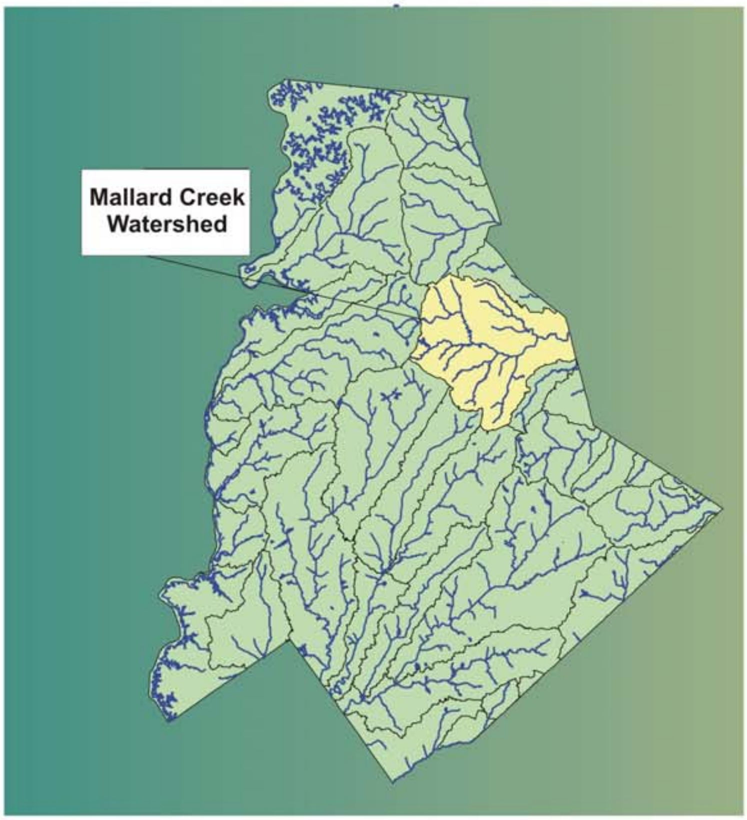
PRELIMINARY ENGINEERING REPORT

Watershed Study No. 2

Mallard Creek Watershed



Prepared for

Mecklenburg
Storm Water Services

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October 2001

Charlotte-Mecklenburg STORM WATER Services

MCSWS Project No. 25001

Mecklenburg County
Storm Water Services

Preliminary Engineering Report
for
Watershed Study No. 2

MALLARD CREEK WATERSHED

Acknowledgement

The project staff of HDR Engineering, Inc. of the Carolinas (HDR) would like to express our sincere appreciation to Mecklenburg County Storm Water Services (MCSWS) for its assistance and support during this project. HDR would especially like to thank Mr. Dave Canaan and his staff.

Disclaimer

This watershed-wide study is for planning purposes only. These study results and recommendations are preliminary and should not be used for construction without additional detailed engineering design analysis.

Certification

I hereby certify that this Preliminary Engineering Report for Watershed Study No. 2, Mallard Creek Watershed, for Mecklenburg County was prepared by me or under my direct supervision.

Signed, sealed, and dated this 26 day of October 2001.

By: ______________________
Seungho Song, PE, CFM
Project Manager

NORTH CAROLINA PROFESSIONAL SEAL 23719 ENGINEER SEUNGHO SONG 26-2001

(SEAL)

Study No. 2, Mallard Creek Watershed Preliminary Engineering Report

MECKLENBURG COUNTY
STORM WATER SERVICES
PRELIMINARY ENGINEERING REPORT
FOR
WATERSHED STUDY NO. 2

MALLARD CREEK WATERSHED

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GLOSSARY

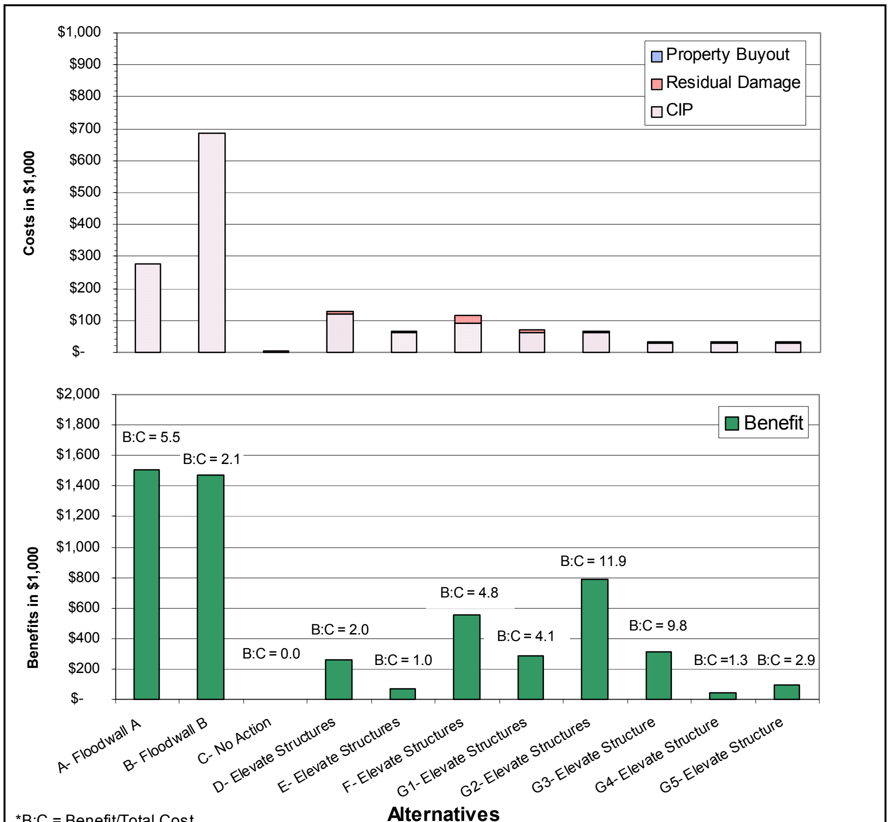
Future Condition Floodplain (FCF):	Floodplain delineated for the 1% chance of flood event in any given year using future land use condition. It is currently defined as Floodplain Land Use Map (FLUM) in Mecklenburg County.
Existing Condition Floodplain:	Floodplain delineated for the 1% chance of flood event in any given year using current land use condition. It is defined as the same as within the Flood Insurance Rate Map (FIRM).
1% Annual Chance Flood:	The 1% annual chance of flood is the flood that has a 1% chance of being equaled or exceeded in any given year, which is referred to as the "100-year flood," in general.
Base Flood Elevation (BFE):	Water surface elevation based on the 1% annual chance flood (100-year flood).

EXECUTIVE SUMMARY

MALLARD CREEK WATERSHED

This Preliminary Engineering Report (PER) summarizes a study focused on flood hazard mitigation and ecological restoration of the Mallard Creek Watershed. This watershed includes the major tributaries of Clarks Creek (3.8 mi), Clarks Creek Tributary No. 1 (1.4 mi), Clarks Creek Tributary No. 1A (1.4 mi), Doby Creek (3.1 mi), Doby Creek Tributary (1.5 mi), Mallard Creek Tributary (0.5 mi), Stoney Creek (4.2 mi), and Stoney Creek Tributary (2.2 mi), and the main stem of Mallard Creek (10.1 mi) from its headwaters to the Mecklenburg County border with Cabarrus County to the east, for the total stream length of 31.5 miles. Mallard Creek is a part of the Yadkin River Basin. Using field visits, available hydraulic information, aerial photographs, Geographic Information Systems (GIS), and a structural flooding damage analysis model, recommendations are proposed to meet the project goals.

The first priority for this study is an economic analysis of flood hazard mitigation for a total of 86 structures located within the limits of the 1% annual chance **Future Condition Floodplain** (FCF). The second priority of this study is ecological restoration through wetland construction and also stream bank stabilization. Twenty-five of these 86 structures have lowest finished floor elevations below the **Base Flood Elevation** (BFE: 1% annual Chance of FCF water surface elevation). Graph E-1 illustrates Benefit:Cost Analysis results of each flood hazard mitigation alternative employed in this study. Economic information is provided in detail in the Appendix Table A-1. Of 86 flood potential structures, nine were constructed before 1973 (Pre-FIRM). A majority of these flooded structures (23) are along Mallard Creek. The total improvement construction costs, operation and maintenance costs, and buyout costs for the improvements in the Mallard Creek watershed are estimated at $1,440,000 (2001 dollars) (Graph E-1, Table E-1).



Graph E-1. Benefits and Costs for All Alternatives.

Figures E-1 and E-2 show representative locations where mitigation options were applied. Figure E-3 exhibits a representative cross section in this location for both existing conditions and mitigation options.

The combination of proposed flood mitigation options includes elevating structures and constructing floodwalls. Sixteen structures-13 along Mallard Creek and one each along Mallard Tributary, Clarks Creek Tributary No. 1A, and Doby Creek-are recommended to be elevated because of their locations. It is not cost-effective to either purchase or protect these properties with floodwalls or levees.

Table E-1
Estimated Costs of Recommended Improvements (2001 Dollars)

	Total	Mallard Creek	Clark and Doby Creeks
Capital Costs	**$1,186,000**	$1,126,000	$60,000
Operating and Maintenance	**$254,000**	$254,000	-
Buyout Costs	-	-	-
Total	**$1,440,000**	**$1,380,000**	**$60,000**

Two floodwalls are recommended to protect eight structures (seven apartment buildings and one commercial structure), all along Mallard Creek. One structure along Mallard Creek is recommended for No Action. Flooding problem locations are assigned a one-letter label as presented in Figures E-4 through E-8, and Figure 20. For areas of clustered structures, a common label is assigned to represent a whole cluster. Problem Area G represents eight structures that are not clustered. The above-mentioned recommended improvements will not impact the BFE of FCF and will reduce the FCF floodplain area (Figures E-1 through E-3). Figure E-4 presents Mallard Creek watershed and sub-watersheds. Figures E-5 through E-8 illustrate recommended improvements along Mallard Creek. Figure E-9 shows Capital Improvement Projects in Mecklenburg County.

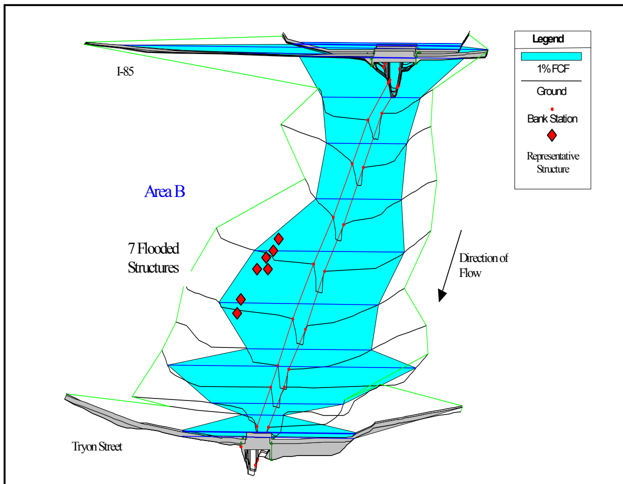
Bridge or culvert improvement options were investigated for the possible lowering of flood stages at flooding problem areas, especially when significant headloss occurs at bridge and/or culvert crossings. By reviewing the HEC-RAS results and water surface profile plots (Appendix Figures A-2 thru A-11), no possible bridge or culvert crossing improvements would significantly benefit upstream flooding problem areas without adverse downstream impacts. Therefore, bridge/culvert improvement options were not considered.

The Mallard Creek watershed (Figure E-4) within Mecklenburg County is 78 percent developed, 62.4 percent of which occurred after 1980. Seventy-five percent of the land use in the watershed is residential. Urban development has changed the landscape of both the watershed and the creek channels. Toby Creek sub-watershed, in the southeastern portion of the watershed, was the earliest to develop, with the most recent development focused in the western headwaters and northern portions of Mallard Creek watershed. This development has been influenced by traffic patterns including Interstates 85 and 485, Harris Boulevard, and the University of North Carolina at Charlotte (UNCC). Recent developments within the university area include a technology and industrial park. In turn, these land use changes have spurred residential development in the watershed. Therefore, the Mallard Creek watershed is known to be among the fastest-growing watersheds within Mecklenburg County.

During field visits, little aquatic wildlife was observed in Mallard Creek and its major tributaries. According to the Mecklenburg County Department of Environmental Protection (MCDEP) monitoring records, from 1994 to 1998 overall water quality has remained fairly consistent in the Mallard Creek watershed. Review of ambient water quality data dating back to 1968 does not reveal significant trends in most of the data over time or by location along the creeks. Current Water Quality Index values indicate an average of "Good" water quality for Mallard Creek, with the best water quality, "Good-Excellent," in Clarks Creek. The Water Quality Index indicates water quality conditions better than the fish and macroinvertebrate communities reflect. The aquatic fauna communities throughout the watershed have consistently ranked "Poor" and "Fair," while fish sampling ranked "Fair" and "Good," which results in a less than desirable diversity of species. This may indicate that aquatic habitat conditions limit these communities to some extent. While aquatic life is present in the creeks, the sand and silt benthic material (with little instream features such as boulders and woody debris) does not provide a protective habitat, and bottom dwelling communities are not as abundant and diverse as may be desired. Bank stabilization projects may improve aquatic habitat, and recommendations include an examination of stream bank instability throughout the watershed.

Sanitary sewers are present along all of Mallard Creek and its major tributaries, and any stream-side capital improvement projects will have to accommodate the existing utilities. These sewers travel to the Mallard Creek Wastewater Treatment Plant near the Cabarrus County line. However, the County's Year 2000 Inter-Agency Coordination of Capital Improvement Projects (CIPs) map (Figure E-9) indicates that Charlotte-Mecklenburg Utilities (CMU) has not proposed any CIP along the entire length of Mallard Creek. MCSWS should continue to coordinate with CMU to identify any potential projects or conflicts that arise in the future. If MCSWS is aware of CMU projects, it may influence the alignment of the relief sanitary sewer to coincide with the recommendations of this report.

The 1999 Mecklenburg County Greenway Master Plan recommends that the greenway system be expanded as a floodplain management buffer and water quality program to include all creeks and streams throughout the County. In the Mallard Creek watershed, 3.6 miles of greenway currently exist along Mallard Creek and Clarks Creek. This greenway connects to the University Research Park Trail, with future plans to extend the greenway along Mallard Creek to the Cabarrus County line. These plans would include access from UNCC and the Mallard Creek Recreation Area. Future plans also include extending the Clarks Creek greenway and adding a greenway along Toby Creek. Property buyout expenses may be shared between MCSWS, Mecklenburg County Park and Recreation Commission (MCPRC), or other County departments should this study area be included in future greenway development. HDR recommends that the MCSWS coordinate with MCPRC and UNCC as plans for the Mecklenburg County greenway system in this watershed continue to develop.



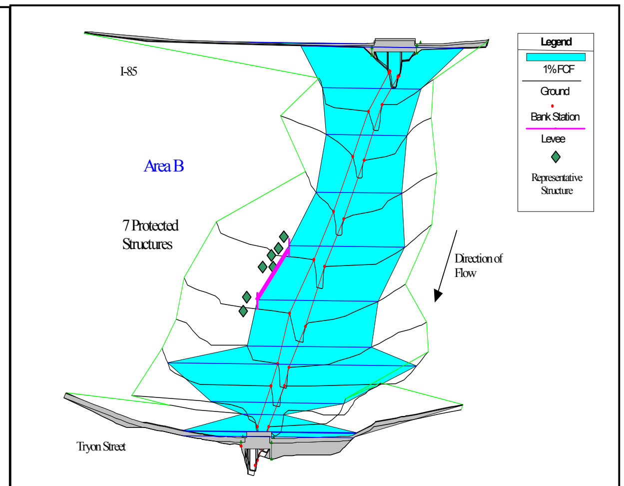


Figure E-1. Mallard Creek, Representative 1% Annual Chance FCF

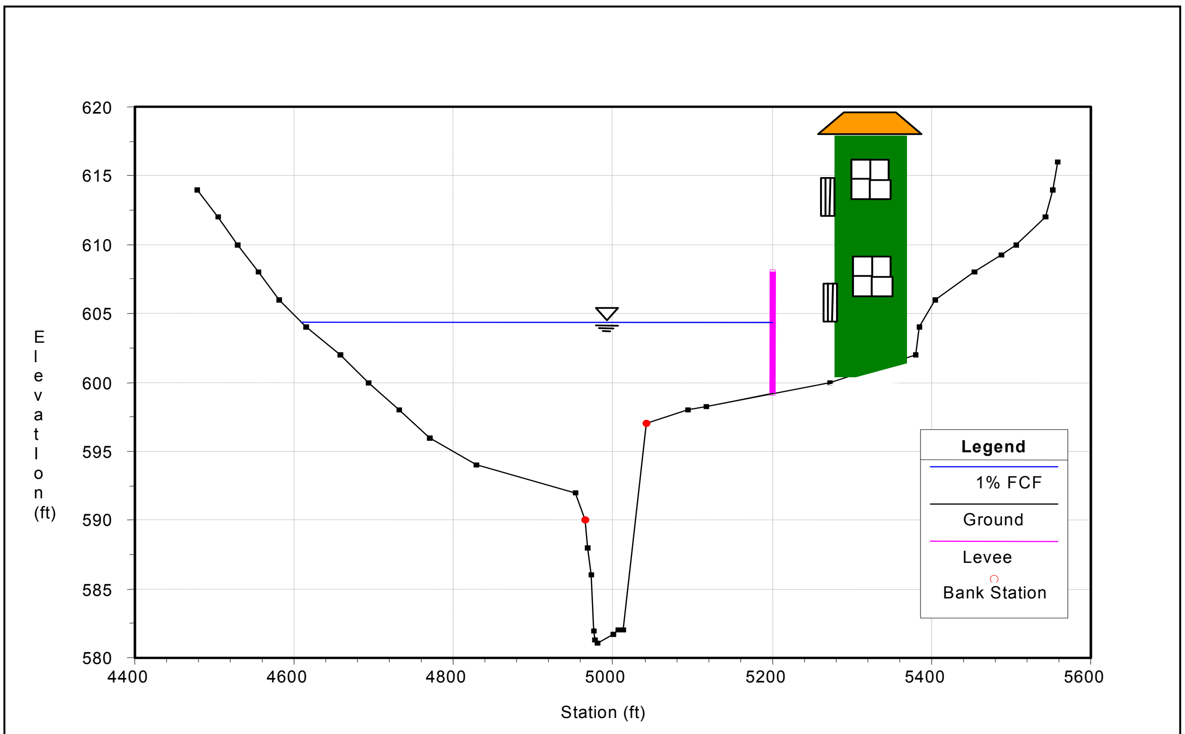
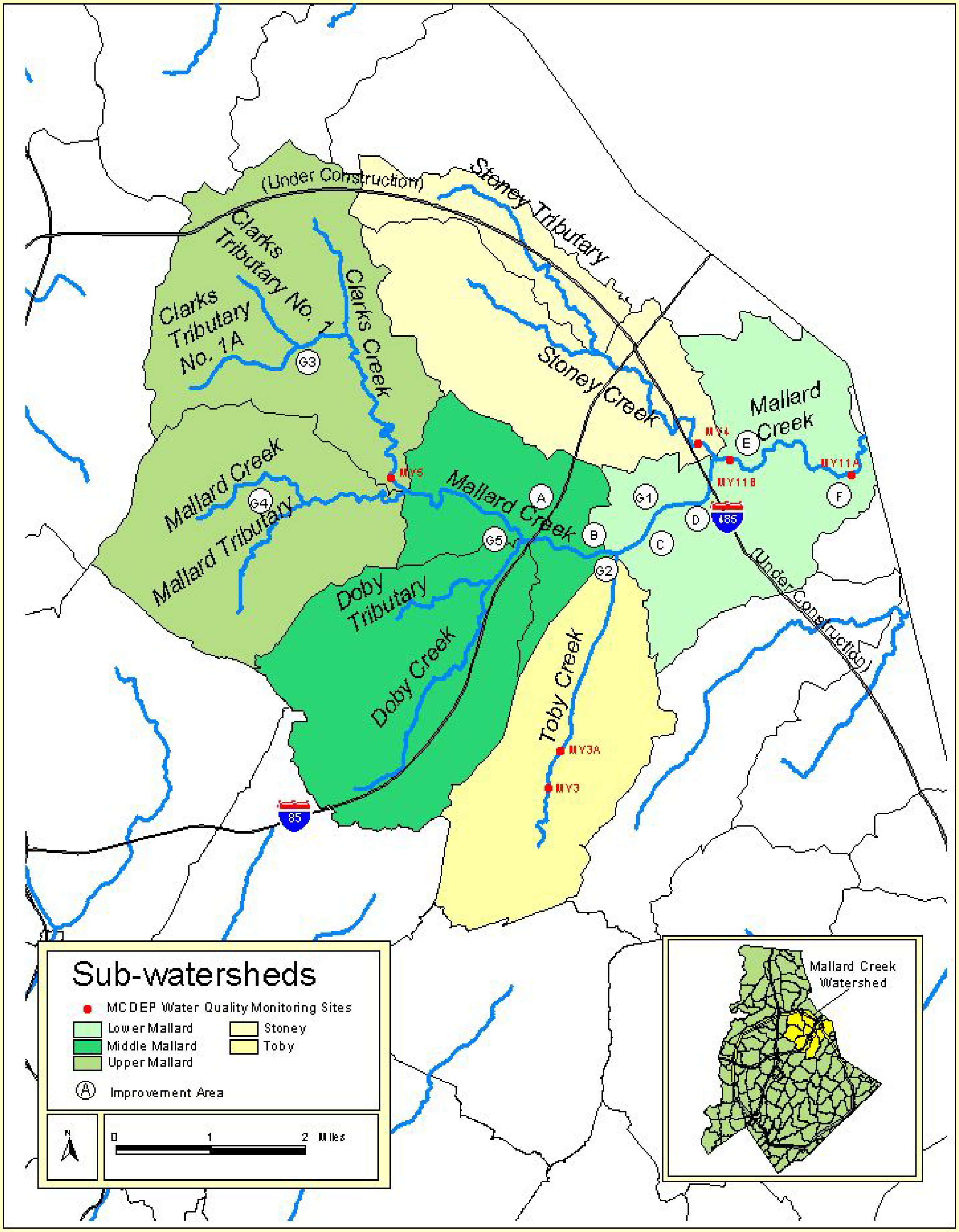


Figure E-3. Typical Cross Section of Recommended Improvements at Mallard Creek, Area B (Facing Downstream)

Figure E-4, Study No. 2: Mallard Creek Watershed



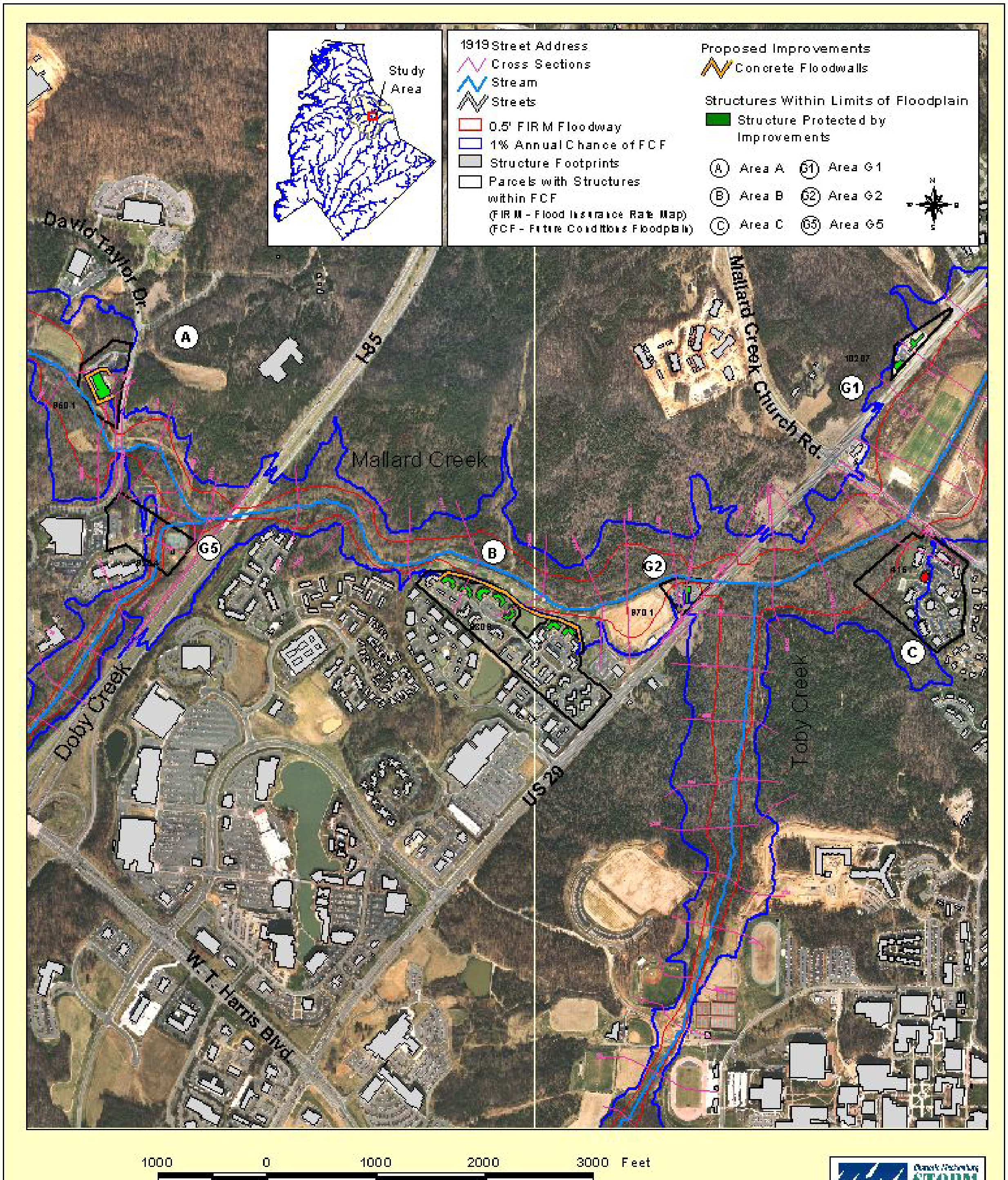


Figure E-5 Study No. 2, Mallard Creek, Recommended Improvements

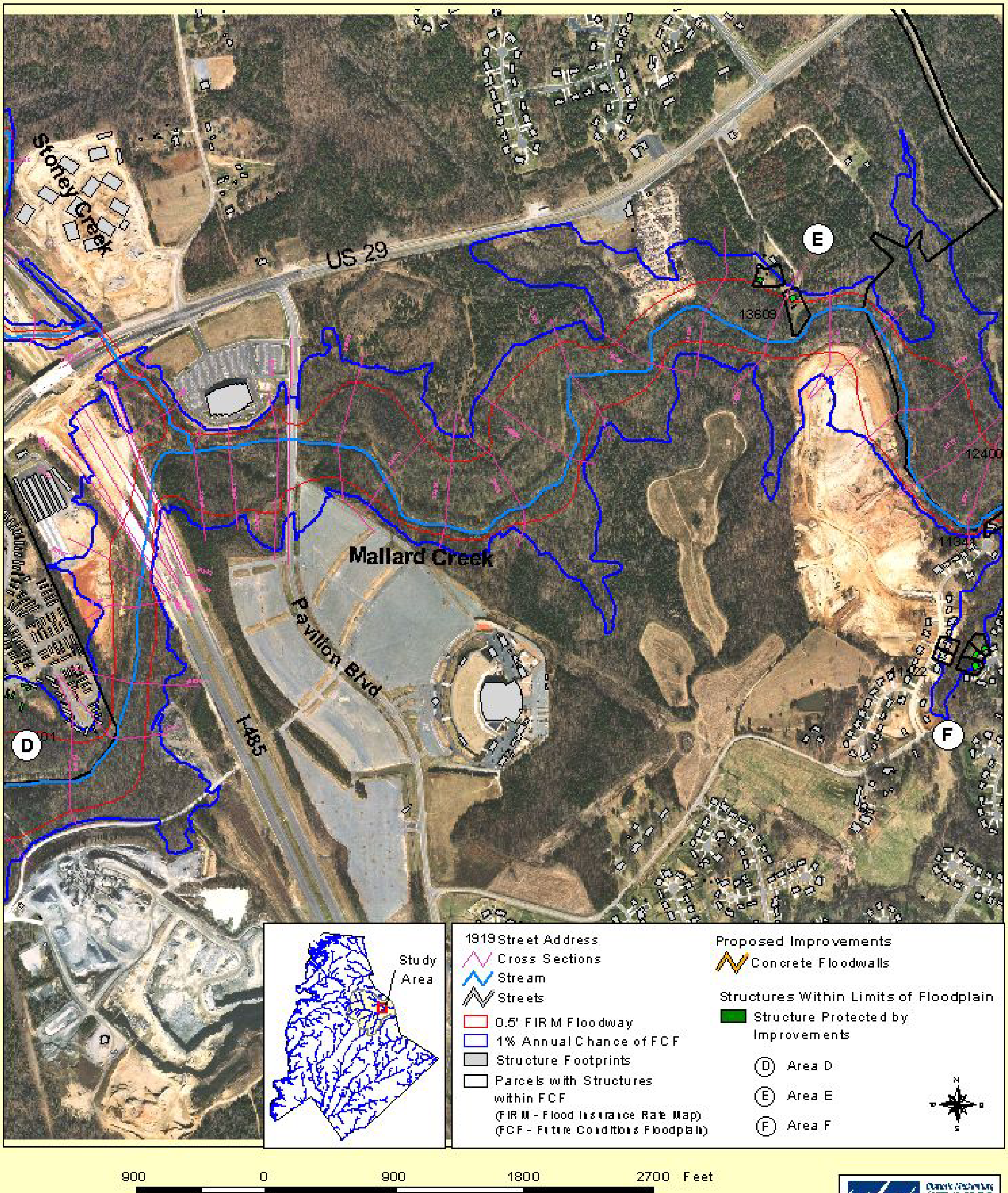


Figure E-6 Study No. 2, Mallard Creek, Recommended Improvements

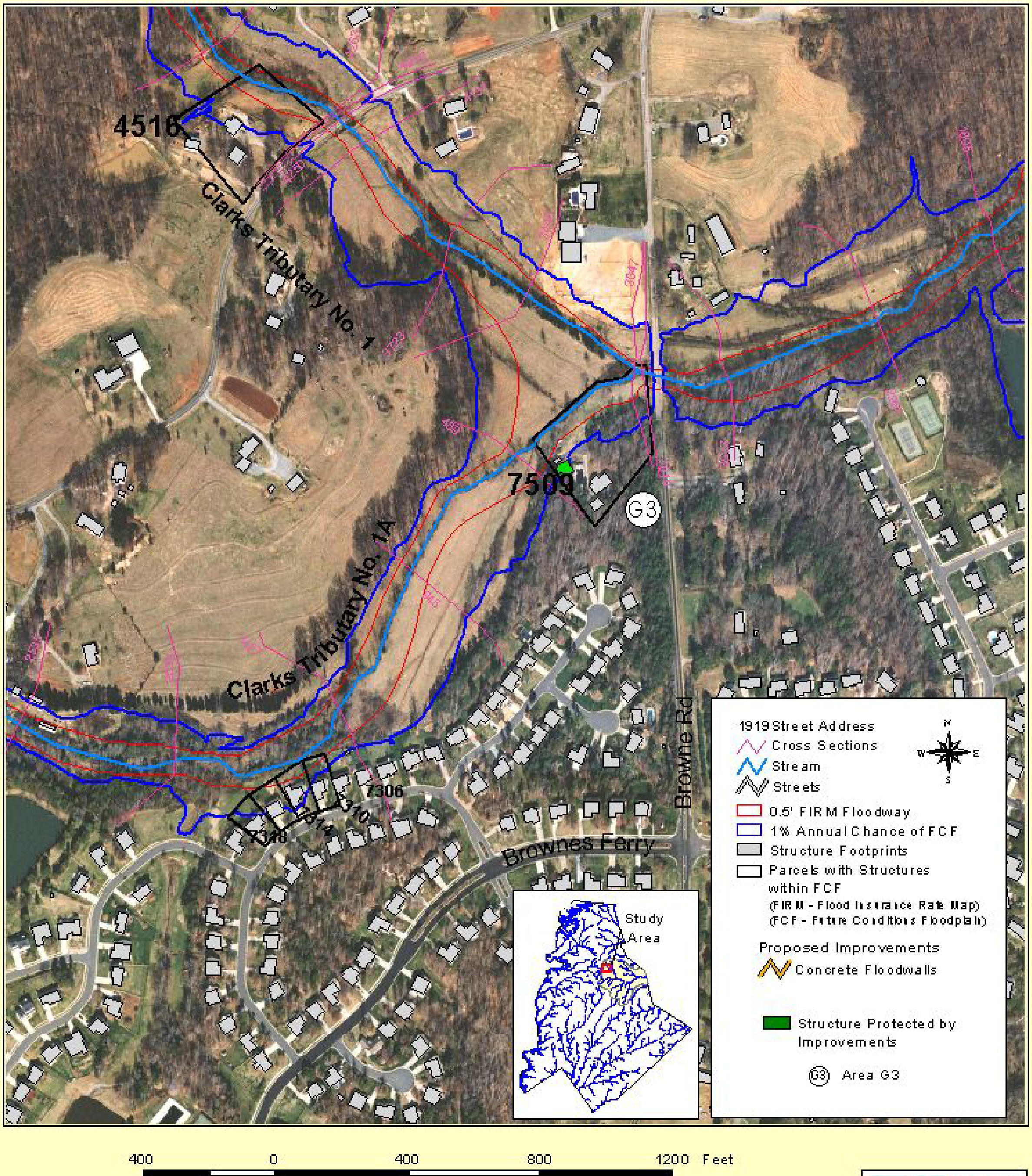


Figure E-7 Study No. 2, Mallard Creek, Recommended Improvements

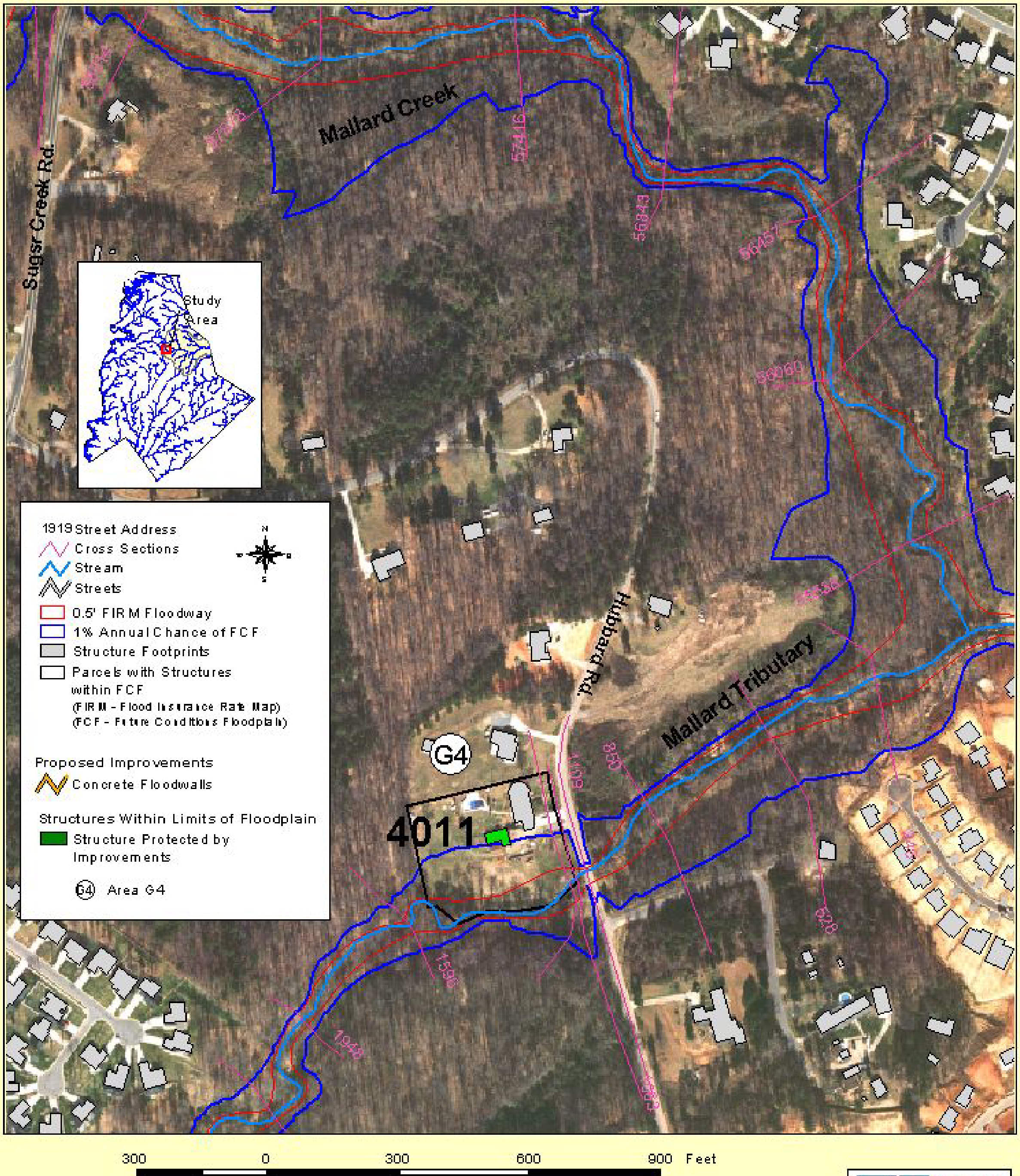
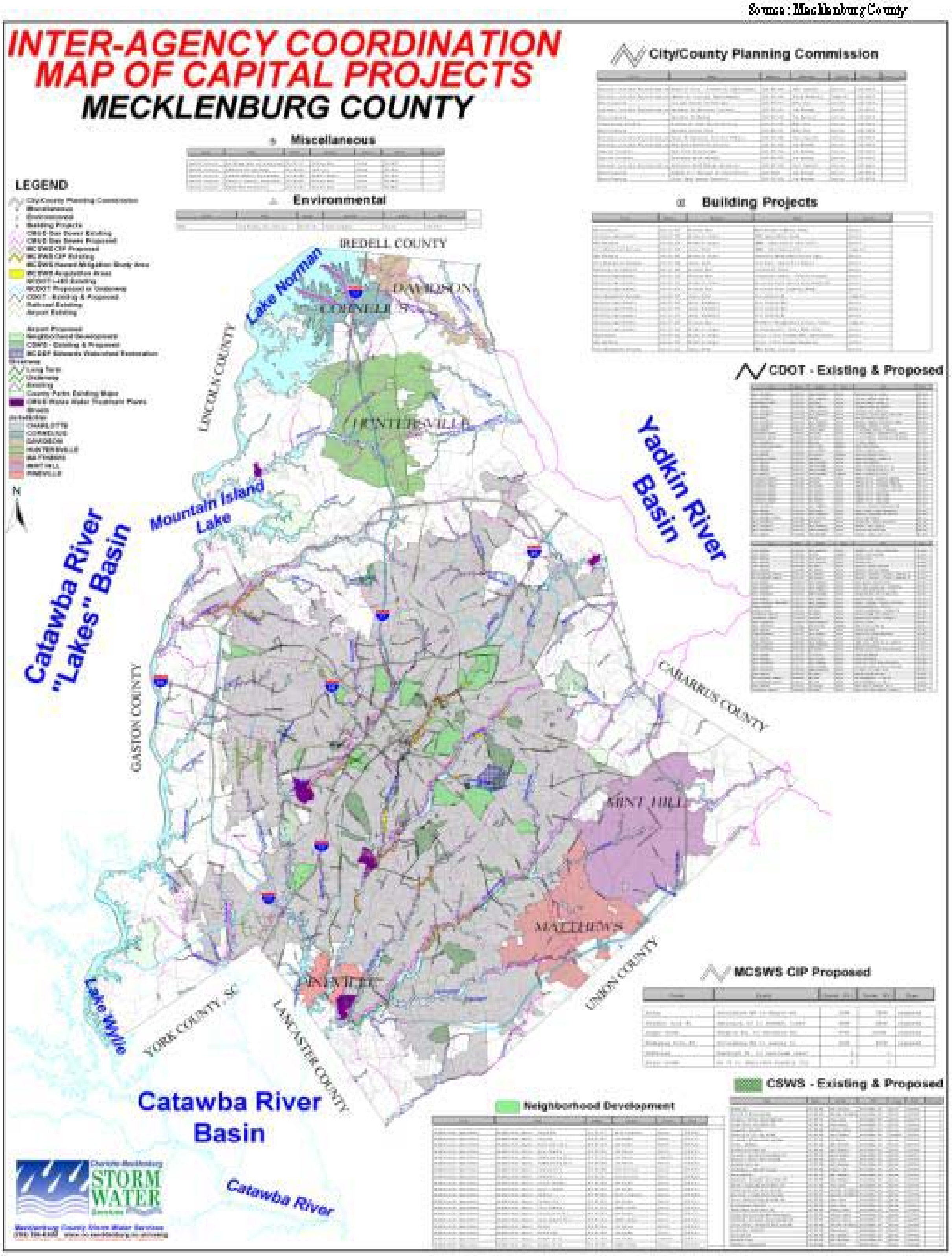


Figure E-8 Study No. 2, Mallard Creek, Recommended Improvements

Figure E-9 Capital Improvement Project Map

Source: Mecklenburg County



1. GENERAL WATERSHED CONDITIONS

1.1 Watershed Characteristics

This 38.5 mi^2 watershed includes the major tributaries of Clarks Creek (3.8 mi), Clarks Creek Tributary No.1 (1.4 mi), Clarks Creek Tributary No. 1A (1.4 mi), Doby Creek (3.1 mi), Doby Creek Tributary (1.5 mi), Mallard Creek Tributary (0.5 mi), Stoney Creek (4.2 mi), and Stoney Creek Tributary (2.2 mi), and the main stem of Mallard Creek (10.1 mi) from its headwaters east to the Mecklenburg County border with Cabarrus County, for the total stream length of 31.5 miles. Field observations of the channel and watershed characteristics were conducted at all road crossings in February 2001. Throughout the watershed, bank conditions vary with the majority lined with thick vegetation. Evidence of channel entrenchment was observed in all channels. Observed bank erosion problems are discussed in Section 1.5, Bank Stability Problem Identification.

Mallard Creek

Beginning west of Old Potters Road, Mallard Creek flows east through farmland and new residential developments into the Rocky River in Cabarrus County. Land use and development patterns in the watershed are discussed in Section 1.2. Only the portion of the creek within the Mecklenburg County border is included in this study. Mallard Creek banks are vegetated, with some observed lower bank erosion. Channel bottom material is mostly sand/silt with cobble present. Larger rocks create riffles in some areas (Figure 1). At a few locations, the downstream faces of culverts exhibited signs of scour. At one location near the Pavilion Boulevard bridge, downcutting was observed on a small intermittent tributary. This tributary is downcutting in an effort to reach the grade of the main stream. The entrenchment of Mallard Creek over time, in turn, is leading to the downcutting of its tributaries to some extent.

Figure 1. Typical Channel, Mallard Creek at David Taylor Drive, Facing Upstream (Roll #1, Photo #23)

Mallard Creek Tributary

Mallard Creek Tributary flows north from its headwaters near Sugar Creek Road to its confluence with Mallard Creek north of Hubbard Road. Its only crossing is a culvert at Hubbard Road, where heavy woody and shrub vegetation lines the banks downstream. On the left bank upstream of the road crossing, landowners mow grass up to the edge of the water line; however, the right bank is protected by thick vegetation.

Figure 2. Typical Channel, Clarks Creek at Dearmon Road, Downstream Face (Roll #1, Photo #2)

Clarks Creek

Clarks Creek flows south, with its headwaters near Fox Glen Road and its confluence with Mallard Creek between W.T. Harris Boulevard and Mallard Creek

Road. Thick vegetated riparian zones line most of the channel, providing shade and stabilization of the banks (Figure 2). From the vantage point of road crossings, riprap, often overgrown with vegetation, was observed as a bank stabilization mechanism. Riprap on the channel bottom also helps to control erosion and sediment movement, and provide instream habitat.

Clarks Creek Tributaries No. 1 and No. 1A

Clarks Creek Tributary No. 1, with its tributary, Clarks Creek Tributary No. 1A, begins to the west of Clarks Creek and joins the main channel between stations 13322 and 13767. Clarks Creek Tributary No. 1A, with its headwaters east of Old Statesville Road, joins Clarks Creek Tributary No. 1 at Browne Road (Figure 3). Davis Lake was created on Clarks Creek Tributary No. 1A, and the channel downstream of the outfall was lined with riprap. Here, flows are typically low. These narrow channels often are lined with thick brushy vegetation as they flow through residential subdivisions. Riprap on the channel bottom also helps to control erosion and sediment movement, and provide instream habitat.

Figure 3. Typical Channels, Confluence of Clarks Creek Tributaries No. 1 and No. 1A (Roll #1, Photo #9)

Doby Creek

Doby Creek flows north from its headwaters near Jeremiah Boulevard along the I-85 corridor to its confluence with Mallard Creek between Research Drive and I-85. This shallow channel exhibits possible degradation, with more current aggradation (Figure 4). Sand bars are found on the inside of meanders and at the upstream face of the W.T. Harris Boulevard box culvert. The channel takes a sharp turn here and, as energy dissipates, sand is deposited at the head of the culvert. A sanitary sewer line crosses the channel just upstream of this culvert. Vegetation lines a majority of the banks; however, excessive sheer stress on an outer meander (left bank) upstream of Governors Road has led to full bank erosion. This problem is further discussed in Section 1.5.

Figure 4. Typical Channel, Doby Creek Upstream of W.T. Harris Boulevard (Roll #2, Photo #23)

Doby Creek Tributary

This narrow channel flows northeast from its headwaters west of IBM Drive to its confluence with Doby Creek near W.T. Harris Boulevard. Woody vegetation lines a majority of the channel banks while riprap at road crossings aids in stabilization. Riprap is also present in the channel, which typically has a sand and silty bottom. The

Figure 5. Typical Channel, Doby Creek Tributary Downstream of IBM Drive (Roll #2, Photo #18)

upper IBM Drive crossing is a series of five culverts, with the right two pipes full of sediment. Downstream of the lower IBM Drive crossing, full bank erosion was observed at a meander in the channel (Figure 5). A sanitary sewer line also crosses the channel at this location. Scour is occurring upstream of W.T. Harris Boulevard.

Stoney Creek

Stoney Creek flows southeast from its headwaters in the most northern reaches of the Mallard Creek watershed to its confluence with Mallard Creek near US Highway 29. Vegetation, as well as riprap near road crossings, stabilizes banks throughout the creek (Figure 6). At the major crossings of I-85, I-485, and US Highway 29, banks are heavily stabilized by large riprap. At I-85, banks are steep but stabilized, and the double-barrel box culvert houses a 3-foot diameter sanitary sewer line in its right cell. At I-485, the channel is realigned to run parallel to the highway. There the banks are steep with riprap and shrub and grass vegetation for stabilization. Throughout the creek, bottom material is sandy with cobble and rocks creating riffles. One location of concern is the culvert crossing at Mallard Creek Road. The corrugated metal arch culvert is supported internally with pillars. Debris is collecting behind these support efforts.

Figure 6. Typical Channel, Stoney Creek near I-85, Looking Downstream (Roll #2, Photo #12)

Stoney Creek Tributary

Stoney Creek Tributary crosses Mallard Creek Road on its eastward journey to join Stoney Creek just west of I-85 (Figure 7). A heavily wooded riparian zone stabilizes the headwaters channel. At Mallard Creek Road, lower bank erosion was observed as well as riprap and kudzu and invasive species. Residential developments are increasing near the stream. Debris is beginning to collect at the Homewood Drive crossing. Riprap also stabilizes this road crossing. This typically narrow channel expands into an eroded pool downstream of Homewood Drive. This problem is further discussed in Section 1.5.

Figure 7. Typical Channel, Stoney Creek Tributary at Homewood Drive, Looking at Upstream Face (Roll #2, Photo #14)

Toby Creek

With its headwaters south of Autumnwood Lane, Toby Creek flows north to its confluence with Mallard Creek near N. Tryon Street and Mallard Creek Church Road. Exposed roots of trees lining the upper reaches of the channel indicate downcutting and bank erosion over time (Figure 8). Thick vegetation lines most of the channel; however, lower toe bank erosion is a concern along Toby Creek. A sandy bottom with some silt characterizes this creek. Channel stabilization problems are present at the Rocky River Road crossing. The addition of riprap in large quantities to the channel has stabilized headcutting at the downstream face of a double barrel culvert. This presents a fish passage problem. Banks are also unstable in this reach and will be further discussed in Section 1.5. Between US 49 and Chancellors Park Drive, the banks are very steep as a result of severe downcutting. Trees along the banks are unstable. A beaver was also observed near its dam in this area. Grade-control structures have been installed downstream of the W.T. Harris Boulevard West ramp from University City Boulevard. The intention of these structures is to limit headcutting. Riprap intended to reduce headcutting has also been added to the mouths of tributaries entering Toby Creek near Toby Creek Road and W.T. Harris Boulevard. Placing riprap for headcutting protection has proven to be effective.

Figure 8. Typical Channel, Toby Creek Downstream of W.T. Harris Boulevard West (Roll #3, Photo #4)

1.2 Watershed Development

For the purpose of watershed development discussion in this study, the Mallard Creek watershed was divided into five sub-watersheds: (1) lower Mallard Creek, (2) middle Mallard Creek and Doby Creek, (3) Stoney Creek, (4) Toby Creek, and (5) a combined upper Mallard and Clarks Creek sub-watershed (Figure E-4). Mallard Creek extends generally west from the County boundary to its headwaters near Old Statesville Road (Hwy 115). Stoney Creek extends northwest from Mallard Creek to its headwaters near Prosperity Church Road. Toby Creek and Doby Creek both extend generally south from Mallard Creek to their headwaters near Old Concord Road and I-85, respectively. Clarks Creek extends from Mallard Creek in a generally northwest direction toward Eastfield Road.

Figure 9. Development, Mallard Creek at Mallard Creek Road, Looking Upstream (Roll #1, Photo #19)

The Mallard Creek watershed is a rapidly developing suburban and commercial watershed (Figure 9). I-85 traverses the watershed, I-485 is under construction, and Highway 49 crosses the watershed diagonally as it passes by UNCC. The UNCC property includes part of Toby Creek, while the IBM Corporate Park is bisected by Doby Creek and one of its tributaries. In turn, these land use changes have spurred residential development in the watershed. Therefore, the Mallard Creek watershed is known to be among the fastest-growing watersheds within Mecklenburg County.

Table 1 summarizes development in the Mallard Creek watershed as a whole. Tables 2 through 6 summarize development in each of the sub-watersheds. More than one-half of the Mallard Creek watershed has developed since 1980 (62.4 percent). Currently 22.3 percent of the watershed is vacant or unclassified, while field visits in February 2001 revealed development is continuing throughout the watershed. The majority of the parcels in the watershed support residential land uses (74.5 percent). Non-residential land uses constitute a very small portion, 3.2 percent, of development. Although the land use and land cover in the entire watershed influence conditions in the stream, the riparian corridor is particularly sensitive to development.

Table 1 Development in the Mallard Creek Watershed*							
	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	961	604	465	3,415	4,849	2,950	13,244
Percentage	7.2%	4.6%	3.5%	25.8%	36.6%	22.3%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	9,295	571	428	2,950	13,244
Percentage	70.2%	4.3%	3.2%	22.3%	100%

* Entire Mallard Creek watershed within Mecklenburg County, including all tributaries (38.5 mi^2)

The lower Mallard Creek sub-watershed below the confluence with Toby Creek reflects the average Mallard Creek development patterns of the watershed as a whole (Table 2). In the lower Mallard Creek sub-watershed, a very small portion of the parcels was developed before 1980 (4.2 percent), with 75.9 percent of development after 1980. Over one-half of this development (54.3 percent) was between 1981 and 1990.

Table 2 Development in the Lower Mallard Creek Watershed*							
	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	51	19	7	989	394	361	1,821
Percentage	2.8%	1.0%	0.4%	54.3%	21.6%	19.8%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	1,314	113	33	361	1,821
Percentage	72.2%	6.2%	1.8%	19.8%	100%

* Lower Mallard Creek watershed below confluence with Toby Creek (6.0 mi^2).

In the middle Mallard Creek sub-watershed including Doby Creek, the majority of the development has been after 1990 (Table 3). Development rates have been consistently high in the middle Mallard Creek sub-watershed, at 21.7 percent between 1981 and 1990 to 26.5 percent between 1991 and 2000. Similar to the other southern sub-watershed, the middle Mallard Creek sub-watershed is 10.3 percent non-residential land use. One influence in this area is W.T. Harris Boulevard.

Table 3 Development in the Middle Mallard Creek Watershed*							
	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	212	164	83	337	411	343	1,550
Percentage	13.7%	10.6%	5.4%	21.7%	26.5%	22.1%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	947	101	159	343	1,550
Percentage	61.1%	6.5%	10.3%	22.1%	100%

* Middle Mallard Creek watershed including Doby Creek (8.8 mi^2)

Stoney Creek sub-watershed, the northernmost portion of the Mallard Creek watershed, has experienced a slower development rate than other portions of the basin (Table 4). Rapid development did not begin until the 1990s (36.6 percent). One influence may be the I-85 corridor, which passes through this watershed. A large portion of Stoney Creek sub-watershed remains undeveloped, with 41.5 percent of parcels vacant or unclassified. Land use here reflects the average Mallard Creek watershed characteristics, with 57.4 percent of the area residential land use.

Table 4
Development in the Stoney Creek Watershed*

	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	90	68	65	71	539	590	1,423
Percentage	6.3%	4.8%	4.6%	5.0%	37.9%	41.5%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	798	19	16	590	1,423
Percentage	56.1%	1.3%	1.1%	41.5%	100%

* Stoney Creek watershed within Mecklenburg County (6.7 mi^2).

Toby Creek sub-watershed is located in the southern portion of the Mallard Creek watershed and experienced the earliest rate of development (Table 5). Before 1980, this 5.1-square mile sub-watershed was 34.5 percent developed. After high development between 1981 and 1990 (34.0 percent), development has shown evidence of slowing. Twenty-four percent of Toby Creek sub-watershed remains undeveloped or unclassified. Land use here reflects the average Mallard Creek watershed characteristics, with 67.9 percent residential land use. Toby Creek sub-watershed has the highest percentage of non-residential land use (8.2 percent), which is due in part to UNCC.

Table 5
Development in the Toby Creek Watershed*

	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	189	206	198	586	130	413	1,722
Percentage	11.0%	12.0%	11.5%	34.0%	7.5%	24.0%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	1,158	10	141	413	1,722
Percentage	67.3%	0.6%	8.2%	24.0%	100%

* Toby Creek watershed (5.1 mi^2).

Development more than doubled in the past two decades in the upper Mallard Creek (headwaters) sub-watershed, from 21.3 percent between 1981 to 1990 to 50.3 percent between 1991 and 2000 (Table 6). This rapid development in the upper Mallard Creek sub-watershed is primarily single family residential (75.6 percent).

Table 6
Development in the Upper Mallard Creek Watershed*

	Year Developed					Vacant/	
	Before 1961	1961-1970	1971-1980	1981-1990	1991-2000	Unclassified	Total
Parcels	416	146	110	1,428	3,373	1,236	6,709
Percentage	6.2%	2.2%	1.6%	21.3%	50.3%	18.4%	100%

	Land Use as of 2000				
	Single Family	Other Residential	Non-Residential	Vacant/ Unclassified	Total
Parcels	5,070	328	76	1,236	6,709
Percentage	75.6%	4.9%	1.1%	18.4%	100%

* Upper Mallard Creek watershed including Clarks Creek (11.9 mi^2).

Sanitary sewers are present along all of Mallard Creek and its major tributaries, and any stream-side capital improvement projects will have to accommodate the existing utilities (Figure 10). These sewers travel to the Mallard Creek Wastewater Treatment Plant near the County line. However, the County's Year 2000 Inter-Agency Coordination of Capital Improvement Projects (CIPs) map does not indicate that CMU has proposed any CIP along the entire length of Mallard Creek. MCSWS should continue to coordinate with CMU to identify any potential projects or conflicts that arise in the future. If MCSWS is aware of CMU projects, it may influence the alignment of the relief sanitary sewer to coincide with the recommendations of this report.

Figure 10. Sanitary Sewer Line Crossing Doby Creek Tributary (Roll #2, Photo #20)

The 1999 Mecklenburg County Greenway Master Plan recommends that the greenway system be expanded as a floodplain management buffer and water quality program to include all creeks and streams throughout the County. In the Mallard Creek watershed, 3.6 miles of greenway currently exist along Mallard Creek and Clarks Creek (Figure 11). This greenway connects to the University Research Park Trail, with future plans to extend the greenway along Mallard Creek to the Cabarrus County line. These plans would include access from UNCC and the Mallard Creek Recreation Area. Future plans also include extending the Clarks Creek greenway to Victoria Avenue and adding 2.6 miles of greenway along Toby Creek from Mallard Creek to West Rocky River Road. Property buyout expenses may be shared between MCSWS, MCPRC, or other County departments should this study area be included in future greenway development. It is recommended that MCSWS coordinate with MCPRC and UNCC as plans for the Mecklenburg County greenway system in this watershed continue to develop.

Figure 11. Mallard Creek Greenway at Mallard Creek Road (Roll #1, Photo #20)

A typical greenway with a creek identification sign within the County is shown in Figure 11-1.

Figure 11-1. MCSWS Creek Identification Sign

1.3 Aquatic Habitat and Environmental Monitoring

Throughout this study watershed, bank conditions vary considerably, but for most of the stream channels both banks are heavily vegetated with brush and trees. Typical current conditions are illustrated throughout this PER (field photos are included in the Appendix and locations are referenced in Figure A-1). The abundant vegetation protects most of the channel banks from severe erosion, and provides intermittent shade and some habitat for wildlife. Many of the banks are steep because of channel downcutting over time. This could be explained as Class III stage, which is degradation in channel evolution. Instream aquatic habitat includes sandy/silt bottom material and intermittent areas of cobble and rock creating riffles. Very little aquatic wildlife was observed in Mallard Creek and its major tributaries. Field surveys for this study were conducted within close proximity to road crossings, and did not include walking along all of the stream channels. Bank stabilization problems are discussed in Section 1.5 and included in the Flood Mitigation Improvement Analysis in Section 3.

Figure 12. Toby Creek, Looking Upstream from Rocky River Road (Roll #3, Photo #10)

MCDEP maintains three ambient water quality sampling and bio-monitoring locations along Mallard Creek, with four other monitoring sites on Clarks Creek, Stoney Creek, and Toby Creek (two sites) (Figure E-4). Doby Creek does not have a monitoring site. An effort was made to look for trends and impacts of individual sub-watersheds (Table 7). Macroinvertebrate and fish community health indices provide valuable information because they reflect both water quality and habitat conditions.

Macroinvertebrate Taxa Richness sampling produced consistently “Poor” rankings throughout the watershed. One location, Mallard Creek at Mallard Creek Church Road (MY11B), indicates a decrease in macroinvertebrate community health from a “Fair” rating in 1994 to a “Poor” rating in 1998. The other recent “Fair” ranking occurred in 1997 on Toby Creek at Knollwood Court (MY3A). These rankings indicate the Mallard Creek watershed does not support a large diversity of aquatic fauna at the macroinvertebrate level-the lower levels of the aquatic system food chain. Water quality and habitat problems influence these communities.

Fish bioassessment on Toby Creek produced recent “Fair” ratings at both sites (MY3 and MY3A), while the Stoney Creek site (MY4) exhibited a “Good” ranking. These results indicate similar fish diversity in the tributaries of Mallard Creek; however, fish bioassessment results are not available for Mallard Creek.

Ambient water quality sampling of the tributaries and Mallard Creek show higher water quality in the tributaries. Consistently, all Mallard Creek sampling sites have produced “Good” water quality rankings. Location MY5, Clarks Creek at Fairmont Road, exhibits an improvement in water quality from a “Good” ranking in 1994 to “Good-Excellent” rankings in 1997 and 1998. The Toby Creek sites indicate a slight

Table 7

MCDEP Water Quality Monitoring Summary

NC Piedmont Macroinvertebrate Taxa Richness		Jun-94		Jun-95		Jun-96		Jun-97		Jun-98	
Site	Location	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating	S_{EPT}	WQ Rating
MY5	Clarks Creek-Fairmont Road	6	Poor	-	-	-	-	3	Poor	4	Poor
MY3	Toby Creek-Rocky River Road W.	6	Poor	-	-	-	-	6	Poor	5	Poor
MY3A	Toby Creek-Knollwood Court	-	-	-	-	-	-	7	Fair	5	Poor
MY4	Stoney Creek-US Highway 29	6	Poor	-	-	-	-	-	-	-	-
MY11A	Mallard Creek-Mallard Crossing Dr	6	Poor	-	-	-	-	3	Poor	-	-
MY11B	Mallard Creek-Blockbuster Blvd	10	Fair	-	-	-	-	2	Poor	2	Poor
MY11C	Mallard Creek-Mallard Crossing Dr	7	Fair	-	-	-	-	-	-	-	-

Fish Bioassessment		Jun-94		Jun-95		Jun-96		Jun-97		Jun-98	
Site	Location	NCIBI	WQ Rating	NCIBI	WQ Rating	NCIBI	WQ Rating	NCIBI	WQ Rating	NCIBI	WQ Rating
MY3	Toby Creek-Rocky River Road W.	-	-	-	-	-	-	-	-	40	Fair
MY3A	Toby Creek-Knollwood Court	-	-	-	-	-	-	44	Fair	40	Fair
MY4	Stoney Creek-US Highway 29	-	-	-	-	50	Good	-	-	-	-

Water Quality Index		Jun-94		Jun-95		Jun-96		Jun-97		Jun-98	
Site	Location	WQI	WQI Rating	WQI	WQ Rating	WQI	WQI Rating	WQI	WQI Rating	WQI	WQI Rating
MY5	Clarks Creek-Fairmont Road	70	Good	-	-	-	-	78	Good-Excellent	83	Good-Excellent
MY3	Toby Creek-Rocky River Road W.	73	Good	-	-	-	-	68	Good	60	Fair-Good
MY3A	Toby Creek-Knollwood Court	-	-	-	-	-	-	84	Good-Excellent	71	Good
MY4	Stoney Creek-US Highway 29	60	Average	-	-	-	-	-	-	-	-
MY11A	Mallard Creek-Mallard Crossing Dr	-	-	-	-	-	-	65	Good	-	-
MY11B	Mallard Creek-Blockbuster Blvd	70	Good	-	-	-	-	72	Good	74	Good
MY11C	Mallard Creek-Mallard Crossing Dr	52	Average	-	-	-	-	65	Good	74	Good

* See Figure E-4 for MCDEP monitoring site locations.

decrease in water quality over the last few years. Upstream at Rocky River Road West (MY3), the water quality ranking decreases from "Good" in 1994 and 1998 to "Fair-Good" in 1998, while downstream at Knollwood Court (MY3A) water quality decreases from "Good-Excellent" in 1997 to "Good" in 1998.

Overall, water quality has remained fairly consistent in the Mallard Creek watershed since 1994. The Water Quality Index indicates water quality conditions better than the fish and macroinvertebrate communities. This may indicate that aquatic habitat conditions limit these communities to some extent. Review of ambient water quality data dating back to 1968 does not reveal significant trends in most of the data over time or by location. However, fecal coliform levels have dropped and pH has increased since the 1968-1970 data. This may be due to improvements to the sanitary sewer infrastructure that eliminated clogged and broken sewer pipes. The Mallard Creek Wastewater Treatment Plant also discharges into this watershed near the Cabarrus County line. The Mallard Creek channel bottom material consisted mainly of sand and silt. Much of this material is probably transported downstream from upstream channel erosion and watershed surface runoff. While there are aquatic life forms present in the creek, the sand and silt benthic material (with few instream features such as boulders and woody debris) does not provide a protective habitat, and bottom dwelling communities are not as abundant and diverse as may be desired.

Problems throughout the watershed include channel entrenchment, sediment transport (sediment accumulation in road crossing culverts), and urban debris (trash, shopping carts). The vegetated riparian zones also may not be providing their full filtering functions because of channel entrenchment throughout the watershed. Entrenchment of a stream channel lowers the water table, with the effect being a loss of water quality improvement for infiltrated water.

1.4 Rosgen Stream Morphology Assessment

River form and fluvial processes evolve simultaneously and operate through mutual adjustments toward self-stabilization (Rosgen 1994). The stream tries to balance the combination of sediment load and sediment size with the stream slope and discharge (Lane 1955). If any one of these components is altered (i.e., smaller sediment load), the opposing side of the balance must adjust proportionally (i.e., decrease in bed slope). If bed slope on a main channel changes, often tributaries will change to meet the main channel. Sediment contributions from this head cutting and degrading also occur. Due to intense development and increased peak flows, fluvial processes in streams may change more rapidly in an urban environment than if the stream was undisturbed.

Figure 13. Riprap Stabilization, Toby Creek at Rocky River Road Looking at Downstream Face (Roll #3, Photo #12)

When humans interfere with fluvial processes by increasing watershed imperviousness and change stream channels by realignment and armoring the banks, the stream counteracts by gradually lowering the bed slope (the flow remains fairly constant once the watershed is developed) in the upstream direction from a control point, such as the confluence with a larger stream or at a culvert. Headcutting in the Mallard Creek watershed was found on the downstream end of the Rocky River Road culvert crossing Toby Creek, where riprap has been added to stabilize the drop-off from the culvert outlet to the stream channel (Figure 13). Review of historical aerial photos shows changes in stream channel alignment. For instance, Stoney Creek has been realigned along I-485 (Figure 14), and Mallard Creek has been realigned to accommodate N. Tryon Street.

Rosgen Level 1 analysis is intended for obtaining a coarse geomorphic characterization that results from the integration of basin relief, landform, and valley morphology (Rosgen 1996). Aerial photos, elevations from HEC-RAS input, 2-foot interval topographic contours, soil survey reports, and field observations were used to conduct Level 1 Analysis.

Figure 14. Realignment, Stoney Creek along I-485 (Roll #2, Photo #9)

For this Level 1 Analysis, sinuosity and channel slope were calculated for each major tributary and Mallard Creek both above and below the confluence with Toby Creek. Rosgen analysis should be done using unique conditions to define each reach, not arbitrary segments chosen from a map. Sinuosity, or the measure of a channel's meanders, varies in the different streams. Typical Piedmont streams are expected to be more sinuous in their natural condition; however, realignment to accommodate urban development often restricts the channel's path. If the channel is the same length as the valley, the sinuosity is 1.0, indicating that the channel has been straightened. Naturally, streams with higher sinuosities generally have lower slopes, and streams with steeper slopes have lower sinuosities. This relationship was observed in the Mallard Creek watershed, as seen in Table 8. Mallard Creek below the confluence with Toby Creek has the greatest sinuosity (1.46) and the lowest slope (0.10%). This low slope is typical for the lower portion of a watershed. Conversely, Toby Creek has the lowest sinuosity (1.01) and the second-highest channel slope (0.66%). Of the tributaries to Mallard Creek, Clarks Creek is the most sinuous at 1.35. In accordance with the inverse relationship between sinuosity and slope, Clarks Creek also exhibits the lowest slope (0.54%) among the tributaries. Note that sinuosity is typically underestimated when calculated from topographic maps due to coarse contour refinement.

Table 8
Rosgen Level 1 Assessment: Geomorphic Characterization

	Channel Length (mi)	Valley Length (mi)	Channel Sinuosity	Channel Slope (percent)
Mallard Creek (above Toby Creek)	5.4	4.5	1.30	0.47
Mallard Creek (below Toby Creek)	5.7	2.9	1.46	0.10
Clarks Creek	3.8	2.8	1.35	0.54
Doby Branch	3.1	2.7	1.14	0.66
Stoney Creek	4.2	3.6	1.16	0.71
Toby Creek	3.3	3.3	1.01	0.66

The urban development of Charlotte has significantly altered the natural stream system; therefore, the influence of the valley type is diminished. The channel types were not selected because they vary greatly, and observations were only taken from road crossings. However, the Rosgen stream type E is typical of Charlotte area urban streams (Doll et. al. 2000). A Type E stream in an urban setting can have moderate entrenchment ratios and lower sinuosities than other Type E streams, as was observed in the Mallard Creek watershed. During field survey, several locations of downcutting were observed, which is a typical Class III Degradation stage in channel evolution. Also some locations exhibit Classes IV or V stages in channel evolution, which are Degradation & Widening and Aggradation & Widening, respectively. Channel bottom material was estimated visually for this study; however, detailed grain size distribution analysis (or representative pebble counts) and shear stress calculations should be conducted to assess the sediment transport capacity of the stream before modifications are made to the channel.

Soils in the Mallard Creek watershed influence how water moves to the streams; however, impervious surfaces can prevent infiltration. These soil types are predominantly well-drained upland soils with clayey subsoil. In the western headwater reaches of the watershed, soils are generally Cecil, with gently sloping to strongly sloping urban areas on well drained soils that have predominantly clayey subsoil, formed in residuum from acid igneous and metamorphic rock. Soils in the headwaters of Stoney Creek are Iredell-Mecklenburg. This soil type has similar characteristics but different origins, formed from rock high in ferromagnesian minerals. The majority of soils in the Mallard Creek watershed are Wilkes-Enon. These sloping, well-drained soils also have clayey subsoil and are formed in residuum from more basic rock. Along the Mallard Creek and Toby Creek channels lies another soil type, Monacan. These somewhat poorly drained floodplain soils are loamy because they are formed from fluvial deposits of sediment (USDA SCS 1980). Some of this soil material has been cut, filled, and graded as development has occurred. These activities have altered the physical characteristics and functions of the soils.

Figure 15. Erosion, Clarks Creek Tributary No. 1 at Hucks Road (Roll #1, Photo #8)

1.5 Bank Stability Problem Identification

Channel instability problems typically fall into two general categories: isolated areas of bank erosion and long-term equilibrium adjustments to changes in the watershed and stream system. The former may be caused by rapid inflow from tributaries, unstable banks, or encroachment of development. The latter is related to larger scale changes in the land use of the watershed and flows in the stream, which manifest in the form of changes to the channel bottom level. An example of this was previously described in Toby Creek (see Section 1.1) where instream structures have been constructed to limit headcutting. Both of these are present in the Mallard Creek watershed.

Figure 16. Bank Erosion, Doby Creek Upstream of Governors Road (Roll #2, Photo #22)

Bank stability problem areas were identified near road crossings and are described with photos below. Each tributary and Mallard Creek show evidence of bank instability. Other problems not visible from these vantage points may exist and should be researched before any bank stabilization projects are planned. Further quantitative studies of bank erosion rates and aquatic habitats throughout the study reach should precede further restoration efforts.

The banks of Clarks Creek Tributary No. 1 are eroding at the Hucks Road bridge (Figure 15). The City flushes a water main weekly into a drainage ditch, contributing to the erosion problem. The stability of a utility pole, visible in the Figure 15, is in jeopardy. This area should be repaired for safety concerns, as well as stream bank stability.

High levels of sheer stress eroding steep banks in entrenched channels can characterize the majority of bank instability in the Mallard Creek watershed. Upstream of Govenors Road, Doby Creek's steep left bank is collapsing due to high sheer stress (Figure 16). Roots are exposed and trees are collapsing into the channel. The left bank of Mallard Creek upstream of I-85 is also suffering from full bank erosion as a result of high sheer stresses on the steep bank (Figure 17). In addition, the right bank of Toby Creek is collapsing as a result of these same factors (Figure 18).

Flows from the culvert outfall at Homewood Drive have eroded a deep pool in Stoney Creek. Here, water velocities are also eroding the banks surrounding this pool (Figure 19). While pools do provide valuable aquatic habitat, this situation is unstable and would benefit from stabilization.

Figure 17. Bank Erosion, Mallard Creek Looking Downstream of I-85 (Roll #2, Photo #1)

Figure 18. Bank Erosion, Toby Creek at Rocky River Rd, View Downstream. (Roll #3 Photo#13)

Figure 19. Bank Erosion,Stoney Creek Downstream of Homewood Drive. (Roll #2 Photo #15)

2. BENEFIT:COST ECONOMIC ANALYSIS

2.1 Riverine and Coastal A-Zone Flood Model Overview

The Riverine and Coastal A-Zone Flood model (RCAZF) (Version 1.0, January 1995), a spreadsheet-based model developed by the Federal Emergency Management Agency (FEMA), was used for estimating damages in this study to be consistent with previous Mecklenburg County flood damage analyses. The estimated damages represent a foundation building block in the benefit:cost (B:C) analysis in this project. This B:C analysis compares benefits, or damages removed by the proposed project, with costs of the proposed flood hazard mitigation project.

Damages induced by flooding were estimated for structures with first finished floor elevations lower than the BFE and located within the 1% annual chance of Future Condition Floodplain (FCF). RCAZF requires four storm events: 10%, 2%, 1%, and 0.2% annual chance flood events, which are typically defined as 10-, 50-, 100-, and 500-year storm events, respectively. The WSEs were modeled using the US Army Corps of Engineers HEC-RAS model (Version 3.0, March 2001) for build-out conditions estimated to occur in year 2020.

RCAZF performs flood damage analysis at two levels. Level One analysis relies heavily on default values built into the model and requires minimum data input from users, while Level Two analysis allows the user to enter structure-specific information. The basic structure information required includes: structure type, size, replacement value, contents value, and various economic data about the use and function of the structure. Estimates of the flood damage vulnerability of the structure and its contents both before and after mitigation are particularly important. In addition to data about the structure under evaluation, B:C analysis of flood hazard mitigation projects requires a quantitative assessment of the degree of flood risk at the site. This assessment is performed automatically by the B:C program using flood data input from the FCF, along with data on the Zero Flood Depth (first finished floor) elevation of the building (RCAZF 1995). To utilize the model capability and site-specific and structure-specific data available to perform the best possible economic analysis, the Level Two analysis was performed for this study.

2.2 Economic Data

The numerous economic attributes were assigned to all flooding structures including the parcel identification number. Each structure was assigned a structure category, such as one-story building without basement, two-story building with basement, etc. The structure category determines which of the unique depth/damage curves the model uses. Each depth/damage curve describes the relationship between the flooding depth and the damage to the structure expressed in percent of the structure value. The flooding depth was calculated as the difference between various WSEs and the first finished floor elevation. Watershed Concepts provided a family of depth/damage curves specific to Mecklenburg County for this analysis.

The structures were also divided into commercial and residential occupancy types. In the model, these were described by the total area occupied by the owner. The residential structures were considered to be 100 percent occupied by the owner, and commercial structures 0 percent occupied by owner. The damages to residential structures consisted of both building and content damages. The model estimates damages to commercial buildings including a portion of the business income losses and displacement costs, leading to damage results slightly higher than those of residential structures of the same value, size, and structure category.

The structure characteristic data were extracted from a database provided by Mecklenburg County. Structure values were increased by 25 percent to reflect the value in 2001 dollars. A content value of 25 percent of the structure value was used to be consistent with the previous Mecklenburg damage analysis. Using the heating area of each structure, the building replacement value was calculated.

The first finished floor elevations for all structures were taken from various sources, such as MCSWS GPS Elevation Certificates, Flood-Proofing Certificates, Dewberry and Davis surveys, and information provided by Watershed Concepts. Each structure was assigned a station value that is a stream distance in feet measured from the confluence of the stream in an upstream direction. The structure station equals the station of the stream cross-section on which the structure is located. Using the station data, the WSE for four frequency storms at each structure location was interpolated and assigned to each structure.

2.3 Hydraulic Data

A HEC-RAS model developed for the Mallard Creek watershed by Watershed Concepts was used to process the hydraulic data for future build-out conditions in the watershed. The modeling output provided the WSEs for four frequency storms, 10%, 2%, 1%, and 0.2% annual chance of flood events, for each stream cross-section throughout the watershed. The WSEs were interpolated to retrieve data for the cross-sections attributed to each structure. Part of the model input includes these WSEs for each structure at each storm frequency. The hydraulic data pertaining to each flooded structure is presented in Appendix Table A-2.

2.4 Modeling Process

RCAZF processes the economic and hydraulic data to estimate the damages to each structure during the four frequency storms. The damages for each storm are then statistically processed to account for the probability of the damage occurrence during any given year. The estimated damage output data is in the form of annual damages.

2.5 Economic Analysis

After assessing the damages to all flooded structures in the watershed, several improvements were evaluated for hydraulic and economic feasibility. Each proposed improvement was analyzed for the hydraulic feasibility of not increasing the 1% annual chance storm WSE to satisfy the County's no-rise criteria. The economic feasibility of improvement is measured by B:C ratio. The B:C ratio is a ratio of benefits obtained by the proposed improvement and cost of the improvement. A B:C ratio greater than 1.0 determines economic feasibility for structural improvements. For property buyout consideration, FEMA considers a B:C ratio greater than 1.0 economically feasible. In other words, if the estimated damages are greater than 100% of the property value, the buyout option is considered feasible.

The potential flood damages to the structure are estimated using the model. The structure attributes are then amended to reflect the improvement, such as elevated finished floor elevation, decreased WSEs, etc. The potential damages to the structure after the improvement is implemented are then calculated. These represent the residual damages after the improvement is implemented. The benefit is calculated as the difference between damages prior to improvement and damages after the improvement is in place. All benefits are calculated on an annual basis. In order to compare them with the cost of improvement and to clearly present them, these were brought to present value by using a 50-year life of the project and the Federal Discount Rate of 5.5 percent (as of January 29, 2001).

Each proposed improvement capital cost, depending on its character, can be represented by a construction cost, and can also include an operation and maintenance (O&M) cost as well as a buyout cost. These construction and buyout costs are estimated in the form of present values. The O&M cost is given on annual basis and is usually associated with pump stations and wetlands, which require constant operation and maintenance. In order to sum all costs associated with improvement, the annual costs were brought to present value by using a 50-year project life and a 5.5 percent discount rate.

The total cost used in B:C analysis includes, in addition to the above mentioned costs, the residual damages, or the damages that remain even after the proposed improvement is implemented. Storms with greater than a 1% annual chance generate damages and are included in the analysis, but the improvement is designed for a 1% annual chance storm.

2.6 Improvements

A number of flood damage mitigation improvement alternatives were carefully considered. Improvements selected due to their hydraulic feasibility include floodwalls, structure elevation, and property buyout. In the case of a floodwall, the benefit was a sum of all damages to be removed by the proposed floodwall. In the Mallard Creek watershed, floodwalls were found to provide cost-effective flood protection that offers, in some cases, creek habitat enhancement as well. Section 3 summarizes the improvements and the economic analysis results for the alternatives. Detailed economic information is provided in Appendix Table A-1.

3. FLOOD HAZARD MITIGATION

3.1 Storm Water Service Requests

One request for service has been recorded in the Mallard Creek watershed (see Figure A-1 in Appendix). The address for this request is:

- 3231 Harris Mill Lane (August 5, 1996)

The parcel 3231 Harris Mill Lane is located on the right bank (looking downstream) of Mallard Creek at the confluence with a small, unnamed tributary between stations 15,391 and 16,089. This parcel is within the FCF; however, the structure is not. The Storm Water Services Requests database provided by the County does not indicate what sort of service was requested. MCSWS indicates that main channel erosion is the major reason for property owners to request service.

3.2 Repetitive Loss Structures

The list of repetitive loss structures within the study area was obtained from MCSWS and is presented in Appendix Table A-3.

3.3 Permanent Storm Water Easements

There are six recorded permanent drainage easements within the limits of the Mallard Creek watershed; however, only two of these provide access to Mallard Creek or its main tributaries. These addresses are:

- 3231 Harris Mill Lane
- 8306 Knollwood Circle

The parcel, 3231 Harris Mill Lane, which is also recorded in the FEMA Regulated Stream Service Requests database, provides 90 linear feet of access to the small, unnamed tributary and Mallard Creek. The second easement, providing 200 linear feet of access to Toby Creek, is 8306 Knollwood Circle.

3.4 Roadway Overtopping Problem Locations

From HEC-RAS modeling results of the Mallard Creek watershed, roadway overtopping locations were investigated based on 1% annual chance of FCF, since all the crossings are over regulated floodways. Table 9 summarizes the roadway overtopping problem location for the study streams.

Because motor vehicles can be swept away in as little as 24 inches of flood flow depth over the road, any roadway overtopping locations need to be identified for emergency response preparations for public safety purposes. The following items are listed for future action:

- Signage of roadway overtopping warning for avoiding road crossing during flood event.
- Coordination with Police Dept. and Fire Dept. for special attention during flood event.
- Routine inspection for bridge/culvert scour and safety conditions, such as a lack of guardrail (or handrail). Guardrail post would give indication of the edge of the structure when inundated during flood flows.

Table 9 Roadway Overtopping Problem Locations					
Mallard Creek	**Crossing Structure Type**	**Culvert Size**	**Top of Road Elevation (FT. NAVD)**	**WSE of 1% FCF (FT.NGVD)**	**Overtopping Depth (FT)**
Pavillion Blvd.	Bridge	-	588.2	592.4	4.2
Mallard Creek Church Road	Bridge	-	594.0	600.7	6.7
N. Tryon Street	Bridge	-	598.0	601.9	3.9
Interstate 85	Bridge	-	608.2	613.2	5.0
David Taylor Drive	Culvert	4-15′ x 12′ Box	611.0	614.3	3.3
Sugar Creek Road	Bridge	-	714.5	715.6	1.1
Old Potters Road	Culvert	8′ RCP	731.5	732.6	1.1
Mallard Creek Tributary					
Hubbard Road	Culvert	2-6′ RCP	679.0	680.1	1.1
Clarks Creek Tributary No. 1					
Browne Road	Culvert	2-8′ RCP	724.8	726.3	1.5
Hucks Road	Bridge	-	729.0	730.7	1.7
Stoney Creek Tributary					
Homewood Drive	Culvert	2-7′ RCP	650.4	651.2	0.8
Mallard Creek Road	Culvert	10′ x 7' RCPE	692.1	693.2	1.1
Toby Creek					
Hwy 49	Culvert	2-10′ x 11′ Box	622.2	622.7	0.5
Chancellor Park Drive	Culvert	5-10′ x 10′ Box	621.4	623.1	1.7
Rock River Road	Culvert	2-11′ x 8′ RCPE	638.6	639.7	1.1

3.5 Flood Mitigation Improvement Analysis

Because 86 structures are within the limits of the 1% annual chance of Future Condition Floodplain of the Mallard Creek watershed, flood protection alternatives were investigated as the first priority for this study. The primary flood damage areas in the Mallard Creek watershed are along Mallard Creek, with single structures on Clarks, Doby, Mallard Tributary, and Clarks Creek Tributary No. 1A Creeks (see Figure A-1 for existing conditions). No structures flood along Toby Creek, Stoney Creek, or its tributary. Of the 86 structures within the limits of the FCF along Mallard Creek, 25 structures flood. Of these structures, 19 are residential land use and six are commercial structures. There are eight single-family residential structures, with values ranging from $31,200 to $233,100, and four mobile homes, each with an estimated structure value of $36,900. Eight multi-family residential structures range in value from $642,500 to $783,200. The six commercial structure values range from $40,000 to $1,463,900.

The improvement alternative analyses use the FCF, which is based on the future ultimate built-out condition. Figure 20 illustrates these recommended improvement alternatives. Table A-1 in the Appendix provides more detailed information about the flood mitigation improvement alternative B:C evaluation.

Table 10
Flooding Structures Summary

	Total	Mallard Creek	Clarks Creek	Doby Creek	Stoney Creek	Toby Creek
Within FCF Floodplain	86	68	10	1	4	3
Pre-FIRM*	9	5	2	-	1	1
Post-FIRM	77	63	8	1	3	2
Finished Floor Inundated in FCF Storm Event	25	23	1	1	-	-
Pre-FIRM*	3	3	-	-	-	-
Post-FIRM	23	20	1	1	-	-
Protected by Floodwalls	8	8	-	-	-	-
Pre-FIRM*	-	-	-	-	-	-
Post-FIRM	8	8	-	-	-	-
Elevate Structures	16	14	1	1	-	-
Pre-FIRM*	3	3	-	-	-	-
Post-FIRM	13	11	1	1	-	-
Recommended Buyout	-	-	-	-	-	-
Pre-FIRM*	-	-	-	-	-	-
Post-FIRM	-	-	-	-	-	-
No Action	2	-	-	-	-	-
Pre-FIRM*	-	-	-	-	-	-
Post-FIRM	2	-	-	-	-	-

* Pre-FIRM structures were constructed before 1973; Post-FIRM structures were constructed in 1973 or later.

Alternative Evaluation

The improvement alternative analyses use the FCF, which is based on the future ultimate built-out condition. Figure 20 illustrates these recommended improvement alternatives.

There are 25 structures in the Mallard Creek watershed that have their lowest floor below the BFE of FCF. These include structures with a basement that is possibly flooding or structures with their first finished floor below the BFE of FCF elevation. The structures were clustered into study areas based on their proximity and possible proposed improvements, such as a floodwall or levee. Each study area was separately analyzed for several improvement alternatives, such as purchase structures, culvert improvements, elevating structures, levees, and upstream detention. The economic effect of the improvement was compared to the "No Action" alternative to determine economic feasibility of the improvement.

Alternative 1 – No Action

Potential flood damages were estimated as part of the damage assessment and improvement option analysis. These figures are based on the damages accrued by flooding structures within the limits of the FCF due to the 10%, 2%, 1%, and 0.2% annual chance of flood frequency storms. The total damages from flooding in the Mallard Creek watershed, if "No Action" was taken, are estimated to be $5,538,700 over the 50-year life of the project (2001 dollars). Each proposed improvement alternative benefit is compared to the damages before the improvement to analyze its economic feasibility.

Alternative 2 – Purchasing Structures

The structures were analyzed as possible buyouts. FEMA justifies property buyout if the B:C ratio is greater than 1.0, or if the estimated structure damages due to flooding exceed 100% of the value of the property (land value and structure value in 2001 dollars). These same structures were also analyzed for possible elevation above the future condition BFE. In all cases, elevating the structure had a far greater B:C ratio than the buyout option, so buyout is not recommended. This is due to the larger expenses associated with property buyouts.

Alternative 3 – Culvert Improvements

The culvert improvements for the Mallard Creek watershed were found to be hydraulically infeasible, and therefore the detailed hydraulic analysis and cost estimates for Alternative 3 were not prepared for this study.

Alternative 4 – Elevating Structures

The structures were analyzed for economic feasibility to avoid flood damages by raising the structures. In the case of elevation, a structure is raised so the first finished floor is 1 foot above the 1% annual chance of future condition water surface elevation. For the purpose of analysis, $3,000 was used as the cost of elevating a mobile home, and $30,000 was used as the present value of the cost of elevating other structure.

Alternative 5 – Concrete Floodwalls

Three floodwalls, A, B, and C, were investigated for economic feasibility along Mallard Creek, while preserving peak flow storage by setting levees back from the edges of the existing banks. The proposed floodwall improvements did not result in any net increase in the Base Flood Elevation.

Alternative 6 – Channel Improvement

Detailed hydraulic analysis and cost estimates for Alternative 6 were not prepared for this study due to the hydraulic infeasibility of this improvement option. This option is also contradictory to Mecklenburg County Creek Use Policy and environmentally detrimental.

Alternative 7 – Upstream Detention

Upstream detention was not considered as a flood mitigation option because of its hydraulic infeasibility.

Problem Area A

In Area A, there is one commercial structure at 9501 David Taylor Road that is flooding in FCF. The depth of BFE of FCF flooding is 4.1 feet. In FIRM, the flooding depth is 1.7 feet.

The analysis in Problem Area A showed two feasible alternatives: purchasing the structure or protecting it with a floodwall. Elevation was not considered because of the structure's large size. The benefits, costs, and B:C ratios for each alternative in Area B are shown in Table 11. The recommended alternative, construction of Floodwall A, has a B:C ratio of 4.9. Floodwall A is located on the left bank of Mallard Creek. It consists of 620 linear feet (LF) of concrete floodwall with a height ranging from 4 to 8 feet. The floodwall is equipped with a pump station. The O&M cost was included in the economic analysis and was estimated to be $5,000 per year.

Table 11
Problem Area A

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$1,507,800	-	-	-
2	Purchasing Structures	-	$1,507,800	$1,875,000	0.1
5*	Floodwall Options	-	$1,507,800	$274,700	4.9

* Recommended Alternative

The recommended improvement alternative was also examined for any adverse impact on the 1% annual chance storm WSE to satisfy the County's no-rise criteria. Table 12 shows comparison of the WSE of the existing and improved conditions. Since there might be unforeseen constraints, such as utility crossings, the proposed improvement was designed with a slightly lower WSE than the existing condition.

Table 12
1% Annual Flood Stages at Area A

	Existing Condition	Improved Condition	Δ h (FT)
X-39,391	614.0	614.0	0.0
X-39,639	614.8	614.8	0.0
X-40,239	615.0	614.8	-0.1

Problem Area B

In Area B, there are seven multi-residential apartment buildings located on Kittansett Drive that are flooding in BFE of FCF. Average depth of FCF flooding is 1.5 feet (with flood depths ranging from 0.1 to 2.7 feet). In FIRM, four apartment buildings have flooded depths greater than 0 feet. Their mean depth of flooding is 0.5 feet (with flood depths ranging from 0.1 to 1.1 feet).

The analysis in Problem Area B showed two feasible alternatives: purchasing structures and protecting structures with Floodwall B. Elevation was not considered because of size constraints. The benefits, costs, and B:C ratios for each alternative in Area B are shown in Table 13. The recommended alternative, Floodwall B, a concrete floodwall with pump station, extends 1,500 LF and protects seven multi-residential structures with lowest finished floor elevations below the BFE of FCF. The O&M cost was included in the economic analysis and was estimated to be $10,000 per year. Channel excavation was also considered to replace flow conveyance removed by the floodwall, resulting in no net increase in the BFE.

Table 13
Problem Area B

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$1,471,500	-	-	-
2	Purchasing Structures	-	$1,471,500	$5,019,900	0.0
5*	Floodwall Options	-	$1,471,500	$685,300	2.1

* Recommended Alternative

The recommended improvement alternative was also examined for any adverse impact on the 1% annual chance storm WSE to satisfy the County's no-rise criteria. Table 14 shows comparison of the WSE of the existing and improved conditions. Since there might be unforeseen constraints, such as utility crossings, the proposed improvement was designed with a slightly lower WSE than the existing condition.

Table 14
1% Annual Flood Stages at Area B

	Existing Condition	Improved Condition	Δ h (FT)
X-34,100	603.7	603.7	0.0
X-34,685	604.4	604.4	0.0
X-35,366	605.5	605.3	-0.2
X-36,040	606.5	606.5	0.0
X-36,755	607.9	607.9	0.0

Problem Area C

In Area C, there is one multi-residential structure at 415 Michelle Linnea Drive that is flooding in FCF. The depth of BFE of FCF flooding is 0.8 feet. The structure is not flooding in FIRM.

The analysis in Problem Area C showed two feasible alternatives: purchasing or protecting the structure with Floodwall C. Elevation was not considered due to the structure's large footprint. The benefits, costs, and B:C ratios for each alternative in Area B are shown in Table 15. Examined Alternative 5, Floodwall C, consists of 620 linear feet (LF) of concrete floodwall with a height ranging from 4 to 8 feet and is equipped with a pump station with estimated O&M cost of $5,000 per year. No action is recommended for this problem area because all alternative B:C ratios are less than 1.0.

Table 15 Problem Area C					
Alternative	**Description**	**Damages**	**Benefits**	**Costs**	**B:C Ratio**
1*	No Action	$87,800	-	-	-
2	Purchasing Structures	-	$87,800	$888,700	0.0
5	Floodwall Options	-	$87,800	$133,700	0.7

* Recommended Alternative

Problem Area D

In Area D, there are four residential manufactured homes located at 101 Perdido Street that are flooding in BFE of FCF. Average depth of FCF flooding is 2.7 feet (with flood depths ranging from 0.8 to 5.6 feet). In FIRM, two homes have flooded depths greater than 0 feet. Their mean depth of flooding is 1.8 feet (with flood depths ranging from 0.7 to 2.9 feet).

The analysis in Problem Area D showed two feasible alternatives: purchasing structures and elevating structures. The benefits, costs, and B:C ratios for the alternatives in Area D are shown in Table 16. Alternative 4, elevation of the structures, is recommended because its B:C ratio is 2.0.

Table 16 Problem Area D					
Alternative	**Description**	**Damages**	**Benefits**	**Costs**	**B:C Ratio**
1	No Action	$262,100	-	-	-
2	Purchasing Structures	-	$262,100	$147,800	1.8
4*	Elevating Structures	$6,600	$255,500	$120,000	2.0

* Recommended Alternative

Problem Area E

Area E represents two single-residential structures located at Circle Drive that are flooding in BFE of FCF. Average depth of FCF flooding is 1.9 feet (with flood depths ranging from 1.6 to 2.1 feet). In FIRM, one house has a flooded depth greater than 0 feet, and that is 0.2 feet.

The analysis in Problem Area E showed two feasible alternatives: purchasing or elevating structures. The benefits, costs, and B:C ratios for alternatives in Area E are shown in Table 17. Elevating structures is recommended because the B:C ratio is 1.0.

Table 17 Problem Area E					
Alternative	**Description**	**Damages**	**Benefits**	**Costs**	**B:C Ratio**
1	No Action	$73,500	-	-	-
2	Purchasing Structures	-	$73,500	$112,400	0.7
4*	Elevating Structures	$7,200	$66,300	$60,000	1.0

* Recommended Alternative

Problem Area F

Area F represents three single-family residential structures located at Dekalb Place that are flooding in BFE of FCF. Average depth of FCF flooding is 1.9 feet (with flood depths ranging from 0.6 to 4.0 feet). In FIRM, one house has a flooded depth greater than 0 feet, and that is 2.3 feet.

The analysis in Problem Area F showed two feasible alternatives: purchasing or elevating structures. The benefits, costs, and B:C ratios for alternatives in Area F are shown in Table 18. While both improvement options have a B:C ratio greater than 1.0, Alternative 4, elevating structures, is recommended because the B:C ratio is higher at 4.8. Some residual damages, $26,000, remain with this improvement option.

Table 18 Problem Area F					
Alternative	**Description**	**Damages**	**Benefits**	**Costs**	**B:C Ratio**
1	No Action	$583,800	-	-	-
2	Purchasing Structures	-	$583,800	$443,900	1.3
4*	Elevating Structures	$26,500	$557,300	$90,000	4.8

* Recommended Alternative

Problem Area G "Not Clustered"

Eight structures were analyzed in Area G "Not Clustered." The structure locations do not permit the usual clustering, because they are scattered throughout the Mallard Creek watershed. Floodwall protection of these properties was not feasible, and therefore not considered.

Two commercial buildings located at 10207 Tryon Street are flooding in BFE of FCF. Average depth of FCF flooding is 3.6 feet (with flood depths of 3.5 and 3.6 feet). In FIRM, both buildings have flooded depths greater than 0 feet. Their mean depth of flooding is 1.1 feet (with flood depths of 1.0 and 1.2 feet). The analysis in this area showed two feasible alternatives: purchasing or elevating structures. The benefits, costs, and B:C ratios for the alternatives are shown in Table 19. Alternative 4, elevating structures, is recommended because the B:C ratio is 4.1.

Table 19 10207 Tryon Street					
Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$300,000	-	-	-
2	Purchasing Structure	-	$300,000	$862,900	0.3
4*	Elevating Structures	$10,200	$289,800	$60,000	4.1

* Recommended Alternative

Two commercial buildings located at 9701 Tryon Street are flooding in BFE of FCF. Average depth of FCF flooding is 2.9 feet (with flood depths of 2.2 and 3.5 feet). In FIRM, two buildings have flooded depths greater than 0 feet. Their mean depth of flooding is 1.5 feet (with flood depths of 0.6 and 2.4 feet). The analysis in this area showed two feasible alternatives: purchasing or elevating structures. The benefits, costs, and B:C ratios for the alternatives are shown in Table 20. Elevating structures is recommended because the B:C ratio is 11.9.

Table 20 9701 Tryon Street					
Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$793,800	-	-	-
2	Purchasing Structure	-	$793,800	$444,900	1.8
4*	Elevating Structures	$6,200	$787,600	$60,000	11.9

* Recommended Alternative

One single-family residential structure located along Clarks 1A Tributary at 7509 Browne Road is flooding in BFE of FCF. The depth of BFE of FCF flooding is 1.7 feet. In FIRM, the flooding depth is 1.0 foot. The analysis in this area showed two feasible alternatives: purchasing or elevating the structure. The benefits, costs, and B:C ratios for the alternatives are shown in Table 21. Although both buyout and elevation are feasible alternatives with B:C ratios greater than 1.0, elevation of the structure is recommended because the B:C ratio is higher at 9.8. Some residual damages of $2,200 remain with this improvement option.

Table 21 7509 Browne Road					
Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$316,900	-	-	-
2	Purchasing Structure	-	$316,900	$202,600	1.6
4*	Elevating Structure	$2,200	$314,700	$30,000	9.8

* Recommended Alternative

One single-family residential structure located along the Mallard Creek Tributary at 4011 Hubbard Road is flooding in BFE of FCF. The depth of BFE of FCF flooding is 0.9 feet. The house is not flooding in FIRM. The analysis in this area showed two feasible alternatives: purchasing or elevating the structure. The benefits, costs, and B:C ratios for the alternatives are shown in Table 22. Elevating the structure is recommended because the B:C ratio is 1.3. A small amount of residual damage, $1,300, is incurred with this alternative.

Table 22
4011 Hubbard Road

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$42,000	-	-	-
2	Purchasing Structure	-	$42,000	$224,200	0.2
4*	Elevating Structure	$1,300	$40,700	$30,000	1.3

* Recommended Alternative

One commercial structure located along Doby Creek at 9234 David Taylor Drive is flooding in BFE of FCF. The depth of BFE of FCF flooding is 5.2 feet. The structure is not flooding in FIRM. The analysis in this area showed two feasible alternatives: purchasing or elevating the structure. The benefits, costs, and B:C ratios for the alternatives are shown in Table 23. Elevating the structure is recommended because the B:C ratio is 2.9.

Table 23
9234 David Taylor Drive

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1	No Action	$99,500	-	-	-
2	Purchasing Structure	-	$99,500	$734,900	0.1
4*	Elevating Structure	$3,200	$96,300	$30,000	2.9

* Recommended Alternative

The basement of one single-family residential structure located along Clark Creek at 2700 Oldenway Drive is flooding in BFE of FCF. The first floor is not flooding in FCF or FIRM. The analysis of this structure showed one possible improvement alternative: purchasing the structure. The benefits, costs, and B:C ratio for the alternative is shown in Table 24. No action is recommended for this problem area because the B:C ratio is less than 1.0. This structure is not included in the total count of structures with finished floor inundated in FCF storm event.

Table 24
2700 Oldenway Drive

Alternative	Description	Damages	Benefits	Costs	B:C Ratio
1*	No Action	$68	-	-	-
2	Purchasing Structure	-	$68	$283,100	0.0

* Recommended Alternative

4. CONCLUSIONS AND RECOMMENDATIONS

While 86 structures are within the FCF boundaries along Mallard Creek and its major tributaries, flooding problems are mostly along Mallard Creek. The primary flood damage areas in the Mallard Creek watershed are along Mallard Creek (22 structures), with single structures on Doby Creek, Mallard Tributary, and Clarks Creek No. 1A Tributary. No structures flood along Clarks Creek, Toby Creek, Stoney Creek, or its tributary. Of the 25 structures with finished floor inundated in FCF storm event, 19 are residential land use and six are commercial structures.

Several alternatives were considered to resolve flooding damage and bank stability problems in the Mallard Creek watershed. Based on the flood damage assessment and B:C analysis, the recommended improvements for the Mallard Creek watershed include a combination of floodwalls, elevating structures, property buyouts, and leaving some flooded structures unprotected (Figure 20). The total estimated cost for these improvements is $1,440,000.

Along Mallard Creek, a total of 22 structures have first finished floors below the water surface elevation of a 1% annual chance storm event. Of these 22 structures, eight can be protected by floodwalls and 13 are recommended for elevation. One multi-residential structure along Mallard Creek is recommended for No Action. One flooding structure along Mallard Tributary is recommended for elevation. The individual flooding structures along Clarks Creek Tributary No. 1A and Doby Creek are also recommended for elevation. Note that the recommended improvement alternatives are subject to change due to unforeseen hardships such as utility or construction conflicts.

The recommendations include further exploration of bank stabilization and/or stream restoration needs within the Mallard Creek watershed. Note that channels were only observed from road crossing vantage points, and further investigation is necessary to prioritize stream bank and channel repairs. Observed bank stabilization problems were identified on Mallard Creek and all its major tributaries. Surveys of the worst bank erosion sites are recommended to determine the rate at which erosion is occurring and to help prioritize future bank restoration projects in the watershed. Engineers should review the erosion occurring on Clarks Creek Tributary No. 1 at Hucks Road because of stability issues concerning a utility pole.

During field visits, little aquatic wildlife was observed in Mallard Creek and its major tributaries. According to the Mecklenburg County Department of Environmental Protection (MCDEP), from 1994 to 1998 overall water quality remained fairly consistent in the Mallard Creek watershed. Review of ambient water quality data dating back to 1968 does not reveal significant trends in most of the data over time or by location along the creeks. Current Water Quality Index values indicate an average of "Good" water quality for Mallard Creek, with the best water quality, "Good-Excellent," in Clarks Creek. The Water Quality Index indicates water quality conditions better than the fish and macroinvertebrate communities. The aquatic fauna communities throughout the watershed have consistently ranked "Poor" and "Fair," while fish sampling ranked "Fair" and "Good," which results in a less than desirable diversity of species. This may indicate that aquatic habitat conditions limit these communities to some extent. While aquatic life is present in the creeks, the sand and silt benthic material (with little instream features such as boulders and woody debris) does not provide a protective habitat, and bottom dwelling communities are not as abundant and diverse as may be desired. Actions such as bank stabilization and stream restoration may improve aquatic habitat conditions and, in turn, improve aquatic community health and diversity.

Finally, the 1999 Mecklenburg County Greenway Master Plan recommends that the greenway system be expanded as a floodplain management buffer and water quality program to include all creeks and streams throughout the County. In the Mallard Creek watershed, 3.6 miles of greenway currently exist along Mallard Creek and Clarks Creek. This greenway connects to the University Research Park Trail, with future plans to extend the greenway along Mallard Creek to the Cabarrus County line. These plans would include access from UNCC and the Mallard Creek Recreation Area. Future plans also include extending the Clarks Creek greenway and adding a greenway along Toby Creek. Property buyout expenses may be shared between MCSWS, Mecklenburg County Park and Recreation Commission (MCPRC), or other County departments should this study area be included in future greenway development. HDR recommends that the MCSWS coordinate with MCPRC and UNCC as plans for the Mecklenburg County greenway system in this watershed continue to develop.

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Figure 20 Study No. 2, Mallard Creek Watershed Proposed Improvements, Sheet 1

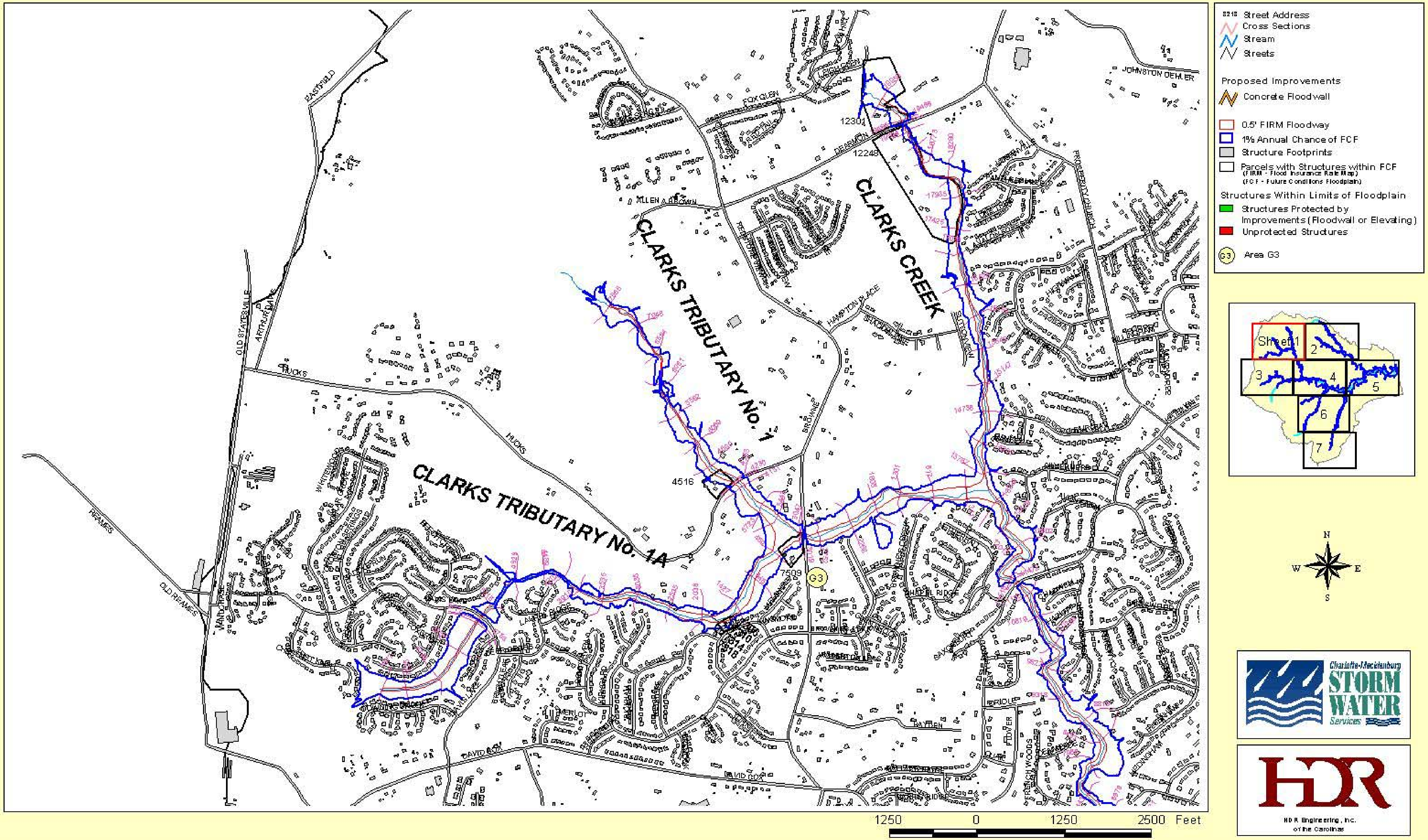


Figure 20 Study No. 2, Mallard Creek Watershed Proposed Improvements, Sheet 2

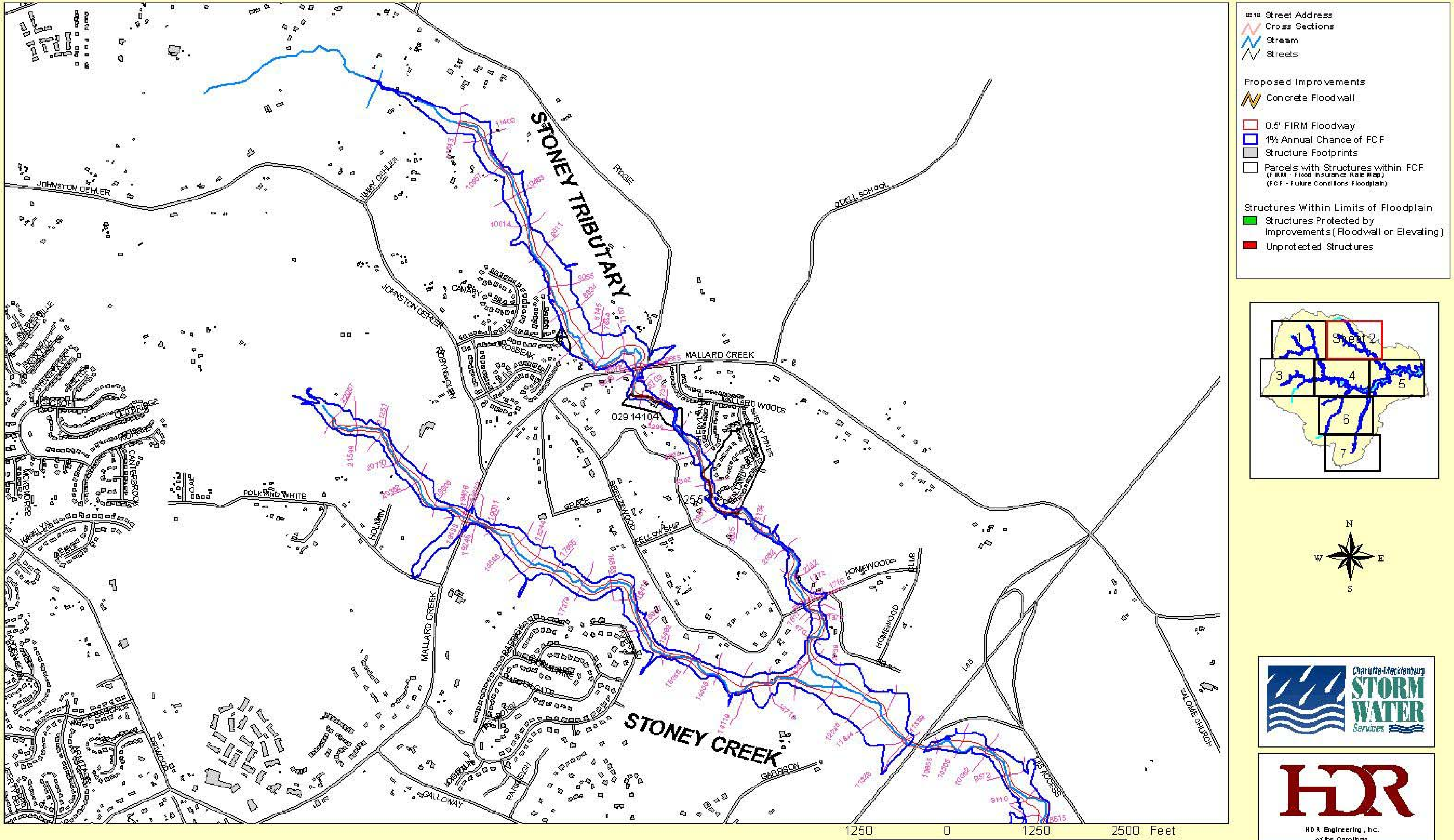


Figure 20 Study No. 2, Mallard Creek Watershed Proposed Improvements, Sheet 3

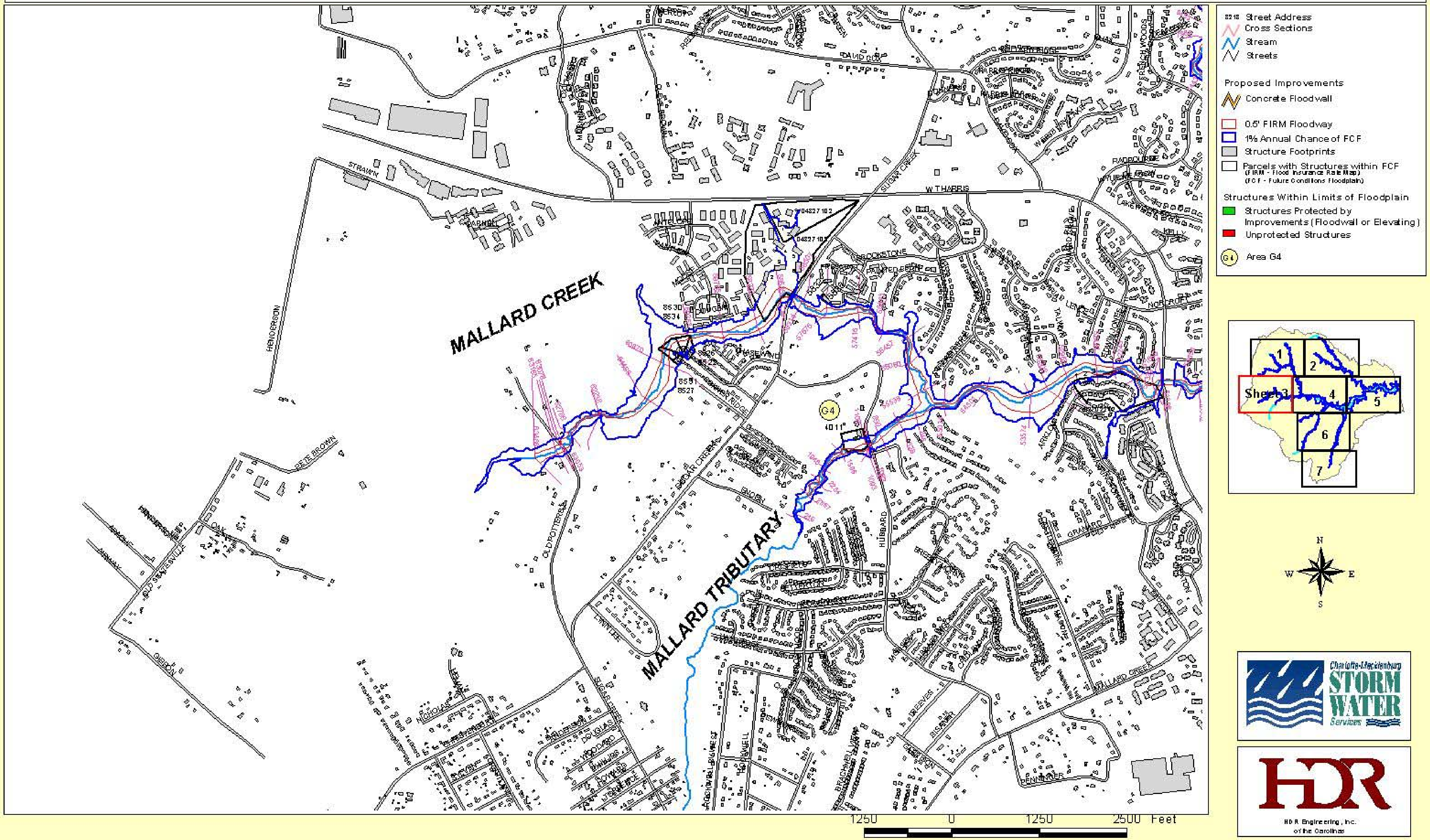


Figure 20 Study No. 2, Mallard Creek Watershed Proposed Improvements, Sheet 4

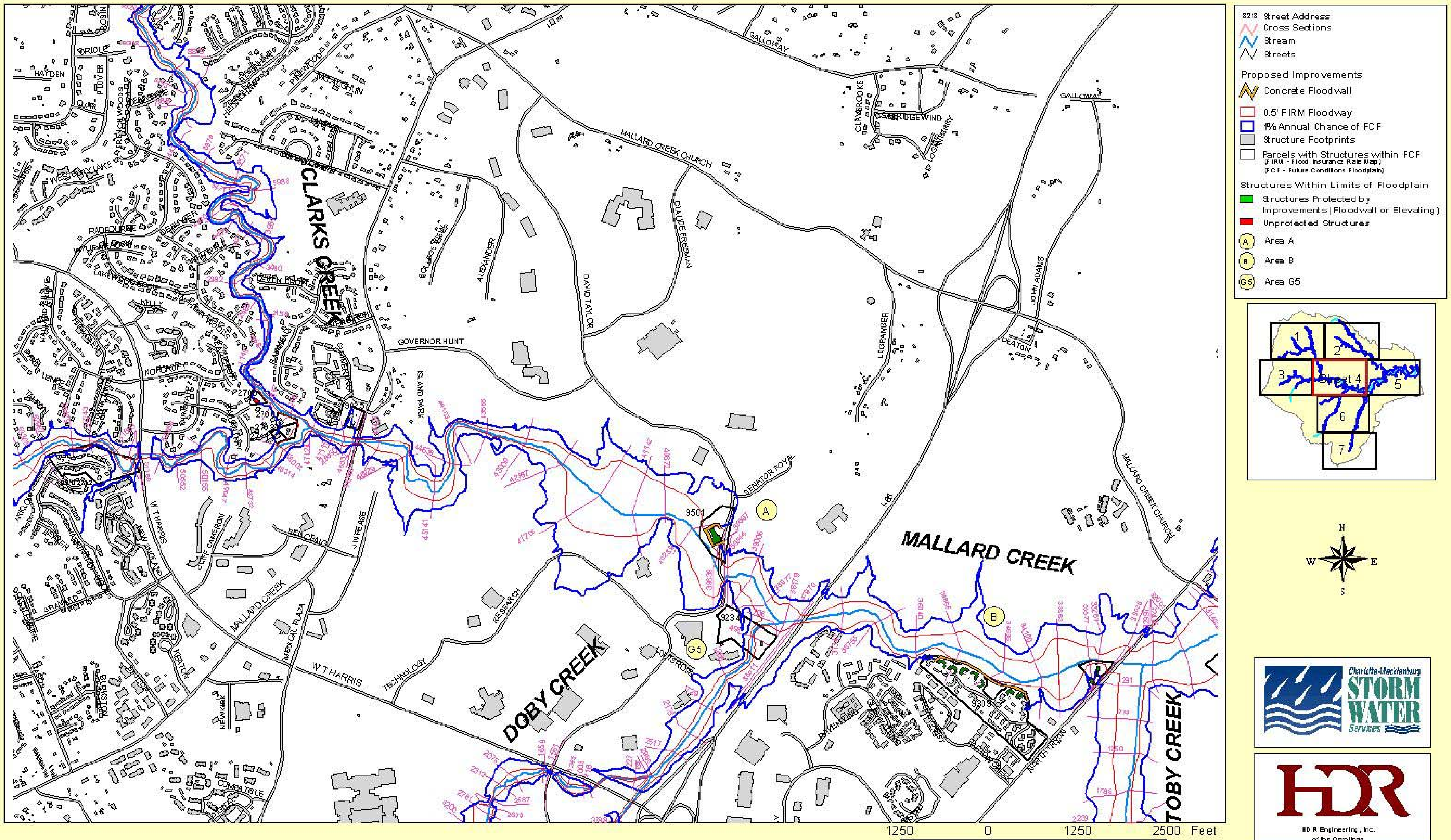


Figure 20 Study No. 2, Mallard Creek Watershed Proposed Improvements, Sheet 5

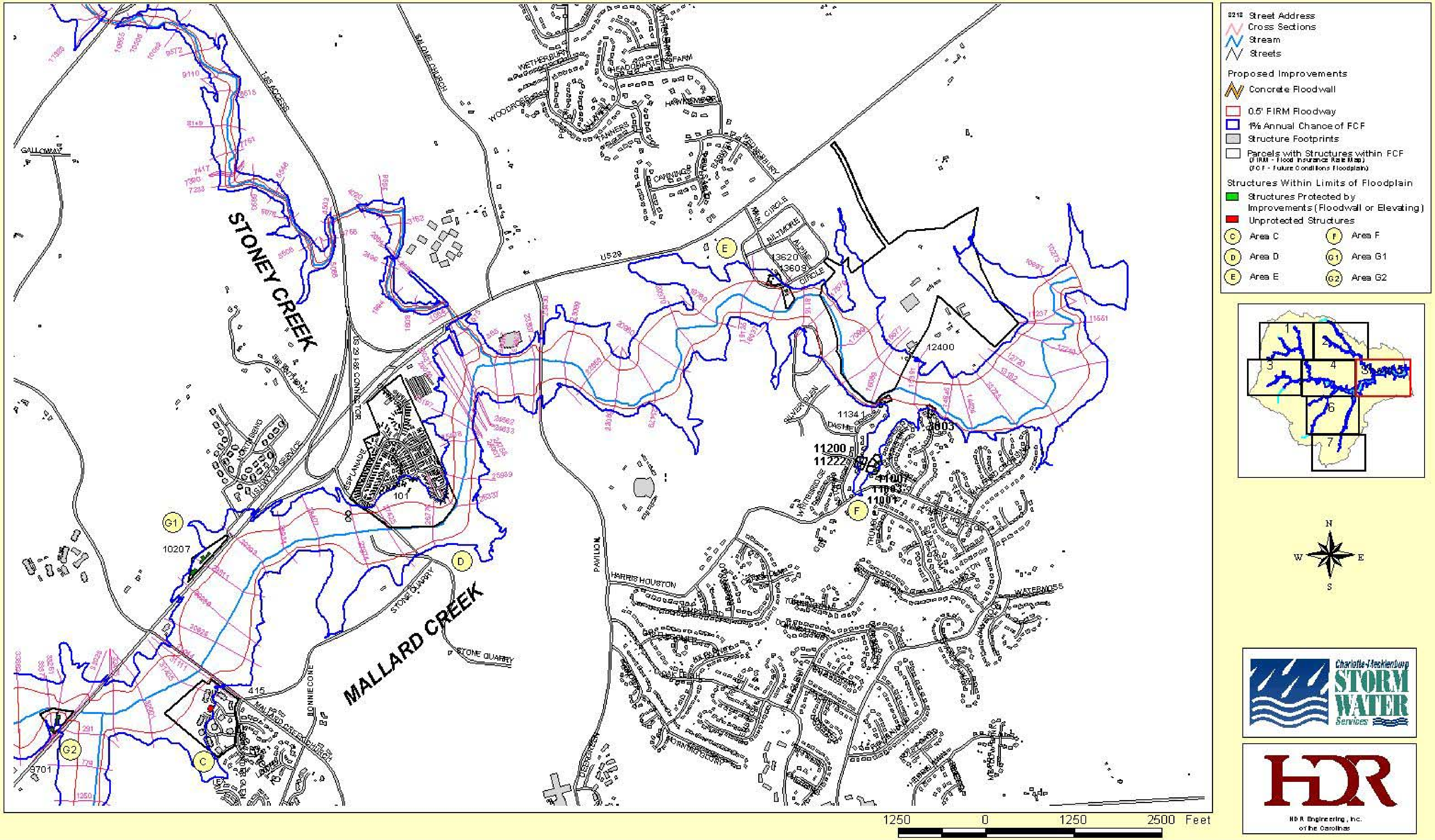


Figure 20 Study No. 2, Mallard Creek Watershed Proposed Improvements, Sheet 6

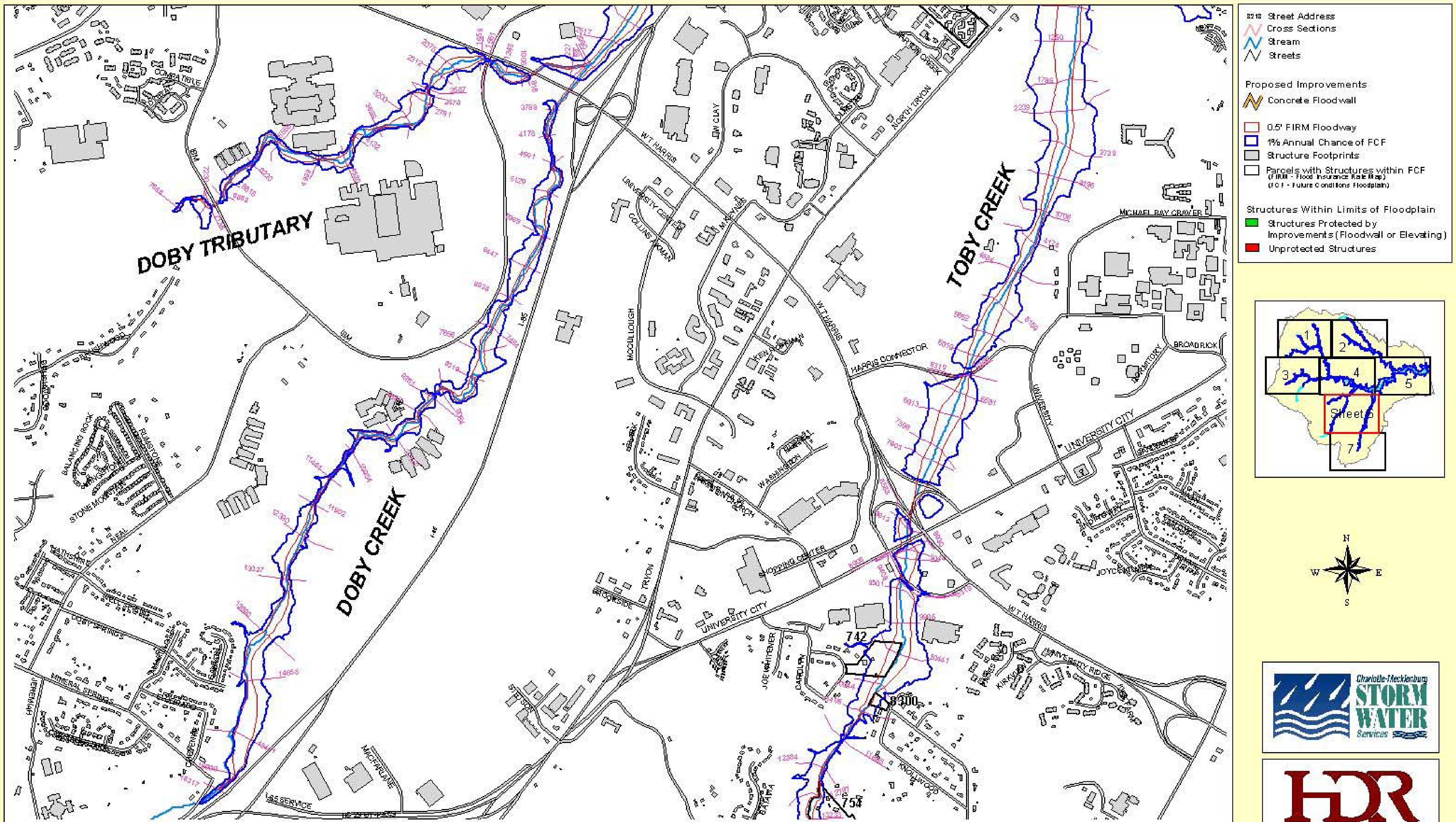
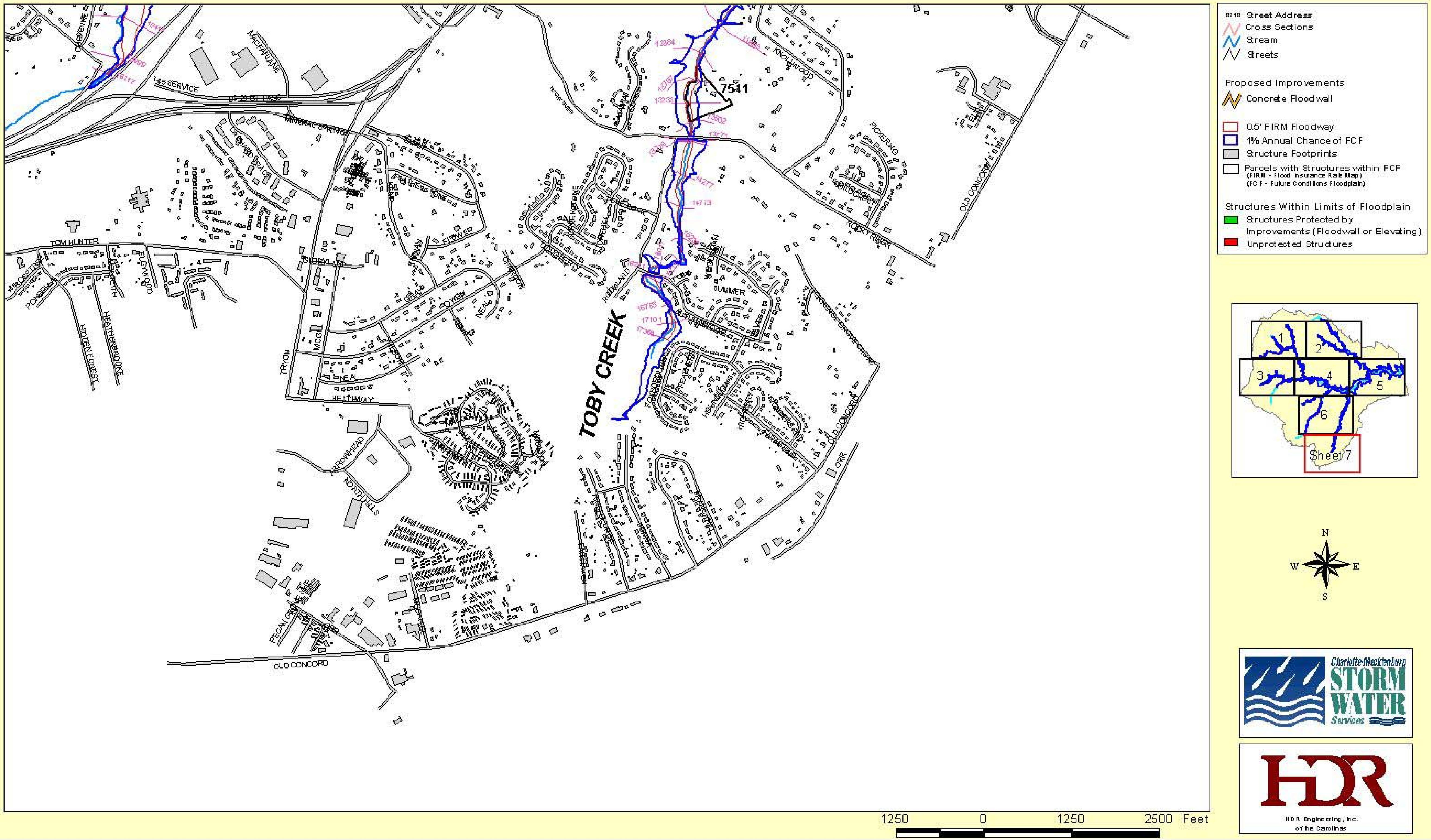


Figure 20 Study No. 2, Mallard Creek Watershed Proposed Improvements, Sheet 7



APPENDIX A

TABLE A-1

Watershed Study No. 2
Mallard Creek Watershed
Alternative Benefit: Cost Evaluation
(Present value in 2001 dollars)

PROBLEM AREAS		BENEFIT	COST					
ID	Description	Benefit[1] in $1,000	Improvement Cost[2] in $1,000	O&M[3] in $1,000	Residual Damage in $1,000	Property Buyout in $1,000	Tota l Cost in $1,000	B:C Ratio
A	Floodwall A (1[4])	1,508	190	85	-	-	275	5.5
B	Floodwall B (7)	1,472	516	169	-	-	685	2.1
C	No Action[5] (1)	-	-	-	88	-	88	-
D	Elevate Structures (4)	256	120	-	7	-	127	2.0
E	Elevate Structures (2)	66	60	-	7	-	67	1.0
F	Elevate Structures (3)	557	90	-	26	-	116	4.8
G1	Elevate Structures (2)	290	60	-	10	-	70	4.1
G2	Elevate Structures (2)	788	60	-	6	-	66	11.9
G3	Elevate Structure (1)	315	30	-	2	-	32	9.8
G4	Elevate Structure (1)	41	30	-	1	-	31	1.3
G5	Elevate Structure (1)	96	30	-	3	-	33	2.9

[1] Benefit is defined as the total damage **removed** by the improvement.
[2] Improvement Cost is defined as the construction cost of the improvement.
[3] O&M Costs are the operating and maintenance costs associated with the proposed improvement.
[4] Number of structures included in problem area improvement analysis.
[5] No Action is recommended for Problem Area C

Floodwall	Description (see Figures E-7 and E-8 for locations)
A	Concrete floodwall on left bank of Mallard Creek with one pump station.
B	Concrete floodwall on right bank of Mallard Creek with one pump station.
D, E, F, G1,G2	Elevating structures located on Mallard Creek.
G3	Elevating structures located on Clark 1A Tributary.
G4	Elevating structures located on Mallard Tributary.
G5	Elevating structures located on Doby Creek.

The floodwalls and berm construction costs include pump stations, standby generator, and contingencies. No utility relocations were considered in the analysis.

Table A-2

Watershed Study No. 2
Mallard Creek Watershed
Flooding Structures Summary

Count	Parcel ID	Stream	Address	Land Use Type[1]	HEC-RAS Station	Finished Floor Elevation	FCF 1% Annual Chance of Flood Elevation	FCF Flood Depth[2] (ft)	FIRM 1% Annual Chance of Flood Elevation	FIRM Flood Depth[2] (ft)	Problem Location ID
1	04735106	Mallard	9501 DAVID TAYLOR DR	C	39777	611.0	615.1	4.1	612.74	1.7	A
2	04719114-1	Mallard	9309 KITTANSETT DR	R	35528	605.7	605.8	0.1	604.0	-1.7	B
3	04719114-2	Mallard	9309 KITTANSETT DR	R	35366	605.2	605.5	0.3	603.8	-1.4	B
4	04719114-3	Mallard	9309 KITTANSETT DR	R	35218	603.2	605.2	2.0	603.5	0.3	B
5	04719114-4	Mallard	9309 KITTANSETT DR	R	35026	602.2	604.9	2.7	603.3	1.1	B
6	04719114-5	Mallard	9309 KITTANSETT DR	R	34685	602.2	604.4	2.2	602.7	0.5	B
7	04719114-6	Mallard	9309 KITTANSETT DR	R	34494	602.4	604.2	1.8	602.5	0.1	B
8	04719114-7	Mallard	9309 KITTANSETT DR	R	34397	602.4	604.1	1.7	602.4	0.0	B
9	04719110-2	Mallard	9701 TRYON ST	C	33377	601.1	603.3	2.2	601.7	0.6	G
10	04719110-1	Mallard	9701 TRYON ST	C	33261	598.1	601.6	3.5	600.5	2.4	G
11	04938201-2	Mallard	415 MICHELLE LINNEA DR	R	31479	600.0	600.8	0.8	598.6	-1.4	C
12	02903121-1	Mallard	10207 TRYON ST	C	29800	596.7	600.3	3.6	597.9	1.2	G
13	02903121-2	Mallard	10207 TRYON ST	C	29745	596.8	600.3	3.5	597.8	1.0	G
14	05103305-2	Mallard	101 PERDIDO ST	R	27172	597.7	598.6	0.9	595.9	-1.8	D
15	05103305-3	Mallard	101 PERDIDO ST	R	27158	595.2	598.6	3.4	595.9	0.7	D
16	05103305-1	Mallard	101 PERDIDO ST	R	27120	597.8	598.6	0.8	595.9	-1.9	D
17	05103305-4	Mallard	101 PERDIDO ST	R	27120	593.0	598.6	5.6	595.9	2.9	D
18	05108355	Mallard	13620 CIRCLE DR	R	18843	585.5	587.6	2.1	585.7	0.2	E
19	05108207	Mallard	13609 CIRCLE DR	R	18581	585.5	587.1	1.6	585.3	-0.2	E
20	05130112	Mallard	11007 DEKALB PL	R	15496	581.7	582.7	1.0	581.0	-0.7	F
21	05130111	Mallard	11003 DEKALB PL	R	15496	582.1	582.7	0.6	581.0	-1.1	F
22	05130110	Mallard	11001 DEKALB PL	R	15496	578.7	582.7	4.0	581.0	2.3	F
23	04316202	Mallard Tributary	4011 HUBBARD RD	R	1251	679.4	680.3	0.9	678.9	-0.5	G
24	02715306	Clark 1A	7509 BROWNE RD	R	356	724.9	726.6	1.7	725.9	1.0	G
25	04714117	Doby	9234 DAVID TAYLOR DR	C	520	608.4	613.6	5.2	602.8	-5.6	G

[1]Land Use Type R is Residential. Land Use Type C is Commercial.
[2]Shading indicates all flooding depths over 4 feet.

Table A-3

Watershed Study No. 2
Mallard Creek Watershed
Repetitive Loss Database

Count	RL Number	Community Number	Date of Loss	Address	City	State	ZIP Code	Pay Building	Pay Cont
1	5276	370158	19901023	5042 SENTINEL POST RD	CHARLOTTE	NC	282267447	$5,870	$0
2	5276	370158	19940818	5042 SENTINEL POST RD	CHARLOTTE	NC	282267447	$5,643	$0
3	5276	370158	19950827	5042 SENTINEL POST RD	CHARLOTTE	NC	282267447	$108,426	$10,870
4	5276	370158	19790323	5042 SENTINEL POST RD	CHARLOTTE	NC	282267447	$3,504	$0
5	5276	370158	19820610	5042 SENTINEL POST RD	CHARLOTTE	NC	282267447	$5,101	$0
6	9041	370159	19850515	511 QUEENS RD	CHARLOTTE	NC	282071423	$8,020	$0
7	9041	370159	19851121	511 QUEENS RD	CHARLOTTE	NC	282071423	$15,320	$1,235
8	9041	370159	19870228	511 QUEENS RD	CHARLOTTE	NC	282071423	$10,953	$0
9	9075	370159	19920617	3404 COMMONWEALTH AVE	CHARLOTTE	NC	282056229	$6,018	$0
10	9075	370159	19930323	3404 COMMONWEALTH AVE	CHARLOTTE	NC	282056229	$6,363	$0
11	9394	370159	19901011	3008 HARBINGER CT	CHARLOTTE	NC	282053849	$1,741	$0
12	9394	370159	19930323	3008 HARBINGER CT	CHARLOTTE	NC	282053849	$3,241	$0
13	9394	370159	19950827	3008 HARBINGER CT	CHARLOTTE	NC	282053849	$4,063	$0
14	18140	370159	19940816	5952 SHARON VIEW RD	CHARLOTTE	NC	282266846	$1,833	$0
15	18140	370159	19950828	5952 SHARON VIEW RD	CHARLOTTE	NC	282266846	$22,962	$14,100
16	18140	370159	19950828	5952 SHARON VIEW RD	CHARLOTTE	NC	282266846	$1,588	$5,300
17	18140	370159	19790323	5952 SHARON VIEW RD	CHARLOTTE	NC	282266846	$5,649	$5,000
18	18140	370159	19820610	5952 SHARON VIEW RD	CHARLOTTE	NC	282266846	$17,703	$8,834
19	18140	370159	19831206	5952 SHARON VIEW RD	CHARLOTTE	NC	282266846	$1,794	$0
20	18140	370159	19790323	5952 SHARON VIEW RD	CHARLOTTE	NC	282266846	$0	$1,000
21	18140	370159	19820610	5952 SHARON VIEW RD	CHARLOTTE	NC	282266846	$340	$2,410
22	18150	370159	19790929	700 KENILWORTH AVE	CHARLOTTE	NC	282042829	$0	$25,000
23	18150	370159	19820610	700 KENILWORTH AVE	CHARLOTTE	NC	282042829	$0	$78,800
24	26970	370159	19820610	2718 CHILTON PL	CHARLOTTE	NC	282072656	$0	$1,387
25	26970	370159	19850515	2718 CHILTON PL	CHARLOTTE	NC	282072656	$1,765	$3,563
26	26970	370159	19850607	2718 CHILTON PL	CHARLOTTE	NC	282072656	$0	$1,903
27	26970	370159	19850817	2718 CHILTON PL	CHARLOTTE	NC	282072656	$2,277	$1,545
28	26970	370159	19950827	2718 CHILTON PL	CHARLOTTE	NC	282072656	$7,700	$6,800
29	26980	370159	19901012	4601 PERTH CT	CHARLOTTE	NC	282153324	$2,418	$0
30	26980	370159	19910111	4601 PERTH CT	CHARLOTTE	NC	282153324	$1,220	$0
31	26981	370159	19901012	4619 PERTH CT	CHARLOTTE	NC	282153355	$3,908	$0
32	26981	370159	19910111	4619 PERTH CT	CHARLOTTE	NC	282153355	$2,290	$0
33	26982	370159	19820610	2009 MILTON RD	CHARLOTTE	NC	282152467	$3,418	$0
34	26982	370159	19850817	2009 MILTON RD	CHARLOTTE	NC	282152467	$1,723	$0
35	26982	370159	19890924	2009 MILTON RD	CHARLOTTE	NC	282152467	$9,135	$0
36	26982	370159	19901012	2009 MILTON RD	CHARLOTTE	NC	282152467	$7,153	$0
37	26982	370159	19910111	2009 MILTON RD	CHARLOTTE	NC	282152467	$9,094	$0
38	26983	370159	19820610	4528 PERTH CT	CHARLOTTE	NC	282153323	$8,035	$0
39	26983	370159	19890924	4528 PERTH CT	CHARLOTTE	NC	282153323	$4,280	$0
40	26983	370159	19901012	4528 PERTH CT	CHARLOTTE	NC	282153323	$1,908	$0

Table A-3 (Continued)

Watershed Study No. 2
Mallard Creek Watershed
Repetitive Loss Database

Count	RL Number	Community Number	Date of Loss	Address	City	State	ZIP Code	Pay Building	Pay Cont
41	26983	370159	19910111	4528 PERTH CT	CHARLOTTE	NC	282153323	$2,445	$0
42	26984	370159	19890924	4512 PERTH CT	CHARLOTTE	NC	282153323	$2,491	$0
43	26984	370159	19901012	4512 PERTH CT	CHARLOTTE	NC	282153323	$1,908	$0
44	26984	370159	19910111	4512 PERTH CT	CHARLOTTE	NC	282153323	$1,580	$0
45	26985	370159	19780622	4539 PERTH CT	CHARLOTTE	NC	282153322	$4,138	$0
46	26985	370159	19820610	4539 PERTH CT	CHARLOTTE	NC	282153322	$5,214	$0
47	26985	370159	19890924	4539 PERTH CT	CHARLOTTE	NC	282153322	$9,296	$0
48	26985	370159	19901012	4539 PERTH CT	CHARLOTTE	NC	282153322	$5,320	$0
49	26986	370159	19890924	4532 PERTH CT	CHARLOTTE	NC	282153323	$3,394	$0
50	26986	370159	19901012	4532 PERTH CT	CHARLOTTE	NC	282153323	$2,418	$0
51	26986	370159	19910111	4532 PERTH CT	CHARLOTTE	NC	282153323	$2,200	$0
52	26987	370159	19780622	4520 PERTH CT	CHARLOTTE	NC	282153337	$10,284	$0
53	26987	370159	19820610	4520 PERTH CT	CHARLOTTE	NC	282153337	$17,939	$0
54	26987	370159	19840329	4520 PERTH CT	CHARLOTTE	NC	282153337	$1,718	$0
55	26987	370159	19850817	4520 PERTH CT	CHARLOTTE	NC	282153337	$1,550	$0
56	26987	370159	19890924	4520 PERTH CT	CHARLOTTE	NC	282153337	$8,983	$0
57	26987	370159	19901012	4520 PERTH CT	CHARLOTTE	NC	282153337	$6,819	$0
58	26987	370159	19910111	4520 PERTH CT	CHARLOTTE	NC	282153337	$2,923	$0
59	26988	370159	19890924	4536 PERTH CT	CHARLOTTE	NC	282153340	$3,765	$0
60	26988	370159	19901012	4536 PERTH CT	CHARLOTTE	NC	282153340	$2,967	$0
61	26988	370159	19910111	4536 PERTH CT	CHARLOTTE	NC	282153340	$1,590	$0
62	27024	370159	19800215	816 NORWOOD DR	CHARLOTTE	NC	282083426	$1,826	$0
63	27024	370159	19820610	816 NORWOOD DR	CHARLOTTE	NC	282083426	$2,807	$0
64	36823	370159	19790415	1308 BRAEBURN RD	CHARLOTTE	NC	282114771	$1,708	$0
65	36823	370159	19790905	1308 BRAEBURN RD	CHARLOTTE	NC	282114771	$5,004	$0
66	44825	370159	19820610	500 OLD BELL RD	MATTHEWS	NC	28105	$1,002	$1,663
67	44825	370159	19901022	500 OLD BELL RD	MATTHEWS	NC	28105	$1,208	$2,212
68	48372	370159	19950827	4039 ABINGDON RD	CHARLOTTE	NC	282113822	$18,058	$6,841
69	48372	370159	19820610	4039 ABINGDON RD	CHARLOTTE	NC	282113822	$7,497	$1,978
70	48372	370159	19890922	4039 ABINGDON RD	CHARLOTTE	NC	282113822	$3,713	$0
71	50775	370159	19810906	1242 ROMANY RD	CHARLOTTE	NC		$1,265	$0
72	50775	370159	19820610	1242 ROMANY RD	CHARLOTTE	NC		$3,347	$0
73	52592	370159	19891001	3801 COUNTRY CLUB DR	CHARLOTTE	NC	282053213	$6,618	$220
74	52592	370159	19901011	3801 COUNTRY CLUB DR	CHARLOTTE	NC	282053213	$2,427	$310
75	52592	370159	19940801	3801 COUNTRY CLUB DR	CHARLOTTE	NC	282053213	$23,770	$4,738
76	52592	370159	19950826	3801 COUNTRY CLUB DR	CHARLOTTE	NC	282053213	$11,187	$4,702
77	53919	370158	19850607	608 KENLOUGH DR	CHARLOTTE	NC	282092853	$1,013	$0
78	53919	370158	19870618	608 KENLOUGH DR	CHARLOTTE	NC	282092853	$652	$680
79	53919	370158	19940719	608 KENLOUGH DR	CHARLOTTE	NC	282092853	$4,130	$2,493
80	56878	370159	19870910	217 WELLINGFORD ST	CHARLOTTE	NC	282136635	$3,744	$0

Table A-3 (Continued)

Watershed Study No. 2
Mallard Creek Watershed
Repetitive Loss Database

Count	RL Number	Community Number	Date of Loss	Address	City	State	ZIP Code	Pay Building	Pay Cont
81	56878	370159	19820610	217 WELLINGFORD ST	CHARLOTTE	NC	282136635	$7,346	$0
82	56878	370159	19901012	217 WELLINGFORD ST	CHARLOTTE	NC	282136635	$3,500	$0
83	56878	370159	19910329	217 WELLINGFORD ST	CHARLOTTE	NC	282136635	$3,154	$0
84	56878	370159	19950828	217 WELLINGFORD ST	CHARLOTTE	NC	282136635	$10,532	$0
85	64458	370159	19820714	227 CHILLINGWORTH LN	CHARLOTTE	NC	282113007	$1,849	$0
86	64458	370159	19920616	227 CHILLINGWORTH LN	CHARLOTTE	NC	282113007	$13,132	$1,175
87	64458	370159	19950827	227 CHILLINGWORTH LN	CHARLOTTE	NC	282113007	$4,865	$0
88	64459	370159	19890922	2422 CLOISTER DR	CHARLOTTE	NC	282113914	$2,587	$250
89	64459	370159	19820610	2422 CLOISTER DR	CHARLOTTE	NC	282113914	$3,550	$2,900
90	64460	370159	19901010	5129 DOLPHIN LN	CHARLOTTE	NC	282153101	$7,729	$600
91	64460	370159	19930324	5129 DOLPHIN LN	CHARLOTTE	NC	282153101	$2,014	$0
92	64461	370159	19820610	400 ALLENDALE PL	CHARLOTTE	NC	282114103	$4,848	$2,726
93	64461	370159	19920615	400 ALLENDALE PL	CHARLOTTE	NC	282114103	$4,777	$0
94	64461	370159	19940818	400 ALLENDALE PL	CHARLOTTE	NC	282114103	$2,796	$0
95	70400	370159	19930313	2009 MILTON RD	CHARLOTTE	NC	282152467	$1,755	$0
96	70400	370159	19940729	2009 MILTON RD	CHARLOTTE	NC	282152467	$2,130	$0
97	70400	370159	19950827	2009 MILTON RD	CHARLOTTE	NC	282152467	$2,270	$0
98	70401	370159	19930313	4539 PERTH CT	CHARLOTTE	NC	282153322	$1,335	$0
99	70401	370159	19940729	4539 PERTH CT	CHARLOTTE	NC	282153322	$1,726	$0
100	70402	370159	19930313	4520 PERTH CT	CHARLOTTE	NC	282153337	$1,130	$0
101	70402	370159	19940729	4520 PERTH CT	CHARLOTTE	NC	282153337	$1,928	$0
102	70402	370159	19950827	4520 PERTH CT	CHARLOTTE	NC	282153337	$2,290	$0
103	73978	370159	19890922	5130 DOLPHIN LN	CHARLOTTE	NC	282153102	$3,355	$0
104	73978	370159	19950828	5130 DOLPHIN LN	CHARLOTTE	NC	282153102	$41,518	$0
105	74906	370159	19890922	5331 DOLPHIN LN	CHARLOTTE	NC	282152205	$1,242	$0
106	74906	370159	19950827	5331 DOLPHIN LN	CHARLOTTE	NC	282152205	$3,337	$0
107	77727	370159	19930323	1100 WILHAVEN DR	CHARLOTTE	NC	282114062	$1,128	$0
108	77727	370159	19950826	1100 WILHAVEN DR	CHARLOTTE	NC	282114062	$7,992	$0
109	80103	370159	19901212	5515 RUTH DR	CHARLOTTE	NC	282152227	$3,394	$0
110	80103	370159	19950827	5515 RUTH DR	CHARLOTTE	NC	282152227	$4,564	$0
111	87688	370159	19891001	3032 HANSON DR	CHARLOTTE	NC	282072620	$1,105	$0
112	87688	370159	19950827	3032 HANSON DR	CHARLOTTE	NC	282072620	$44,189	$0
113	87689	370159	19920615	2500 CLOISTER DR	CHARLOTTE	NC	282113916	$4,582	$0
114	87689	370159	19950827	2500 CLOISTER DR	CHARLOTTE	NC	282113916	$2,624	$0

Figure A-1 Study No. 2, Mallard Creek Watershed Existing Conditions, Sheet 1

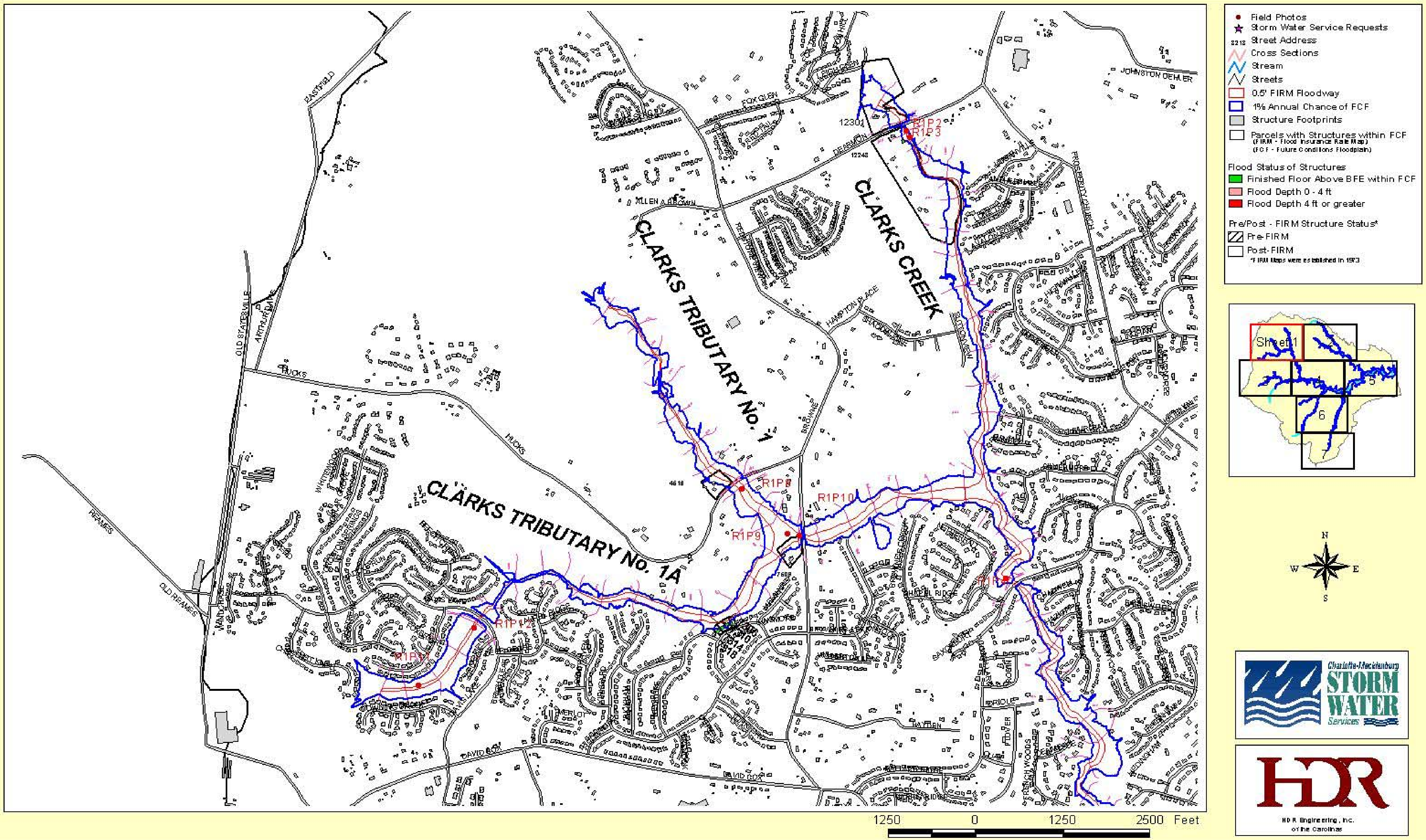


Figure A-1 Study No. 2, Mallard Creek Watershed Existing Conditions, Sheet 2

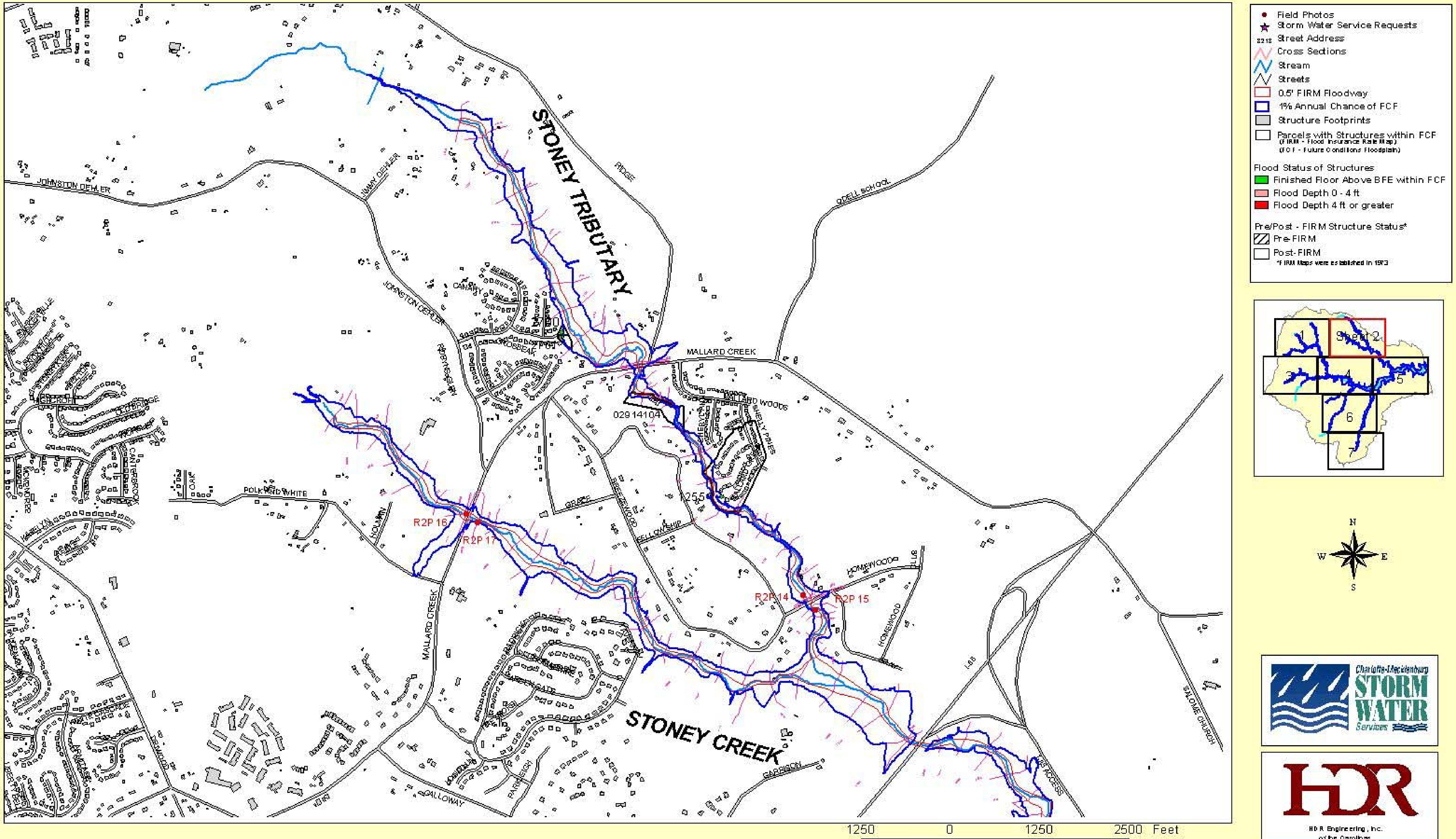


Figure A-1 Study No. 2, Mallard Creek Watershed Existing Conditions, Sheet 3

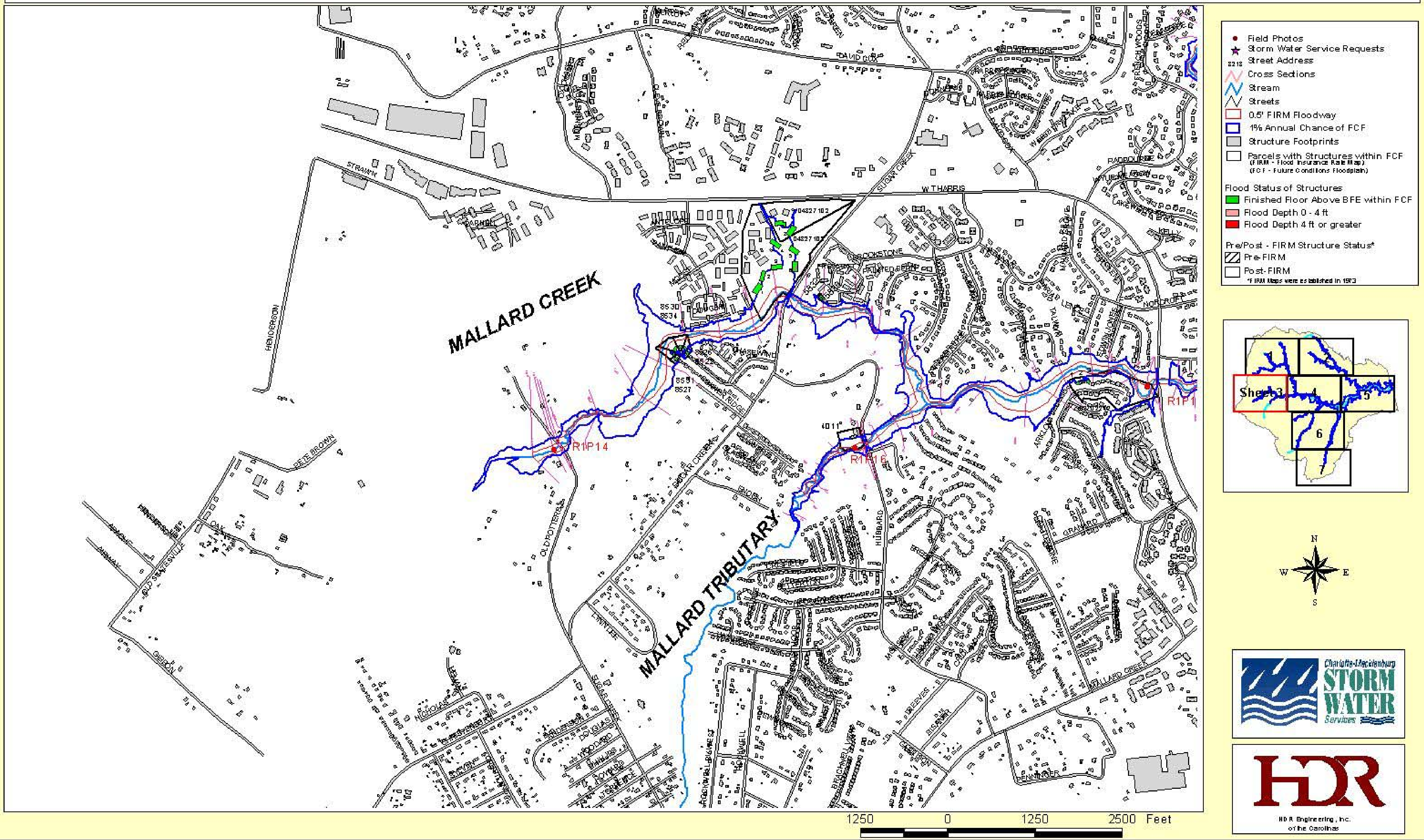


Figure A-1 Study No. 2, Mallard Creek Watershed Existing Conditions, Sheet 4

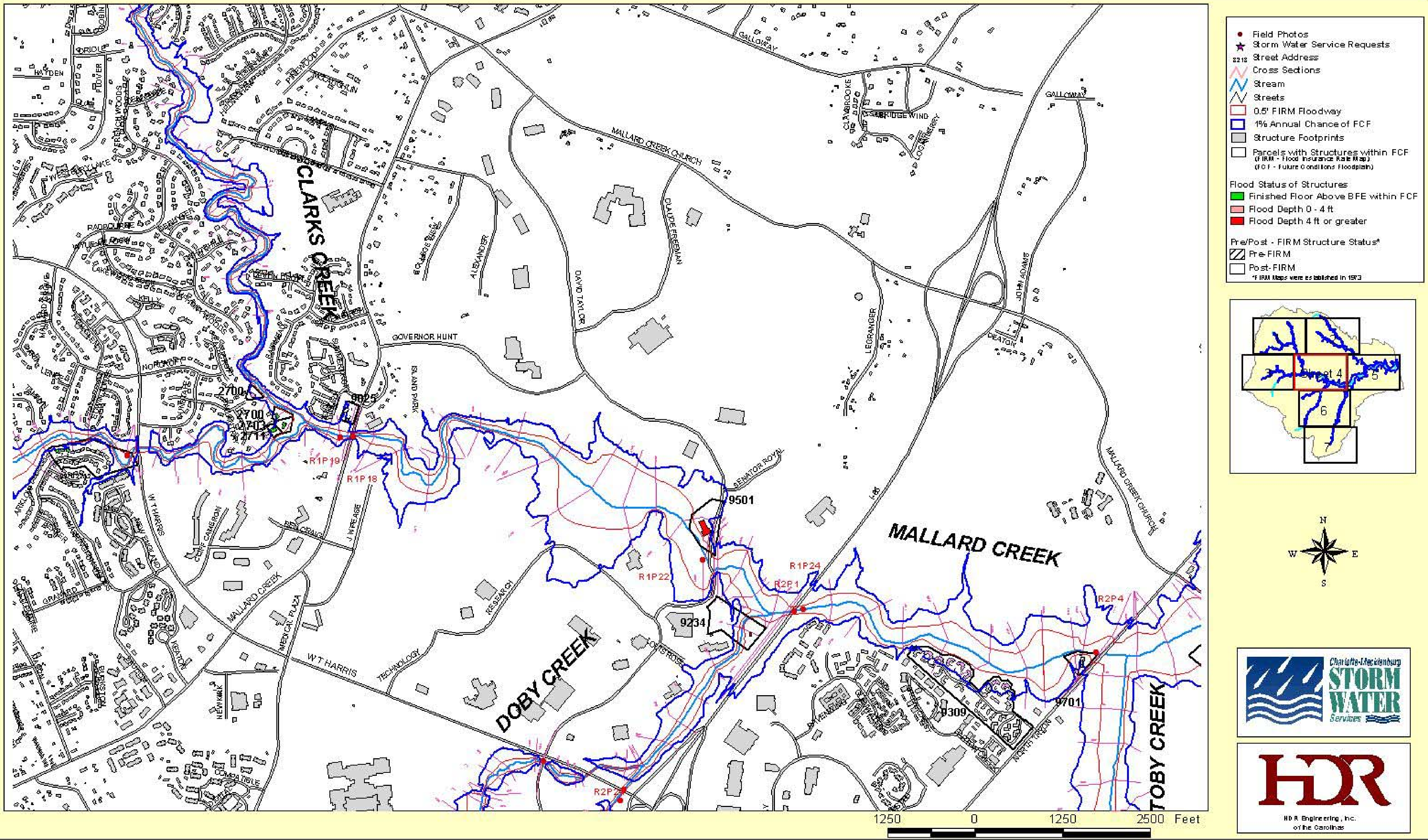


Figure A-1 Study No. 2, Mallard Creek Watershed Existing Conditions, Sheet 5

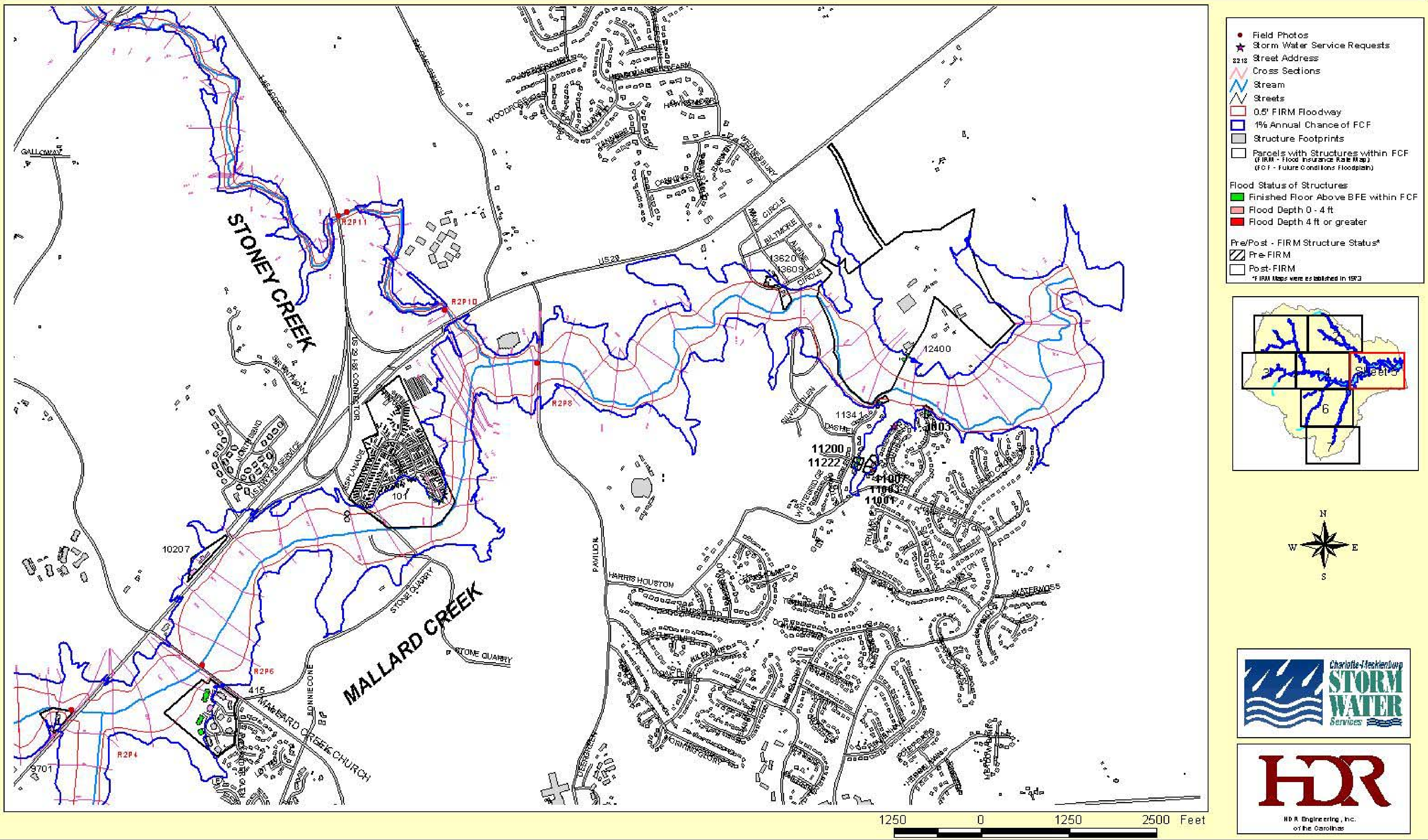


Figure A-1 Study No. 2, Mallard Creek Watershed Existing Conditions, Sheet 6

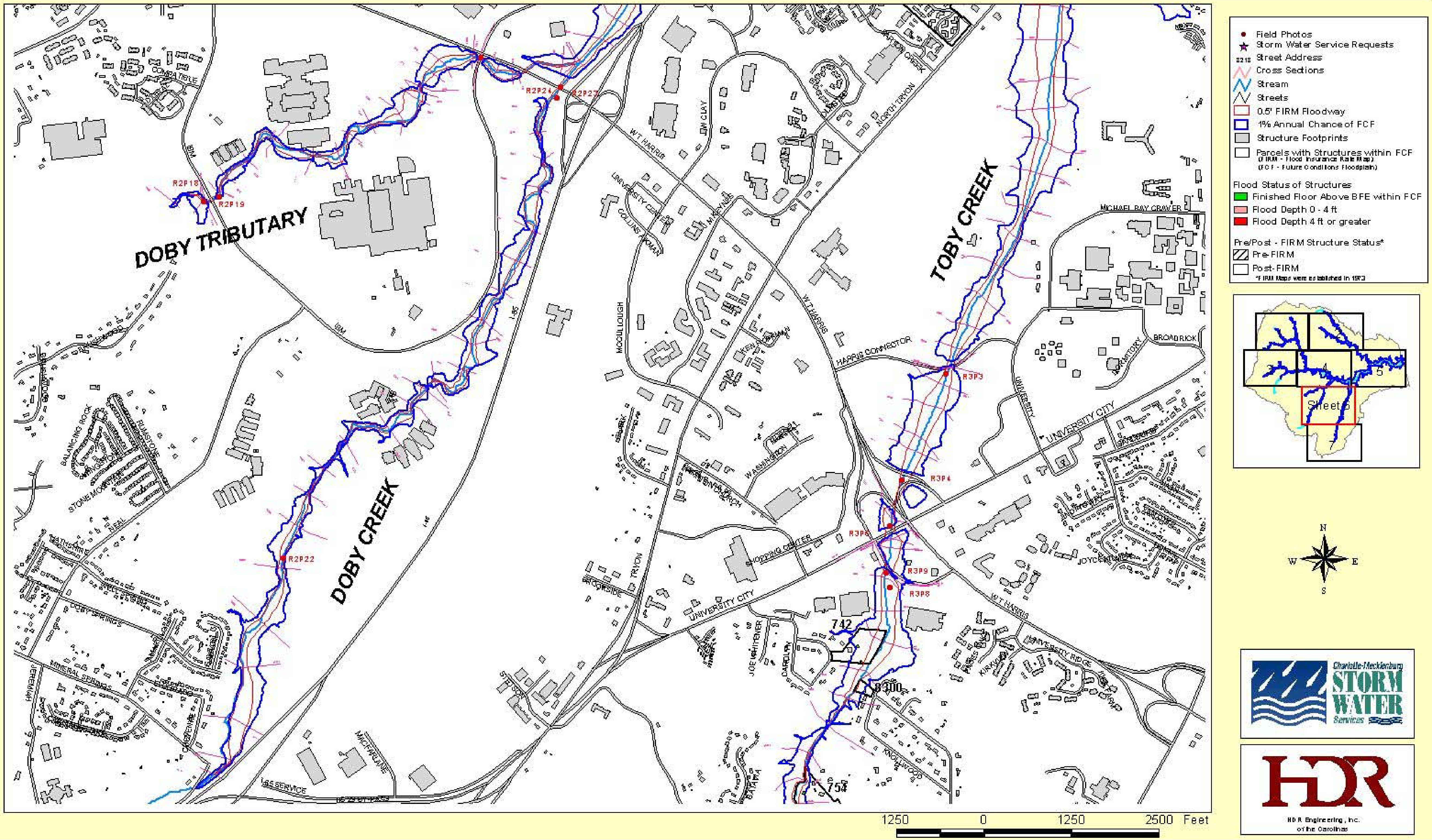
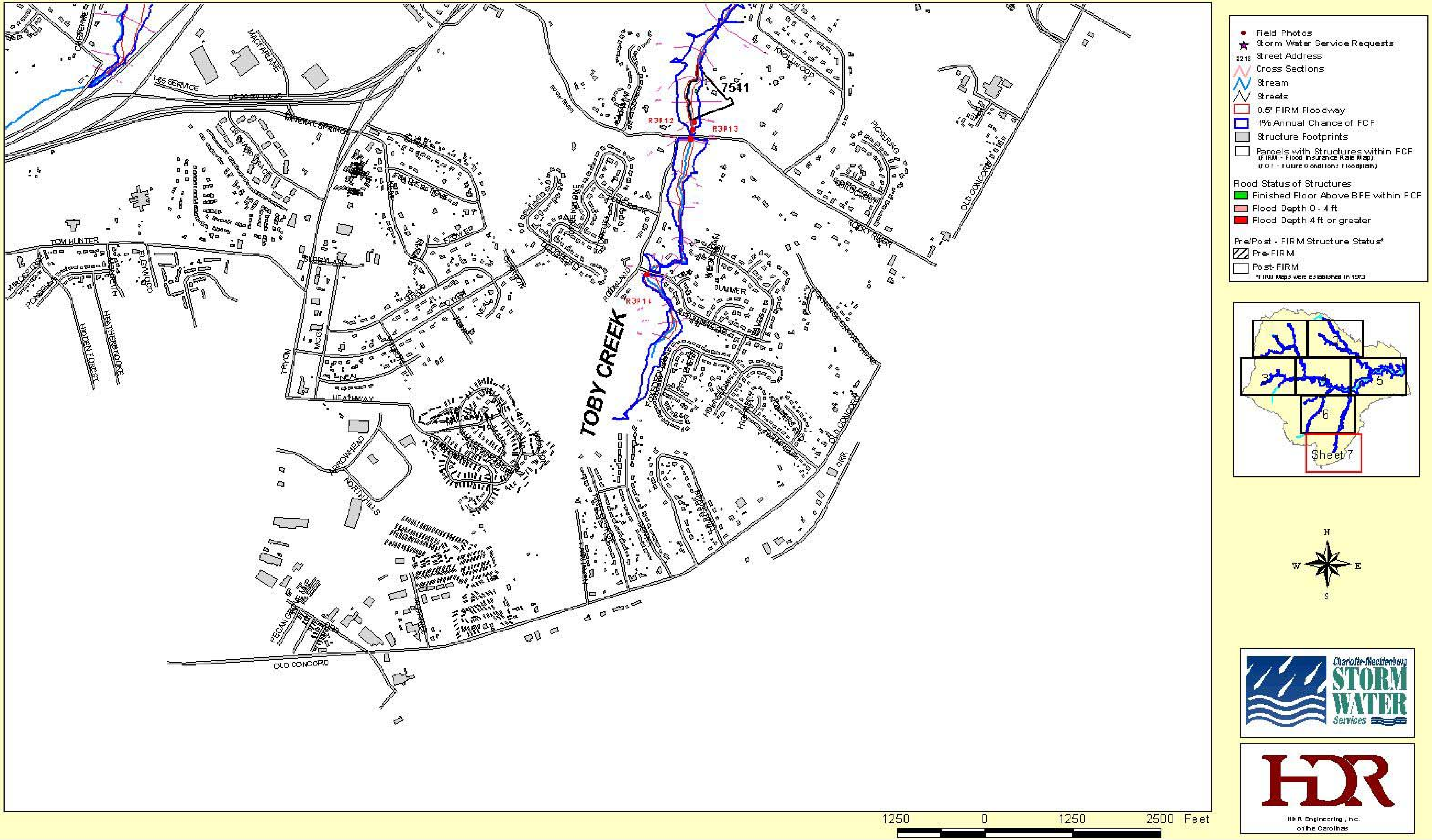


Figure A-1 Study No. 2, Mallard Creek Watershed Existing Conditions, Sheet 7



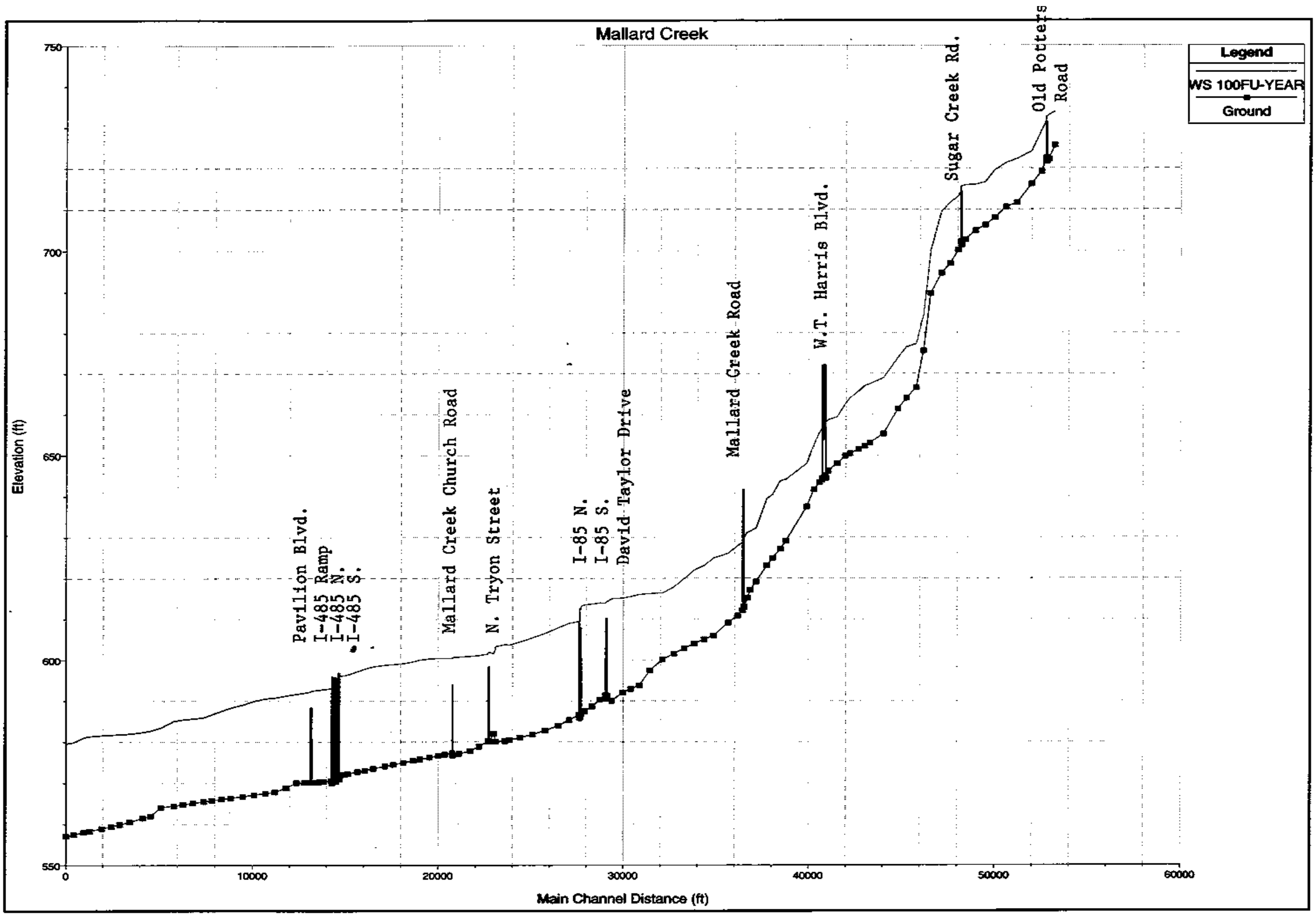
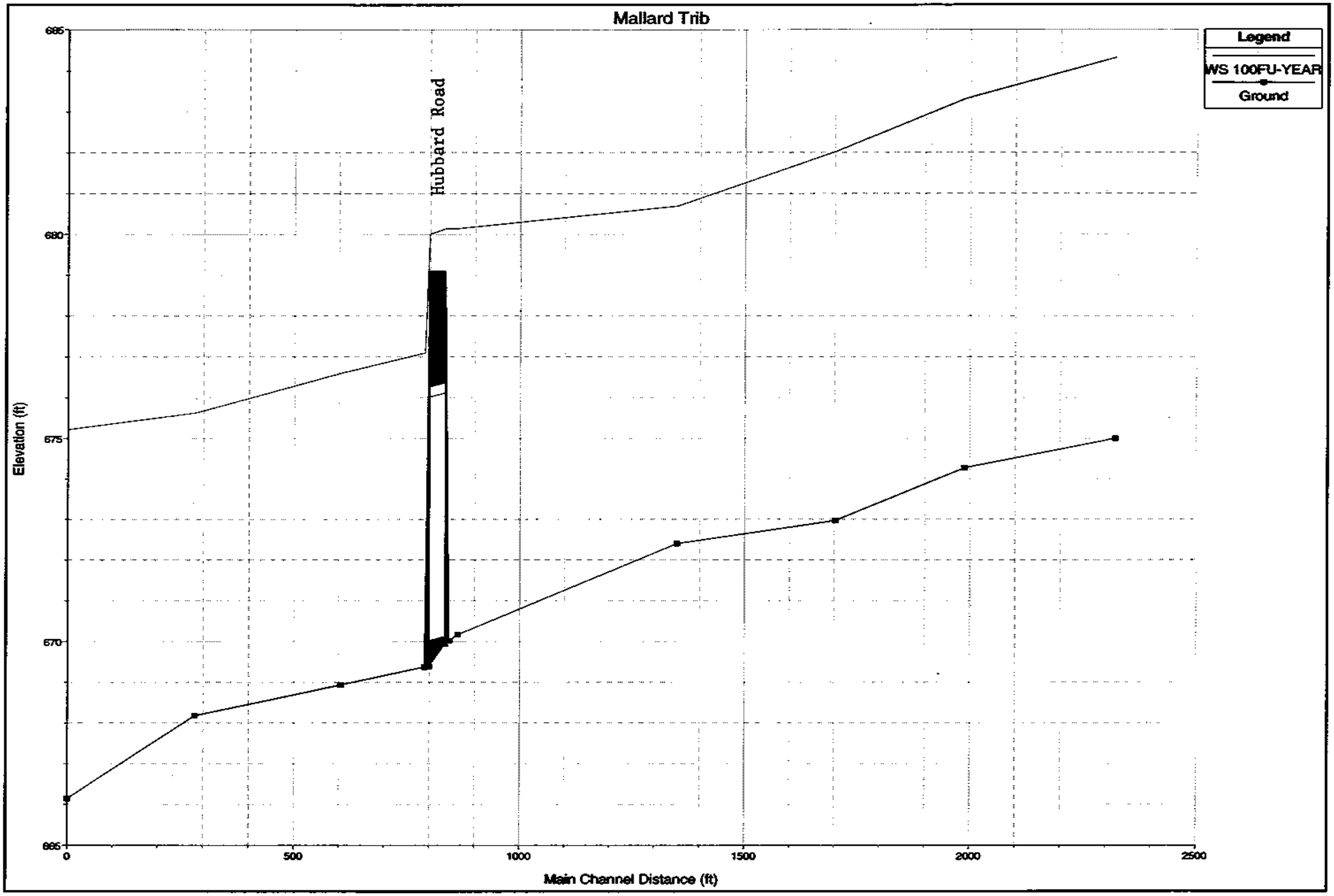

Mallard Creek
Legend
WS 100FU-YEAR
Ground
Elevation (ft)
Main Channel Distance (ft)
750
700
650
600
550
0
10000
20000
30000
40000
50000
60000
Pavilion Blvd.
I-485 Ramp
I-485 N.
I-485 S.
Mallard Creek Church Road
N. Tryon Street
I-85 N.
I-85 S.
David Taylor Drive
Mallard Creek Road
W.T. Harris Blvd.
Sugar Creek Rd.
Old Potters Road

FIGURE A-2



Mallard Trib
Legend
WS 100FU-YEAR
Ground
Hubbard Road
Elevation (ft)
Main Channel Distance (ft)
665
670
675
680
685
0
500
1000
1500
2000
2500

FIGURE A-3

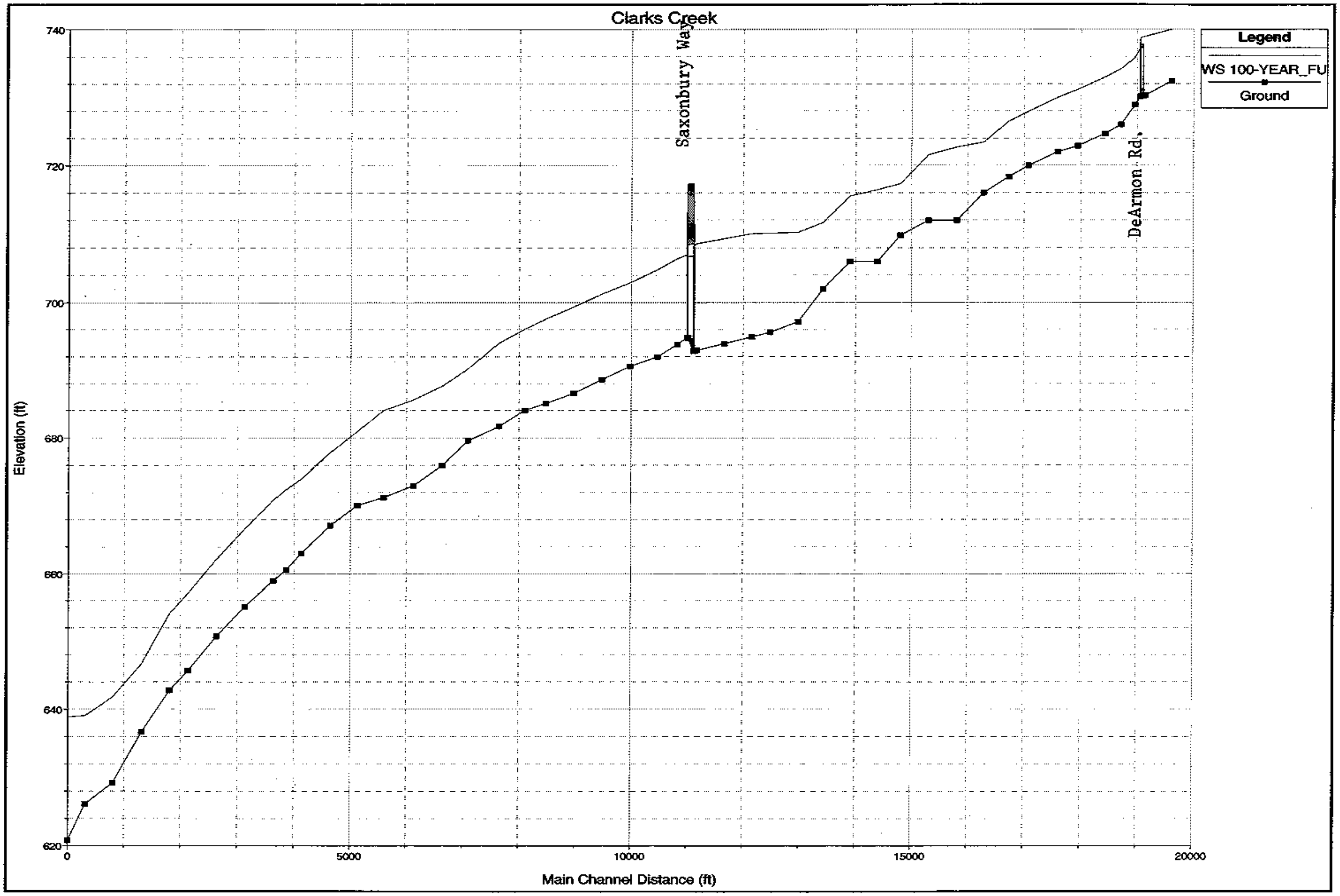

Clarks Creek
Saxonbury Way
DeArmon Rd.
Legend
WS 100-YEAR_FU
Ground
Elevation (ft)
Main Channel Distance (ft)
740
720
700
680
660
640
620
0
5000
10000
15000
20000

FIGURE A-4

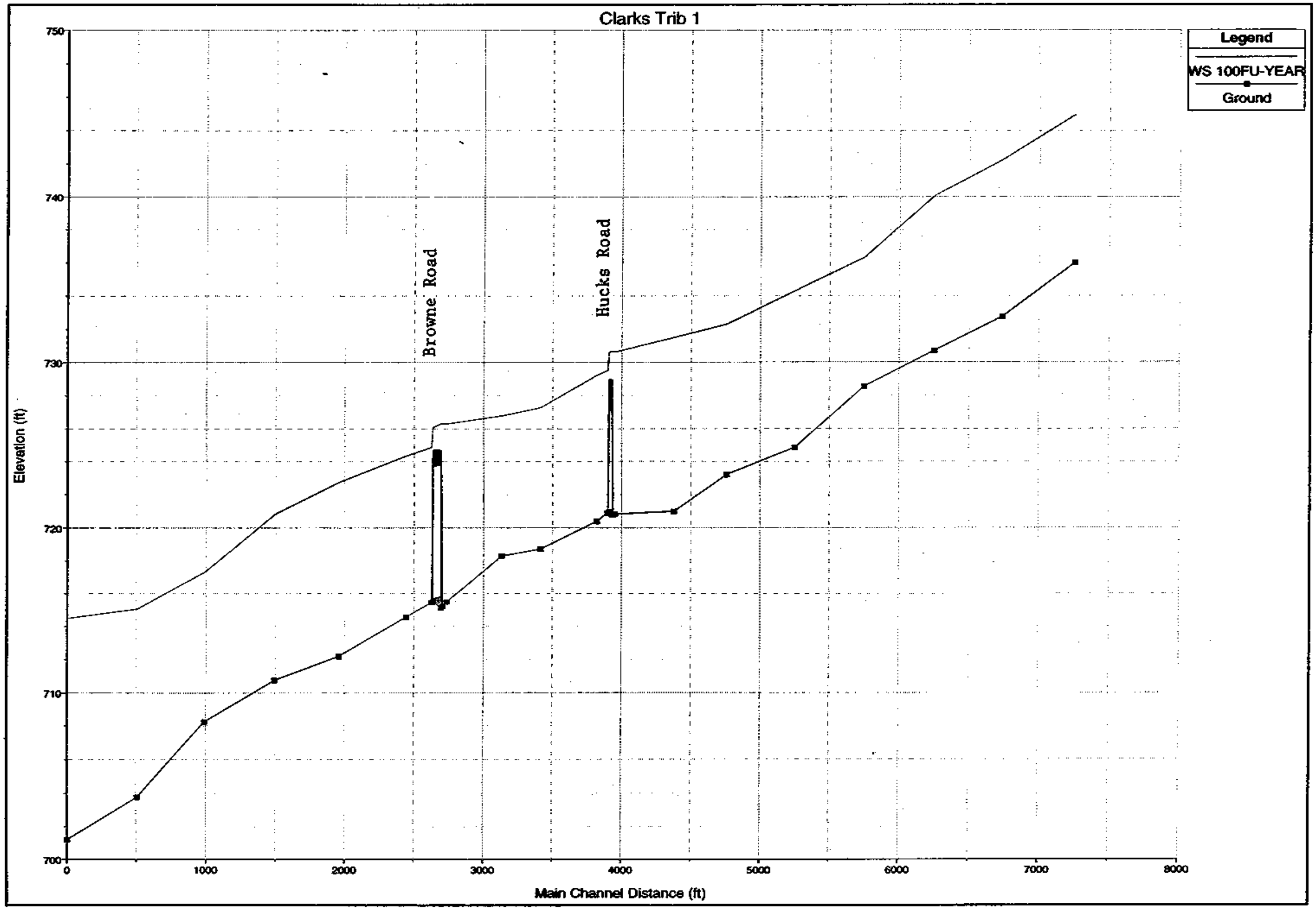
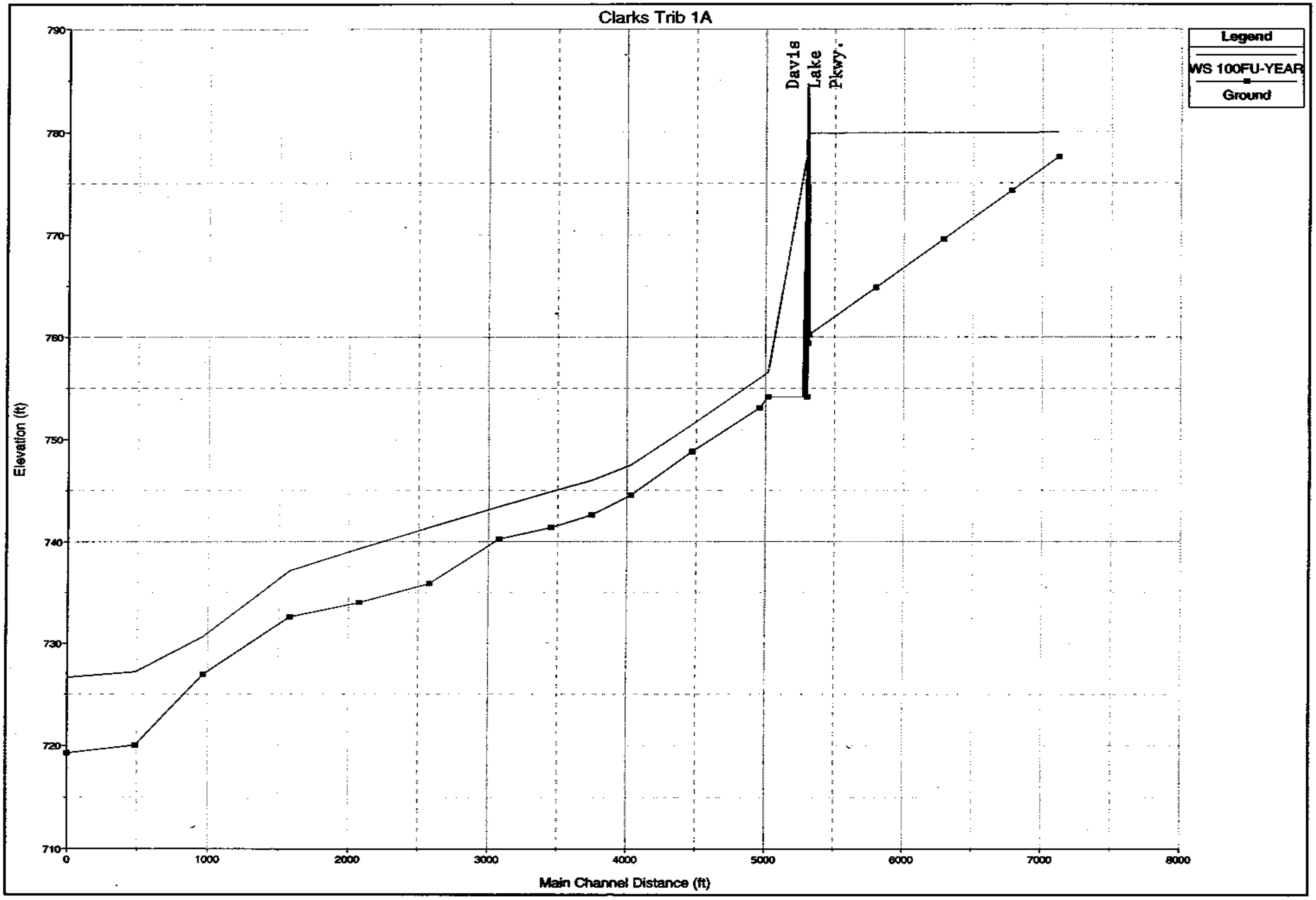

Clarks Trib 1
Legend
WS 100FU-YEAR
Ground
Browne Road
Hucks Road
Elevation (ft)
750
740
730
720
710
700
0
1000
2000
3000
4000
5000
6000
7000
8000
Main Channel Distance (ft)

FIGURE A-5



Clarks Trib 1A
Davis Lake Pkwy.
Legend
WS 100FU-YEAR
Ground
Elevation (ft)
Main Channel Distance (ft)
790
780
770
760
750
740
730
720
710
0
1000
2000
3000
4000
5000
6000
7000
8000

FIGURE A-6

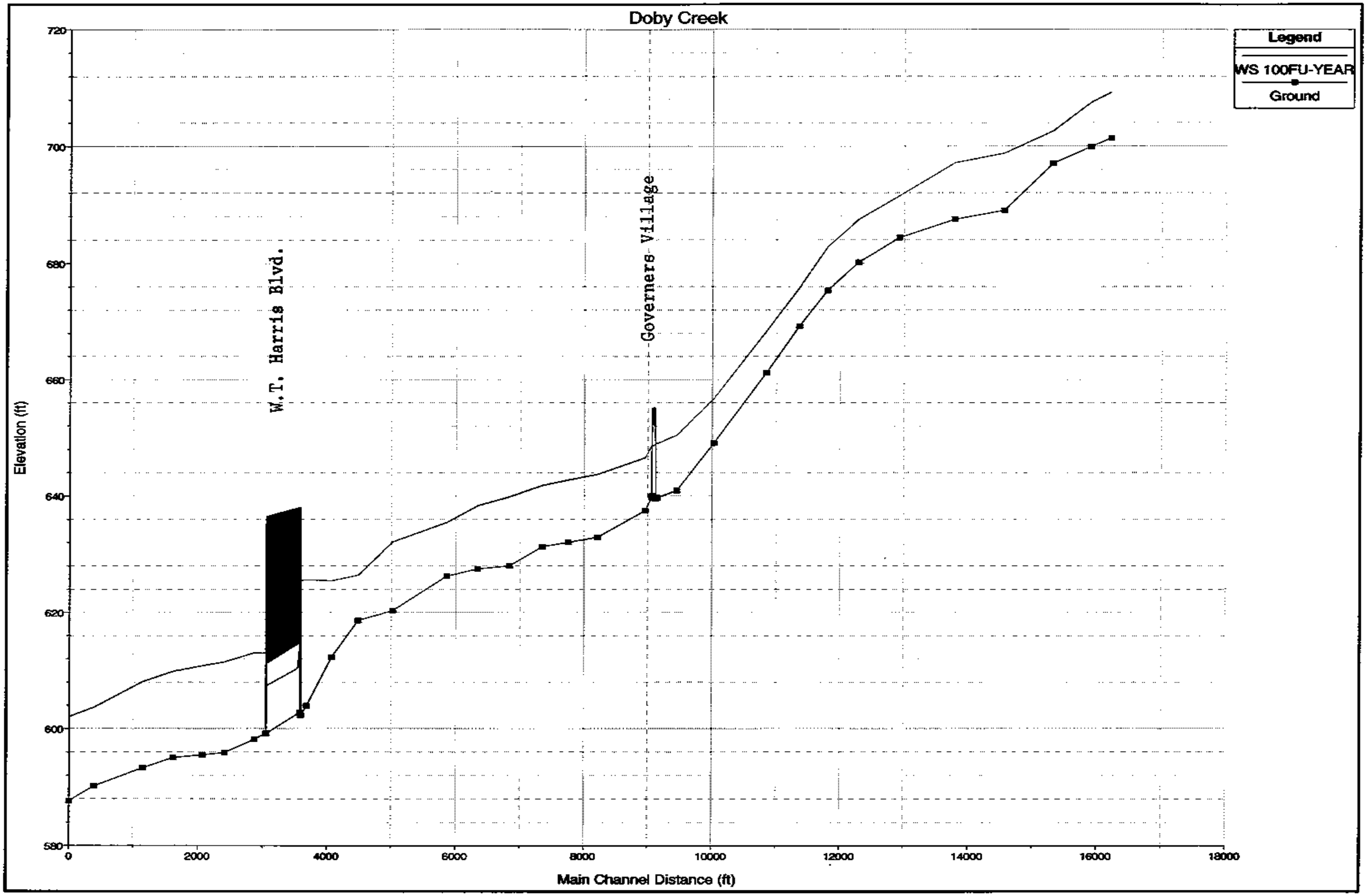

Doby Creek
Legend
WS 100FU-YEAR
Ground
Elevation (ft)
Main Channel Distance (ft)
W.T. Harris Blvd.
Governers Village
720
700
680
660
640
620
600
580
0
2000
4000
6000
8000
10000
12000
14000
16000
18000

FIGURE A-7

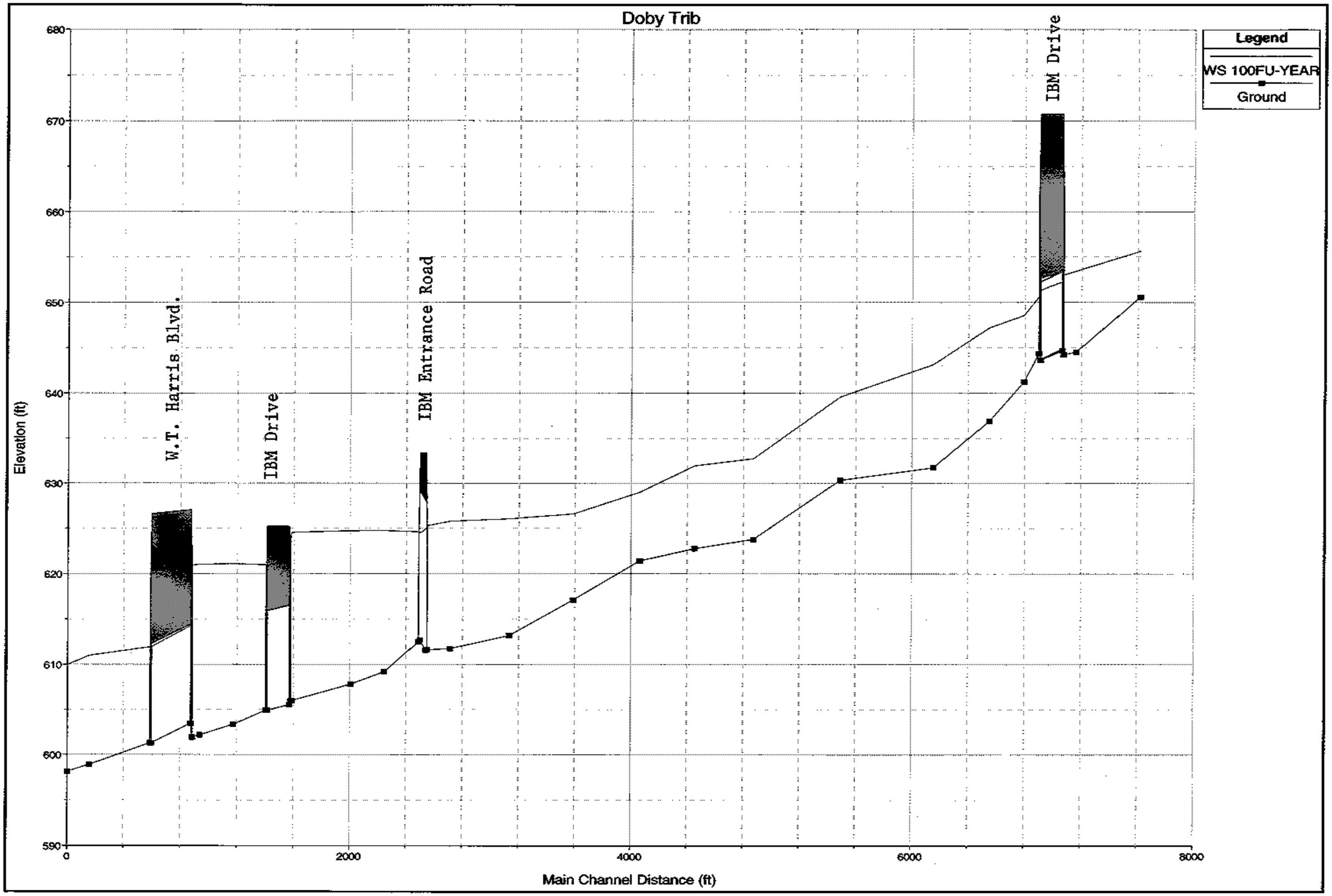
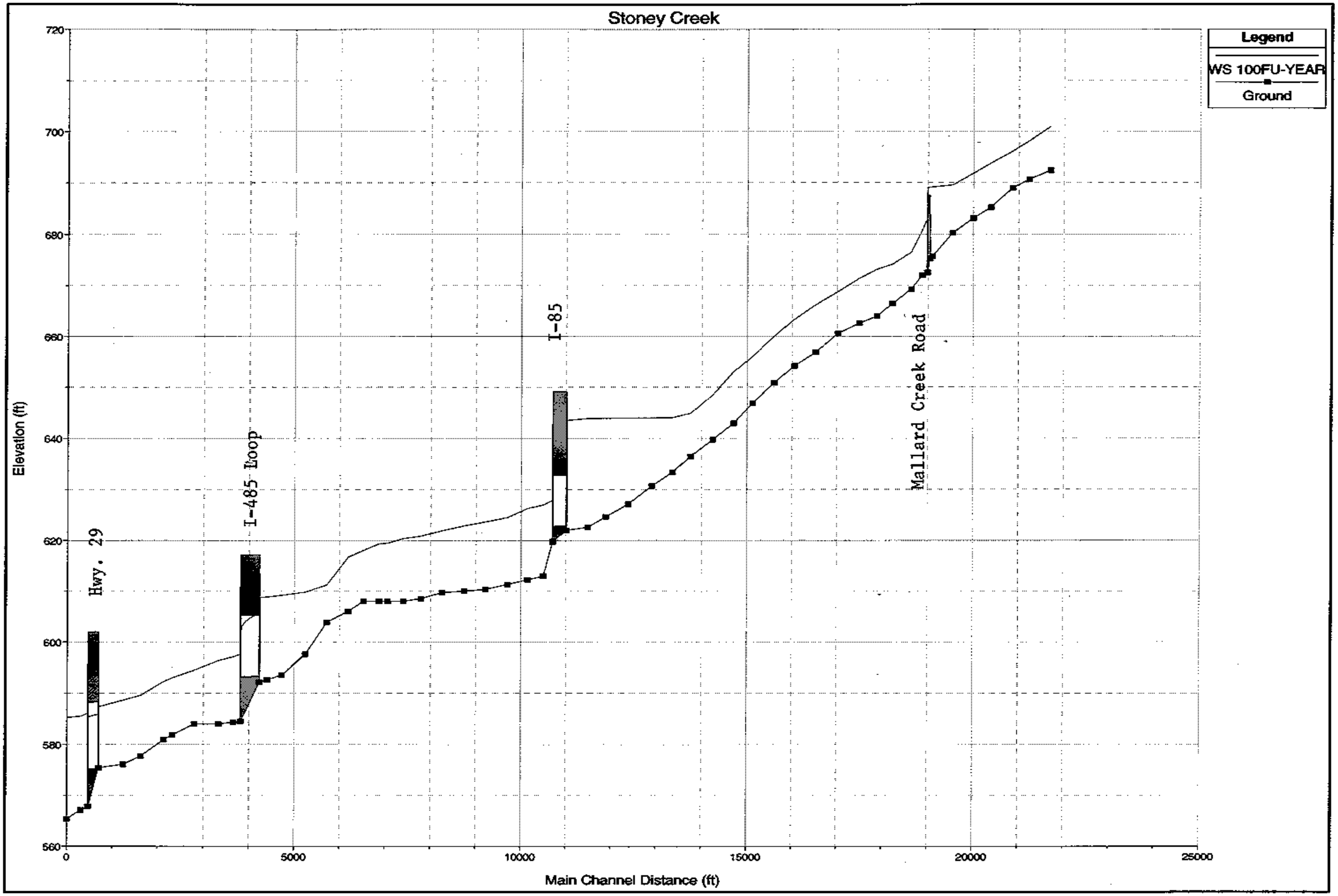

Doby Trib
Legend
WS 100FU-YEAR
Ground
W.T. Harris Blvd.
IBM Drive
IBM Entrance Road
IBM Drive
Elevation (ft)
Main Channel Distance (ft)
680
670
660
650
640
630
620
610
600
590
0
2000
4000
6000
8000

FIGURE A-8



Stoney Creek
Legend
WS 100FU-YEAR
Ground
Elevation (ft)
720
700
680
660
640
620
600
580
560
0
5000
10000
15000
20000
25000
Main Channel Distance (ft)
Hwy. 29
I-485 Loop
I-85
Mallard Creek Road

FIGURE A-9

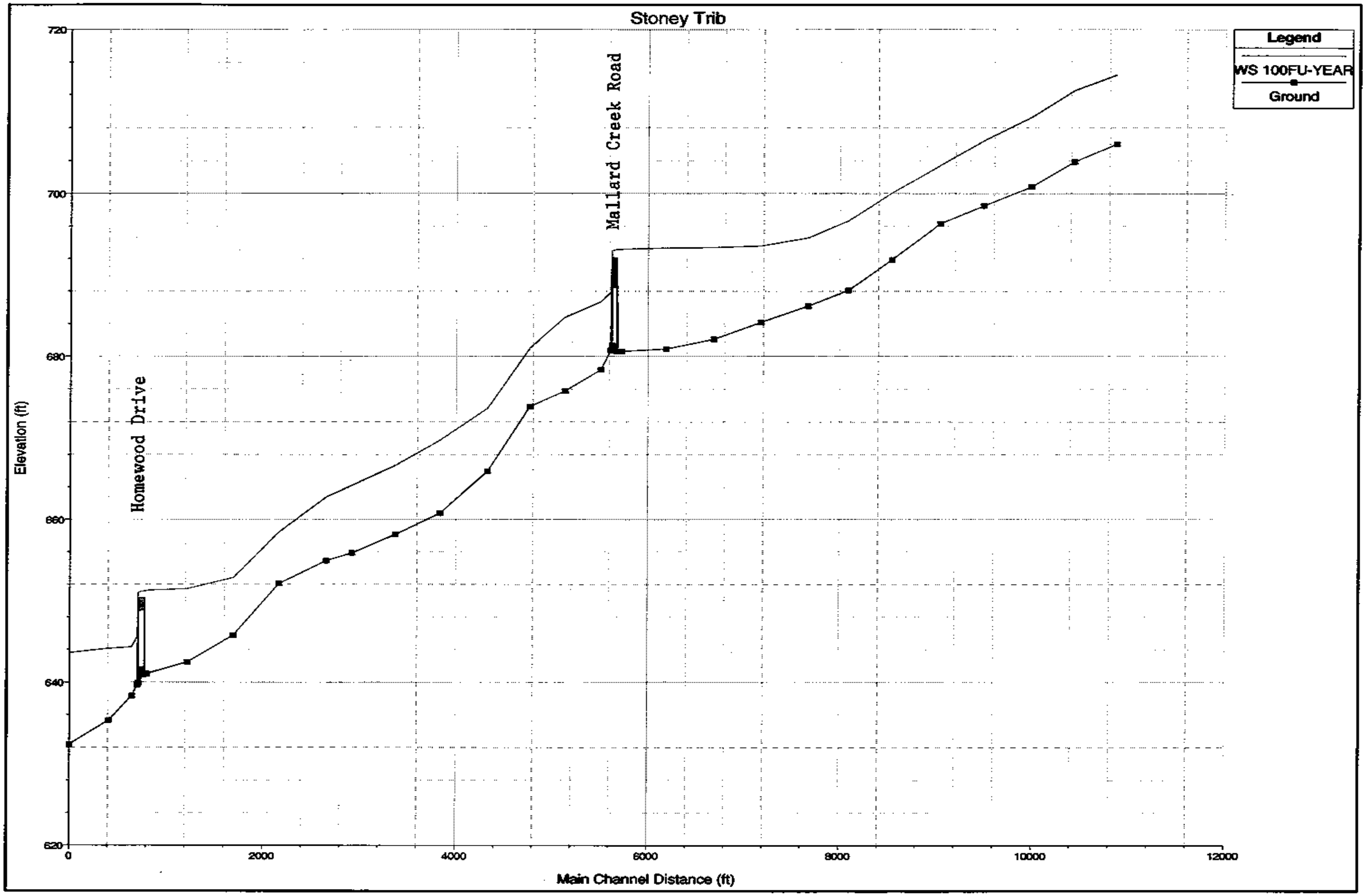
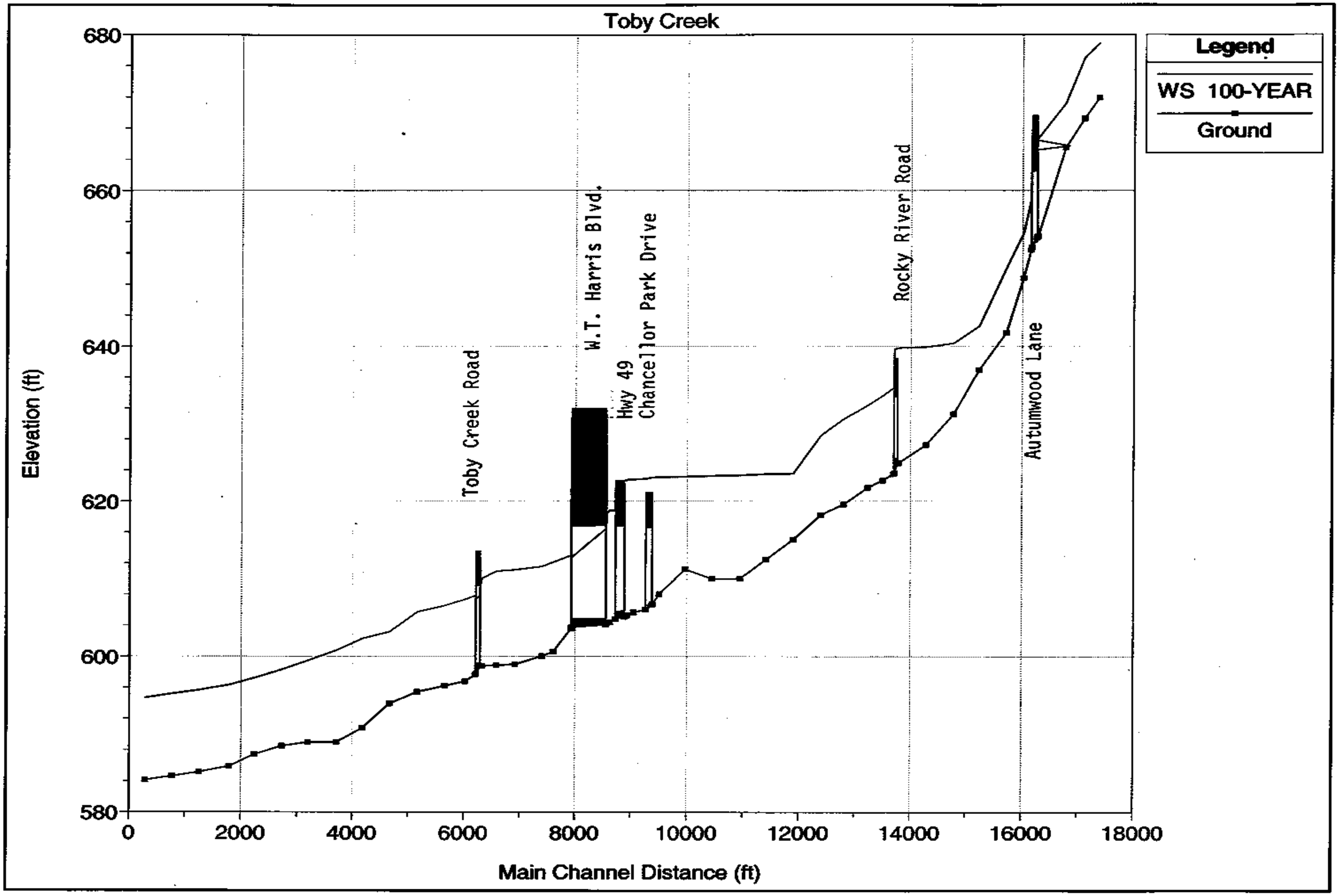

Stoney Trib
Legend
WS 100FU-YEAR
Ground
Mallard Creek Road
Homewood Drive
Elevation (ft)
720
700
680
660
640
620
0
2000
4000
6000
8000
10000
12000
Main Channel Distance (ft)

FIGURE A-10



Toby Creek
Elevation (ft)
680
660
640
620
600
580
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Main Channel Distance (ft)
Legend
WS 100-YEAR
Ground
Toby Creek Road
W.T. Harris Blvd.
Hwy 49
Chancellor Park Drive
Rocky River Road
Autumnwood Lane

FIGURE A-11

APPENDIX B

Clarks Creek View, D/S Roll #1 Photo #2
DOWNSTREAM FACE OF 3 BARRELCMPA 102”x72” CROSSING AT DEARMON RD.

Clarks Creek View, D/S Roll #1 Photo #3
EROSION OBSERVED ON RIGHT BANK, LOOKING DOWNSTREAM OF DEARMON ROAD CROSSING.

Clarks Creek View, U/S Roll # Photo #4
DEVELOPMENT UPSTREAM OF SAXONBURY WAY CROSSING.

Clarkes Creek Tributary #1 View, D/S Roll #1 Photo #8
EROSION OBSERVED AT DOWNSTREAM SIDE OF HUCKS ROAD CROSSING. CITY WATER MAIN FLUSHED WEEKLY INTO DRAINAGE CHANNEL.

Clarks Creek Tributary #1 View, U/S Roll #1 Photo #9
CONFLUENCE OF CLARKS CREEK TRIBUTARY #1 AND CLARKS CREEK TRIBUTARY #1A UPSTREAM OF BROWNE ROAD CROSSING.

Clarks Creek Tributary #1 View, U/S Roll #1 Photo #10
UPSTREAM FACE OF DOUBLE BARREL CMPA CROSSING AT BROWNE ROAD.

Clarks Creek Tributary #1A Roll #1 Photo #11
INTAKE STRUCTURES AT DAVIS LAKE.

Clarks Creek Tributary #1A View, D/S Roll #1 Photo #12
RIPRAP CHANNEL DOWNSTREAM OF DAVIS LAKE OUTLET STRUCTURE. MOWING TO EDGE OF STREAM CHANNEL.

Doby Creek View U/S Roll #2 Photo # 22
BANK EROSION UPSTREAM OF GOVERNOR HUNT MIDDLE SCHOOL ROAD CONCRETE BRIDGE CROSSING.

Doby Creek View U/S Roll #2 Photo #24
UPSTREAM FACE OF 12’x11’ CONCRETE BOX CULVERT CROSSING W.T. HARRIS BOULEVARD. BOX CULVERT BENDS UNDER ROAD.

Doby Creek Tributary # 1 View D/S Roll #2 Photo #18
RIGHTBANK EROSION DOWNSTREAM OF IBM DRIVE (UPPER) CULVERT CROSSING.

Doby Creek Tributary # 1 View D/S Roll #2 Photo #19
DOWNSTREAM FACE OF 5 BARRELS 7’ 10’ CMP CROSSING AT IBM DRIVE (UPPER). SEDIMENT PRESENT IN 2 LEFT BARRELS.

Mallard Creek View, U/S Roll #1 Photo #14
UPSTREAM VIEW OF BRIDGE CROSSING AT SUGAR CREEK ROAD.

Mallard Creek View, U/S Roll #1 Photo #18
EXTENSIVE DEPOSITION IN UPSTREAM FACE OF 4 BARREL 13’ x 9’ BOX CULVERT CROSSING AT W.T. HARRIS BOULEVARD.

Mallard Creek View, U/S Roll #1 Photo #19
DEVELOPMENT UPSTREAM OF MALLARD CREEK ROAD CROSSING. RIFFLE AREA WITH WOODY VEGETATION LINING CHANNEL.

Mallard Creek View, U/S Roll #1 Photo #22
SCOUR ON UPSTREAM FACE OF 4 BARREL 12’ x 15’ CONCRETE BOX CULVERT CROSSING AT DAVID TAYLOR DRIVE. SEDIMENT DEPOSITED IN 3 BARRELS OF CROSSING.

Mallard Creek View, D/S Roll #1 Photo #24
DOWNSTREAM FACE OF 2 BRIDGE CROSSINGS AT I-85. ENTRENCHED, STRAIGHT CHANNEL.

Mallard Creek View, D/S Roll #2 Photo #1
EXTENSIVE RIGHT BANK EROSION NEAR I-85 CROSSING. EXPOSED ROOTS AND TREE COLLAPSED.

Mallard Creek View, D/S Roll #2 Photo #4
LOWER BANK EROSION AT N. TRYON STREET. SANITARY SEWER CROSSING IN BACKGROUND.

Mallard Creek View, D/S Roll #2 Photo #6
BRIDGE CROSSING AT MALLARD CREEK CHURCH ROAD. PEDESTRIAN BRIDGE AND NCDOT MITIGATION WETLAND PRESENT IN BACKGROUND.

Mallard Creek View, U/S Roll #2 Photo #8
TRIBUTARY EROSION AND DOWNCUTTING IN RIGHT BANK NEAR PAVILION ROAD BRIDGE CROSSING.

Mallard Creek Tributary View U/S Roll #1 Photo #16
UPSTREAM SIDE OF HUBBARD ROAD. CULVERT CROSSING. LEFT BANK IS MOWED TO EDGE, BRUSH AND HEAVY VEGETATION PRESENT ON RIGHT BANK.

Stoney Creek View, U/S Roll #2 Photo #10
UPSTREAM FACE OF 3 BARREL 11' x 13' CONCRETE BOX CULVERT CROSSING AT US 29/TRYON STREET. COBBLES HAVE ACCUMULATED IN RIGHT 2 BARRELS.

Stoney Creek Vew D/S Roll #2 Photo #11
DOWNSTREAM OF I-485 BOX CULVERT CROSSING. BANKS STABILIZED WITH RIPRAP.

Stoney Creek View inside culvert Roll #2 Photo #16
INSIDE OF 12’ x 7.5’ CMPA AT MALLARD CREEK ROAD. CULVERT IS COLLAPSING AND CURRENTLY SUPPORTED BY PILLARS. DEBRIS IS COLLECTING INSIDE CULVERT.

Stoney Creek View D/S Roll #2 Photo #17
THICK VEGETATION DOWNSTREAM OF MALLARD CREEK ROAD. ROCKS IN CREEK CREATE RIFFLE.

Stoney Creek Tributary View U/S Roll #2 Photo #14
DEBRIS BLOCKING UPSTREAM FACE OF 2 BARREL 6'8" CMP CROSSING AT HOMEWOOD DRIVE.

Stoney Creek Tributary View D/S Roll #2 Photo #15
LARGE POOL AND ERODED RIGHT BANK (LOOKING DOWNSTREAM) OF HOMEWOOD DRIVE CULVERT CROSSING.

Toby Creek View U/S Roll #3 Photo #3
UPSTREAM FACE OF 3 BARREL 10'x 9' BOX CULVERT CROSSING AT TOBY CREEK ROAD. DEPOSITION PRESENT AT UPSTREAM SIDE, DOWNCUTTING OCCURRING DOWNSTREAM.

Toby Creek View D/S Roll #3 Photo #4
GRADE CONTROL IN FORM OF 2 WOOD PLANKS PRESENT DOWNSTREAM OF CONCRETE BOX CULVERT CROSSING AT RAMP TO WEST HARRIS BLVD FROM UNIVERSITY CITY BLVD SOUTH.

Toby Creek View U/S Roll #3 Photo #6
SEVERE DOWNCUTTING UPSTREAM OF CONCRETE BOX CULVERT CROSSING HWY 49. OBSERVED BEAVER.

Toby Creek View U/S Roll #3 Photo #8
UPSTREAM FACE OF 5 BARREL 10’ x 10’ CONCRETE BOX CULVERT CROSSING CHANCELLORS PARK. DEPOSITION PRESENT IN 4 BARRELS.

Toby Creek View D/S Roll #3 Photo #9
DRAINAGE ON LEFT BANK NEAR CHANCELLORS PARK CULVERT CROSSING. HEAD CUTTING PREVENTION MEASURES PRESENT.

Toby Creek View D/S Roll #3 Photo #12
DROPOFF AT DOWNSTREAM FACE OF 2 BARREL 12’ x 18’ CMPA ROCKY RIVER ROAD CROSSING.

Toby Creek View D/S Roll #3 Photo #13
BANK EROSION DOWNSTREAM OF ROCKY RIVER ROAD CROSSING.

Toby Creek View U/S Roll #3 Photo #14
MILD BANK EROSION UPSTREAM OF AUTUMNWOOD CT. CULVERT CROSSING.