

PRELIMINARY ENGINEERING REPORT

Morningside Drive – Bolin Forest Drive Hydrologic Report

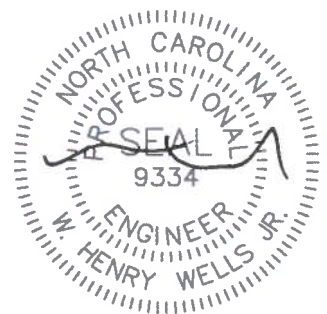
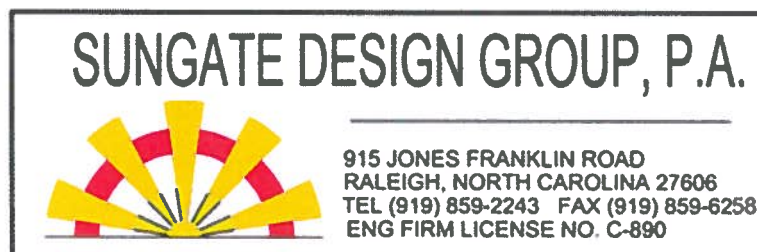


FOR

**THE TOWN OF CARRBORO
CARRBORO, NORTH CAROLINA**

May 16, 2016

PREPARED BY:



5/16/16

MORNINGSIDE DRIVE – BOLIN FOREST DRIVE PRELIMINARY HYDROLOGIC REPORT

I. Project Background

Sungate Design Group, PA (Sungate) was contracted by the Town of Carrboro to conduct a preliminary hydrologic study to evaluate possible mitigation alternatives to address frequent flooding which occurs along the Unnamed Tributary to Bolin Creek (UT to Bolin Creek) in the vicinity of the crossings of Morningside Drive, Robert Hunt Drive, and Bolin Forest Drive. The headwaters of UT to Bolin Creek originate to the west of Morningside Drive and flow east to the confluence with Bolin Creek approximately 2700' downstream of Bolin Forest Drive.

The purpose of the study is to address flooding complaints of property owners adjacent to UT to Bolin Creek received by the Town. The property owners at Lots 103, 105, and 107 Morningside Drive experience periodic flooding of the land adjacent to Morningside Drive. Sungate received no reports of the structures located on the lots experiencing flood damage above the finished floor elevation. However, the flooding does impact the accessibility to the structures located on Lots 103 and 105 when the associated driveways are inundated. In September 2012, a heavy rainfall event caused flood damage to vehicles parked at both Lots 103 and 105 Morningside Drive. In addition to the flooding on adjacent properties, Morningside Drive overtops with relative frequency. The roadway sag provides overflow that has been adequate to prevent flooding of the structures on Lots 103, 105, and 107, but portions of the properties are below the road elevation at the driveways and parking areas. Most recently, rainfall events in December 2015 overtopped Morningside Drive.

The property owner at Lot 205 Robert Hunt Drive experiences periodic flooding of the land adjacent to Robert Hunt Drive. The property owner experienced damaging flooding in the structure's crawlspace in June 2013. Most recently, rain events in December 2015 created non-damaging flooding that encroached on the foundation of the structure and outdoor HVAC equipment according to the land owner.

In addition to the previously mentioned properties, 104 Morningside Drive, 214 Robert Hunt Drive and Lot 310 Bolin Forest Drive reported periodic flooding to Sungate. According to TOC property records, the structures on the affected properties on Morningside Drive were built in 1979. The affected structures on Robert Hunt Drive were built in 1991. Additionally, 310 Bolin Forest Drive was built in 1979.

II. Preliminary Data Gathering

Sungate obtained available TOC GIS, zoning, and contour data to create a study base map. USGS topographic mapping was also obtained from the web. The USDA NRCS Web Soil Survey was referenced to determine hydrologic soil types for watershed area. The stream in this area is not included in the FEMA flood study area according to the latest DFIRM maps from the North Carolina Floodplain Mapping Program (NCFMP).

III. Field Reconnaissance and Survey

Sungate completed several site visits to visually observe the site and verify the existing drainage patterns and drainage areas. Measurements of the existing pipes were taken, and detailed field surveys were completed for this analysis, including stream cross sections, location and elevation of relevant drainage features, and foundation and finished floor elevations of structures in the vicinity of the stream with a reasonable threat of flooding. Sungate corresponded with landowners in the field when available to collect historical accounts of local flooding.

The following are the size of the cross-pipes found during the course of the SDG survey:

Morningside Drive:	1@24" Reinforced Concrete Pipe
Robert Hunt Drive:	3@30" Reinforced Concrete Pipes
Bolin Forest Drive:	1@60"x44" Corrugated Metal Pipe Arch

The existing crossing at Morningside drive consists of two separate 18" Reinforced Concrete Pipes (RCP) (**see Attachments 1 & 2**) that collect and merge into the 24" RCP crossing. The existing crossing at Robert Hunt drive consists of three 30" RCPs with Flared End Sections (FES) at the inlet and outlet of each pipe (**see Attachment 3**). The pipes are situated on a very sharp skew to the stream and roadway. The FESs at the inlet side have been modified by cutting away a portion of the structure that would otherwise be impeding flow due to the skew of the pipes to the stream. The existing crossing at Bolin Forest Drive is a 60"x44" Corrugated Metal Pipe Arch (CMPA) that has been mitered to conform to the roadway fill at the inlet and outlet (**see Attachment 4**).

In general, UT to Bolin Creek has incised banks and a natural floodplain. Incised banks are caused by a stream receiving more water than it was naturally intended to, and is often associated with development and urbanization. Despite being incised, the banks of UT to Bolin Creek appear stable with mature vegetation.

There is an existing stormwater detention basin that discharges into UT to Bolin creek approximately 180 feet downstream of Robert Hunt drive. The berm at the outlet of the basin has been breached and the outlet pipe joints have separated (**see Attachment 5**). However, the original site drainage plans were recovered, and it appears that the basin was designed to detain a very small amount of water for an insignificant period of time. In the scope of the rainfall events in this study, the detention basin would provide very little flooding relief even if it were functioning properly.

Some of the roadway cross pipes conveying stormwater to UT to Bolin Creek other than at Morningside Drive, Robert Hunt Drive, and Bolin Forest Drive appear to be undersized. However, Sungate has received no reports of flooding from these and they may provide unintended stormwater detention that can relieve flooding issues along UT to Bolin Creek. On UT to Bolin Creek, A 24" RCP drive pipe exists under an access road on 106 Morningside Drive that appears to be undersized according to the Carrboro LUO. Sungate understands that the road provided access to a sewage pump station that has since been removed.

IV. Preliminary Engineering Evaluation

Basin Characteristics:

The total study drainage area and each sub-basin were delineated using the available contour data and TOC stormwater inventory data. Drainage areas were field verified by Sungate. The study area includes UT to Bolin Creek beginning at Morningside Drive to approximately 120' downstream of the driveway bridge at 310 Bolin Forest Drive. The total drainage area for UT to Bolin Creek within the study area is 107 acres (**see Appendix A**). According to the latest TOC zoning maps, the land within the contributing drainage area is zoned for Residential use (100%) (**see Appendix B**). The drainage area is entirely built out with 40.3 acres (38%) of impervious surface. USDA NRCS soil survey identifies the native soils as silt loams and sandy loams that belong mostly to Hydrologic Soil Group "B" (75%), with some soils belonging to Hydrologic Soil Group "D" (25%) (**see Appendix C**). Soils in group "B" are loamy in nature and have a low-to-moderate runoff potential when thoroughly wetted due to their moderately high infiltration rate. Soils in group "D" are clayey in nature and have the highest runoff potential due to slow infiltration rates when fully wetted.

Hydrologic Analysis:

A hydrologic model of the drainage basin was completed using the basin characteristics and a HydroCAD model. HydroCAD is a Computer Aided Design system for modeling Hydrology and Hydraulics of stormwater runoff. The program is based on hydrology techniques developed by the SCS/NRCS and models complex watersheds. Peak discharge rates were determined using the SCS method for the 2, 10, 25, and 100-year storm recurrence intervals for the existing conditions and several alternatives. The calculated discharges at each existing road crossing are as follows:

Morningside Drive

Drainage Area= 33.7 acres

<u>Frequency</u>	<u>24-Hour Rainfall</u> (Inches)	<u>Peak Flow Rate</u> <u>Existing Conditions</u> (cubic feet/second)
2-Year	3.5	63
10-Year	5.1	116
25-Year	6.0	148
100-Year	7.4	198

Robert Hunt Drive

Drainage Area= 40.2 acres

<u>Frequency</u>	<u>24-Hour Rainfall</u> (Inches)	Peak Flow Rate <u>Existing Conditions</u> (cubic feet/second)
2-Year	3.5	53
10-Year	5.1	129
25-Year	6.0	167
100-Year	7.4	225

Bolin Forest Drive

Drainage Area= 95.4 acres

<u>Frequency</u>	<u>24-Hour Rainfall</u> (Inches)	Peak Flow Rate <u>Existing Conditions</u> (cubic feet/second)
2-Year	3.5	136
10-Year	5.1	264
25-Year	6.0	331
100-Year	7.4	492

The calculated discharges take into consideration the passive stormwater detention that is provided by undersized cross-pipes at each existing crossing as evidenced by the discharge at Robert Hunt Drive being lower than the discharge at the upstream crossing of Morningside Drive in the 2-year rainfall event.

Hydraulic Analysis:

The hydraulics of each existing road crossing was evaluated. According to the Carrboro LUO, each crossing should be sized to handle the 25-year storm event. All three crossings fail to meet this standard. Based on the computed discharges shown above and considering the physical constraints presented by maintaining the current roadway grade, each crossing needs to be sized equivalent to the following sizes to meet the Carrboro LUO standard; Morningside Drive requires 4@42" RCP, Robert Hunt Drive requires 4@48" RCP, and Bolin Forest Drive requires 3@54" RCP.

A HEC-RAS model was created to predict existing flooding and analyze potential flooding with each alternative for each storm recurrence interval studied. HEC-RAS is a one-dimensional hydraulic modeling program developed by the US Army Corps of Engineers to analyze stream hydraulics and estimate water surface elevations for complex stream systems. The study area was modeled using site topography acquired from NRCS bare earth LiDAR contours in conjunction with the field surveyed stream cross sections and topography. In addition to the road crossings at Morningside Drive, Robert Hunt Drive, and Bolin Forest Drive, the driveway bridge crossing for Lot 310 Bolin Forest Drive (**see Attachment 6**) was included in the model. The discharges calculated in the HydroCAD model were input into the HEC-RAS model.

The HydroCAD and HEC-RAS models were used to analyze thirteen alternatives with differing pipe sizes and configurations. For each alternative, the HydroCAD model was used to calculate the amount and timing of stormwater discharge from each sub-basin within the project to determine peak discharges at each crossing. The model accounted for stormwater attenuation provided by undersized cross-pipes and associated flood storage that can impact flood elevations. The geometry and calculated hydrology of each alternative were input into HEC-RAS, and the flooding mitigation potential was analyzed using the results.

Results:

Most of the thirteen alternatives produced similar results. Therefore, the three alternatives that offer the greatest reduction in flooding and most insight into selecting a solution were chosen to be presented below. The models were run and the resulting water surface elevations were compared with the existing conditions along with the foundation and finished floor elevations of the adjacent structures in the study.

Existing Conditions

According to the model, flooding from UT to Bolin Creek reaches the foundation of the following dwellings within the study area in at least one of the studied storm events:

104 Morningside Drive	207 Robert Hunt Drive	300 Robert Hunt Drive
106 Morningside Drive	214 Robert Hunt Drive	105 Jasmine Court
201 Robert Hunt Drive	216 Robert Hunt Drive	114 Jasmine Court
205 Robert Hunt Drive	218 Robert Hunt Drive	310 Bolin Forest Drive

The following number of dwellings were impacted under the existing conditions:

<u>2-Year</u>	<u>10-Year</u>	<u>25-Year</u>	<u>100-Year</u>
3	9	10	12

Alternative #1

The first alternative would eliminate the crossing and remove roadway fill at Morningside Drive, Robert Hunt Drive, and Bolin Forest Drive. This is a far-reaching alternative that should not be pursued due to the decrease in connectivity that it would cause. However, it was necessary to model this alternative to provide a base flood elevation and floodplain area that existed before the roads were constructed. According to the model, this alternative provides a maximum decrease in flooding on a dwelling of 1.8' at 218 Robert Hunt Drive in the 10 year storm event. Additionally, the model indicates that Morningside Drive will no longer overtop in any of the analyzed storm events. The maximum increase in flooding on a dwelling is 1.3' at 310 Bolin Forest Drive in the 2 year storm event.

The following number of dwellings were impacted under the first alternative:

<u>2-Year</u>	<u>10-Year</u>	<u>25-Year</u>	<u>100-Year</u>
2	7	11	11

Alternative #2

The second alternative would upgrade the crossings at Morningside Drive, Robert Hunt Drive, and Bolin Forest Drive to culverts that would meet the Carrboro LUO standards. These upgrades consist of 3@42" RCP at Morningside Drive, 4@48" RCP at Robert Hunt Drive, and 3@54" RCP at Bolin Forest Drive. According to the model, this alternative provides a maximum decrease in flooding on a dwelling of 2.4' at 218 Robert Hunt Drive in the 10 year storm event. Additionally, the model indicates that Morningside Drive will no longer overtop in any of the analyzed storm events. The maximum increase in flooding on a dwelling is 1.3' at 310 Bolin Forest Drive in the 2 year storm event.

The following number of dwellings were impacted under the second alternative:

<u>2-Year</u>	<u>10-Year</u>	<u>25-Year</u>	<u>100-Year</u>
2	6	10	11

Alternative #3

The third alternative is a combination of the first two alternatives in an attempt to maximize the decrease in flooding at 205 Robert Hunt Drive, the only dwelling that has sustained significant damage directly due to flooding from UT to Bolin Creek that Sungate has been made aware of. This alternative would upgrade the crossing at Morningside Drive to 3@42" RCP, remove the crossing and roadway fill at Robert Hunt Drive, and upgrade the crossing at Bolin Forest Drive to 3@54" RCP. According to the model, this alternative provides a maximum decrease in flooding on a dwelling of 2.4' at 218 Robert Hunt Drive in the 10 year storm event. Additionally, the model indicates that Morningside Drive will no longer overtop in any of the analyzed storm events. The maximum increase in flooding on a dwelling is 1.3' at 310 Bolin Forest Drive in the 2 year storm event. The decrease in flooding at 205 Robert Hunt Drive was not significantly different than the decreases offered by the first two alternatives, indicating that the culverts in Alternative 2 are properly sized for the stream and that removing a roadway crossing doesn't significantly improve flooding issues for the study area.

The following number of dwellings were impacted under the third alternative:

<u>2-Year</u>	<u>10-Year</u>	<u>25-Year</u>	<u>100-Year</u>
2	6	10	11

Alternative #4

A fourth alternative of providing detention or other infiltration devices in the watershed was also thoroughly investigated. As previously mentioned, the contributing drainage area is completely built out. No areas were identified that were owned by the Town where detention facilities could be constructed or other “green” retrofit techniques employed to reduce the run-off rate significantly. There are no privately owned tracts where there is sufficient open area to provide site detention or other infiltration devices that would significantly benefit property owners. It is, therefore, imperative that stormwater detention and infiltration be required when infill projects are proposed within the watershed to reduce the discharge to UT to Bolin Creek.

Summary

The three alternatives presented in this study are as follows:

	<u>Alt. 1</u>	<u>Alt. 2</u>	<u>Alt. 3</u>
Morningside Drive	Remove Crossing	3@42” RCP	3@42” RCP
Robert Hunt Drive	Remove Crossing	4@48” RCP	Remove Crossing
Bolin Forest Drive	Remove Crossing	3@54” RCP	3@54” RCP

All three alternatives resulted in reductions in overtopping of Morningside Drive in all storm events analyzed. In general, flood elevations were reduced for properties on Robert Hunt Drive, but increased in elevation and frequency on 105 Jasmine Court and 310 Bolin Forest Drive.

Change in the 100-Year water surface elevation (ft):

	<u>Existing</u>	<u>Alt. 1</u>	<u>Alt. 2</u>	<u>Alt. 3</u>
103 Morningside Drive*	Impact	No Impact	No Impact	No Impact
105 Morningside Drive*	Impact	No Impact	No Impact	No Impact
104 Morningside Drive	Impact	0.0	0.0	0.0
106 Morningside Drive	Impact	0.0	0.0	0.0
201 Robert Hunt Drive	Impact	-0.3	-0.3	-0.3
205 Robert Hunt Drive	Impact	-0.3	-0.3	-0.3
207 Robert Hunt Drive	Impact	-0.3	-0.3	-0.3
105 Jasmine Court	Impact	+0.2	+0.2	+0.2
114 Jasmine Court	Impact	No Impact	No Impact	No Impact
214 Robert Hunt Drive	Impact	-0.5	-0.9	-0.9
216 Robert Hunt Drive	Impact	-0.5	-0.9	-0.9
218 Robert Hunt Drive	Impact	-0.5	-0.9	-0.9
300 Robert Hunt Drive	Impact	-0.6	-1.0	-1.0
310 Bolin Forest Drive	Impact	+0.4	+0.2	+0.2

*Impact to parking and access only

Note: ‘No Impact’ indicates flood waters do not reach dwelling

Change in the 25-Year water surface elevation (ft):

	<u>Existing</u>	<u>Alt. 1</u>	<u>Alt. 2</u>	<u>Alt. 3</u>
103 Morningside Drive*	Impact	No Impact	No Impact	No Impact
105 Morningside Drive*	Impact	No Impact	No Impact	No Impact
104 Morningside Drive	Impact	0.0	0.0	0.0
106 Morningside Drive	Impact	0.0	0.0	0.0
201 Robert Hunt Drive	Impact	-0.3	-0.3	-0.3
205 Robert Hunt Drive	Impact	-0.3	-0.3	-0.3
207 Robert Hunt Drive	Impact	-0.3	-0.3	-0.3
105 Jasmine Court	No Impact	+0.3	+0.3	+0.3
114 Jasmine Court	No Impact	No Impact	No Impact	No Impact
214 Robert Hunt Drive	Impact	-1.1	-1.4	-1.4
216 Robert Hunt Drive	Impact	-1.1	-1.4	-1.4
218 Robert Hunt Drive	Impact	-1.1	-1.5	-1.5
300 Robert Hunt Drive	Impact	-1.3	No Impact	No Impact
310 Bolin Forest Drive	Impact	+0.4	+0.4	+0.4

*Impact to parking and access only

Note: 'No Impact' indicates flood waters do not reach dwelling

Change in the 10-Year water surface elevation (ft):

	<u>Existing</u>	<u>Alt. 1</u>	<u>Alt. 2</u>	<u>Alt. 3</u>
103 Morningside Drive*	Impact	No Impact	No Impact	No Impact
105 Morningside Drive*	Impact	No Impact	No Impact	No Impact
104 Morningside Drive	Impact	0.0	0.0	0.0
106 Morningside Drive	No Impact	No Impact	No Impact	No Impact
201 Robert Hunt Drive	Impact	-0.3	-0.3	-0.3
205 Robert Hunt Drive	Impact	-0.3	-0.3	-0.3
207 Robert Hunt Drive	Impact	-0.3	-0.3	-0.3
105 Jasmine Court	No Impact	No Impact	No Impact	No Impact
114 Jasmine Court	No Impact	No Impact	No Impact	No Impact
214 Robert Hunt Drive	Impact	No Impact	No Impact	No Impact
216 Robert Hunt Drive	Impact	-1.6	-1.7	-1.7
218 Robert Hunt Drive	Impact	-1.8	No Impact	No Impact
300 Robert Hunt Drive	Impact	No Impact	No Impact	No Impact
310 Bolin Forest Drive	Impact	+0.4	+0.4	+0.4

*Impact to parking and access only

Note: 'No Impact' indicates flood waters do not reach dwelling

Change in the 2-Year water surface elevation (ft):

	<u>Existing</u>	<u>Alt. 1</u>	<u>Alt. 2</u>	<u>Alt. 3</u>
103 Morningside Drive*	No Impact	No Impact	No Impact	No Impact
105 Morningside Drive*	Impact	No Impact	No Impact	No Impact
104 Morningside Drive	No Impact	No Impact	No Impact	No Impact
106 Morningside Drive	No Impact	No Impact	No Impact	No Impact
201 Robert Hunt Drive	No Impact	No Impact	No Impact	No Impact
205 Robert Hunt Drive	No Impact	No Impact	No Impact	No Impact
207 Robert Hunt Drive	Impact	+0.1	+0.1	+0.1
105 Jasmine Court	No Impact	No Impact	No Impact	No Impact
114 Jasmine Court	No Impact	No Impact	No Impact	No Impact
214 Robert Hunt Drive	No Impact	No Impact	No Impact	No Impact
216 Robert Hunt Drive	Impact	No Impact	No Impact	No Impact
218 Robert Hunt Drive	Impact	No Impact	No Impact	No Impact
300 Robert Hunt Drive	No Impact	No Impact	No Impact	No Impact
310 Bolin Forest Drive	No Impact	+1.3	+1.3	+1.3

*Impact to parking and access only

Note: 'No Impact' indicates flood waters do not reach dwelling

For complete hydraulic model results with changes in flood elevation offered by each alternative, please see **Appendix D**. It should be noted that the model did not indicate that any dwellings in the study would be impacted above the finished floor elevation, but significant damage and financial loss can occur from flooding of crawl spaces and other ancillary items below the finished floor elevation.

V. Conclusions

Based on the above information and computations, it does not appear that a single solution exists that will decrease flooding impacts for all affected property owners. The number of property owners that are potentially impacted by flooding along UT to Bolin Creek and the number of existing road crossings make this a complex issue. The model indicates that reduction in flood elevations upstream will likely cause an increase in flood elevations downstream. Potentially significant reductions in flood impacts can be achieved, but the improvements will not be without increased impacts elsewhere.

The majority of impacts to flood elevations provided by the alternatives in the study are relatively minor despite the significant increase in pipe sizes in the analyzed alternatives. This is likely due to the fact that the existing crossings overtop the roadway or divert stormwater into other drainage areas to provide flooding relief before a significant amount of stormwater can be detained in lower frequency storms.

It appears that most of the structures that are experiencing flooding in this study were built in the natural floodplain. Floodplains are vital to the stability of streams and their ability to abate

downstream flooding. Floodplains do get flooded as part of a properly functioning and healthy stream. Due to this, even the best-case alternative studied is not capable of eliminating the threat of flooding to the majority of dwellings in the study.

VI. Recommendation

The three alternatives presented in this study are as follows:

	<u>Existing</u>	<u>Alt. 1</u>	<u>Alt. 2</u>	<u>Alt. 3</u>
Morningside Drive	1@24" RCP	Remove Crossing	3@42" RCP	3@42" RCP
Robert Hunt Drive	3@30" RCP	Remove Crossing	4@48" RCP	Remove Crossing
Bolin Forest Drive	1@60"x44" CMPA	Remove Crossing	3@54" RCP	3@54" RCP

Sungate's recommendation to the Town is to retain the existing culverts in the current configuration. Each alternative presented above provides a decrease in flooding elevations and frequency for some property owners, but harms downstream property owners with increased flooding elevations and frequency. While some damage has been reported due to flooded crawl spaces, the hydraulic model does not indicate that flood waters would reach the finished floor elevation of any home included in this study during any storm studied herein with the existing culverts in place. Additionally, the majority of the homes that experience flooding issues according to the model are located within the natural floodplain of UT to Bolin Creek and would experience flooding even if the streets had not been constructed. With an emphasis on the increased potential for flooding of downstream property owners, Sungate does not recommend that the culverts at Morningside Drive, Robert Hunt Drive, and Bolin Forest Drive be upgraded.

It is recommended that this flooding event be added to the Town's list of flooding problems and to be evaluated for inclusion in one of the tiers (TBD).

**Morningside Drive
100-Year Storm Event**



Impact to parking and access, no impact to dwelling
Impact to foundation, but below Finished Floor Elevation
Impact above the Finished Floor Elevation
Impact to Garage, but below Finished Floor Elevation

	<u>Dwelling</u>	<u>Existing</u>	<u>Alt #1</u>	<u>Alt #2</u>	<u>Alt #3</u>
1	103 Morningside Drive	Impact	---	---	---
2	105 Morningside Drive	Impact	---	---	---
	Morningside Drive	1-24" RCP	Remove Crossing	3-42" RCP	3-42" RCP
3	104 Morningside Drive	Impact	Impact	Impact	Impact
4	106 Morningside Drive	Impact	Impact	Impact	Impact
5	201 Robert Hunt Drive	Impact	Impact	Impact	Impact
6	205 Robert Hunt Drive	Impact	Impact	Impact	Impact
7	207 Robert Hunt Drive	Impact	Impact	Impact	Impact
	Robert Hunt Drive	3-30" RCP	Remove Crossing	4-48" RCP	Remove Crossing
8	105 Jasmine Court	Impact	Impact	Impact	Impact
9	114 Jasmine Court	Impact	---	---	---
10	214 Robert Hunt Drive	Impact	Impact	Impact	Impact
11	216 Robert Hunt Drive	Impact	Impact	Impact	Impact
12	218 Robert Hunt Drive	Impact	Impact	Impact	Impact
13	300 Robert Hunt Drive	Impact	Impact	Impact	Impact
	Bolin Forest Drive	1-60"x44" CMPA	Remove Crossing	3-54" RCP	3-54" RCP
14	310 Bolin Forest Drive	Impact	Impact	Impact	Impact

**Morningside Drive
25-Year Storm Event**



Impact to parking and access, no impact to dwelling
Impact to foundation, but below Finished Floor Elevation
Impact above the Finished Floor Elevation
Impact to Garage, but below Finished Floor Elevation

	<u>Dwelling</u>	<u>Existing</u>	<u>Alt #1</u>	<u>Alt #2</u>	<u>Alt #3</u>
1	103 Morningside Drive	Impact	---	---	---
2	105 Morningside Drive	Impact	---	---	---
	Morningside Drive	1-24" RCP	Remove Crossing	3-42" RCP	3-42" RCP
3	104 Morningside Drive	Impact	Impact	Impact	Impact
4	106 Morningside Drive	Impact	Impact	Impact	Impact
5	201 Robert Hunt Drive	Impact	Impact	Impact	Impact
6	205 Robert Hunt Drive	Impact	Impact	Impact	Impact
7	207 Robert Hunt Drive	Impact	Impact	Impact	Impact
	Robert Hunt Drive	3-30" RCP	Remove Crossing	4-48" RCP	Remove Crossing
8	105 Jasmine Court	---	Impact	Impact	Impact
9	114 Jasmine Court	---	---	---	---
10	214 Robert Hunt Drive	Impact	Impact	Impact	Impact
11	216 Robert Hunt Drive	Impact	Impact	Impact	Impact
12	218 Robert Hunt Drive	Impact	Impact	Impact	Impact
13	300 Robert Hunt Drive	Impact	Impact	---	---
	Bolin Forest Drive	1-60"x44" CMPA	Remove Crossing	3-54" RCP	3-54" RCP
14	310 Bolin Forest Drive	Impact	Impact	Impact	Impact

**Morningside Drive
10-Year Storm Event**



Impact to parking and access, no impact to dwelling
Impact to foundation, but below Finished Floor Elevation
Impact above the Finished Floor Elevation
Impact to Garage, but below Finished Floor Elevation

	<u>Dwelling</u>	<u>Existing</u>	<u>Alt #1</u>	<u>Alt #2</u>	<u>Alt #3</u>
1	103 Morningside Drive	Impact	---	---	---
2	105 Morningside Drive	Impact	---	---	---
	Morningside Drive	1-24" RCP	Remove Crossing	3-42" RCP	3-42" RCP
3	104 Morningside Drive	Impact	Impact	Impact	Impact
4	106 Morningside Drive	---	---	---	---
5	201 Robert Hunt Drive	Impact	Impact	Impact	Impact
6	205 Robert Hunt Drive	Impact	Impact	Impact	Impact
7	207 Robert Hunt Drive	Impact	Impact	Impact	Impact
	Robert Hunt Drive	3-30" RCP	Remove Crossing	4-48" RCP	Remove Crossing
8	105 Jasmine Court	---	---	---	---
9	114 Jasmine Court	---	---	---	---
10	214 Robert Hunt Drive	Impact	---	---	---
11	216 Robert Hunt Drive	Impact	Impact	Impact	Impact
12	218 Robert Hunt Drive	Impact	Impact	---	---
13	300 Robert Hunt Drive	Impact	---	---	---
	Bolin Forest Drive	1-60"x44" CMPA	Remove Crossing	3-54" RCP	3-54" RCP
14	310 Bolin Forest Drive	Impact	Impact	Impact	Impact

**Morningside Drive
2-Year Storm Event**

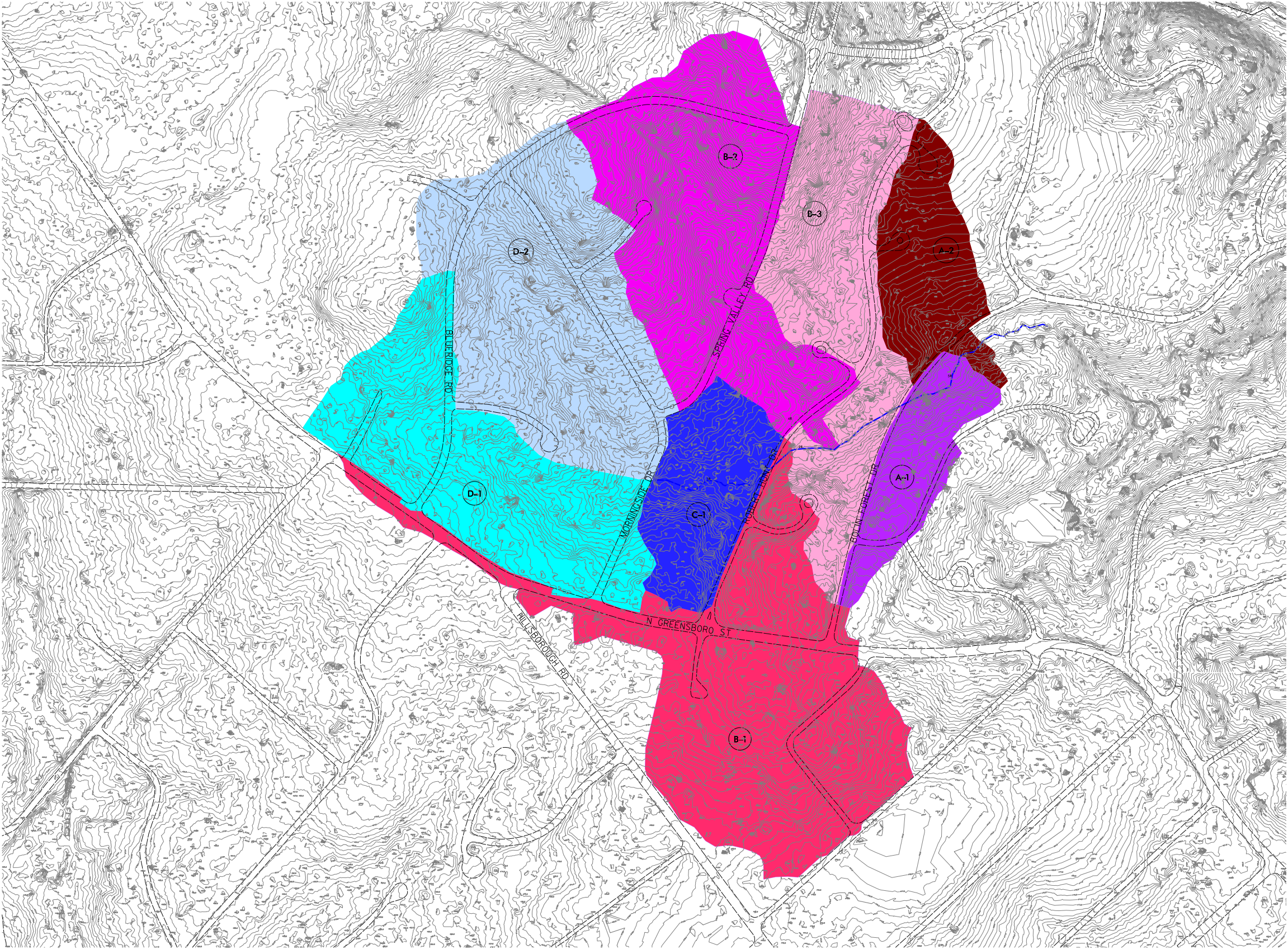


Impact to parking and access, no impact to dwelling
Impact to foundation, but below Finished Floor Elevation
Impact above the Finished Floor Elevation
Impact to Garage, but below Finished Floor Elevation

	<u>Dwelling</u>	<u>Existing</u>	<u>Alt #1</u>	<u>Alt #2</u>	<u>Alt #3</u>
1	103 Morningside Drive	---	---	---	---
2	105 Morningside Drive	Impact	---	---	---
	Morningside Drive	1-24" RCP	Remove Crossing	3-42" RCP	3-42" RCP
3	104 Morningside Drive	---	---	---	---
4	106 Morningside Drive	---	---	---	---
5	201 Robert Hunt Drive	---	---	---	---
6	205 Robert Hunt Drive	---	---	---	---
7	207 Robert Hunt Drive	Impact	Impact	Impact	Impact
	Robert Hunt Drive	3-30" RCP	Remove Crossing	4-48" RCP	Remove Crossing
8	105 Jasmine Court	---	---	---	---
9	114 Jasmine Court	---	---	---	---
10	214 Robert Hunt Drive	---	---	---	---
11	216 Robert Hunt Drive	Impact	---	---	---
12	218 Robert Hunt Drive	Impact	---	---	---
13	300 Robert Hunt Drive	---	---	---	---
	Bolin Forest Drive	1-60"x44" CMPA	Remove Crossing	3-54" RCP	3-54" RCP
14	310 Bolin Forest Drive	---	Impact	Impact	Impact

REVISIONS

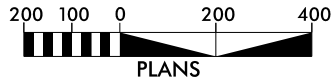
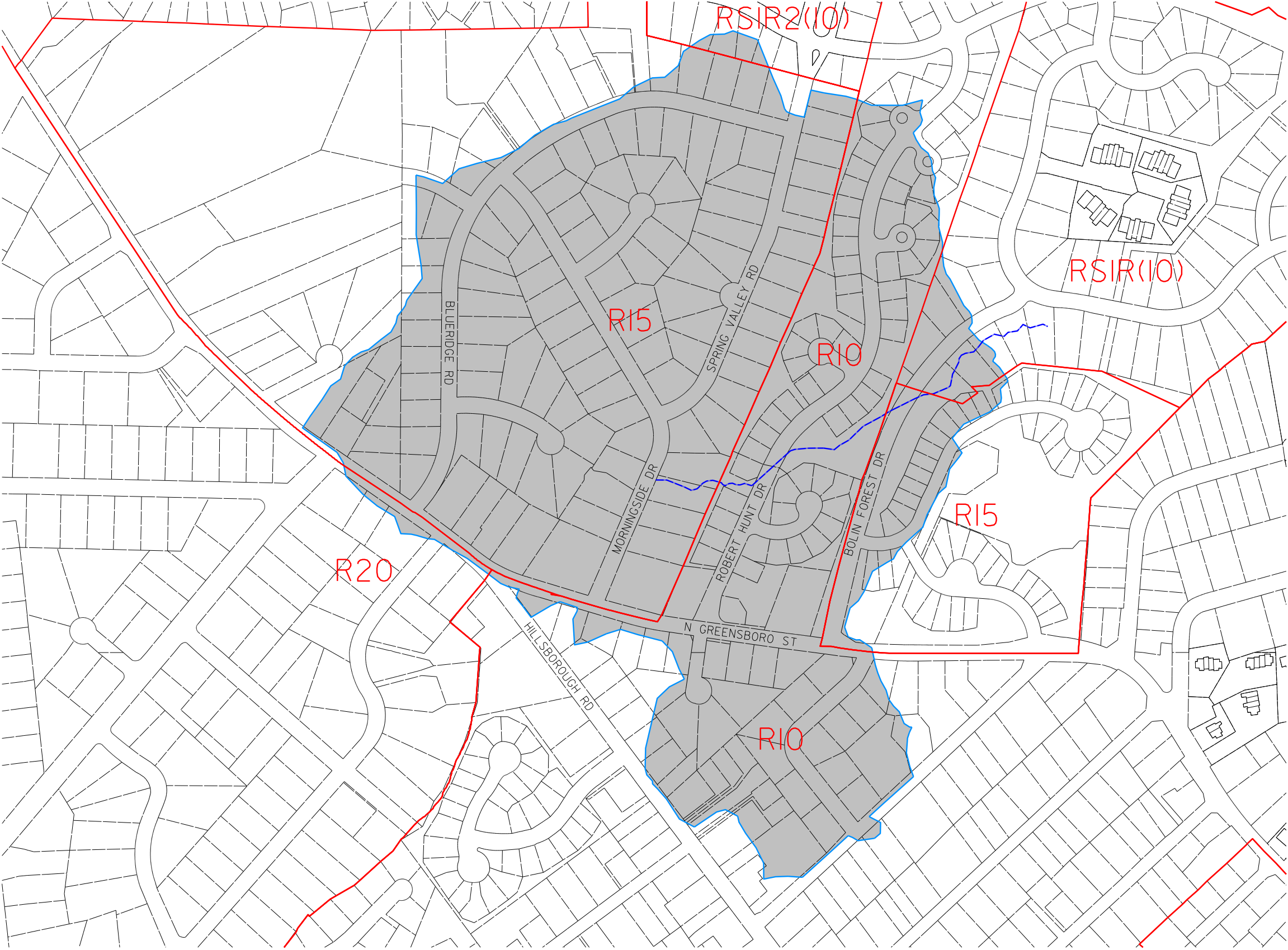
APPENDIX A
MORNINGSIDE DRIVE - BOLIN FOREST DRIVE
DRAINAGE AREA



PROJECT REFERENCE NO.	SHEET NO.
MORNINGSIDE DRIVE	A
R/W SHEET NO.	
ROADWAY DESIGN ENGINEER	HYDRAULICS ENGINEER

REVISIONS

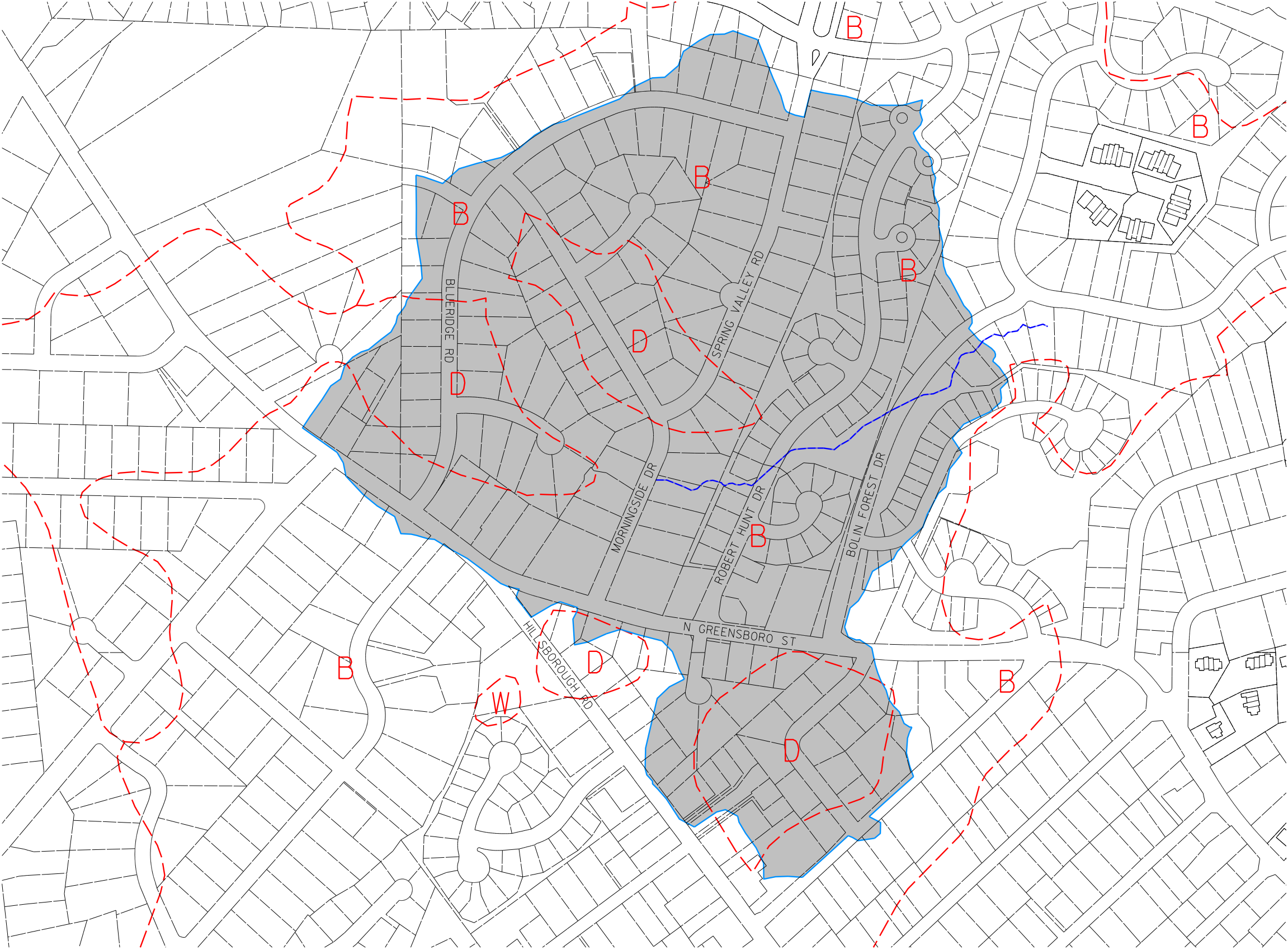
APPENDIX B
MORNINGSIDE DRIVE – BOLIN FOREST DRIVE
ZONING MAP



PROJECT REFERENCE NO.		SHEET NO.	
MORNINGSIDE DRIVE		B	
R/W SHEET NO.			
ROADWAY DESIGN ENGINEER		HYDRAULICS ENGINEER	

REVISIONS

APPENDIX C
MORNINGSIDE DRIVE – BOLIN FOREST DRIVE
SOILS MAP – HYDROLOGIC SOIL GROUP



PROJECT REFERENCE NO.		SHEET NO.	
MORNINGSIDE DRIVE		C	
R/W SHEET NO.			
ROADWAY DESIGN ENGINEER		HYDRAULICS ENGINEER	

Appendix D

FF=Finised Floor Elevation
NG@F= Elevation where foundation
meets natural ground

Home	Parking	462.88
105 Morningside	Road CL	463.51

Home	FF	465.13
104 Morningside	NG@F	460.27

Home	FF	463.27
106 Morningside	NG@F	459.57

Home	FF	460.5
205 Robert Hunt	NG@F	457.73

Home	FF	460.5
205 Robert Hunt	NG@F	457.84

Home	FF	457.15
105 Jasmine	NG@F	456.61

Home	FF	460.26
114 Jasmine	NG@F	455.84

River Sta	Profile	Existing	Alternate 1		Alternate 2		Alternate 3	
		W.S. Elev (ft)	W.S. Elev (ft)	Diff (ft)	W.S. Elev (ft)	Diff (ft)	W.S. Elev (ft)	Diff (ft)
1510	100 Yr	464.43	462.63	-1.80	462.64	-1.79	462.64	-1.79
	25 Yr	464.30	462.44	-1.86	462.42	-1.88	462.42	-1.88
	10 Yr	464.23	462.21	-2.02	462.20	-2.03	462.20	-2.03
	2 Yr	463.88	461.95	-1.93	461.94	-1.94	461.94	-1.94
1439	100 Yr	461.71	461.74	0.03	461.71	0.00	461.71	0.00
	25 Yr	461.47	461.48	0.01	461.47	0.00	461.47	0.00
	10 Yr	461.27	461.27	0.00	461.27	0.00	461.27	0.00
	2 Yr	460.65	460.83	0.18	460.81	0.16	460.81	0.16
1380	100 Yr	461.09	461.08	-0.01	461.09	0.00	461.09	0.00
	25 Yr	460.87	460.88	0.01	460.87	0.00	460.87	0.00
	10 Yr	460.69	460.72	0.03	460.71	0.02	460.71	0.02
	2 Yr	460.06	460.21	0.15	460.19	0.13	460.19	0.13
1291	100 Yr	459.87	459.87	0.00	459.87	0.00	459.87	0.00
	25 Yr	459.67	459.68	0.01	459.67	0.00	459.67	0.00
	10 Yr	459.49	459.51	0.02	459.5	0.01	459.5	0.01
	2 Yr	458.89	459.15	0.26	459.12	0.23	459.12	0.23
1189	100 Yr	458.88	458.66	-0.22	458.65	-0.23	458.65	-0.23
	25 Yr	458.62	458.44	-0.18	458.42	-0.20	458.42	-0.20
	10 Yr	458.45	458.29	-0.16	458.29	-0.16	458.29	-0.16
	2 Yr	457.96	458.04	0.08	458.04	0.08	458.04	0.08
1131	100 Yr	458.90	458.58	-0.32	458.58	-0.32	458.58	-0.32
	25 Yr	458.62	458.36	-0.26	458.35	-0.27	458.35	-0.27
	10 Yr	458.45	458.19	-0.26	458.18	-0.27	458.18	-0.27
	2 Yr	457.61	457.73	0.12	457.70	0.09	457.70	0.09
1086	100 Yr	458.82	457.98	-0.84	457.97	-0.85	457.97	-0.85
	25 Yr	458.54	457.80	-0.74	457.79	-0.75	457.79	-0.75
	10 Yr	458.37	457.52	-0.85	457.51	-0.86	457.51	-0.86
	2 Yr	457.00	456.80	-0.20	456.78	-0.22	456.78	-0.22
1070	100 Yr	458.83	458.05	-0.78	457.37	-1.46	458.03	-0.80
	25 Yr	458.56	457.69	-0.87	457.13	-1.43	457.67	-0.89
	10 Yr	458.39	457.42	-0.97	456.92	-1.47	457.40	-0.99
	2 Yr	457.09	456.85	-0.24	456.38	-0.71	456.81	-0.28
853	100 Yr	456.92	457.11	0.19	457.09	0.17	457.09	0.17
	25 Yr	456.51	456.81	0.30	456.82	0.31	456.82	0.31
	10 Yr	456.43	456.56	0.13	456.54	0.11	456.54	0.11
	2 Yr	455.45	455.81	0.36	455.74	0.29	455.74	0.29
796	100 Yr	456.17	456.41	0.24	456.38	0.21	456.39	0.22
	25 Yr	455.75	456.10	0.35	455.98	0.23	455.98	0.23
	10 Yr	455.07	455.82	0.75	455.79	0.72	455.79	0.72
	2 Yr	454.30	454.58	0.28	454.52	0.22	454.52	0.22
754	100 Yr	455.98	455.79	-0.19	455.64	-0.34	455.66	-0.32
	25 Yr	455.41	455.10	-0.31	455.10	-0.31	455.10	-0.31
	10 Yr	455.09	454.75	-0.34	454.77	-0.32	454.77	-0.32
	2 Yr	453.20	453.69	0.49	453.66	0.46	453.66	0.46

Home 216 Robert Hunt	FF	456.77	545	100 Yr	455.54	455.06	-0.48	454.67	-0.87	454.68	-0.86
	NG@F	452.58		25 Yr	455.13	454.02	-1.11	453.70	-1.43	453.70	-1.43
	Garage	454.77		10 Yr	454.86	453.26	-1.60	453.12	-1.74	453.12	-1.74
				2 Yr	452.73	452.33	-0.40	452.20	-0.53	452.20	-0.53
Home 218 Robert Hunt	FF	457.24	483	100 Yr	455.54	455.05	-0.49	454.65	-0.89	454.67	-0.87
	NG@F	452.55		25 Yr	455.13	453.98	-1.15	453.62	-1.51	453.62	-1.51
	Garage	455.24		10 Yr	454.86	453.11	-1.75	452.51	-2.35	452.51	-2.35
				2 Yr	452.66	451.26	-1.40	450.83	-1.83	450.83	-1.83
Home 300 Robert Hunt	FF	458.83	441	100 Yr	455.52	454.90	-0.62	454.54	-0.98	454.56	-0.96
	NG@F	453.63		25 Yr	455.11	453.82	-1.29	453.46	-1.65	453.46	-1.65
	Garage	457.4		10 Yr	454.85	452.95	-1.90	452.30	-2.55	452.30	-2.55
				2 Yr	452.67	451.33	-1.34	449.94	-2.73	449.94	-2.73
			340	100 Yr	451.22	453.39	2.17	451.87	0.65	451.88	0.66
				25 Yr	450.30	451.47	1.17	451.30	1.00	451.30	1.00
				10 Yr	449.84	450.85	1.01	450.76	0.92	450.76	0.92
				2 Yr	449.02	449.64	0.62	449.56	0.54	449.56	0.54
			304	100 Yr	450.63	451.07	0.44	450.89	0.26	450.90	0.27
				25 Yr	450.17	450.74	0.57	450.67	0.50	450.67	0.50
				10 Yr	449.91	450.46	0.55	450.42	0.51	450.42	0.51
				2 Yr	448.99	449.79	0.80	449.74	0.75	449.74	0.75
			183	100 Yr	450.31	450.83	0.52	450.59	0.28	450.59	0.28
				25 Yr	449.87	450.42	0.55	450.35	0.48	450.35	0.48
				10 Yr	449.62	450.14	0.52	450.10	0.48	450.10	0.48
				2 Yr	448.41	449.51	1.10	449.45	1.04	449.45	1.04
			134	100 Yr	450.30	450.79	0.49	450.56	0.26	450.57	0.27
				25 Yr	449.87	450.40	0.53	450.34	0.47	450.34	0.47
				10 Yr	449.62	450.13	0.51	450.09	0.47	450.09	0.47
				2 Yr	448.30	449.52	1.22	449.46	1.16	449.46	1.16
Home 310 Bolin Forest	FF	452.2	104	100 Yr	450.01	450.42	0.41	450.20	0.19	450.20	0.19
	NG@F	449.03		25 Yr	449.66	450.09	0.43	450.04	0.38	450.04	0.38
				10 Yr	449.46	449.87	0.41	449.84	0.38	449.84	0.38
				2 Yr	448.03	449.37	1.34	449.32	1.29	449.32	1.29
			91	100 Yr	448.96	449.43	0.47	449.25	0.29	449.26	0.30
				25 Yr	448.72	449.04	0.32	448.99	0.27	448.99	0.27
				10 Yr	448.35	448.86	0.51	448.83	0.48	448.83	0.48
				2 Yr	447.48	448.19	0.71	448.12	0.64	448.12	0.64
			74	100 Yr	448.84	449.33	0.49	449.14	0.30	449.15	0.31
				25 Yr	448.16	448.94	0.78	448.87	0.71	448.87	0.71
				10 Yr	447.75	448.69	0.94	448.64	0.89	448.64	0.89
				2 Yr	446.82	447.50	0.68	447.42	0.60	447.42	0.60
			0	100 Yr	447.45	447.56	0.11	447.49	0.04	447.49	0.04
				25 Yr	447.02	447.22	0.20	447.15	0.13	447.15	0.13
				10 Yr	446.79	446.95	0.16	446.91	0.12	446.91	0.12
				2 Yr	445.71	446.37	0.66	446.31	0.60	446.31	0.60

Attachment 1



18" RCP – Looking downstream toward Morningside Drive

Attachment 2



18" RCP – Looking downstream toward Morningside Drive

Attachment 3



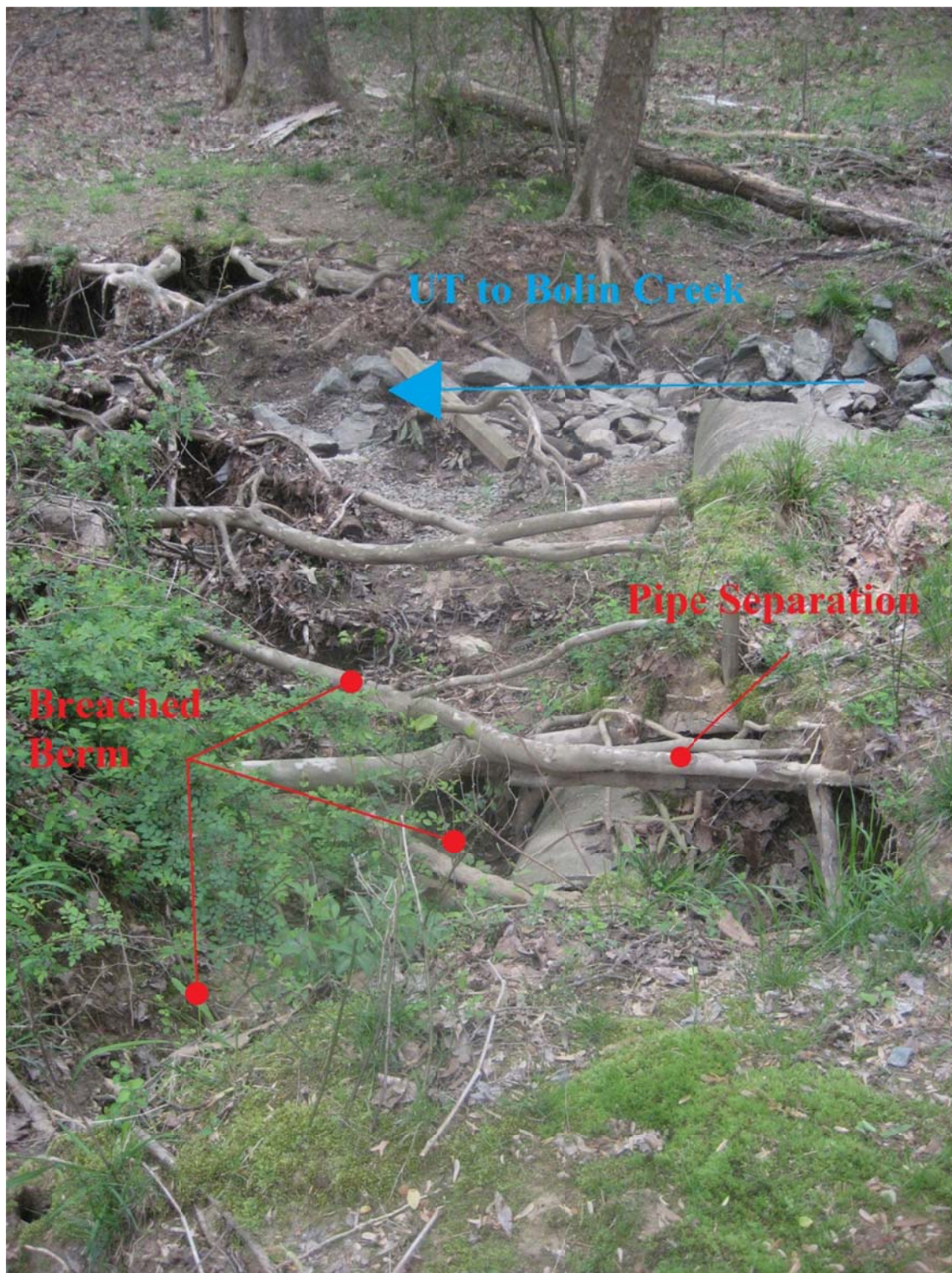
3@30" RCP with Flared End Sections – Looking downstream toward Robert Hunt Drive

Attachment 4



60"x44" CMPA - looking upstream toward Bolin Forest Drive

Attachment 5



Outlet of breached detention basin downstream of Robert Hunt Drive

Attachment 6



Driveway bridge at 310 Bolin Forest Drive