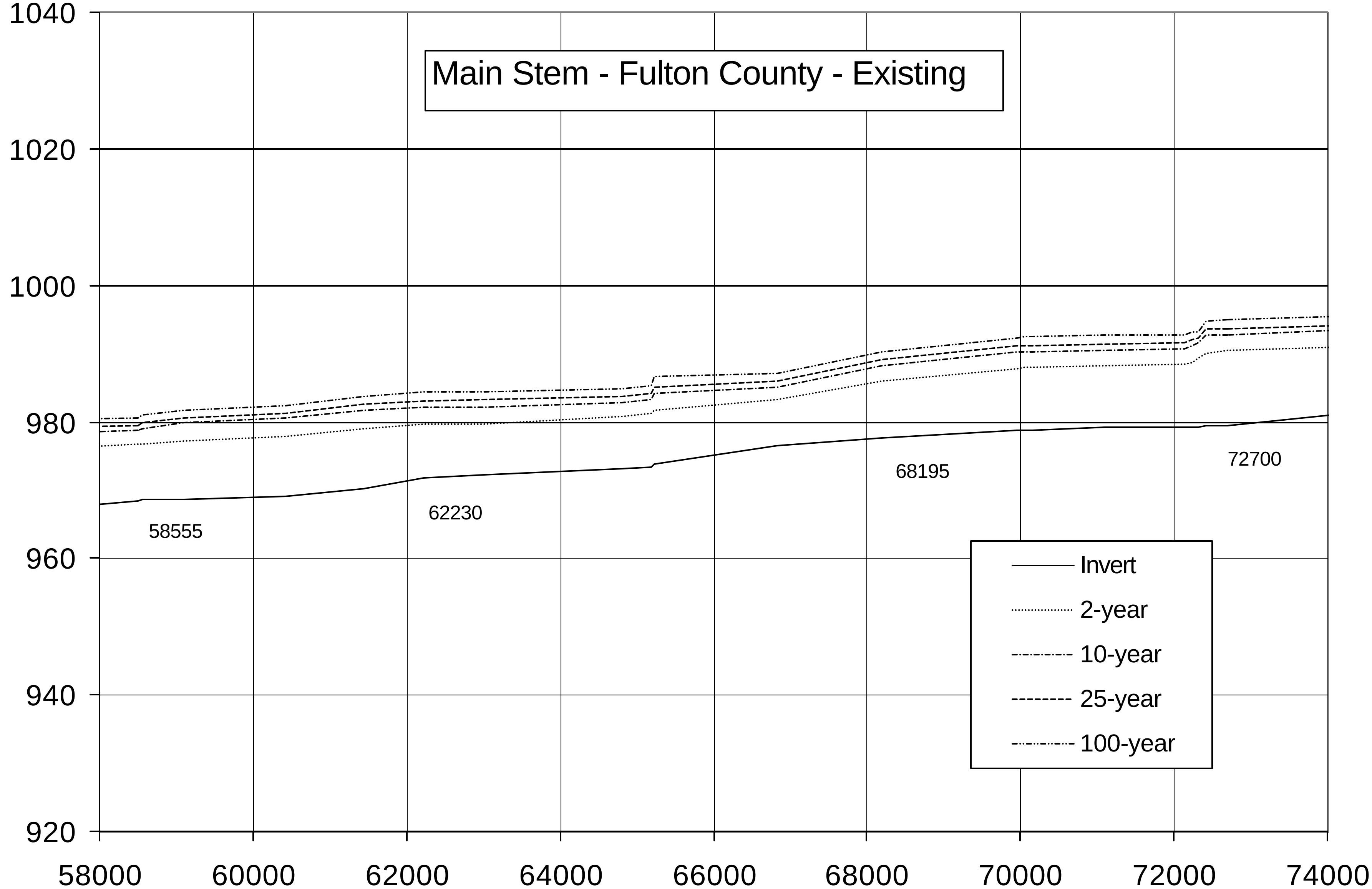
Saw Mill Branch- Existing
1160
1140
1120
1100
1080
1060
1040
0
2000
4000
6000
8000
10000
12000
14000
16000
10950
9100
5200
2200
0
Invert
2-year
10-year
25-year
100-year



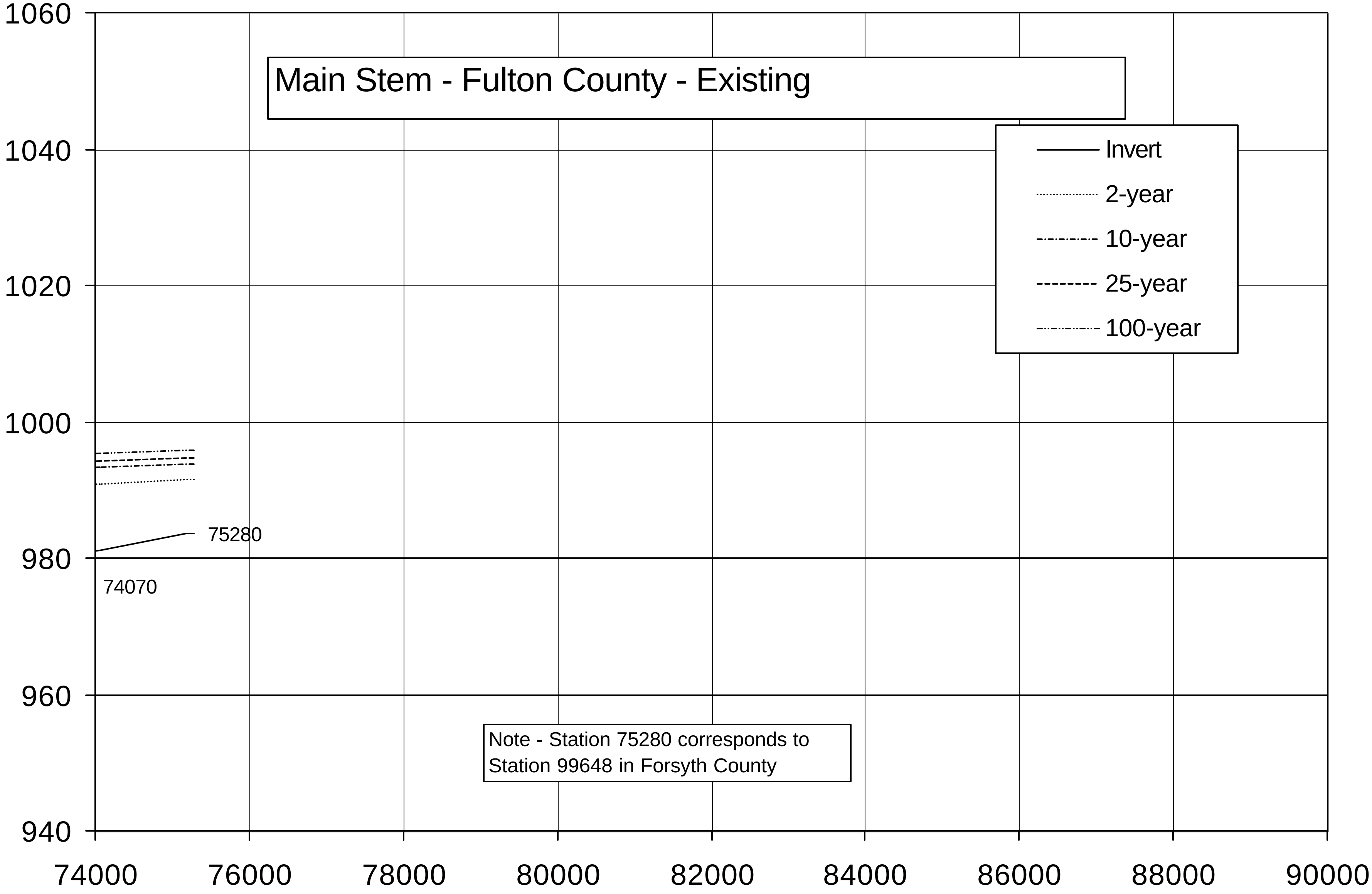
Main Stem - Fulton County - Existing
Invert
2-year
10-year
25-year
100-year
13961
21120
1020
1000
980
960
940
920
900
10000
12000
14000
16000
18000
20000
22000
24000
26000

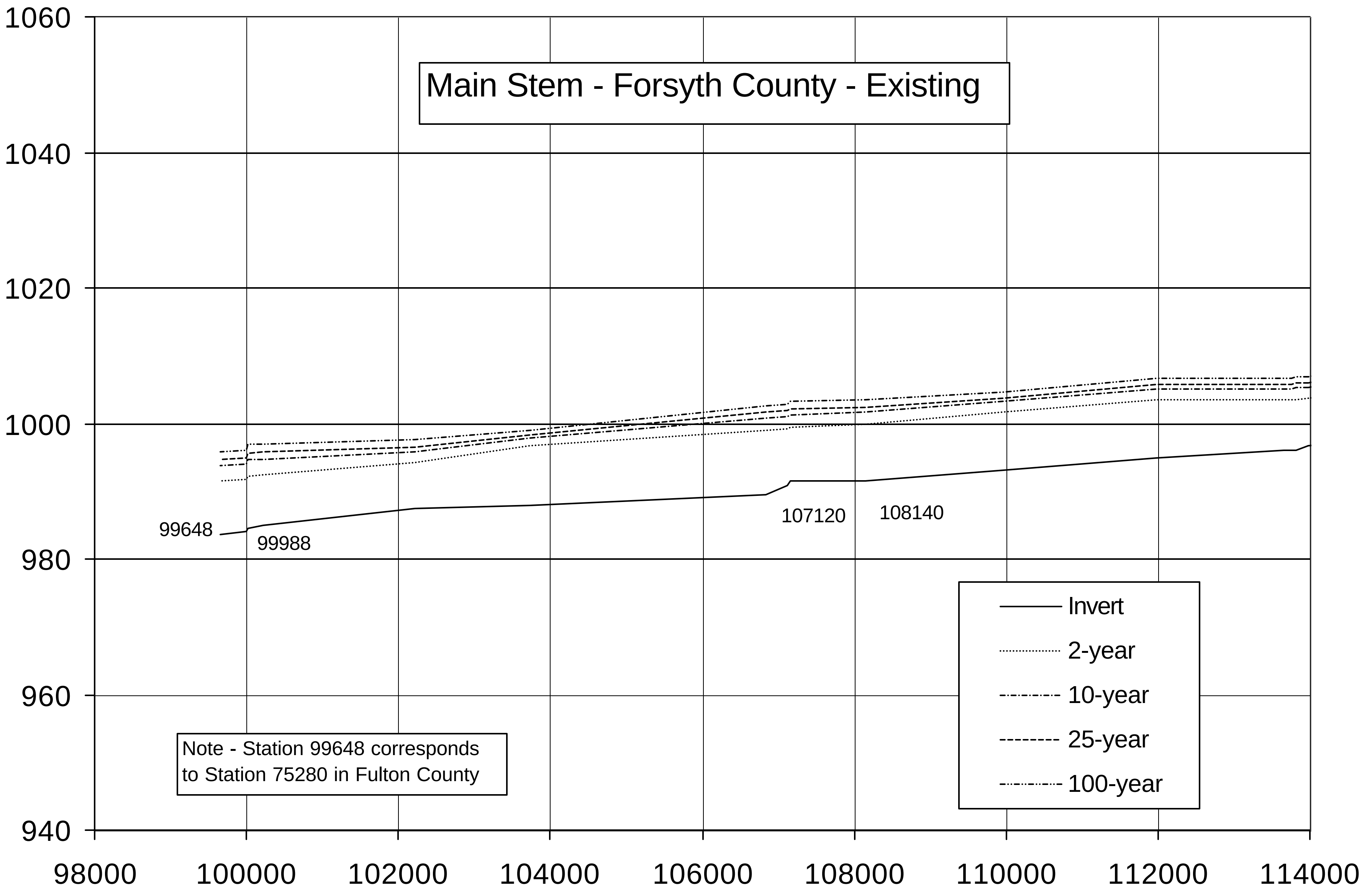

Main Stem - Fulton County - Existing
1020
1000
980
960
940
920
900
26000
28000
30000
32000
34000
36000
38000
40000
42000
25760
30270
34150
36730
Invert
2-year
10-year
25-year
100-year

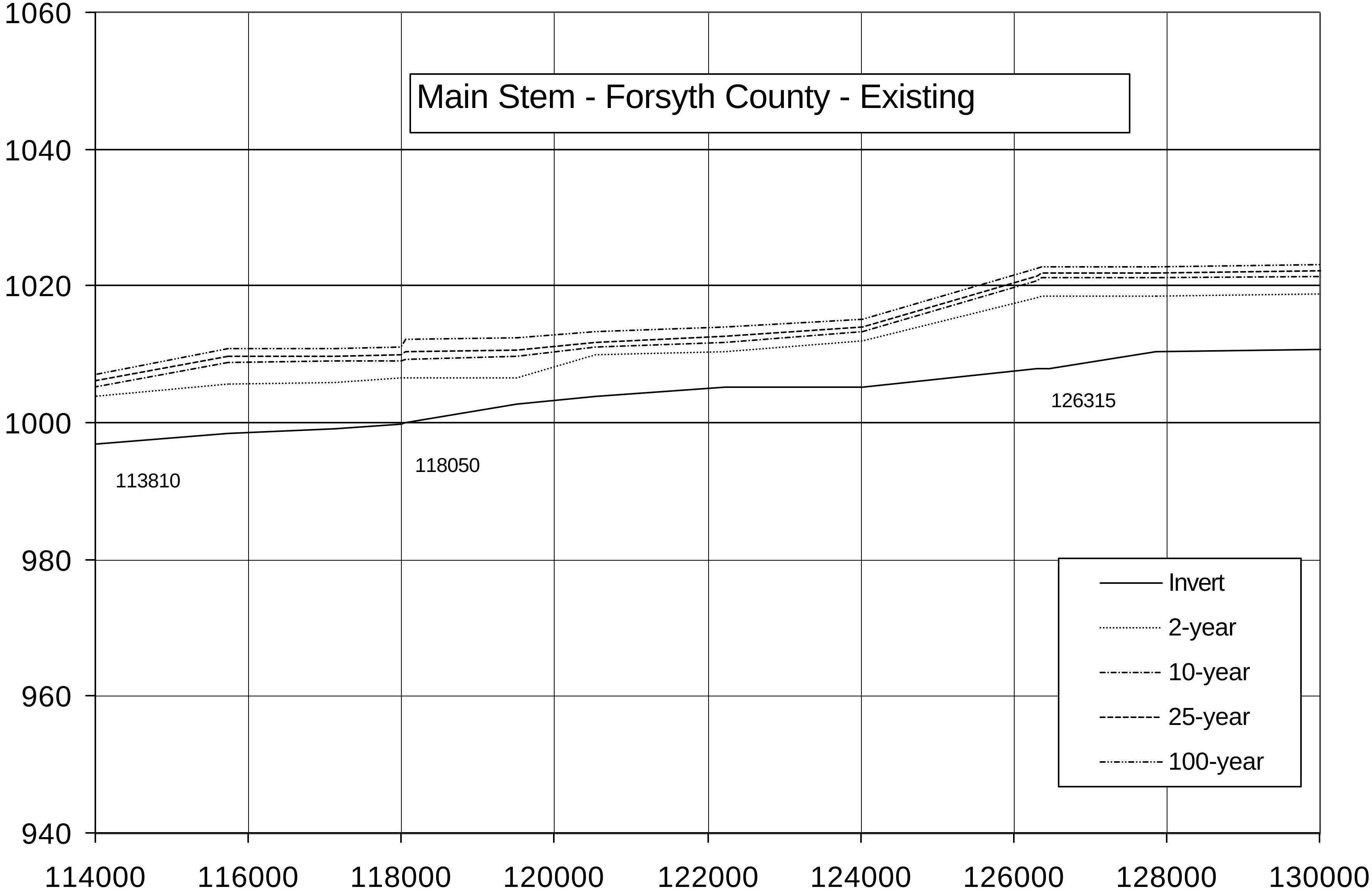

Main Stem - Fulton County - Existing
1020
1000
980
960
940
920
900
42000
44000
46000
48000
50000
52000
54000
56000
58000
44420
51920
53860
Invert
2-year
10-year
25-year
100-year

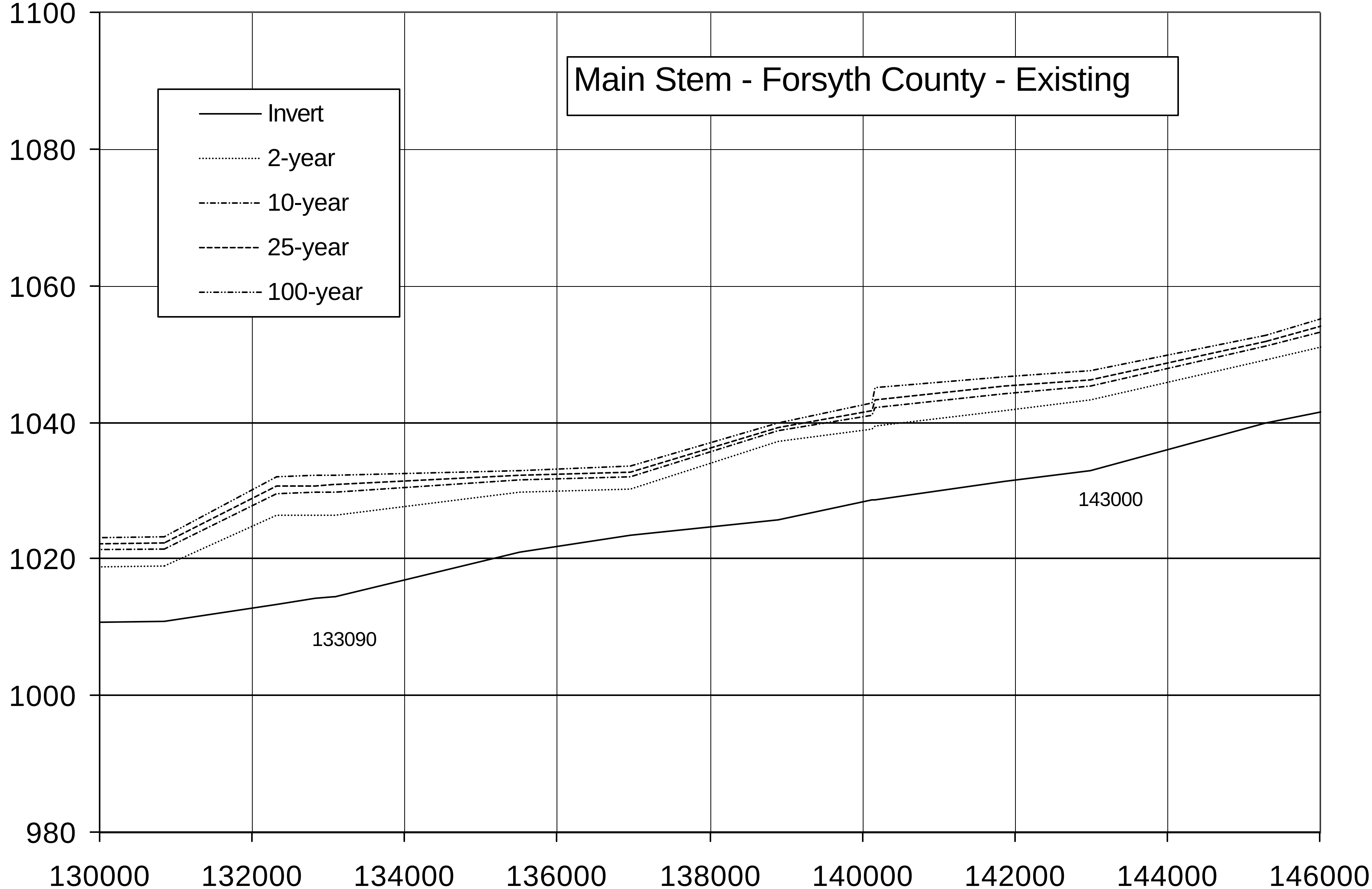


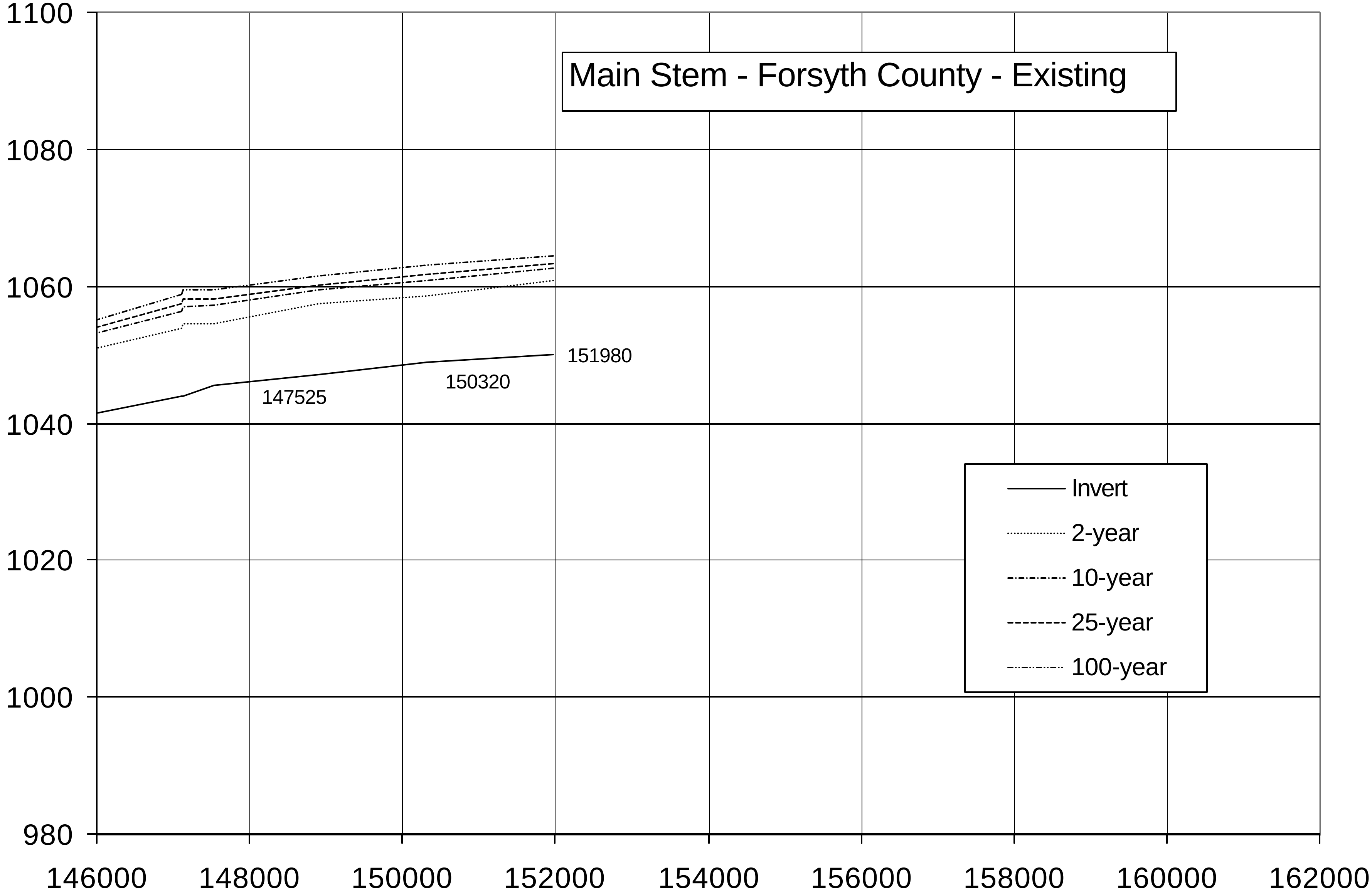
Main Stem - Fulton County - Existing
1040
1020
1000
980
960
940
920
58000
60000
62000
64000
66000
68000
70000
72000
74000
58555
62230
68195
72700
Invert
2-year
10-year
25-year
100-year


Main Stem - Fulton County - Existing
Invert
2-year
10-year
25-year
100-year
75280
74070
Note - Station 75280 corresponds to Station 99648 in Forsyth County
1060
1040
1020
1000
980
960
940
74000
76000
78000
80000
82000
84000
86000
88000
90000

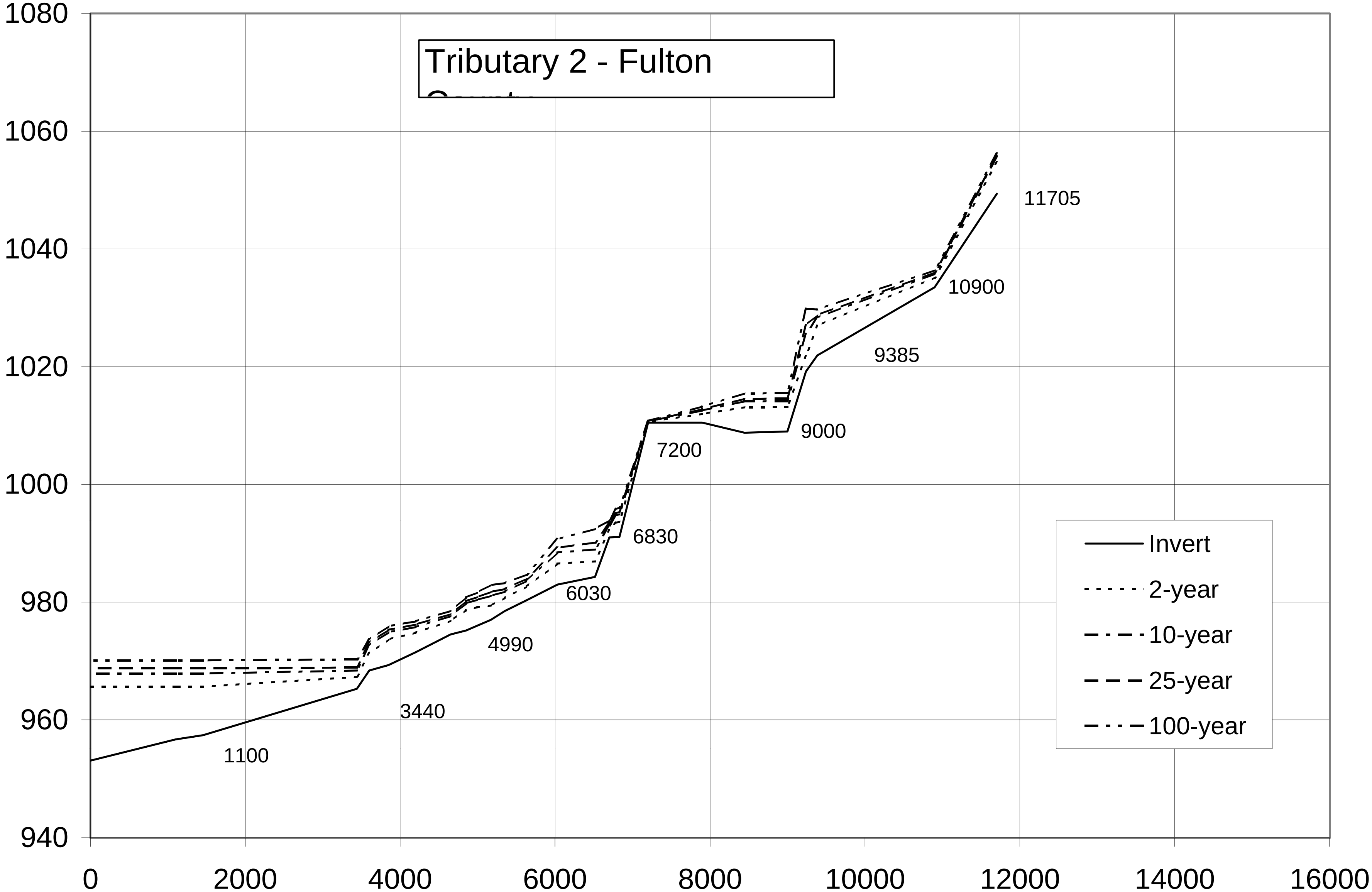

Main Stem - Forsyth County - Existing
1060
1040
1020
1000
980
960
940
98000
100000
102000
104000
106000
108000
110000
112000
114000
99648
99988
107120
108140
Invert
2-year
10-year
25-year
100-year
Note - Station 99648 corresponds to Station 75280 in Fulton County


Main Stem - Forsyth County - Existing
1060
1040
1020
1000
980
960
940
114000
116000
118000
120000
122000
124000
126000
128000
130000
113810
118050
126315
Invert
2-year
10-year
25-year
100-year

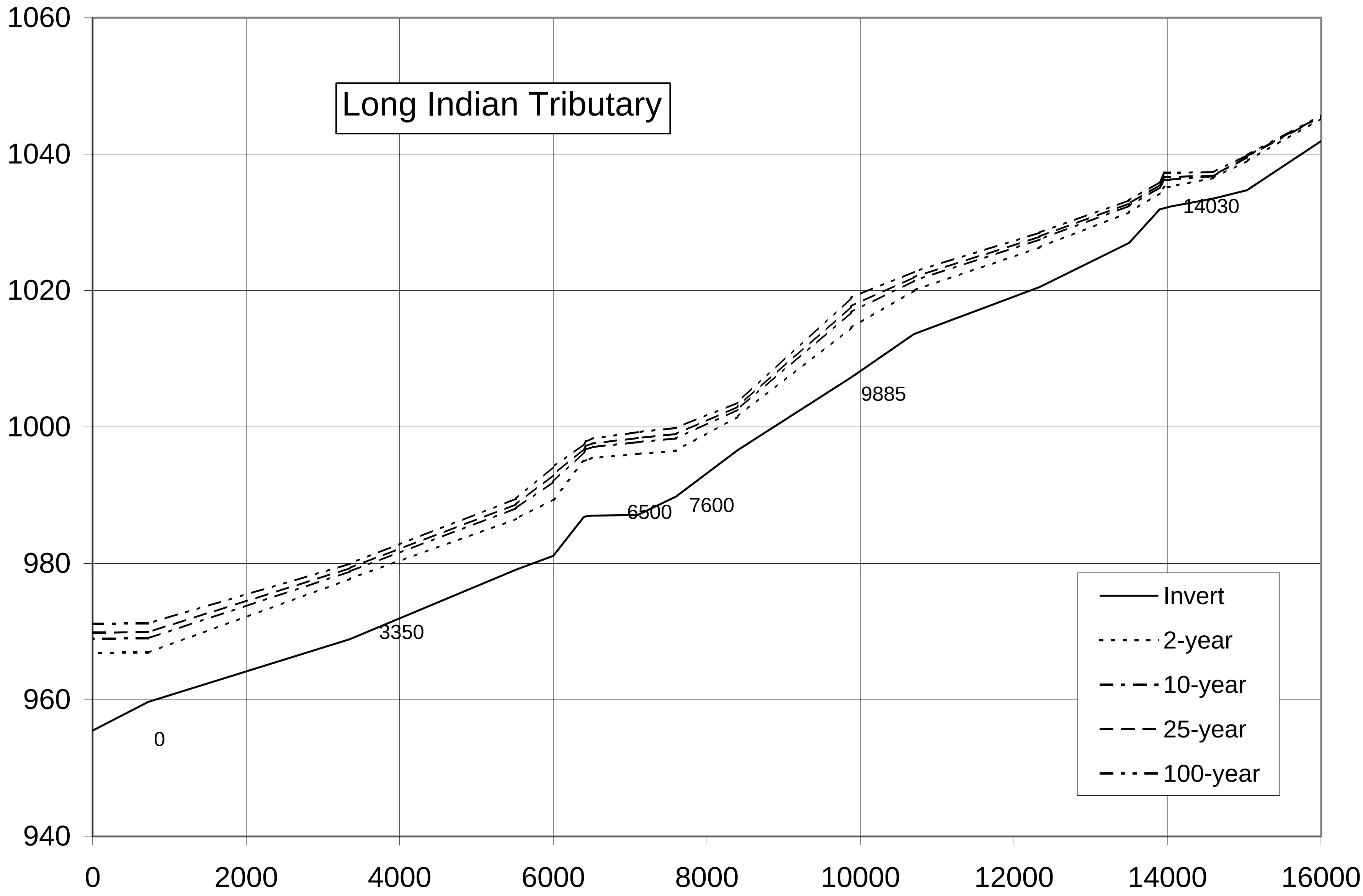

Main Stem - Forsyth County - Existing
Invert
2-year
10-year
25-year
100-year
1100
1080
1060
1040
1020
1000
980
130000
132000
134000
136000
138000
140000
142000
144000
146000
133090
143000

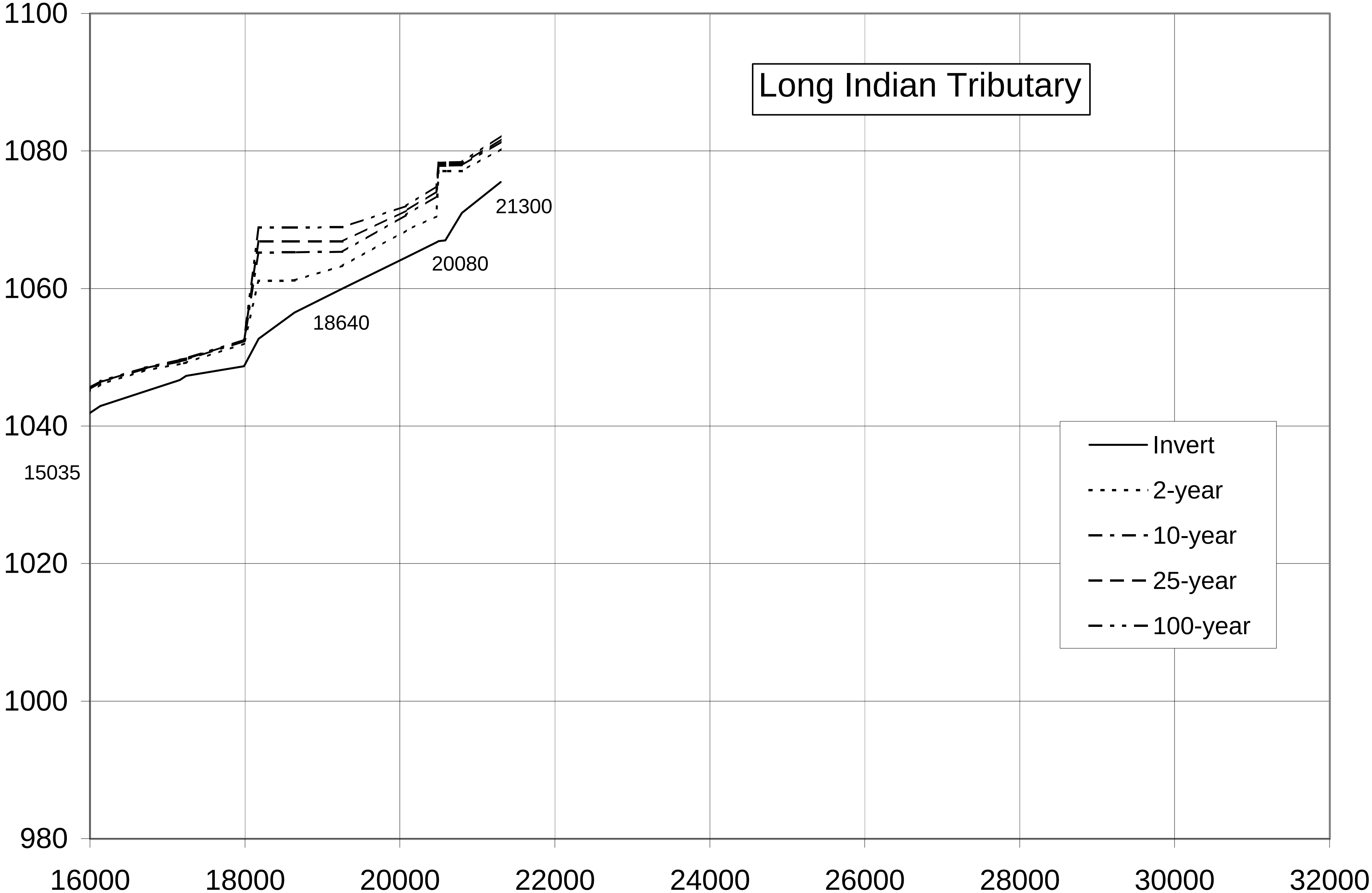

Main Stem - Forsyth County - Existing
1100
1080
1060
1040
1020
1000
980
146000
148000
150000
152000
154000
156000
158000
160000
162000
151980
150320
147525
Invert
2-year
10-year
25-year
100-year

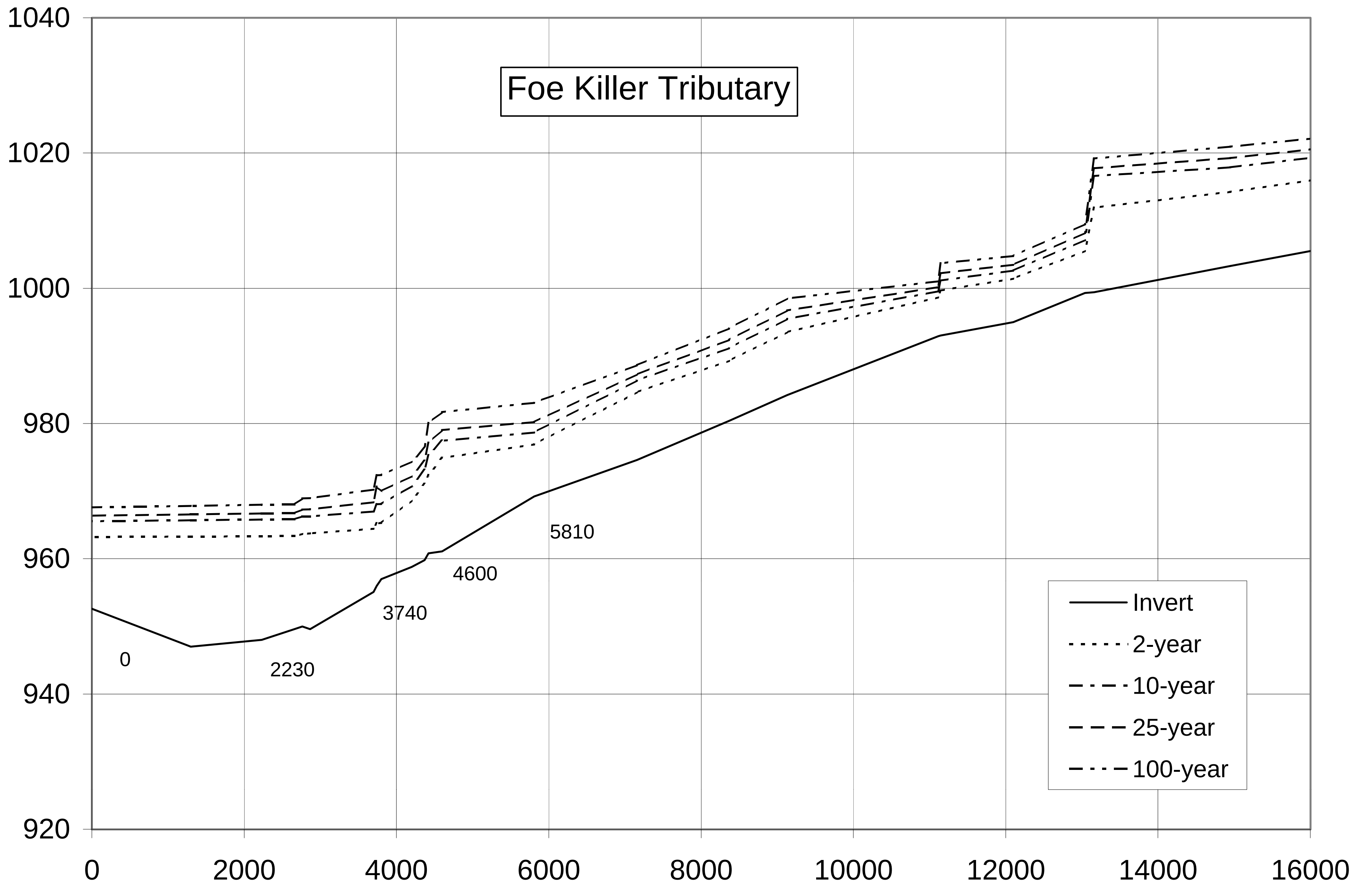
Appendix C
Flood Profiles for Selected Locations for Future Conditions

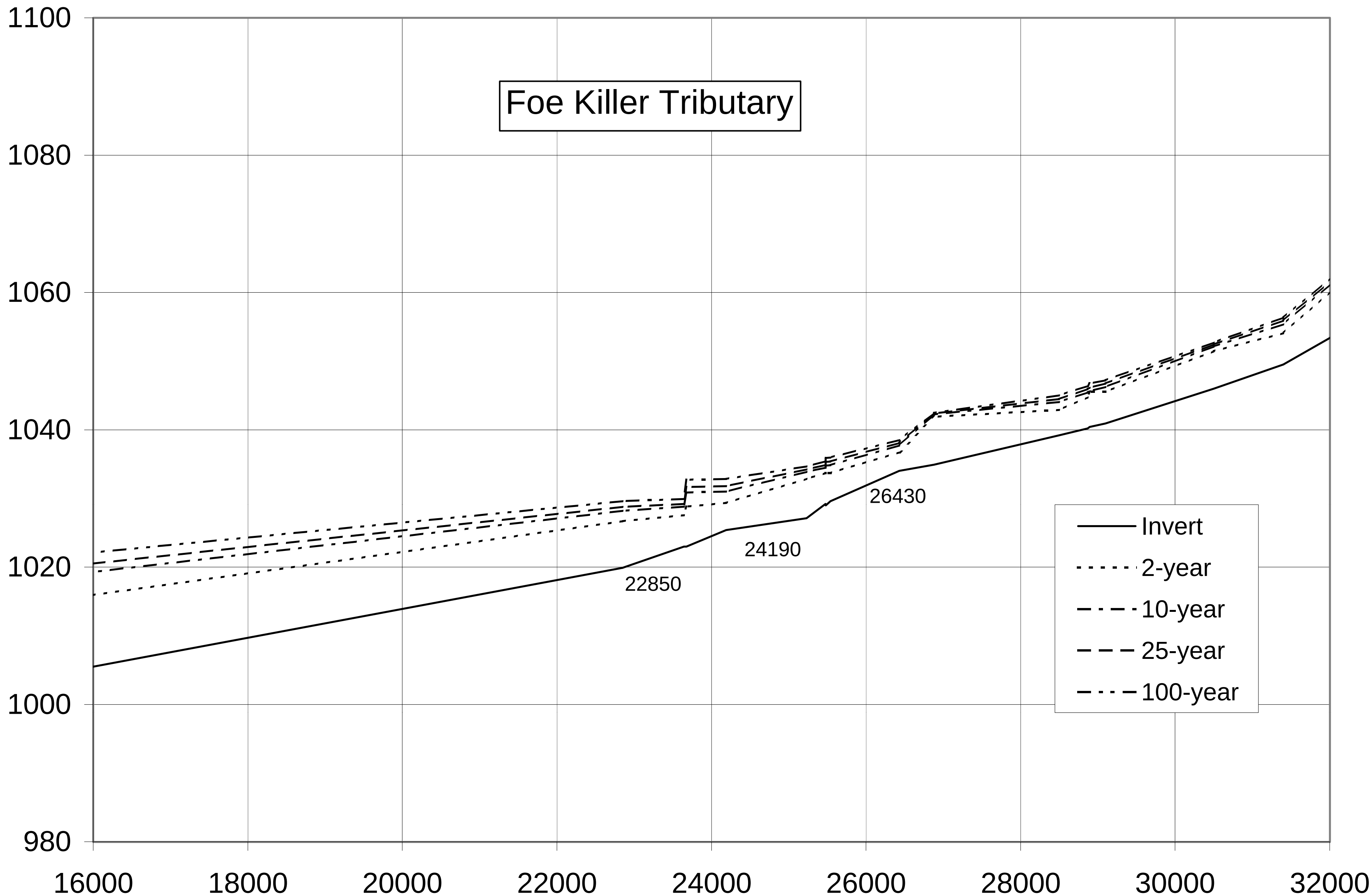


Tributary 2 - Fulton County
1080
1060
1040
1020
1000
980
960
940
0
2000
4000
6000
8000
10000
12000
14000
16000
11705
10900
9385
9000
7200
6830
6030
4990
3440
1100
Invert
2-year
10-year
25-year
100-year


Long Indian Tributary
1060
1040
1020
1000
980
960
940
0
2000
4000
6000
8000
10000
12000
14000
16000
0
3350
6500
7600
9885
14030
Invert
2-year
10-year
25-year
100-year

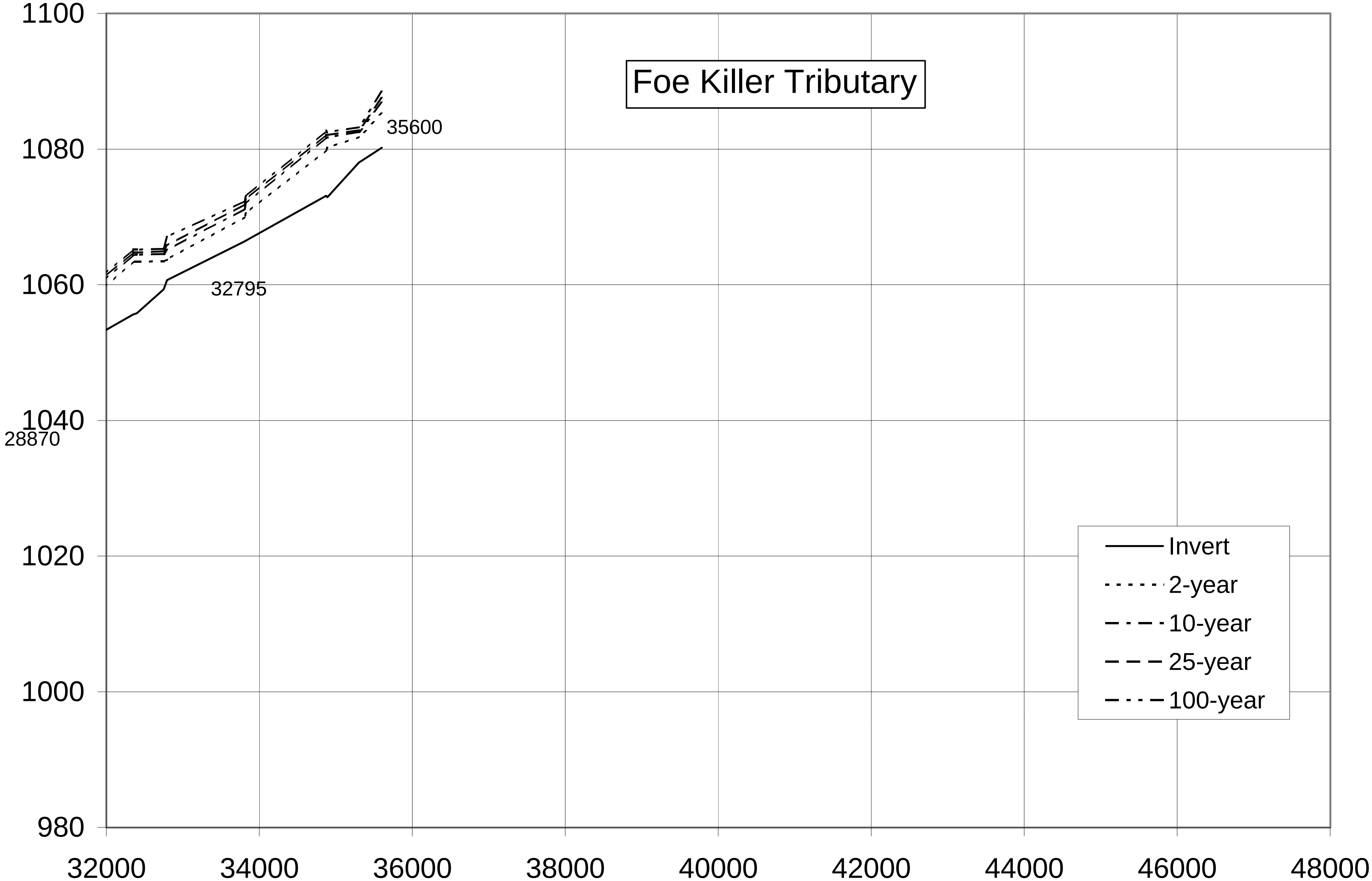

Long Indian Tributary
1100
1080
1060
1040
1020
1000
980
16000
18000
20000
22000
24000
26000
28000
30000
32000
15035
18640
20080
21300
Invert
2-year
10-year
25-year
100-year


Foe Killer Tributary
1040
1020
1000
980
960
940
920
0
2000
4000
6000
8000
10000
12000
14000
16000
0
2230
3740
4600
5810
Invert
2-year
10-year
25-year
100-year

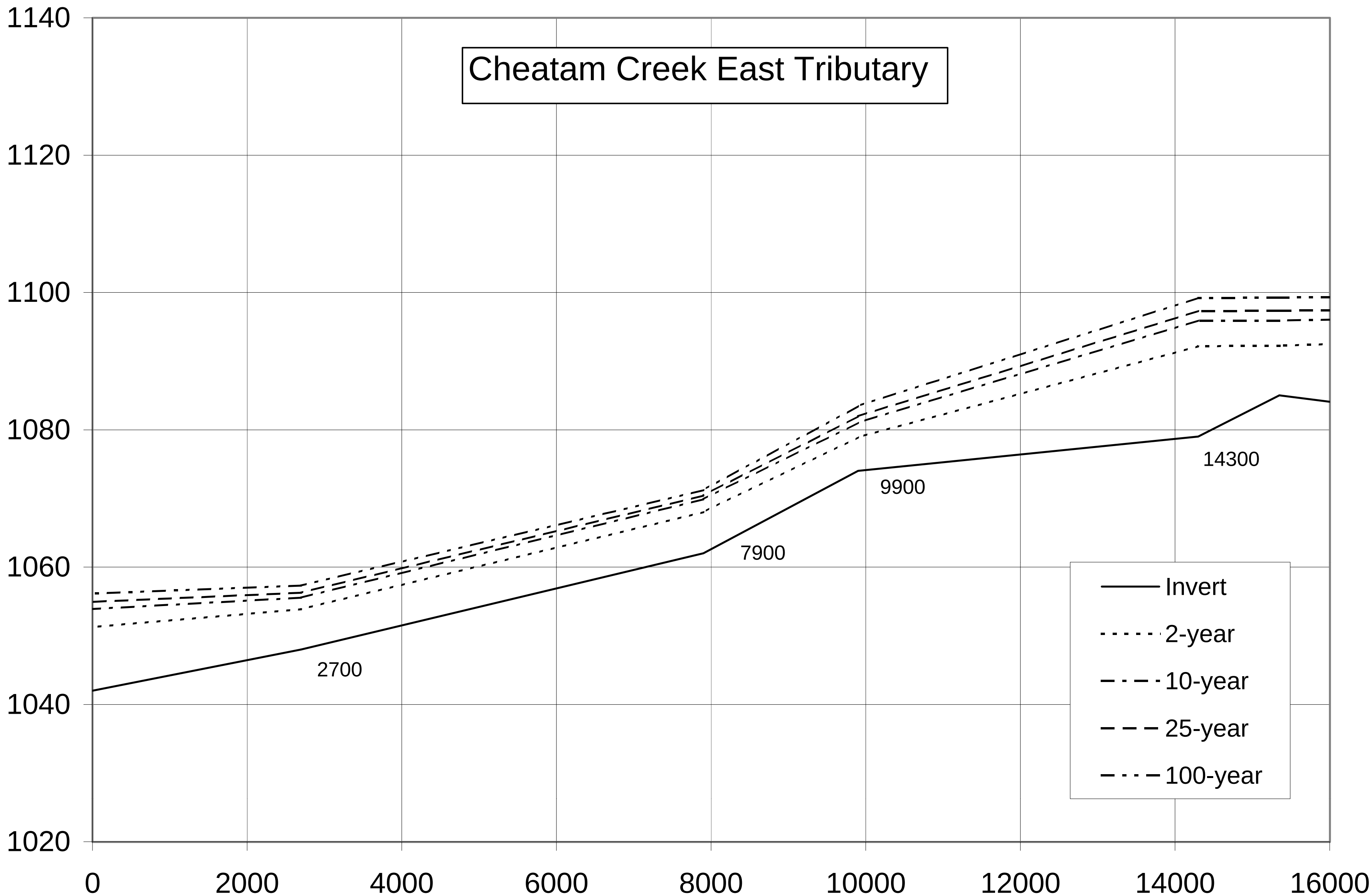


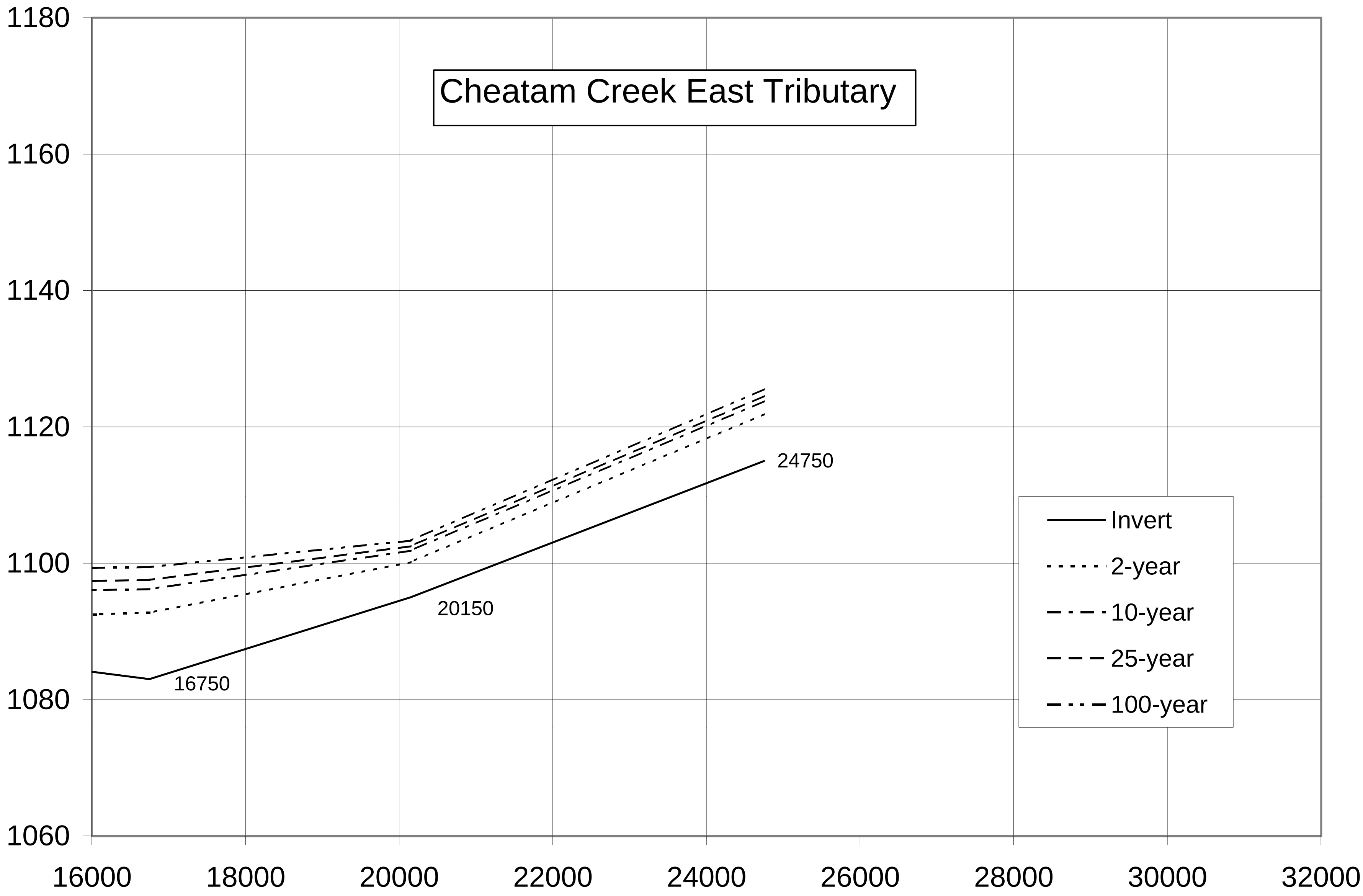
Foe Killer Tributary
1100
1080
1060
1040
1020
1000
980
16000
18000
20000
22000
24000
26000
28000
30000
32000
22850
24190
26430
Invert
2-year
10-year
25-year
100-year

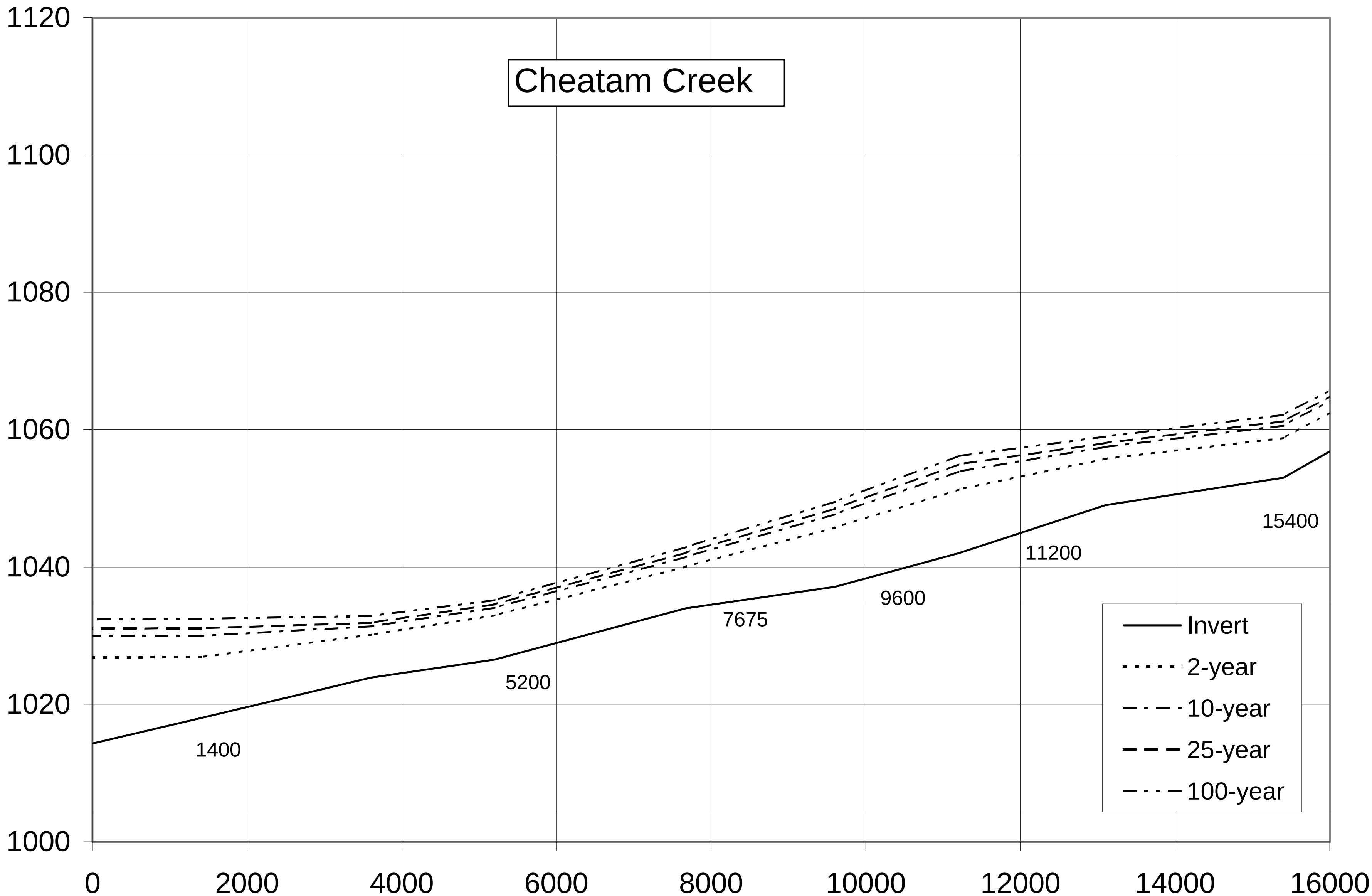
7160



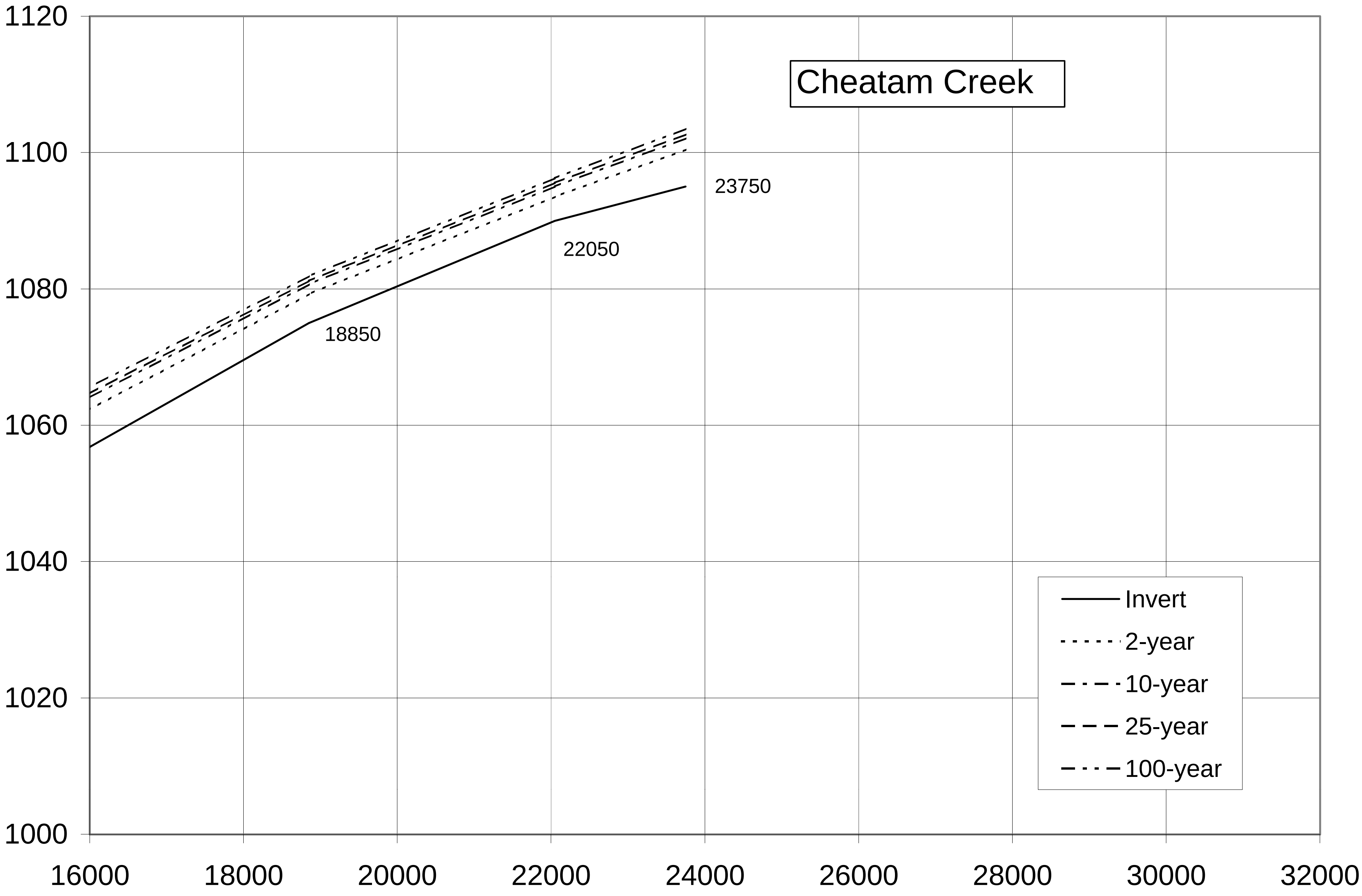
Foe Killer Tributary
1100
1080
1060
1040
1020
1000
980
32000
34000
36000
38000
40000
42000
44000
46000
48000
35600
32795
28870
Invert
2-year
10-year
25-year
100-year

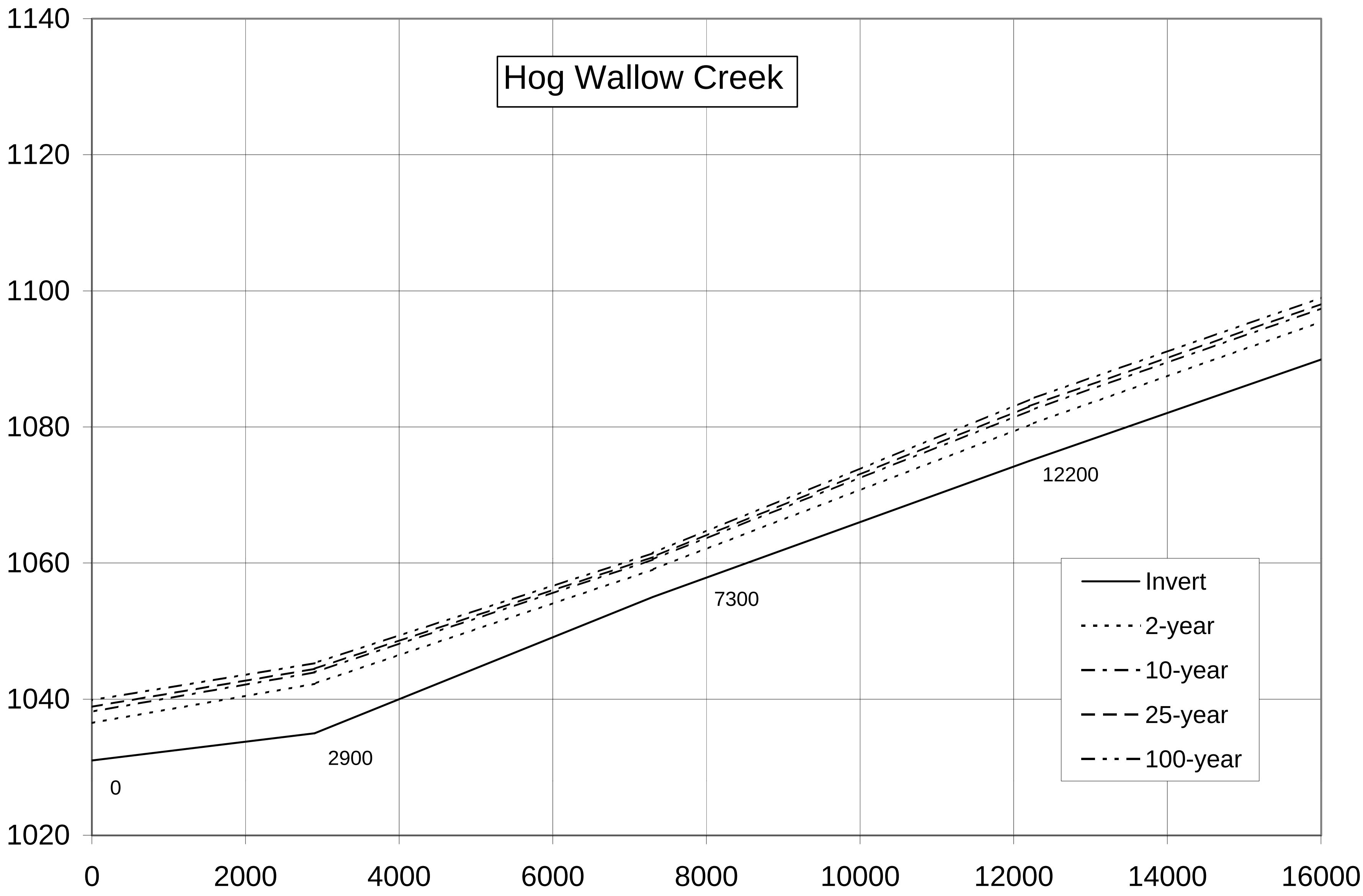

Cheatam Creek East Tributary
1140
1120
1100
1080
1060
1040
1020
0
2000
4000
6000
8000
10000
12000
14000
16000
2700
7900
9900
14300
Invert
2-year
10-year
25-year
100-year

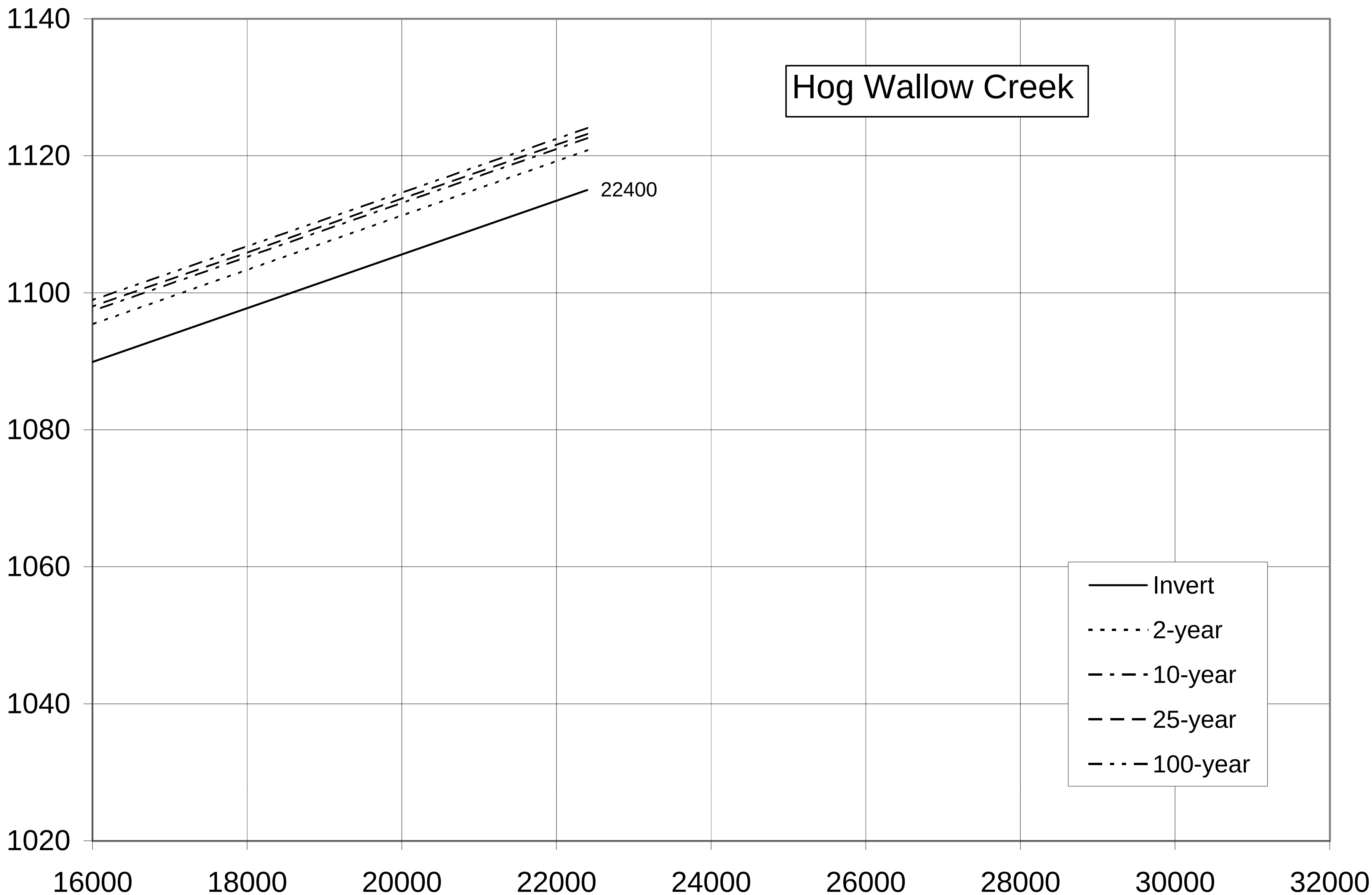

Cheatam Creek East Tributary
1180
1160
1140
1120
1100
1080
1060
16000
18000
20000
22000
24000
26000
28000
30000
32000
16750
20150
24750
Invert
2-year
10-year
25-year
100-year

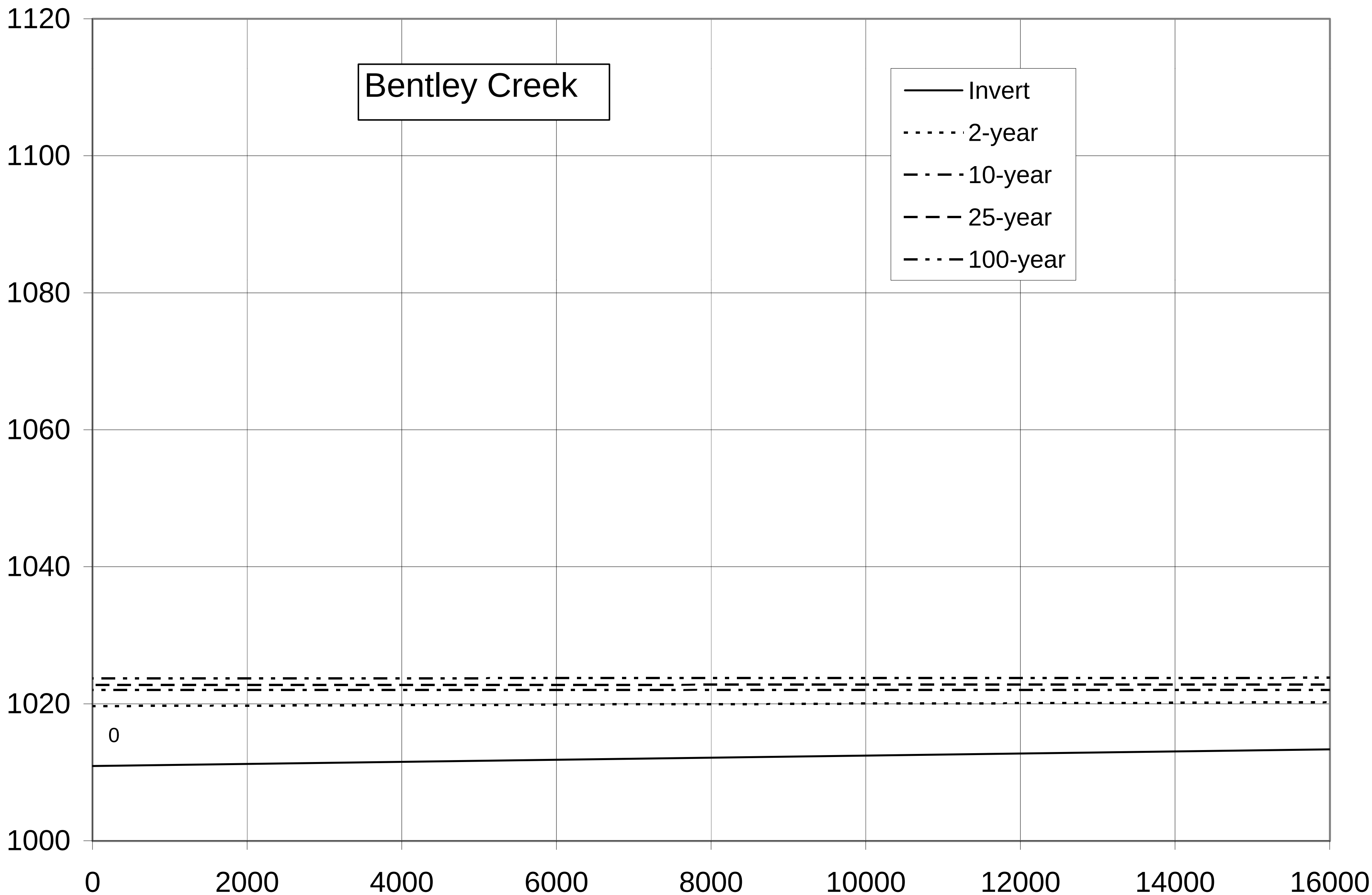


Cheatam Creek
1120
1100
1080
1060
1040
1020
1000
0
2000
4000
6000
8000
10000
12000
14000
16000
1400
5200
7675
9600
11200
15400
Invert
2-year
10-year
25-year
100-year

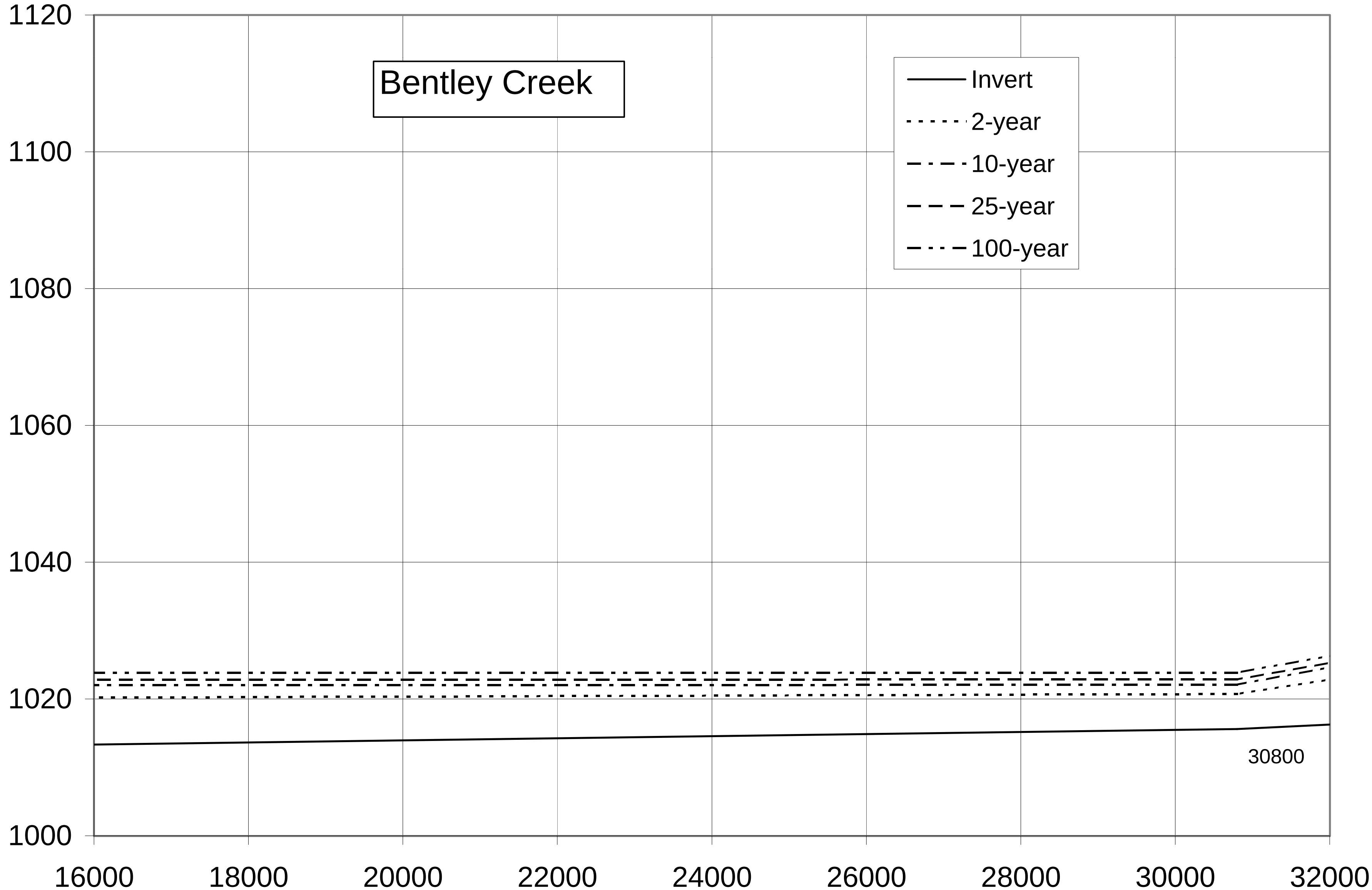

Cheatam Creek
1120
1100
1080
1060
1040
1020
1000
16000
18000
20000
22000
24000
26000
28000
30000
32000
18850
22050
23750
Invert
2-year
10-year
25-year
100-year


Hog Wallow Creek
1140
1120
1100
1080
1060
1040
1020
0
2000
4000
6000
8000
10000
12000
14000
16000
0
2900
7300
12200
Invert
2-year
10-year
25-year
100-year

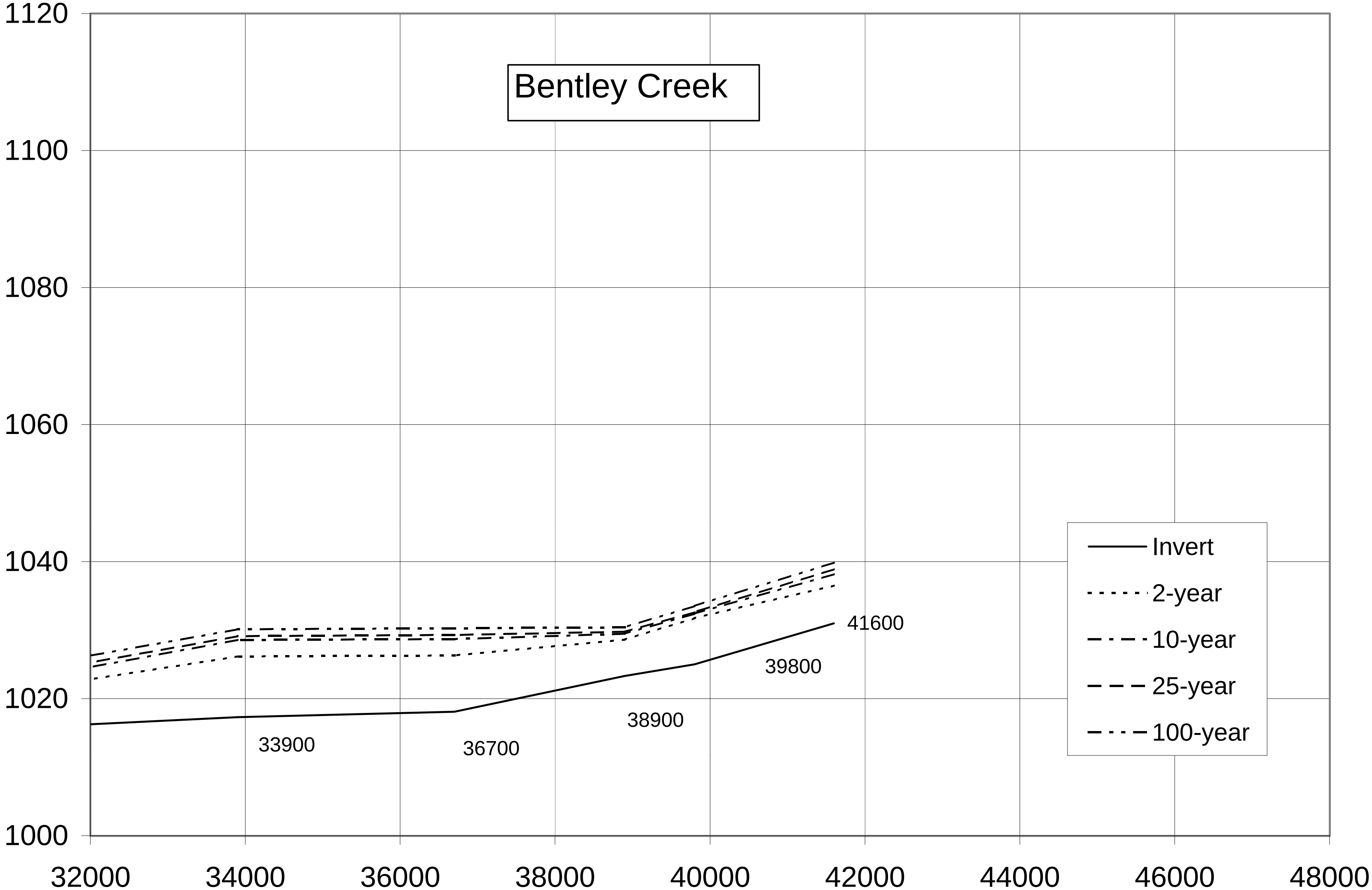

Hog Wallow Creek
22400
Invert
2-year
10-year
25-year
100-year
1140
1120
1100
1080
1060
1040
1020
16000
18000
20000
22000
24000
26000
28000
30000
32000



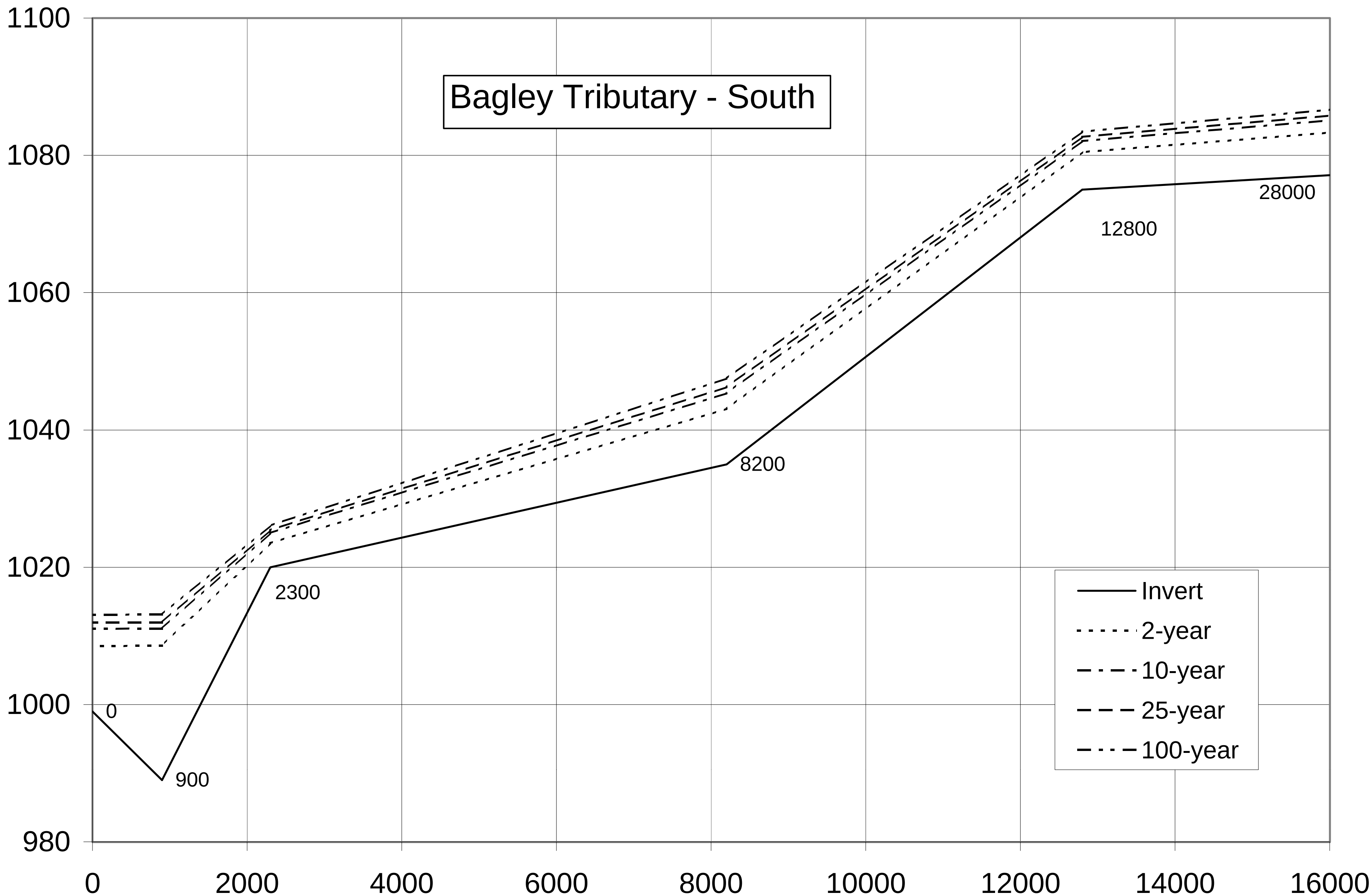
Bentley Creek
Invert
2-year
10-year
25-year
100-year
1120
1100
1080
1060
1040
1020
1000
0
0
2000
4000
6000
8000
10000
12000
14000
16000



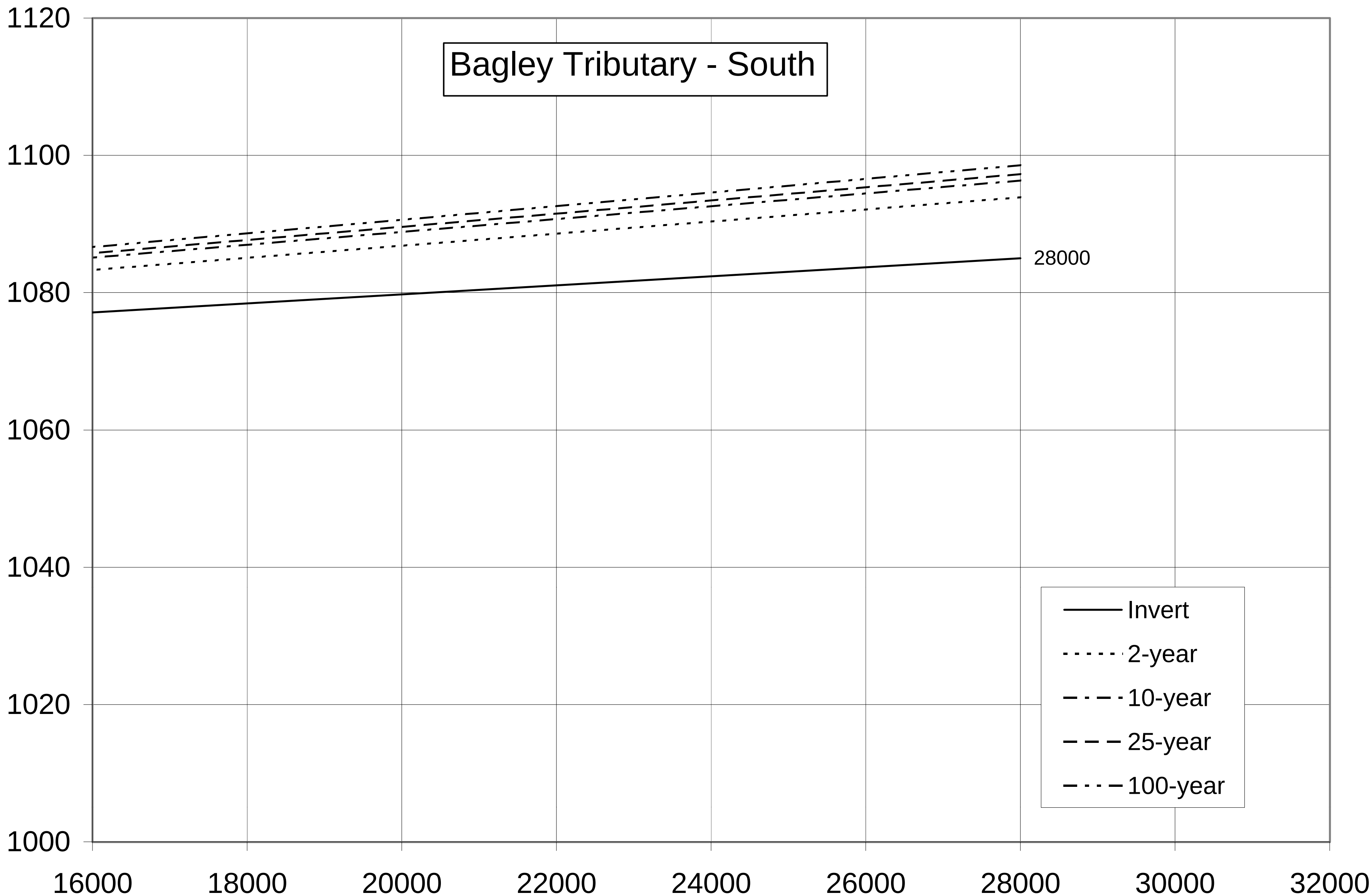
Bentley Creek
Invert
2-year
10-year
25-year
100-year
30800
1120
1100
1080
1060
1040
1020
1000
16000
18000
20000
22000
24000
26000
28000
30000
32000



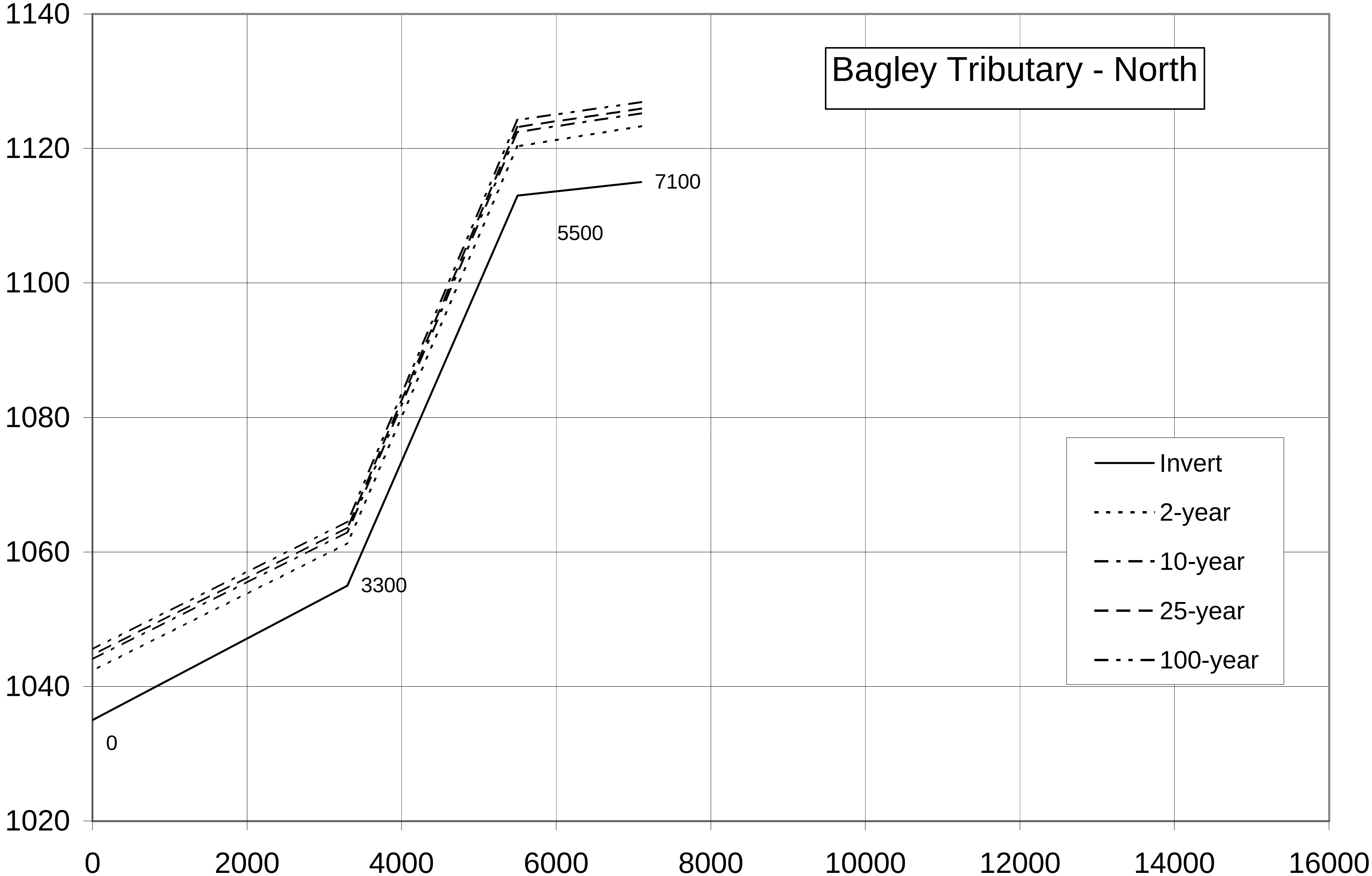
Bentley Creek
1120
1100
1080
1060
1040
1020
1000
32000
34000
36000
38000
40000
42000
44000
46000
48000
33900
36700
38900
39800
41600
Invert
2-year
10-year
25-year
100-year

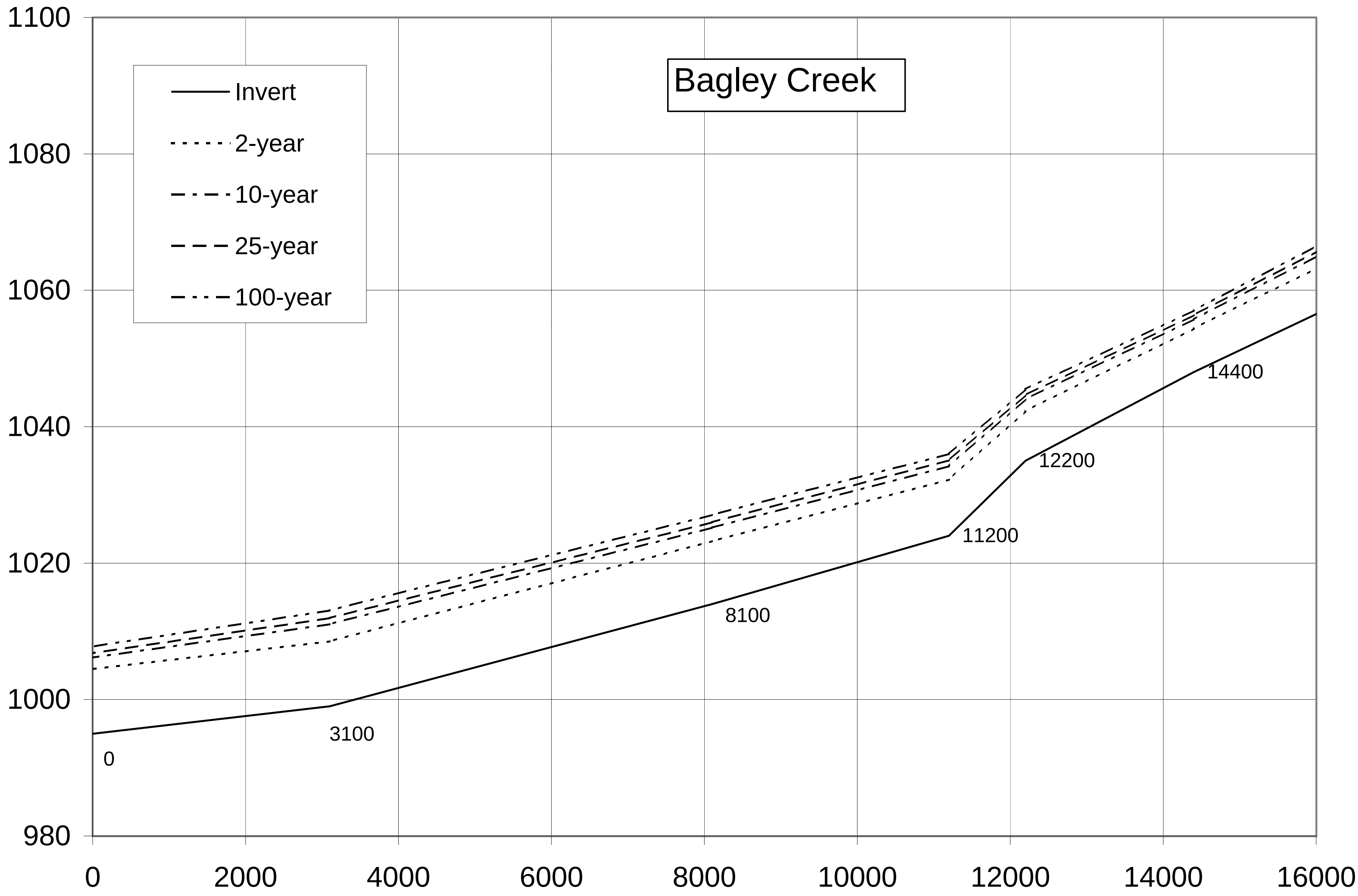


Bagley Tributary - South
1100
1080
1060
1040
1020
1000
980
0
2000
4000
6000
8000
10000
12000
14000
16000
0
900
2300
8200
12800
28000
Invert
2-year
10-year
25-year
100-year

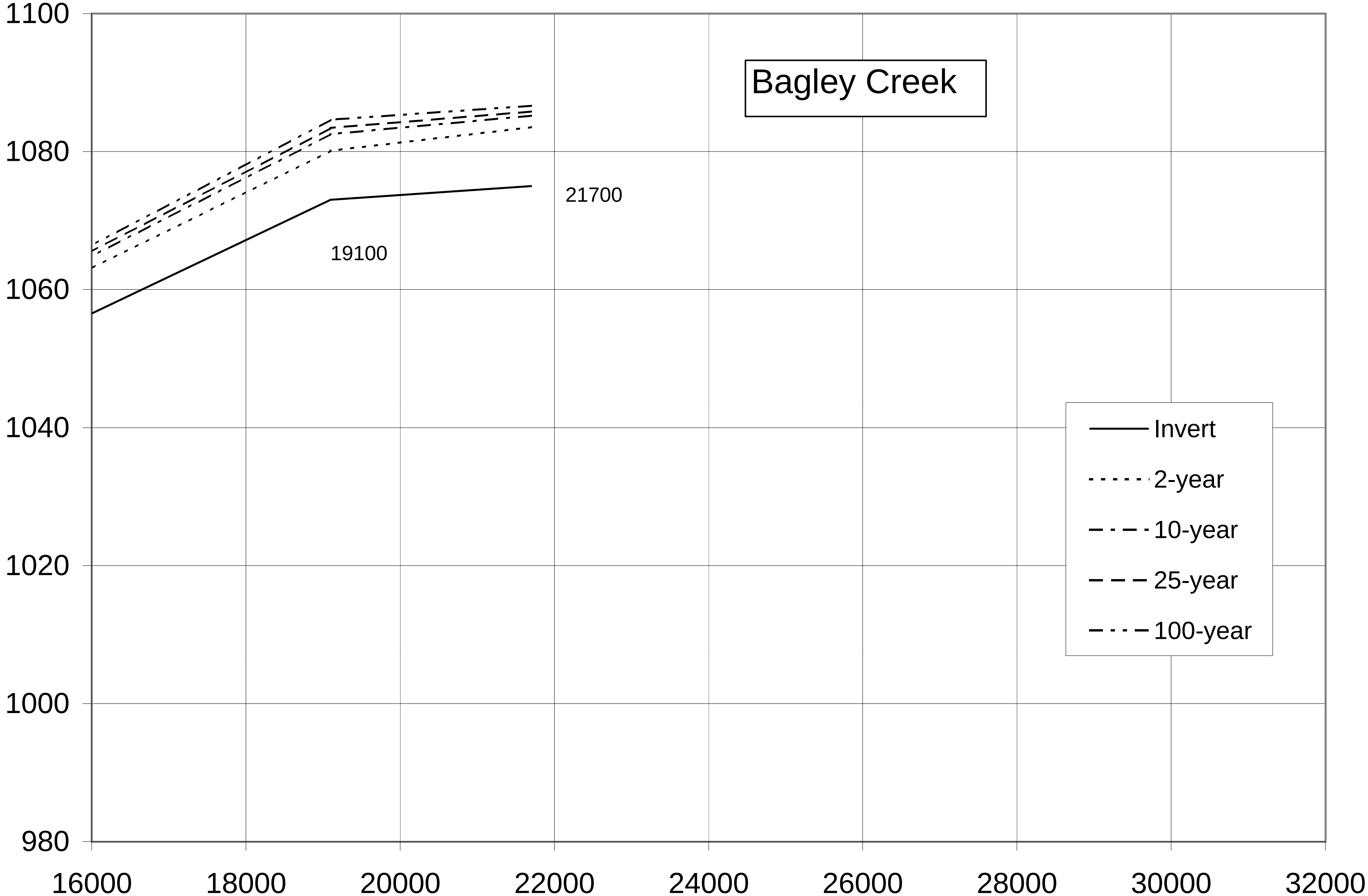


Bagley Tributary - South
1120
1100
1080
1060
1040
1020
1000
16000
18000
20000
22000
24000
26000
28000
30000
32000
28000
Invert
2-year
10-year
25-year
100-year

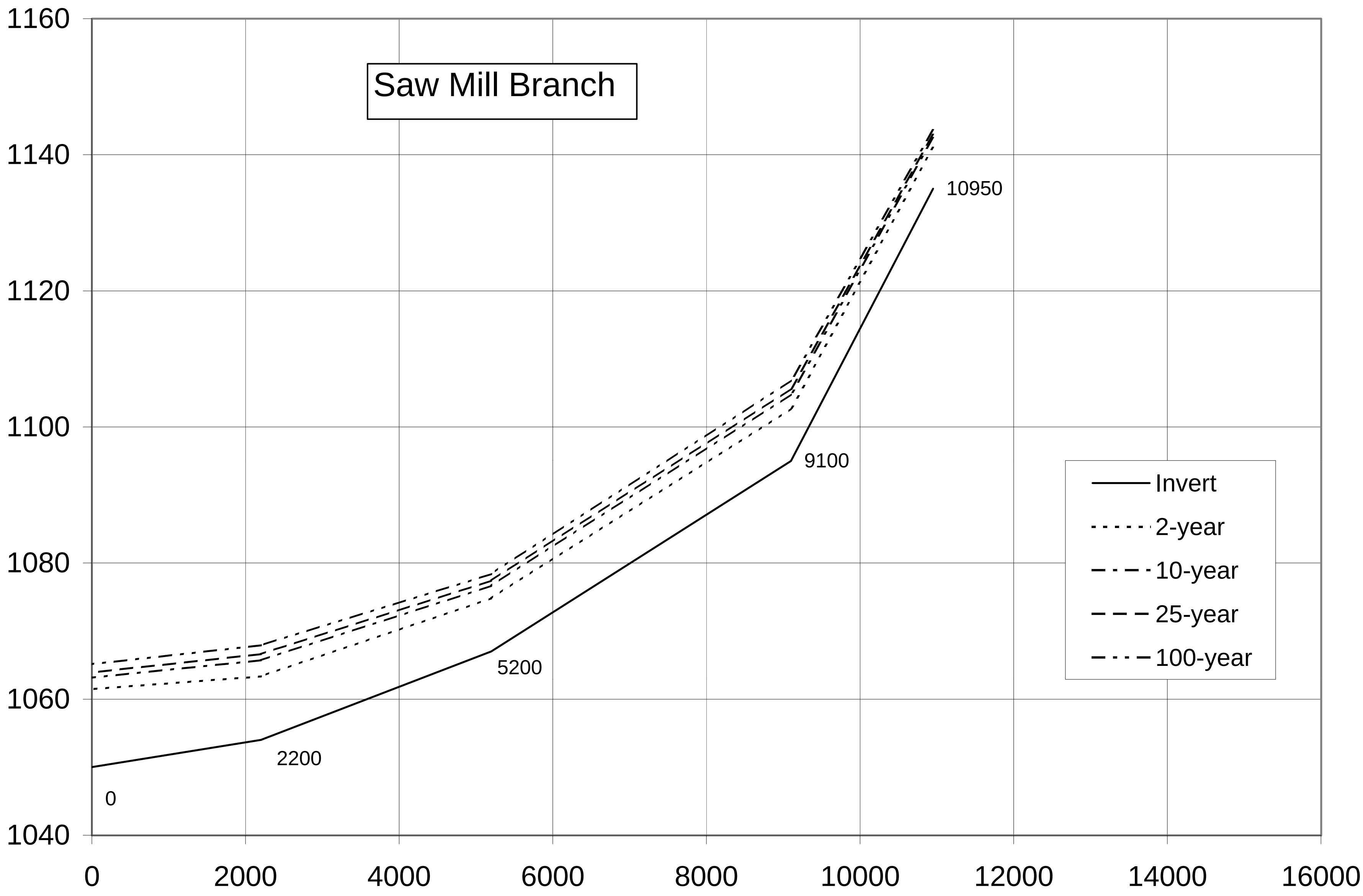

Bagley Tributary - North
1140
1120
1100
1080
1060
1040
1020
0
2000
4000
6000
8000
10000
12000
14000
16000
7100
5500
3300
0
Invert
2-year
10-year
25-year
100-year

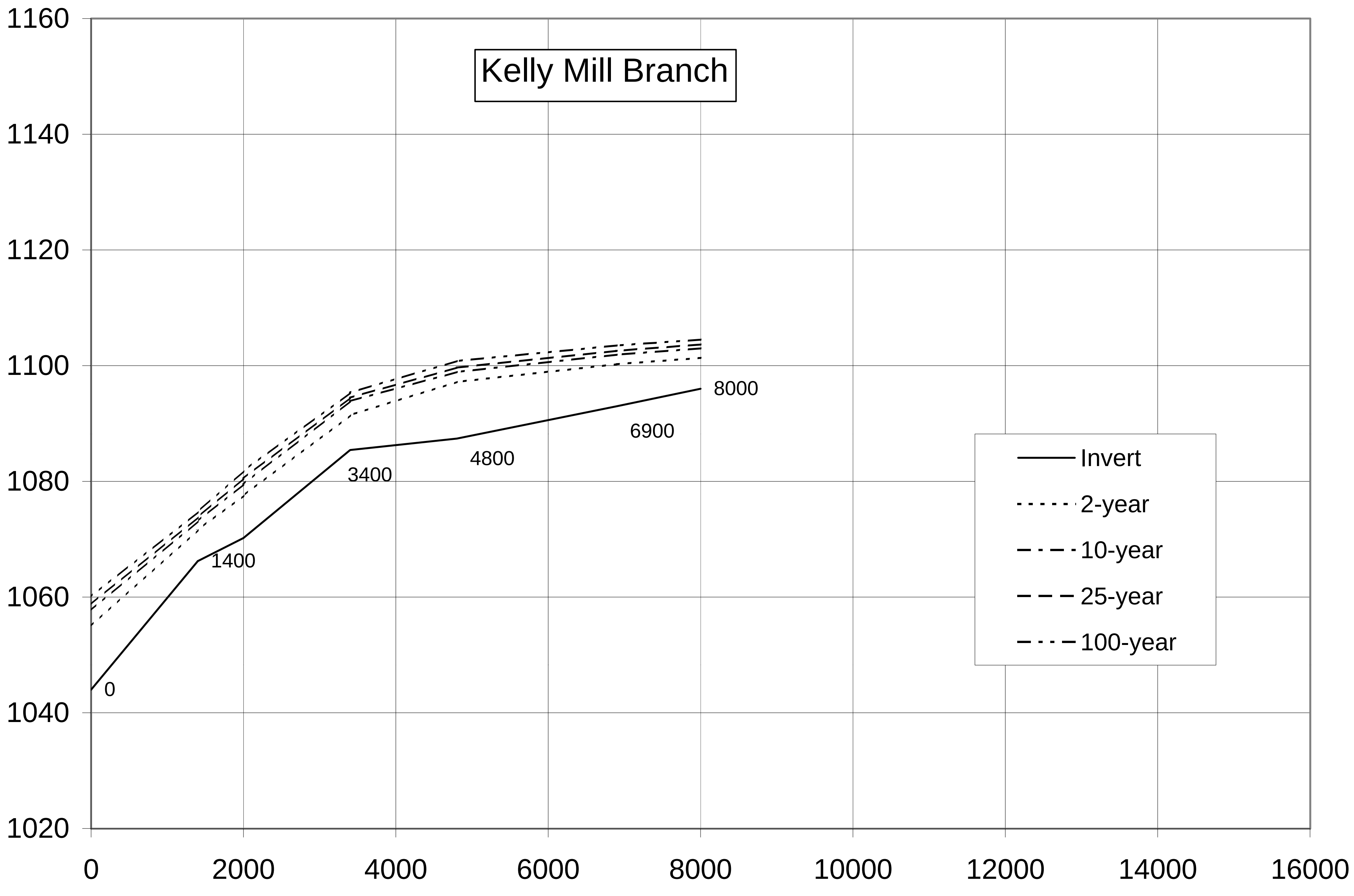


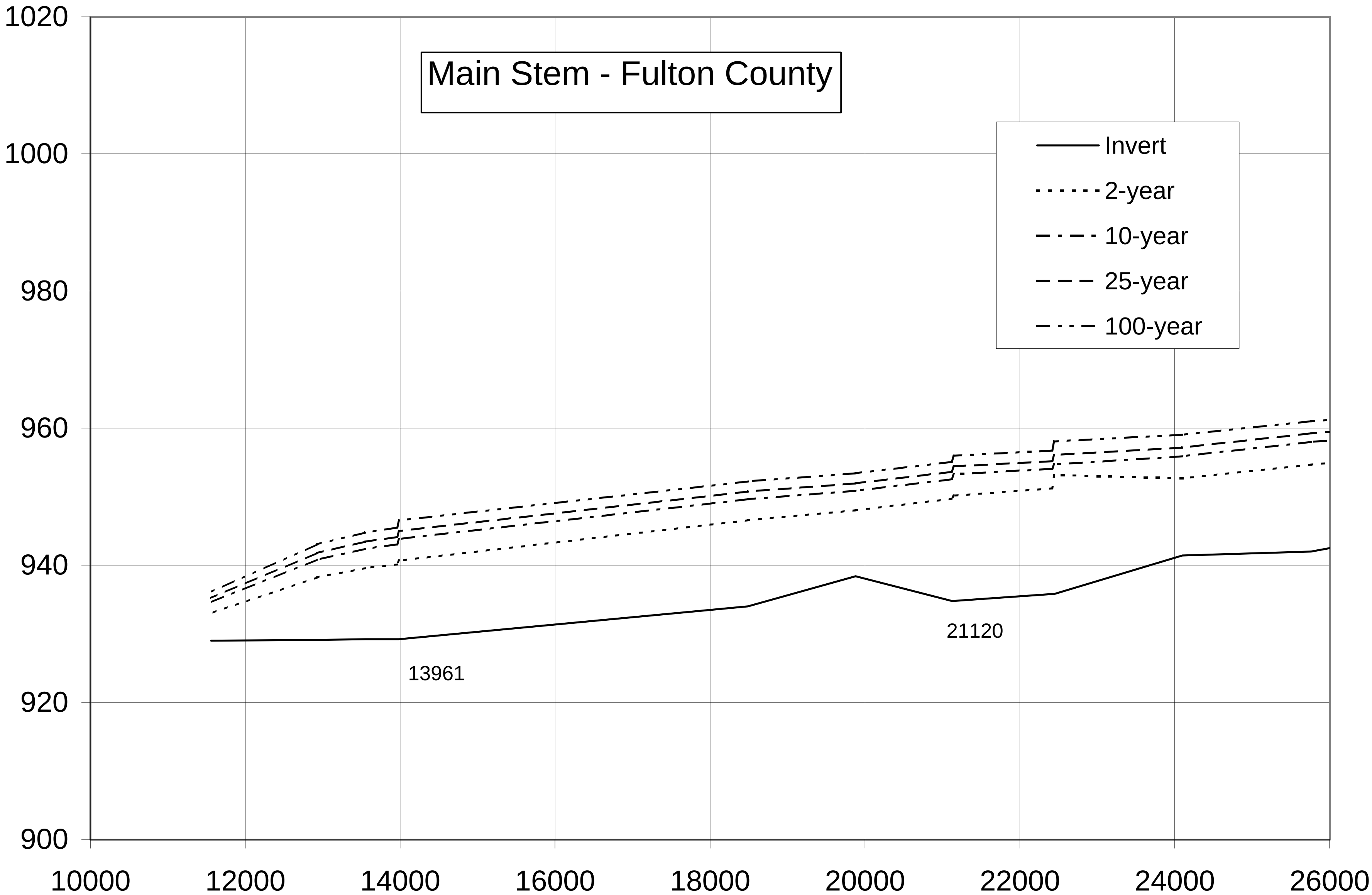
Bagley Creek
Invert
2-year
10-year
25-year
100-year
1100
1080
1060
1040
1020
1000
980
0
2000
4000
6000
8000
10000
12000
14000
16000
0
3100
8100
11200
12200
14400

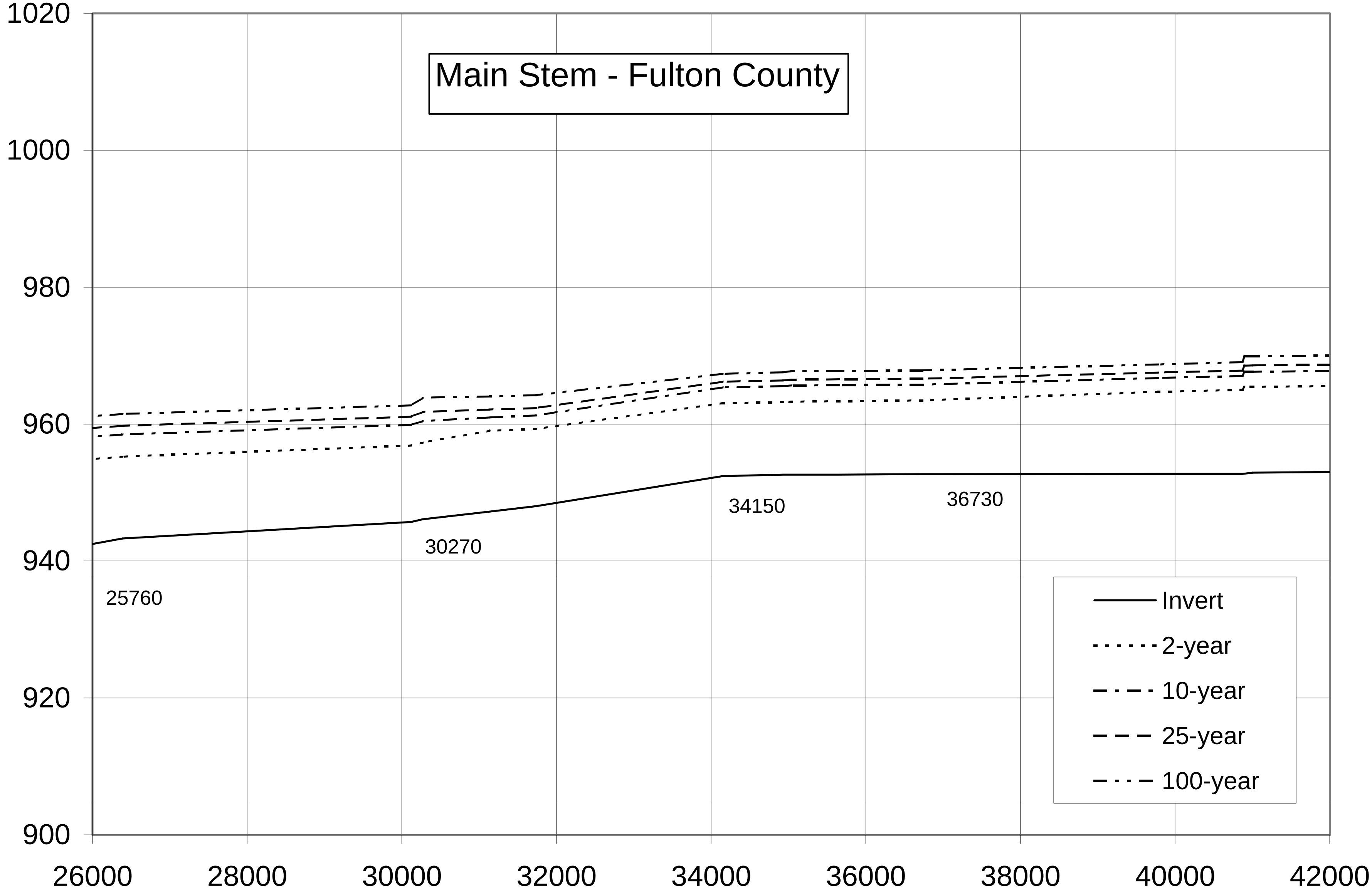


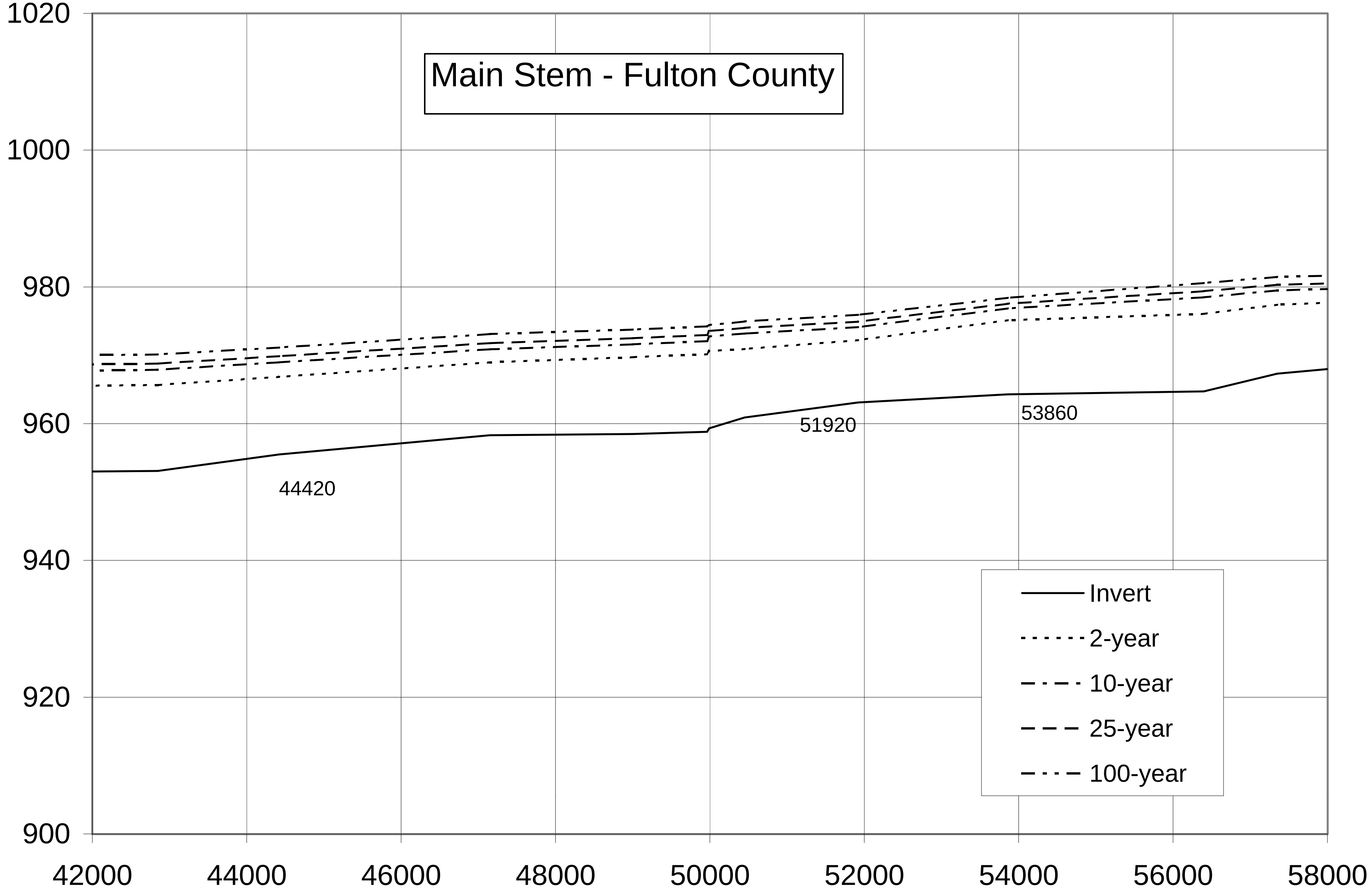
Bagley Creek
1100
1080
1060
1040
1020
1000
980
16000
18000
20000
22000
24000
26000
28000
30000
32000
19100
21700
Invert
2-year
10-year
25-year
100-year

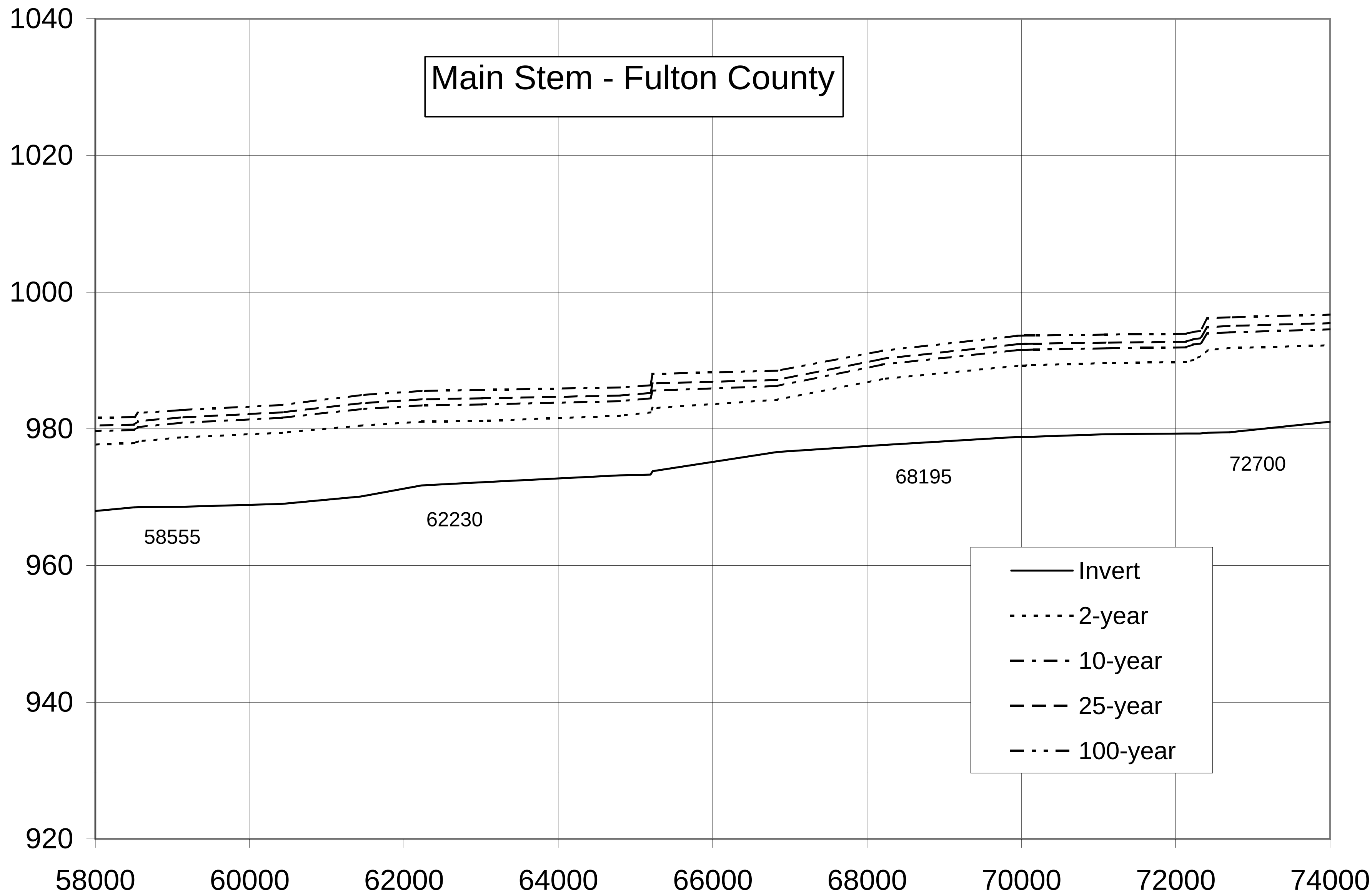

Saw Mill Branch
1160
1140
1120
1100
1080
1060
1040
0
2000
4000
6000
8000
10000
12000
14000
16000
0
2200
5200
9100
10950
Invert
2-year
10-year
25-year
100-year


Kelly Mill Branch
1160
1140
1120
1100
1080
1060
1040
1020
0
2000
4000
6000
8000
10000
12000
14000
16000
0
1400
3400
4800
6900
8000
Invert
2-year
10-year
25-year
100-year

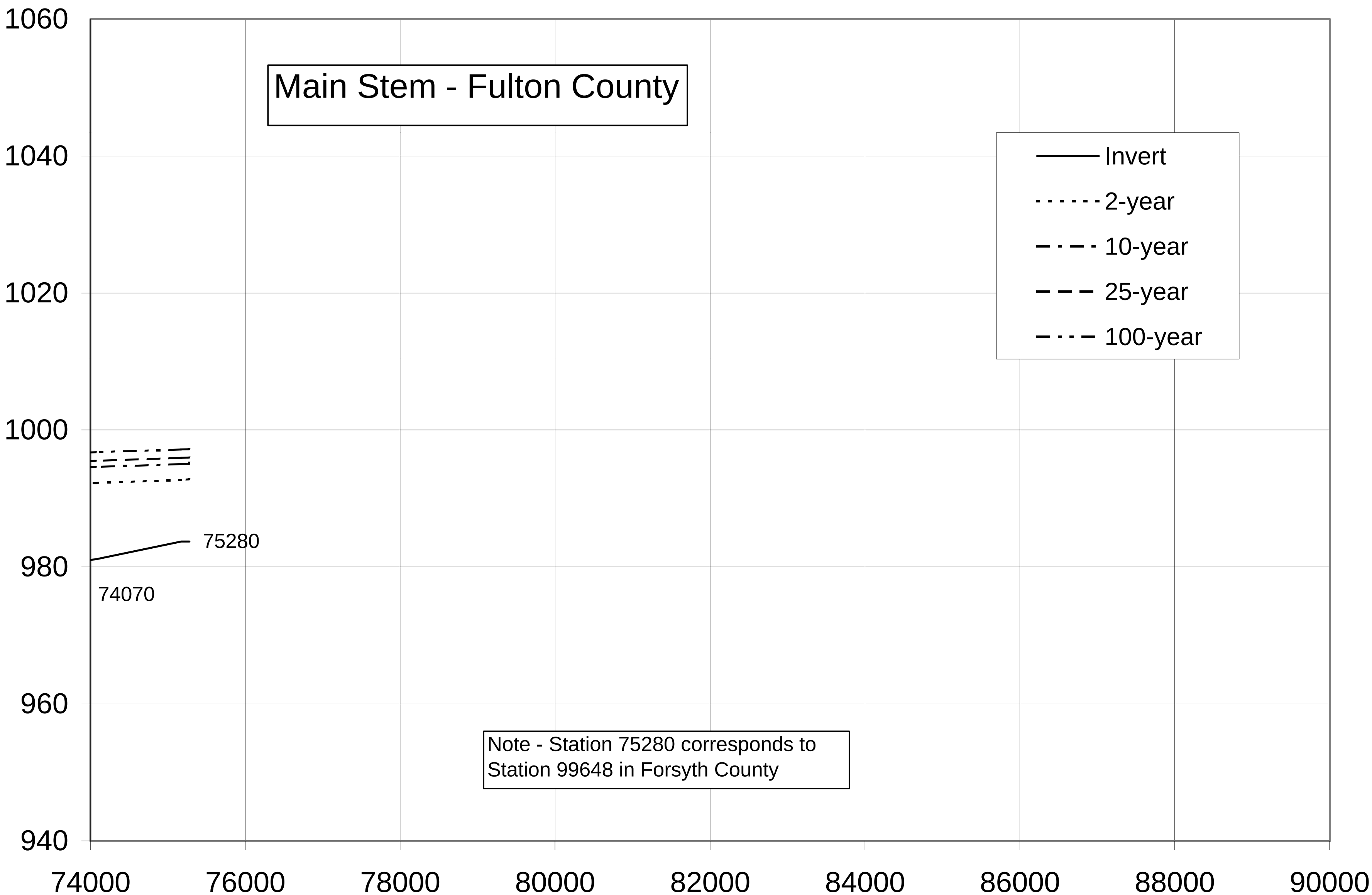

Main Stem - Fulton County
Invert
2-year
10-year
25-year
100-year
13961
21120
1020
1000
980
960
940
920
900
10000
12000
14000
16000
18000
20000
22000
24000
26000


Main Stem - Fulton County
1020
1000
980
960
940
920
900
26000
28000
30000
32000
34000
36000
38000
40000
42000
25760
30270
34150
36730
Invert
2-year
10-year
25-year
100-year

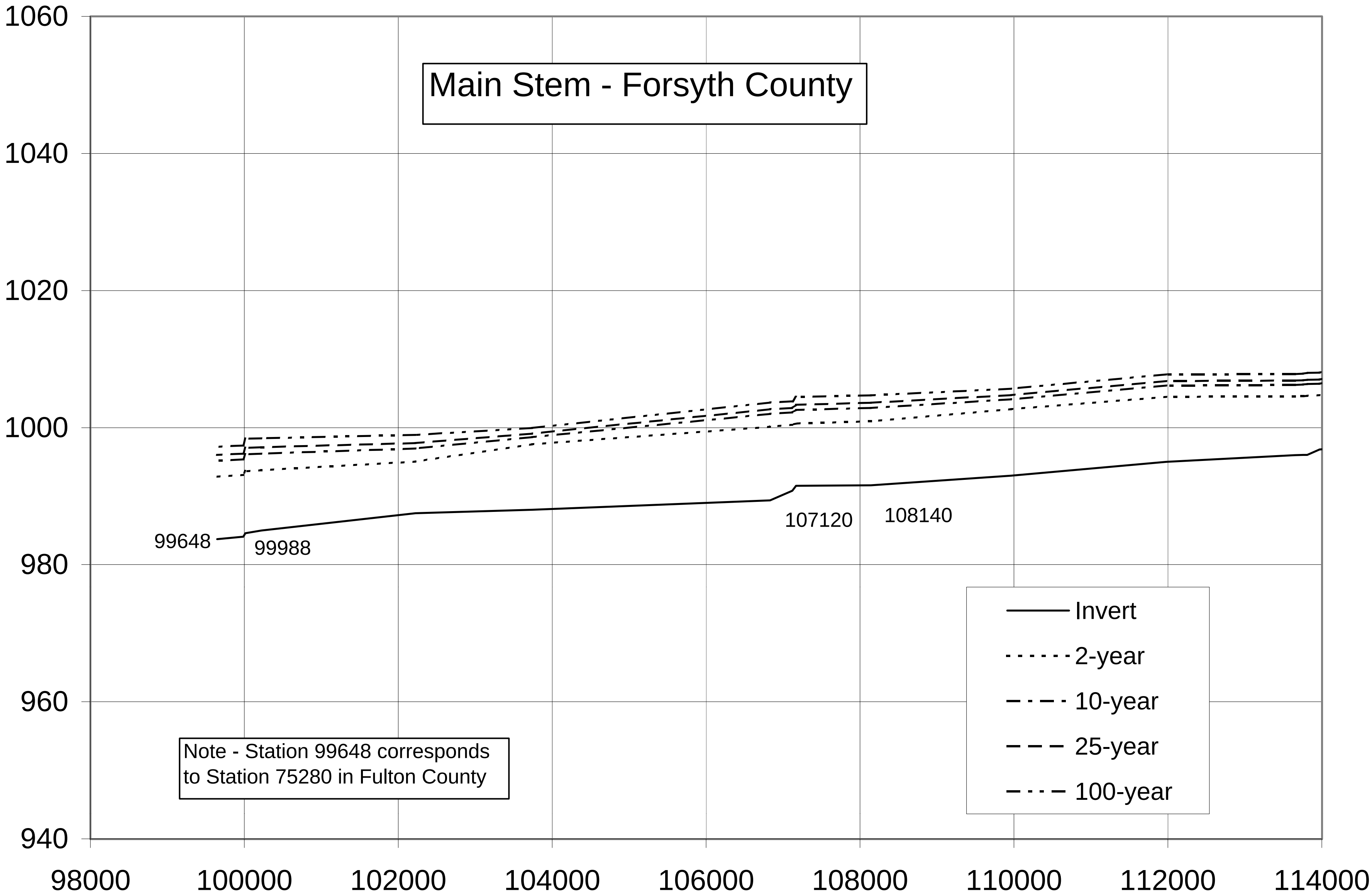

Main Stem - Fulton County
1020
1000
980
960
940
920
900
42000
44000
46000
48000
50000
52000
54000
56000
58000
44420
51920
53860
Invert
2-year
10-year
25-year
100-year



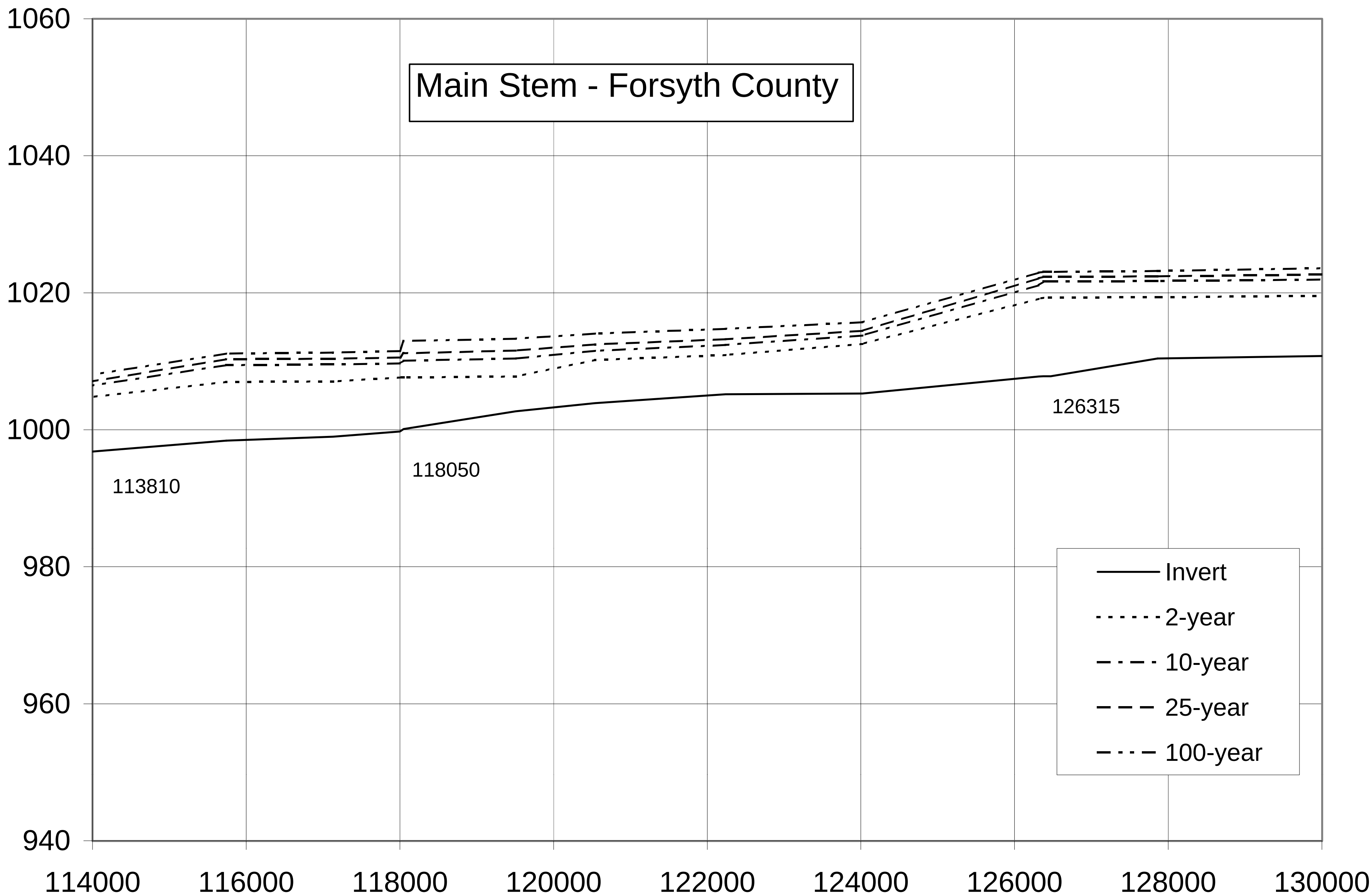
Main Stem - Fulton County
1040
1020
1000
980
960
940
920
58000
60000
62000
64000
66000
68000
70000
72000
74000
58555
62230
68195
72700
Invert
2-year
10-year
25-year
100-year

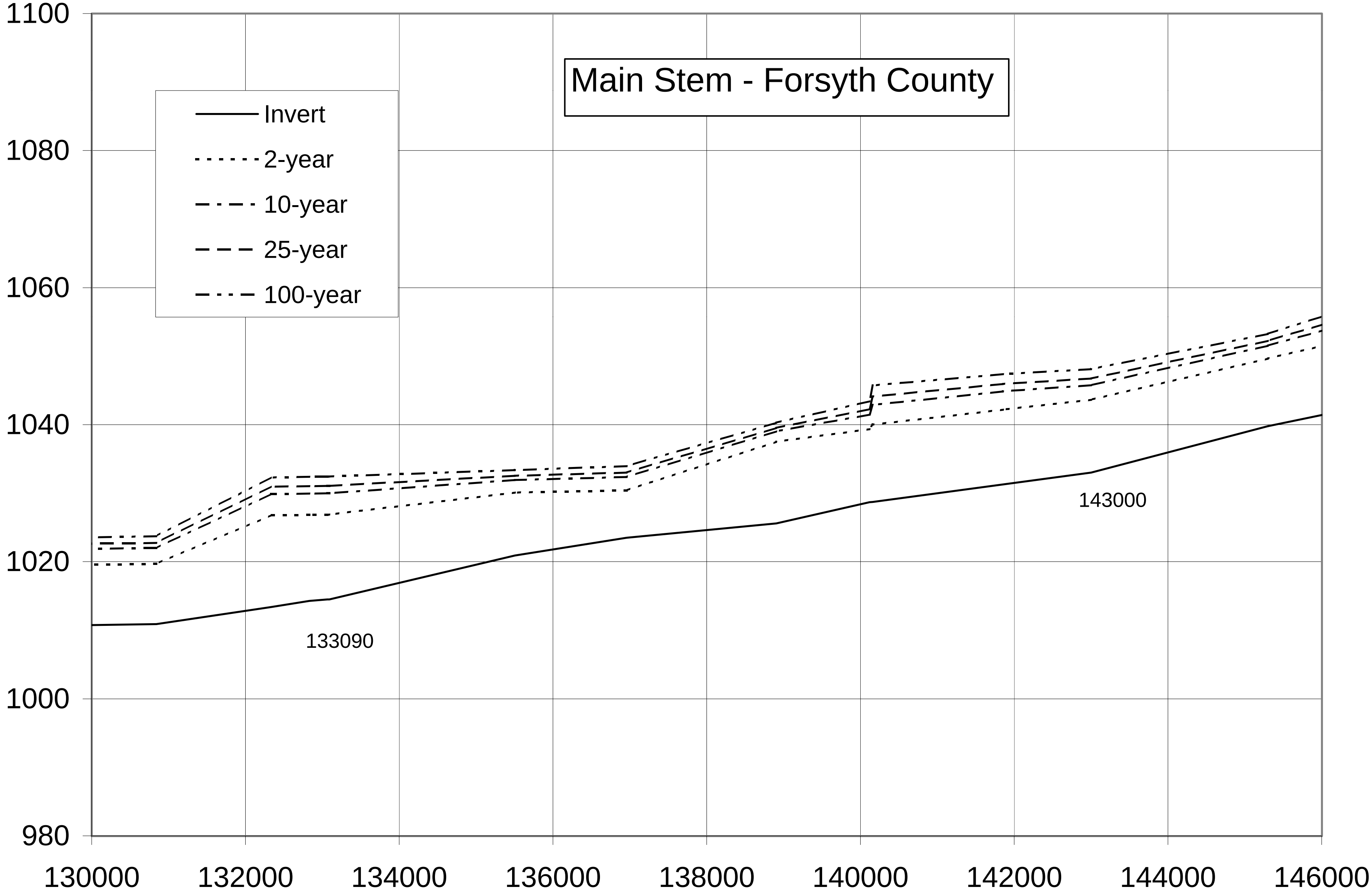


Main Stem - Fulton County
Invert
2-year
10-year
25-year
100-year
75280
74070
Note - Station 75280 corresponds to
Station 99648 in Forsyth County
1060
1040
1020
1000
980
960
940
74000
76000
78000
80000
82000
84000
86000
88000
90000

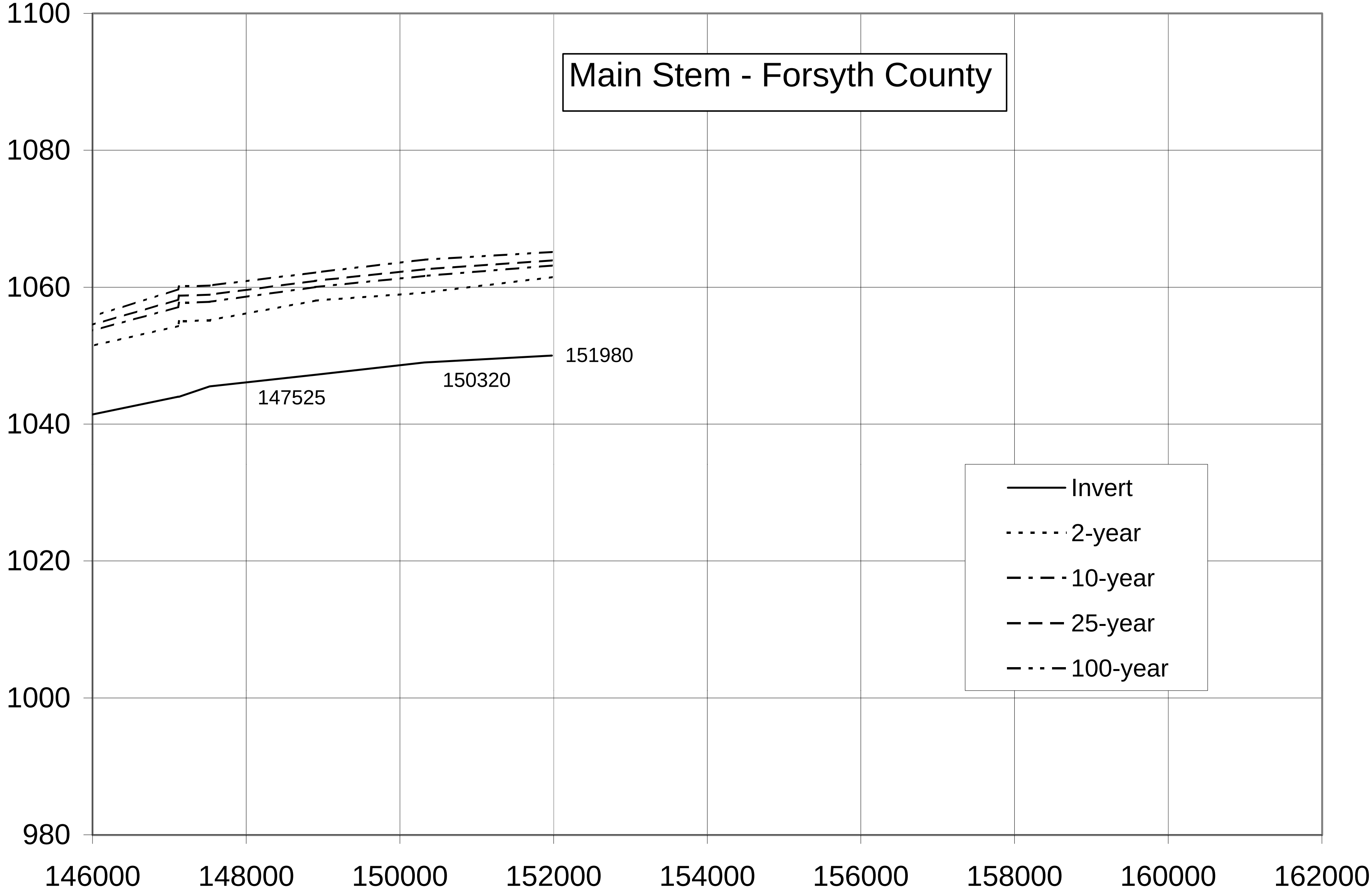


Main Stem - Forsyth County
1060
1040
1020
1000
980
960
940
98000
100000
102000
104000
106000
108000
110000
112000
114000
99648
99988
107120
108140
Invert
2-year
10-year
25-year
100-year
Note - Station 99648 corresponds to Station 75280 in Fulton County


Main Stem - Forsyth County
1060
1040
1020
1000
980
960
940
114000
116000
118000
120000
122000
124000
126000
128000
130000
113810
118050
126315
Invert
2-year
10-year
25-year
100-year



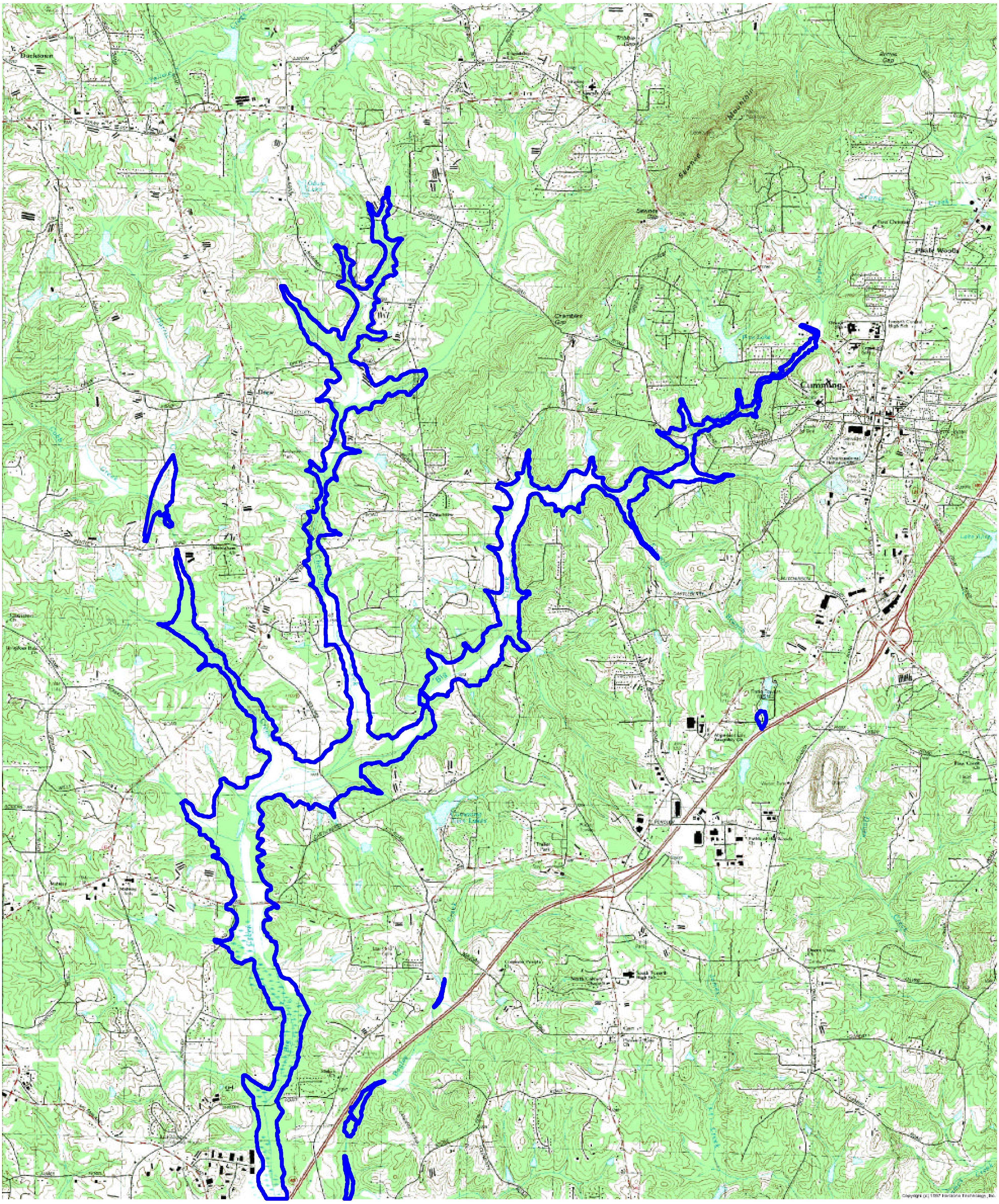
Main Stem - Forsyth County
Invert
2-year
10-year
25-year
100-year
1100
1080
1060
1040
1020
1000
980
130000
132000
134000
136000
138000
140000
142000
144000
146000
133090
143000



Main Stem - Forsyth County
1100
1080
1060
1040
1020
1000
980
146000
148000
150000
152000
154000
156000
158000
160000
162000
151980
150320
147525
Invert
2-year
10-year
25-year
100-year

Appendix D
Floodplain Maps

100 Year Flood Plain Boundaries (Existing Conditions)
ARC Big Creek Study



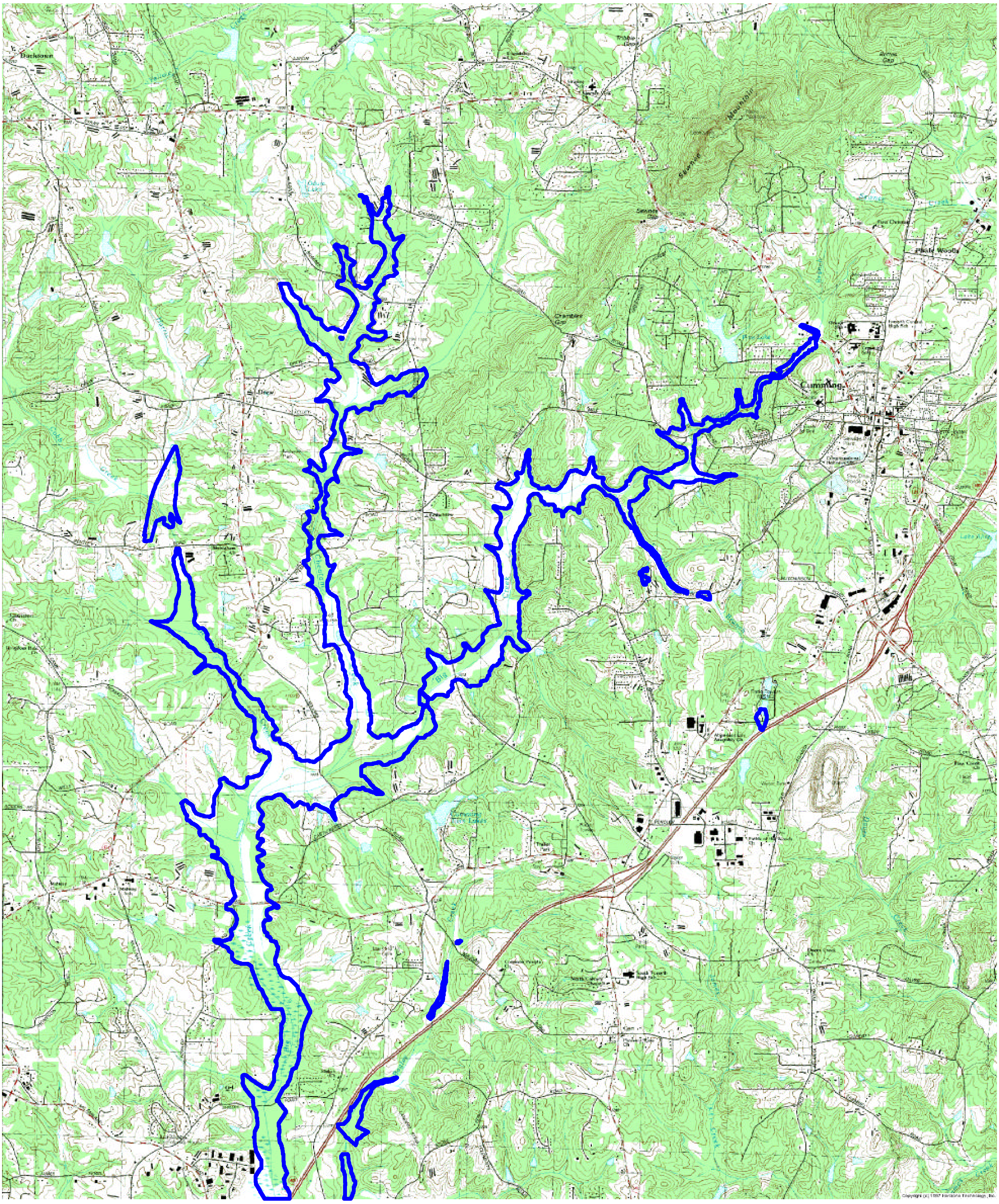
Cumming Quad Sheet

A B

N

2000 0 2000 4000 Feet

100 Year Flood Plain Boundaries (Future Conditions)
ARC Big Creek Study



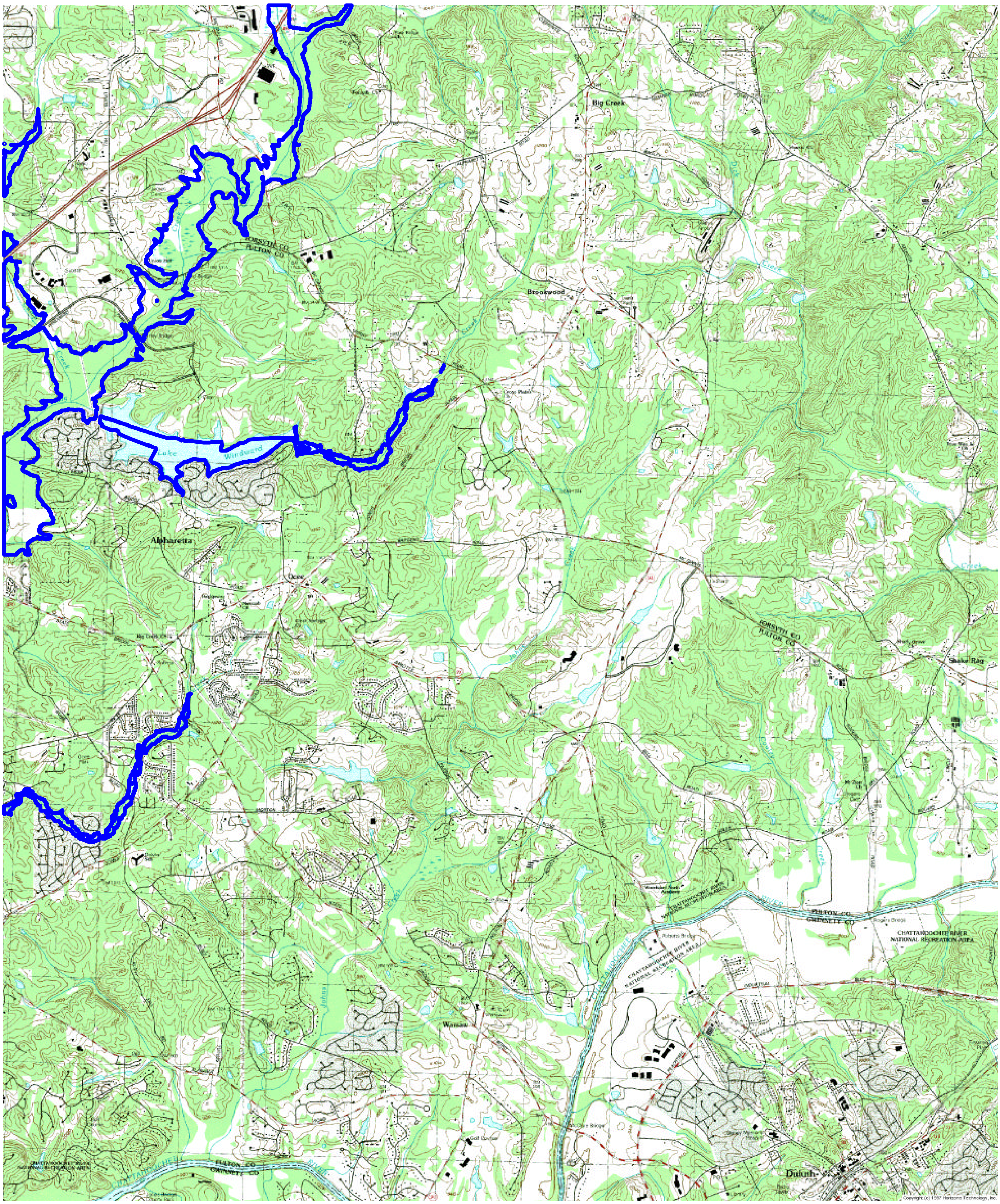
Cumming Quad Sheet

A B

N

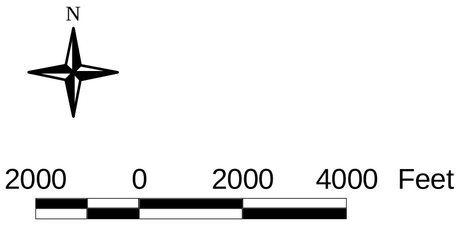
2000 0 2000 4000 Feet

100 Year Flood Plain Boundaries (Existing Conditions)
ARC Big Creek Study

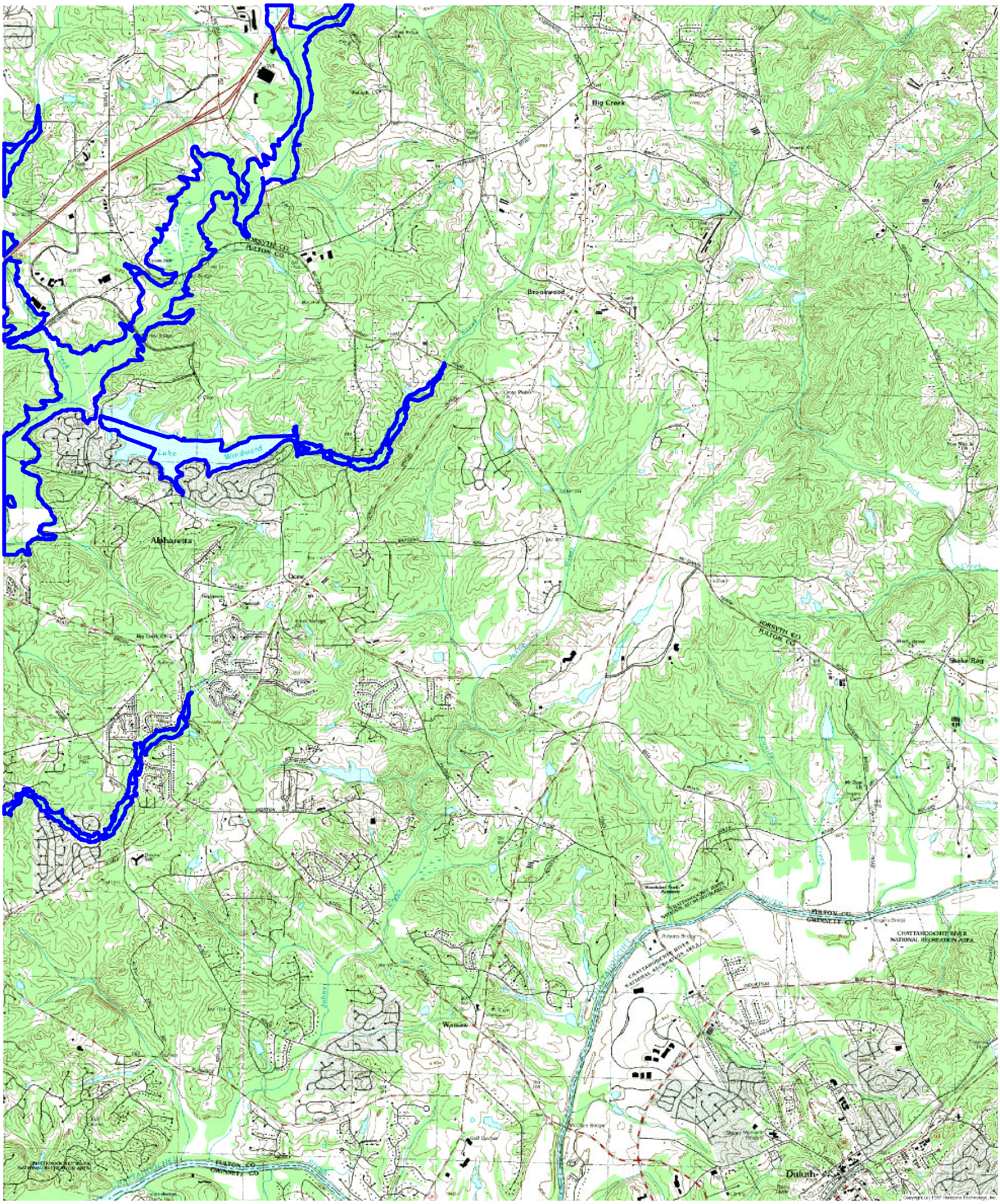


Duluth Quad Sheet

A B



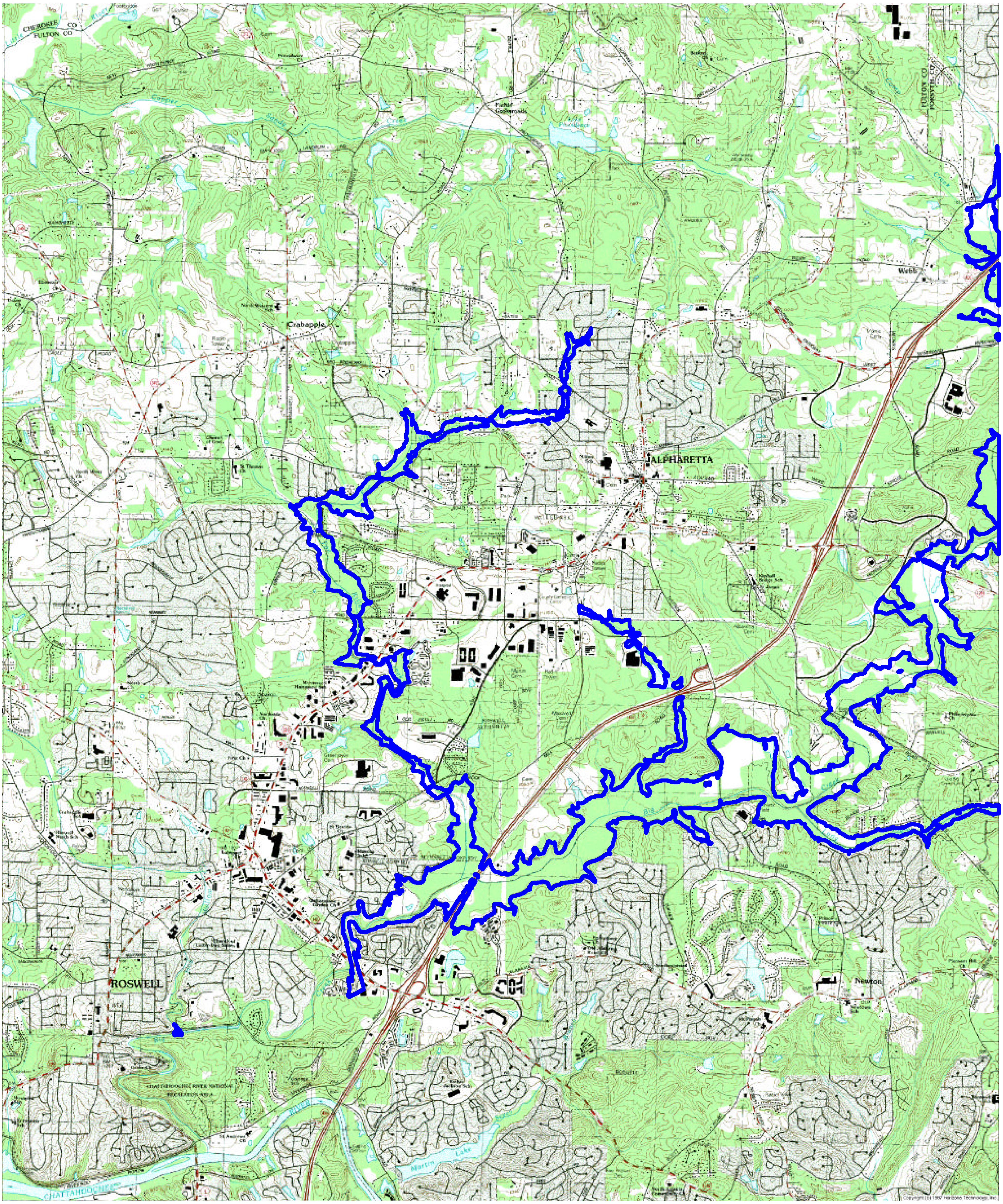
100 Year Flood Plain Boundaries (Future Conditions)
ARC Big Creek Study



Duluth Quad Sheet

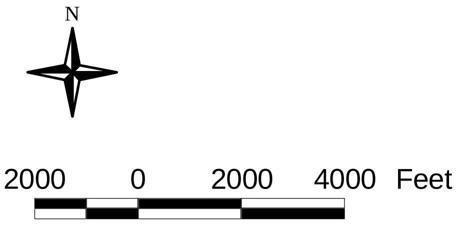
A B

100 Year Flood Plain Boundaries (Existing Conditions)
ARC Big Creek Study

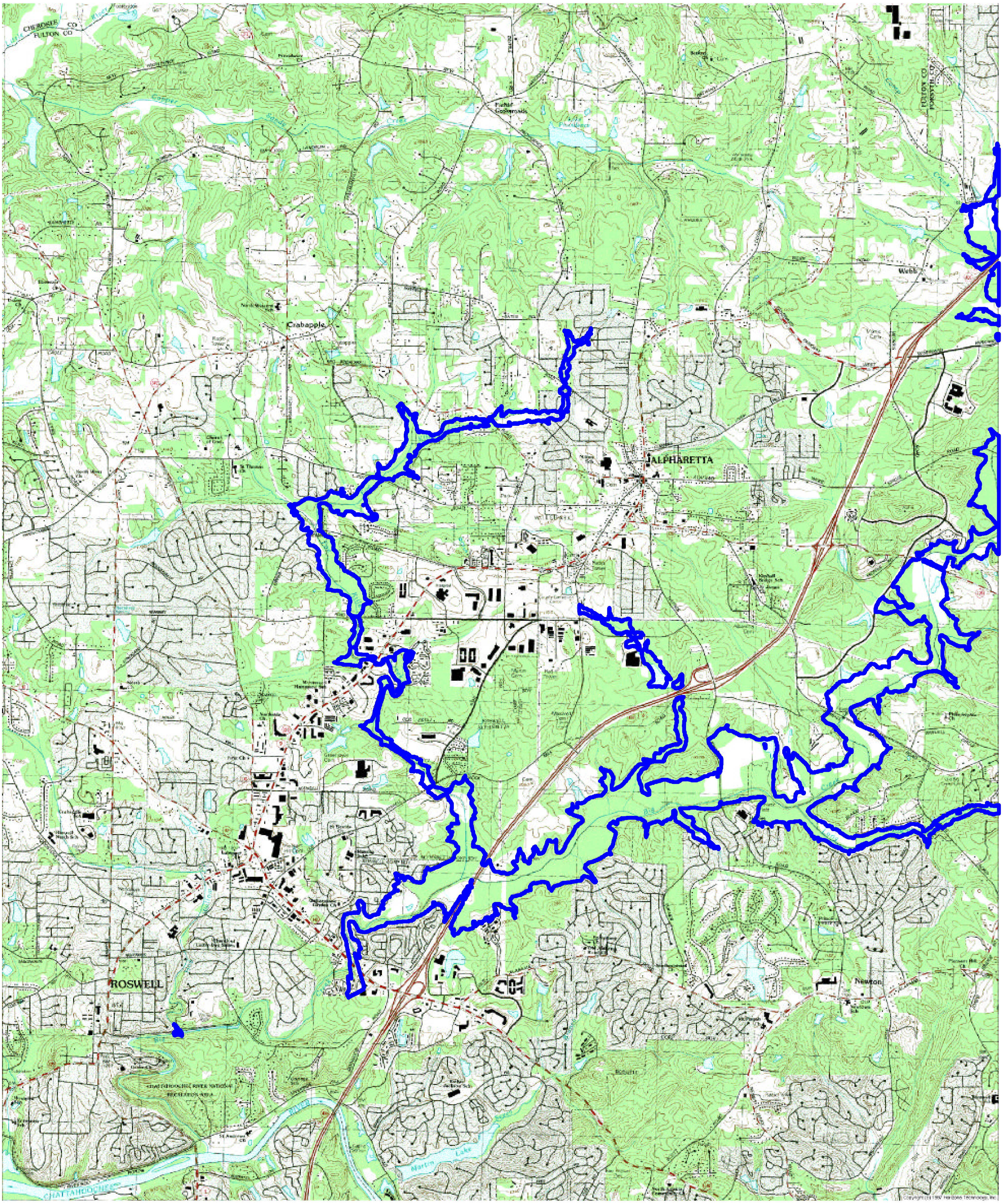


Roswell Quad Sheet

A B



100 Year Flood Plain Boundaries (Future Conditions)
ARC Big Creek Study



Roswell Quad Sheet

A B