

FLOOD STUDY  
FOR  
WINDY OAK DRIVE DRAINAGE IMPROVEMENTS

NASHVILLE, NORTH CAROLINA

PREPARED FOR  
TOWN OF NASHVILLE, NORTH CAROLINA

PREPARED BY  
KIKER STORMWATER SOLUTIONS



IN CONJUNCTION WITH



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DAVID J. KIKER, PE

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## SECTION 1.0 INTRODUCTION

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A section of the South Creek Drive drainage system located from Windy Oak Drive to just downstream of Laurel Spring Drive is flat, undersized and has a relatively high overtopping elevation. This section of the drainage system is contributing to routine flooding at both 215 Windy Oak Drive, further upstream at the fairly recently constructed Birchwood Homes subdivision along Par Drive and along Village Lane. Both Par Drive and Village Lane experience roadway flooding several times per year as floodwaters backup behind Windy Oak Drive. In addition, the home at 215 Windy Oak Drive experiences crawl space flooding after storm flows overtop Windy Oak Drive. The crawl space at this home is set below the roadway overtopping elevation at Windy Oak Drive, which makes this home subject to flooding. This flood study was developed to identify drainage system improvements that would reduce the frequency and severity of flooding at these known locations of flooding without causing adverse flooding downstream.

An EPA SWMM model was developed by Kiker Stormwater Solutions (KSS) as part of this flood study to model the existing drainage system's response to various frequency rainfall events and to develop a series of drainage improvements to mitigate future flooding. EPA SWMM is a fully dynamic model that can evaluate open and closed drainage systems, account for flood attenuation from natural and manmade storage areas, and assess downstream impacts from making upstream improvements. The goal of this flood study was to identify a series of cost-effective drainage improvements that reduce flooding upstream of Windy Oak Drive while not adversely impacting properties located further downstream along the drainage system.



**Photo 1: 215 Windy Oak Drive**

The success of this project will be driven by how much Windy Oak Drive can be lowered without adversely impacting downstream flooding at Laurel Spring Drive and the functionality of the properties from 215 Windy Oak Drive to Laurel Spring Drive. The lower Windy Oak Drive is lowered the lower flood elevations will be in the Par Drive and Village Lane will be in the large flood events. The more Windy Oak Drive is lowered, the less flood storage will be available upstream and the higher the potential to increase downstream flooding. The more Windy Oak Drive is lowered, the more the yards along this drainage corridor will also need to be lowered. This may impact nearby fences, root systems of trees

## SECTION 1.0 INTRODUCTION

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and the functionality of the properties. The KSS report is a planning level report that did not involve a detailed survey of underground utilities that may exist in the project area. Prior to construction, it is recommended that a more rigorous evaluation will be needed for the underground utilities. It is also recommended that one-on-one meetings be set up with property owners to go over the goals of the project and to solicit feedback that may be helpful in avoiding potential issues and adversely impacting affected property owners.

### Modeling Methodology

Because of the complex nature of the drainage system (floodplain storage areas upstream of Windy Oak Drive, open systems, roadway culverts, closed pipe systems and the challenges with an extremely flat slope), EPA Storm Water Management Model (SWMM) version 5.1 is being used to model this drainage system. EPA SWMM simulates the surface runoff response to precipitation for an interconnected system of surfaces, channels, closed pipes and areas of attenuation. EPA SWMM will attenuate peak flows behind undersized culverts located at stream crossings with areas of floodplain storage such as Windy Oak Drive. During large storm events, floodwater will rise and store behind Windy Oak Drive until eventually overtopping the road and flooding the crawl space at 215 Windy Oak Drive. When this happens, Par Drive and Village Lane are inundated by the backwater of this undersized downstream culvert.

EPA SWMM combines hydrology and hydraulics, which allows the user to account for this attenuation effect while efficiently and accurately determining how improvements can affect both the upstream and downstream drainage system. The 10-, 25-, 50-, 100-, and 500-year floods were modeled using synthetic rainfall events based on a standard NRCS Type II distribution. EPA and NRCS methods were used to translate hydrographs and calculate infiltration rates for the study. Input data required to run this type of model include the following data:

- Basin areas
- Basin widths
- Basin slopes
- Basin percent impervious
- Hydrologic soil group classifications
- Landuse
- Rainfall data
- Stage-area relationships behind roadway or railroad embankments

The following sections provide additional information regarding the input data developed for this flood study:

### Sub-Basin Delineation and Elevations Data

Sub-basins were delineated for the project's watershed using 2-foot contour interval mapping generated from LiDAR data downloaded from the NC OneMap website. The LiDAR data was collected in 2015 as part of the North Carolina Floodplain Mapping Program's (NCFMP) statewide initiative to update FEMA maps across the state. An Arc-Hydro tool that automates the process of delineating sub-basins of a watershed was used to generate sub-basins at the main hydraulic points of interest. The initial Arc-Hydro generated sub-basin divides were validated and modified based on a July 17, 2020 field investigation that identified local drainage swales, pipe systems and natural divides to better define sub-basin divides. A total of four (4) sub-basins were delineated ranging in size from 29 to 72 acres for a total drainage area at the outfall near South Creek Drive of 182.1 acres (see Exhibit 1).

The following table summarizes the sub-basin areas in the South Creek Drive drainage system that were modeled as part of this study:

**SECTION 2.0**  
**EXISTING CONDITIONS MODEL DEVELOPMENT**

**Table 1: Summary of Drainage Areas**

Sub-Basin ID	Drainage Area (acres)
#1 <i>Blue</i>	47.7
#2 <i>Yellow</i>	29.2
#3 <i>Green</i>	33.7
#4 <i>Orange</i>	71.5

**Total Drainage Area = 182.1 acres (0.28 sq. mi.)**

Elevation data was entered into the EPA SWMM model to represent the surface of the channel, floodplain, parking lots, buildings, and roads. This input data was generated from the following sources:

- Topographic Mapping (2-foot contour interval) Generated from NCEM’s 2015 Digital Elevation Model (DEM).
- Survey data collected by Stocks Engineering for various site development projects over the years.
- Elevation data collected in July 2020 by staff of Stock Engineering using known elevations from historical survey as a relative benchmark.

Soils

Soils used to calculate the NRCS curve number for the pervious portions of the sub-basins were obtained from the soil survey maps found online at the following USDA website: [websoilsurvey.sc.egov.usda.gov](http://websoilsurvey.sc.egov.usda.gov). The following table summarizes the Hydrologic Soil Group for the primary soil groups found in the watershed:

**Table 2: Summary of NRCS Hydrologic Soil Groups**

Soil Name	Hydrologic Soil Group	% of Watershed
Bonneau Loamy Sand	A	14%
Norfolk Loamy Sand	B	16%
Norfolk Urban	B	20%
Rains Sandy Loam	B/D (assumed B)	50%

As shown in Table 2, the soils in the watershed are predominantly well-draining soils. The Rains soils are considered well-draining (hydrologic soil group B) if a drainage system with open ditches or channels is present. It was assumed that the Rains soils found in the South Creek Drive watershed are from hydrologic soil group B. EPA-SWMM uses the hydrologic soil group in the development of the runoff curve numbers (RCNs) for the pervious land cover found in the watershed only.

Land Use and NRCS Curve Numbers

Loss rates for this study are based on the EPA method, which uses the percent impervious values for each sub-basin along with NRCS curve numbers for those areas of the sub-basin that have a pervious land cover. Percent impervious values for this study are based on future conditions land use cover obtained from a recent aerial and GIS map of the watershed showing lot layouts. Table 3 shows the percent impervious values calculated for each of the three sub-basins. A weighted RCN for the pervious portions of each sub-basin ranged from 58 to 61. This runoff off curve number was calculated by weighting the percentage of woods and well-maintained grass for each of the two NRCS Hydrologic Soil Groups. The following table summarizes the existing conditions hydrologic input for land use and other SWMM input parameters for this project:

**SECTION 2.0**  
**EXISTING CONDITIONS MODEL DEVELOPMENT**

**Table 3: Future Conditions Hydrologic Input**

Sub-Basin ID	Drainage Area (ac)	Basin Slope (%)	Basin Width (ft.)	% Impervious	Pervious RCN
#1	47.7	1.26%	989	34	61
#2	29.2	0.63%	727	21	54
#3	33.7	0.53%	667	33	54
#4	71.5	1.16%	1001	25	54

Rainfall

An NRCS Type II storm with a 24-hour duration was input along with rainfall depths obtained for the Town of Nashville for the 1-, 2-, 10-, 25-, and 100-year floods. Total rainfall depths for the modeled frequency storms shown in Table 4 were based on data published on the NOAA website, [http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc\\_pfds.html](http://hdsc.nws.noaa.gov/hdsc/pfds/orb/nc_pfds.html).

**Table 4: NOAA 24-Hour Rainfall Depths for Nashville, NC**

Flood Frequency	Rainfall Depth (inches)
1-Year	2.69
2-Year	3.26
5-Year	4.19
10-Year	5.01
25-Year	6.24
100-Year	8.53

Hydrograph Translation

EPA SWMM methodologies use several input parameters that are not found in other commonly used models. The basin width is a parameter unique to SWMM that typically represents the watershed area divided by the longest flow path. The basin slope is the overall sub-basin grade change divided by the longest flow path. These parameters are used to calculate the response of the watershed to rainfall by defining the basin's shape (narrow or wide) and overall slope. The EPA SWMM model uses the basin width and basin slope parameters to create the unit hydrograph used in the model that will translate the rainfall into runoff.

Storage and Flood Routing

Downstream of Par Drive is a 1.0-acre detention pond originally design to attenuate peak flows from the upstream residential development. The stage-area relationship of this detention facility was input into the EPA-SWMM model to account for its effect in reducing downstream peak flows. The following table summarizes the stage-area relationship for this pond:

**Table 5: Stage-Area Relationship at Par Drive Detention Facility**

Elevation (Ft NAVD '88)	Area (acres)
179.93	0.00
180	0.00
182	0.28
184	0.77
186	0.85

**SECTION 3.0**  
**EXISTING CONDITIONS MODEL RESULTS**

The following series of tables reflect the existing conditions model results taken directly out of the EPA-SWMM model for the 5-, 10-, and 100-flood frequencies. Table 6 summarizes the existing conditions peak flows at key locations along the drainage system along with the pipe capacity of the subject culvert at the initiation of overtopping.

**Table 6: Comparison of Existing Conditions Flows with Culvert Capacity**

Location	Culvert Size & Material	Pipe Capacity at Overtopping (cfs)	5-Year Peak Flow (cfs)	10-Year Peak Flow (cfs)	100-Year Peak Flow (cfs)
Windy Oak Drive	24" RCP	21	38	66	156
Laurel Spring Drive	Twin 24" RCPs	39	42	70	175
South Creek Drive	Twin 42" RCPs	191	96	108	225

Peak flows for the 5-, 10- and 100-year flood events were determined by manually adjusting the EPA-SWMM model to eliminate flood attenuation upstream of Windy Oak Drive. An evaluation of Table 6 shows that Windy Oak Drive is conveying just over 50% of the 5-year flood while Laurel Spring Drive is almost conveying the 5-year flood event. In addition, Table 6 is showing South Creek Drive conveying the vast majority of the 100-year flood event prior to overtopping. The following table summarizes the water surface elevations at the roadway crossings found in this study:

**Table 7: Existing Conditions Water Surface Elevations at Roadway Crossings**

Location	Overtopping Elev. (Ft NAVD '88)	5-Year WSEL (Ft NAVD '88)	10-Year WSEL (Ft NAVD '88)	100-Year WSEL (Ft NAVD '88)	100-Year Overtopping Depth
Windy Oak Drive	183.79	182.01	184.03	184.75	0.96
Laurel Spring Drive	180.02	178.12	179.28	180.87	0.85
South Creek Drive	177.86	175.43	175.73	178.49	0.63

WSEL: water surface elevation

Table 7 shows both Windy Oak Drive meeting a 5-year level of service (LOS) and Laurel Spring Drive and South Creek Drive both meeting a 10-year LOS. Inundating depths for all three road crossings are less than a foot in the 100-year flood event. The only reason Windy Oak Drive and Laurel Spring Drive are shown to meet the 5- and 10-year level of service is because they are of the large areas of natural floodplain storage located upstream of Windy Oak Drive.

Model Validation

To help validate model results, feedback from several residents that live on Par Drive and Windy Oak Drive highwater marks were obtained. The following table summarizes that feedback:

**SECTION 3.0**  
**EXISTING CONDITIONS MODEL RESULTS**

**Table 8: Historical Feedback**

<b>Resident Name</b>	<b>Address</b>	<b>Feedback</b>	<b>Highwater Mark</b>
Casey Norman	700 Par Drive	Floodwaters have reached a depth of 15" in the low point of Par Drive in front of her home. This has happened on more than one occasion. The Normans moved in in March 2020. Floodwaters will stay up for 3 to 6 hours.	HWM = 183.14' + 1.25' = <b>184.29'</b>
Celeste Johnson	701 Par Drive	Floodwaters will get over the first brick step going up to the home and this is at least a foot in the road. The road floods multiple times per year. The Johnsons moved in in December 2016. Floodwaters do not die down 30 minutes after a rainfall event. It takes several hours.	Confirmed mark from Casey Norman

HMW = high water mark

To reduce flooding in the Par Drive and Village Lane areas along with 215 Windy Oak Drive, a series of drainage improvement alternatives were developed. A review of the existing conditions water surface profile (Exhibit 2) shows that Windy Oak Drive is a bottleneck and causing floodwaters to backup prior to overtopping the yard at 215 Windy Oak Drive. The existing 24-inch diameter reinforced concrete closed pipe system is undersized and conveying less than 33% of the 10-year peak flow. A review of the existing conditions profiles shows the overtopping elevation at Windy Oak Drive is set approximately 0.8 feet above the minimum road elevation at Par Drive. If the existing 24-inch diameter closed pipe system is surcharged or flowing overland at Windy Oak Drive, the Par Drive and Village Lane areas are severely flooded. For this reason, drainage improvements presented in this report focused on increasing the closed pipe system's capacity between Windy Oak Drive and Laurel Spring Drive and lowering the overtopping elevation at this bottleneck area.

As shown in Exhibit 2, a significant volume of flood storage is occurring in the channel and floodplain areas immediately upstream of 215 Windy Oak Drive. However, the US Army Corps of Engineers does not allow inline detention so a proposed detention pond located upstream of Windy Oak Drive was not evaluated as part of this study. An alternative that lowers the overtopping elevation at Windy Oak Drive to provide flood relief upstream needs to confirm that downstream properties in the Laurel Spring Drive area are not adversely impacted. Should an alternative that lowers the overtopping elevation at Windy Oak Drive move forward it will be critical to fully engage and communicate with the impacted property owners. Lowering the ground surface too much may have adverse impacts to the aesthetics and function of this area of residents' side and front yards. Impacts to private utilities, roadway safety, driveways, fences, trees and other infrastructure may need to take place prior to the selection of a final design alternative. The following design alternatives are presented in this report:

- **Alternative #1:** Alternative #1 make no changes to the existing 24" diameter closed pipe system however the overtopping elevation from 215 Windy Oak Drive to Laurel Spring Drive is lowered by approximately 2 feet with this with this alternative. This is the least expensive alternative presented in this report but also one that may not achieve all the flood reduction goals of the Town.
- **Alternative #2:** Alternative #2 replaces the existing 24-inch diameter pipe with a new 48-inch diameter closed pipe system and lowers the overtopping elevation from 215 Windy Oak Drive to Laurel Spring Drive by approximately 2 feet. This alternative is relatively expensive; however, it will result in a significant reduction to upstream flooding. No drainage improvements are proposed to Laurel Spring Drive.
- **Alternative #3:** Alternative #3 replaces the existing 24-inch diameter pipe with twin 48-inch diameter flanking pipes from the upstream side of 215 Windy Oak Drive to Laurel Spring Drive, and lowers to the overtopping elevation from 215 Windy Oak Drive to Laurel Spring Drive. No drainage improvements are proposed to Laurel Spring Drive. Short of replacing the closed pipe system with an open channel, this alternative maximizes the flood reduction potential of the drainage system at Windy Oak Drive.
- **Alternative #4:** Alternative #4 replaces the existing 24-inch roadway culvert with twin 48-inch diameter flanking RCPs from the upstream side of 215 Windy Oak Drive to the downstream side of Windy Oak Drive and replaces the Laurel Spring Drive pipes with triple 36-diameter RCPs. In addition, this alternative involves the replacement of the remaining closed system downstream of Windy Oak Drive with a

trapezoidal open channel. This alternative maximizes the upstream flood reduction potential and removes some of the more expensive pipe construction cost. It is anticipated that Alternative #4 will meet resistance from property owners due to concerns with having an open channel in the front or side of the impacted properties.

- **Alternative #5:** Alternative #5 replaces the existing 24-inch diameter pipe with twin 48-inch diameter flanking pipes from the upstream side of 215 Windy Oak Drive to Laurel Spring Drive, replaces the Laurel Spring Drive pipes with triple 36-diameter RCPs and makes no adjustments to the overtopping elevation from 215 Windy Oak Drive to Laurel Spring Drive. The property owners located between Windy Oak Drive and Laurel Spring Drive are considered “non-benefiters” and therefore an alternative was developed to eliminate the need to regrade yards to convey larger storm events. This alternative was developed with the anticipation that residents will not want to be part of a project that involves lowering the side of their property to convey larger flood events.

Alternatives presented in this report reflect both a 5-year and 10-year level of service (LOS) while targeting a goal of limiting the 100-year flood depths in the road to 1.0 foot or less. A 5-year LOS is presented to help determine the potential cost savings from meeting a lower LOS. The hydraulic performance for each of the different alternatives is presented in Exhibit 3. A more detailed summary of the Alternative #1 through #5 drainage improvements is provided in the following sections:

#### Alternative #1

The design focused on lowering Windy Oak by approximately 2.0 feet with no changes to the existing 24-inch closed pipe system. Alternative #1 was developed to achieve a 5-year level of service at Par Drive for the least cost possible. The following is a summary of the drainage improvements associated with Alternative #1 (see Exhibit 4):

- Grade a 134 linear feet of trapezoidal channel from the upstream end of 215 Windy Oak Drive to the road.
- Lower Windy Oak Drive by approximately 2.0 feet so that the overtopping elevation is 182.15 feet. Other measures may be necessary to allow Windy Oak Drive to overtop in a relatively small flood events (2-year flood and greater).
- Grade a 270 linear feet of grass-lined trapezoidal swale from the downstream side of 215 Windy Oak Drive to Laurel Spring Drive.

The Alternative #1 drainage system improvements will bring Par Drive up to a 5-year LOS and reduces the 100-year flood depth at Par Drive from 1.95 feet to 1.07 feet. Peak flows at Laurel Spring Drive for the 5-, 10- and 100-year flood events increase by 3, 33, and 84 cfs when compared to the pre-project conditions. Adverse flooding will be seen at Windy Oak Drive and downstream through Laurel Spring Drive. No significant adverse impacts are experienced at South Creek Drive as a result of the Alternative #1 improvements. To minimize costs, no drainage improvements are proposed at Laurel Spring Drive as part of this alternative. The estimated cost of construction for this alternative is \$75,324. A copy of the engineer’s estimate of probable cost for Alternative #1 can be found in Exhibit 5.

Alternative #2

Alternative #2 replaces the existing 24-inch diameter RCP with 466 linear feet of 48-inch diameter RCP, and lowers Windy Oak Drive. Alternative #2 achieves a 10-year LOS at Par Drive and a significant reduction to the frequency of flooding at Windy Oak Drive. The following is a summary of the drainage improvements associated with Alternative #2 (see Exhibit 6):

- Replace 466 linear feet of existing 24-inch diameter RCP with of 48-inch diameter RCP.
- Grade 134 linear feet of grass-lined trapezoidal swale from the upstream end of 215 Windy Oak Drive to the road.
- Lower Windy Oak Drive by approximately 2.0 feet so that the overtopping elevation is 182.15 feet. Other measures may be necessary to allow Windy Oak Drive to overtop in a relatively small flood events (2-year flood and greater).
- Grade a 270 linear feet of grass-lined trapezoidal swale from the downstream side of 215 Windy Oak Drive to Laurel Spring Drive.

The Alternative #2 drainage system improvements will bring Par Drive up to a 10-year LOS, Windy Oak Drive up to a 5-year LOS and reduces the 100-year flood depth at Par Drive from 1.95 feet to 0.83 feet. Peak flows at Laurel Spring Drive for the 5-, 10- and 100-year flood events increase by 15, 28, and 51 cfs when compared to the pre-project conditions. To minimize costs no drainage improvements are proposed at Laurel Spring Drive as part of this alternative. The estimated cost of construction for this alternative is \$316,451. A copy of the engineer's estimate of probable cost for Alternative #2 can be found in Exhibit 7.

Alternative #3

Alternative #3 replaces the existing 24-inch diameter RCP with 466 linear feet of twin 48-inch diameter RCP, and lowers Windy Oak Drive. No drainage improvements are proposed to Laurel Spring Drive to help keep costs down. Short of replacing the closed pipe system with an open channel, this alternative maximizes the flood reduction potential of the drainage system at Windy Oak Drive. Alternative #3 achieves a 10-year LOS at both Par Drive and Windy Oak Drive. The following is a summary of the drainage improvements associated with Alternative #3 (see Exhibit 8):

- Replace 466 linear feet of existing 24-inch diameter RCP with of twin 48-inch diameter RCP.
- Grade a 134 linear feet of trapezoidal open channel from the upstream end of 215 Windy Oak Drive to the Windy Oak Drive.
- Lower Windy Oak Drive by approximately 2.0 feet so that the overtopping elevation is 182.15 feet. Other measures may be necessary to allow Windy Oak Drive to overtop in a relatively small flood events (2-year flood and greater).
- Grade a 270 linear feet of grass-lined trapezoidal swale from the downstream side of 215 Windy Oak Drive to Laurel Spring Drive.

The Alternative #3 drainage system improvements will bring Par Drive and Windy Oak Drive up to a 10-year LOS and reduces the 100-year flood depth at Par Drive from 1.95 feet to 0.64 feet. Peak flows at Laurel Spring Drive for the 5-, 10- and 100-year flood events increase by 43, 58, and 41 cfs when compared to the pre-project conditions. The estimated cost of construction for this alternative is \$439,425. A copy of the engineer's estimate of probable cost for Alternative #3 can be found in Exhibit 9.

Alternative #4

Alternative #4 replaces the existing 24-inch diameter RCP with 466 linear feet of twin 48-inch diameter RCP, lowers Windy Oak Drive and replaces much of the Windy Oak Drive closed pipe system with an open channel. Alternative #4 achieves a 10-year LOS at Par Drive, Windy Oak Drive and Laurel Spring Drive. The following is a summary of the drainage improvements associated with Alternative #4 (see Exhibit 10):

- Replace 134 linear feet of existing 24-inch diameter RCP (from 215 Windy Oak Drive to the downstream side of Windy Oak Drive) with a grass-lined trapezoidal open channel.
- Install a new concrete headwall at the upstream side of Windy Oak Drive.
- Replace 62 linear feet of existing 24-inch diameter RCP (from 215 Windy Oak Drive to the downstream side of Windy Oak Drive) with of twin 48-inch diameter RCP.
- Lower Windy Oak Drive by approximately 2.0 feet so that the overtopping elevation is 182.15 feet. Other measures may be necessary to allow Windy Oak Drive to overtop in a relatively small flood events (2-year flood and greater).
- Replace 270 linear feet of 24-inch diameter RCP with grass-lined trapezoidal open channel from the downstream side of 215 Windy Oak Drive to Laurel Spring Drive.
- Replace 72 linear feet of twin 24-inch diameter RCP with triple 36-inch diameter RCPs at Laurel Spring Drive and the crossing immediately downstream.

The Alternative #4 drainage system improvements will bring Windy Oak Drive and Laurel Spring Drive up to a 10-year LOS and eliminate flooding in the 100-year flood at Par Drive. There are no peak flows increases at Laurel Spring Drive with Alternative #4. The 100-year flood has reduced as much as 55 cfs when compared to the pre-project conditions at Laurel Spring Drive. The estimated cost of construction for this alternative is \$369,352. A copy of the engineer's estimate of probable cost for Alternative #4 can be found in Exhibit 11.

Alternative #5

Alternative #5 replaces the existing 24-inch diameter RCP with 466 linear feet of twin 48-inch diameter RCP, replaces the Laurel Spring Drive pipes with triple 36-inch diameter RCPs and make no changes to the overtopping elevation of Windy Oak Drive or the front and side yards along this drainage corridor to Laurel Spring Drive. Alternative #5 achieves a 10-year LOS at Par Drive, Windy Oak Drive and Laurel Spring Drive. As noted previously, the property owners located between Windy Oak Drive and Laurel Spring Drive are considered "non-benefiters" and therefore an alternative was developed to eliminate the need to regrade yards to convey larger storm events. This alternative was developed with the anticipation that residents will not want to be part of a project that involves lowering the side of their property to convey larger flood events. The following is a summary of the drainage improvements associated with Alternative #5 (see Exhibit 12):

- Replace 466 linear feet of existing 24-inch diameter RCP with of twin 48-inch diameter RCP.
- Replace 72 linear feet of twin 24-inch diameter RCP with triple 36-inch diameter RCPs at Laurel Spring Drive and the crossing immediately downstream.

The Alternative #5 drainage system improvements will bring Par Drive, Windy Oak Drive and Laurel Spring Drive up to a 10-year LOS and eliminates flooding in the 100-year flood at Par Drive. There are no peak flows increases at Laurel Spring Drive with Alternative #5.

## SECTION 4.0 DESIGN ALTERNATIVES

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The 100-year flood depth at Par Drive has been reduced from 1.95 feet to 0.88 feet when compared to the pre-project conditions. The estimated cost of construction for this alternative is \$562,465. A copy of the engineer's estimate of probable cost for Alternative #4 can be found in Exhibit 13.

**SECTION 4.0**  
**DESIGN ALTERNATIVES**

**Table 9: Summary of System Performance – Water Surface Elevations**

Alt#	Windy Oak Drive Proposed Pipe	Laurel Spring Drive Proposed Pipe	Overtopping Elevation at Windy Oak Drive (ft. NAVD '88)	Flood Elevations Upstream of 215 Windy Oak Drive				100-Year WSEL (ft. NAVD '88)	100-Year Flood Depth (ft)	100-Year WSEL (ft. NAVD '88)	100-Year Flood Depth (ft)
				5-Year WSEL (ft. NAVD '88)	5-Year Flood Depth (ft)	10-Year WSEL (ft. NAVD '88)	10-Year Flood Depth (ft)				
Existing	24" RCP	Twin 24-inch RCPs	183.79	183.66	0.52	184.28	1.14	185.09	1.95		
1	24" RCP	No changes	182.16	182.92	-0.22	183.19	0.05	184.21	1.07		
2	48" RCP	No changes	182.16	182.14	-1.00	182.74	-0.4	183.97	0.83		
3	Twin 48" RCPs	No changes	182.16	182.02	-1.12	182.38	-0.76	183.78	0.64		
4	Twin 48" RCPs + Open Channel	Triple 36" RCPs	182.16	180.34	-2.8	180.90	-2.24	183.08	-0.06		
5	Twin 48" RCPs	Triple 36" RCPs	183.79 (No changes)	180.81	-2.33	181.40	-1.74	184.02	0.88		

100-year flood depths shown in Table 9 are at Par Drive

**Table 10: Summary of System Performance - Peak Flows**

Alt#	Windy Oak Drive Proposed Pipe	Laurel Spring Drive Proposed Pipe	Overtopping Elevation at Windy Oak Drive (ft. NAVD '88)	Windy Oak Drive Overflow			Laurel Spring Drive Overflow		
				5-yr Peak Flow (cfs)	10-yr Peak Flow (cfs)	100-yr Peak Flow (cfs)	5-yr Peak Flow (cfs)	10-yr Peak Flow (cfs)	100-yr Peak Flow (cfs)
Existing	24" RCP	Twin 24-inch RCPs	183.79	0	26	200	0	0	165
1	24" RCP	No changes	182.16	42	74	285	3	33	249
2	48" RCP	No changes	182.16	0	30	230	15	28	216
3	Twin 48" RCPs	No changes	182.16	0	0	184	43	58	206
4	Twin 48" RCPs + Open Channel	Triple 36" RCPs	182.16	0	0	109	0	0	110
5	Twin 48" RCPs	Triple 36" RCPs	183.79 (No changes)	0	0	1	0	0	32

**SECTION 5.0**  
**COST ESTIMATES**

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The cost estimates provided in this report were prepared to assist the Town of Nashville staff in making planning level decisions and prioritizing improvements for the storm drainage improvements. These cost estimates are not final design estimates and were developed using recent bid tabulations from other communities and NCDOT projects within North Carolina. They include surveying, permitting, engineering, legal, and administrative costs. A summary of each of the alternative's level of service and drainage improvement costs is presented in Table 9. The cost estimates are approximate and are subject to change due to local costs for materials, delivery, construction, land or easement acquisitions, the bid climate as well as other factors.

**Table 9: Preliminary Project Cost Estimates**

Alternative	Par Drive Level of Service	Cost
#1	5-Year LOS	\$75,324
#2	10-Year LOS	\$316,451
#3	10-Year LOS	\$439,425
#4	100-Year LOS	\$369,352
#5	25-Year LOS	\$562,465

Additional permitting will be required from NCDENR Land Quality for an erosion control permit. There are no anticipated permitting costs for a PCN to the US Army Corps of Engineers for potential stream and wetland impacts.

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CONCLUSIONS AND RECOMMENDATIONS

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As shown in this flood study, the existing drainage system between Windy Oak Drive and Laurel Spring Drive is undersized and causing flooding upstream. The overtopping elevation where water crests Windy Oak Drive is set approximately 0.75 feet above the minimum roadway elevation at Par Drive. Five drainage improvement alternatives were evaluated as part of this flood study to help reduce flooding along Par Drive, Village Lane and at 215 Windy Oak Drive. Based only performance and without consideration of cost, Alternative #4 would be the recommended alternative to mitigate future flooding in the Par Drive and Village Lane neighborhoods. This is a relatively cost-effective alternative that achieves or exceeds design goals. It is anticipated that this alternative will receive resistance from property owners not wanting to construct an open channel along the side of their property.

Should property owners not be on board with Alternative #4, Alternative #2 would be the next recommended alternative. Alternative #2 involves replacing the 24-inch diameter closed pipe system and replacing it with a 48-inch diameter reinforced concrete pipe from the upstream side 215 Windy Oak Drive to Laurel Spring Drive. This alternative also involves lowering the overtopping elevation of Windy Oak Drive by approximately 2.0 feet. Because the yards upstream and downstream of Windy Oak Drive are currently set high, the Alternative #2 improvements will require that a grass-lined swale be graded from the upstream side 215 Windy Oak Drive to Laurel Spring Drive. The residents living in the Windy Oak Drive downstream to Laurel Spring Drive are not experiencing frequent flooding and therefore are considered "non-benefiters". For this reason, it will be critical to engage these residents with a series of one-on-one field meetings to share with them the proposed plans and potential impacts to their property. Alternative #2 is one of the more cost-effective alternatives that reduces the impacts to residents along the Windy Oak to Laurel Spring Drive corridor while achieving a 10-year level of service with roadway flooding for Par Drive and Village Lane. 100-year flood elevations at Par Drive will reduce from a depth of 1.95 feet to a depth of 0.83 feet. This is a significant reduction that will allow residents or emergency responders to use Par Drive or Village Lane during a 100-year flood. First flood elevation in the Par Drive area are set above the 100-year flood elevation.

## List of Exhibits

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### South Creek Drive Flood Study NASHVILLE, NC

-  Sub-basin Outlets
-  Nashville City Limits
-  Building Footprints
-  Parcels
-  Drainage Ditches
-  Detention Basin
-  NHD Streams
-  NHD Waterbodies

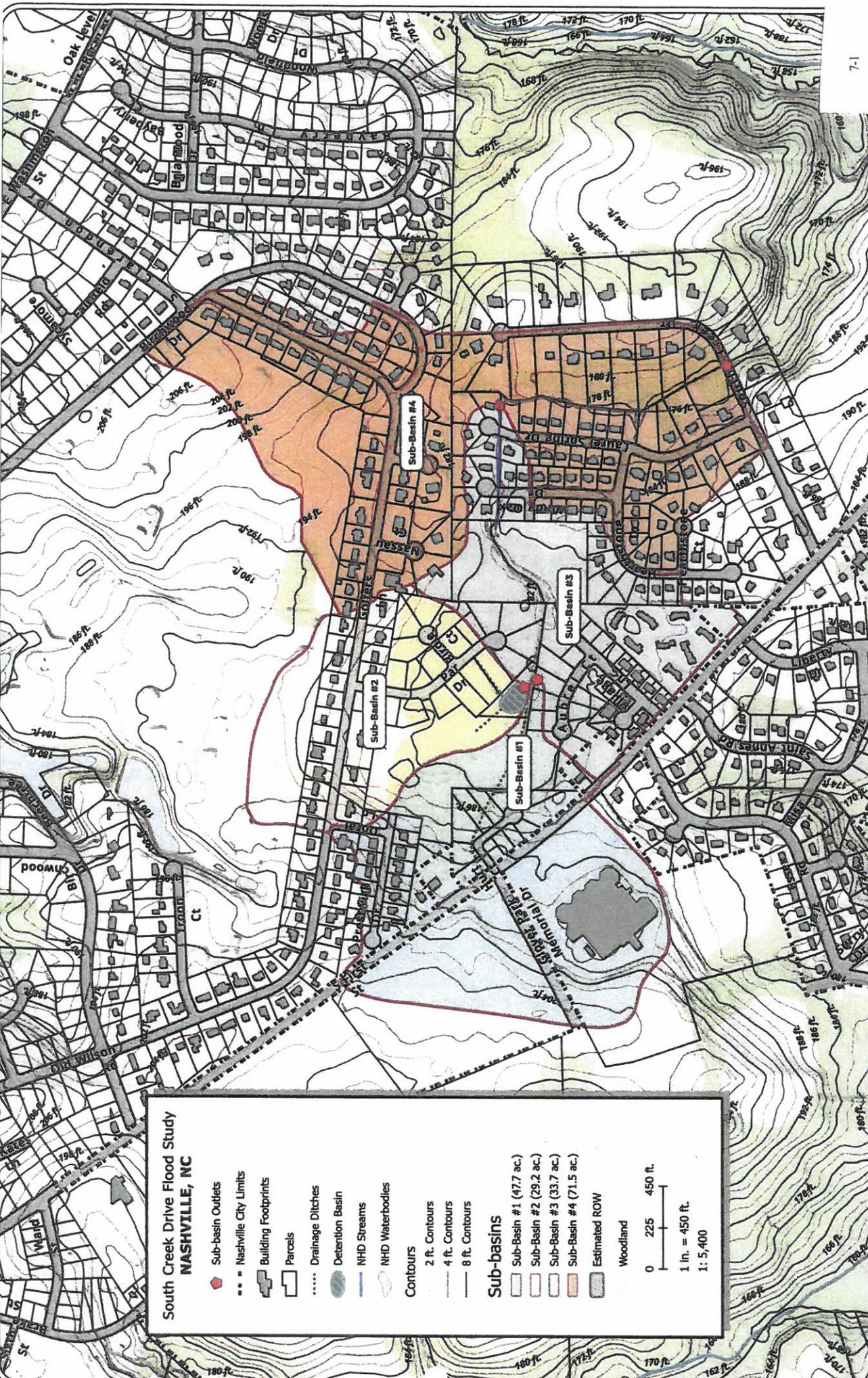
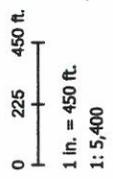
- Contours**
-  2 ft. Contours
  -  4 ft. Contours
  -  8 ft. Contours

#### Sub-basins

-  Sub-Basin #1 (47.7 ac.)
-  Sub-Basin #2 (29.2 ac.)
-  Sub-Basin #3 (33.7 ac.)
-  Sub-Basin #4 (71.5 ac.)

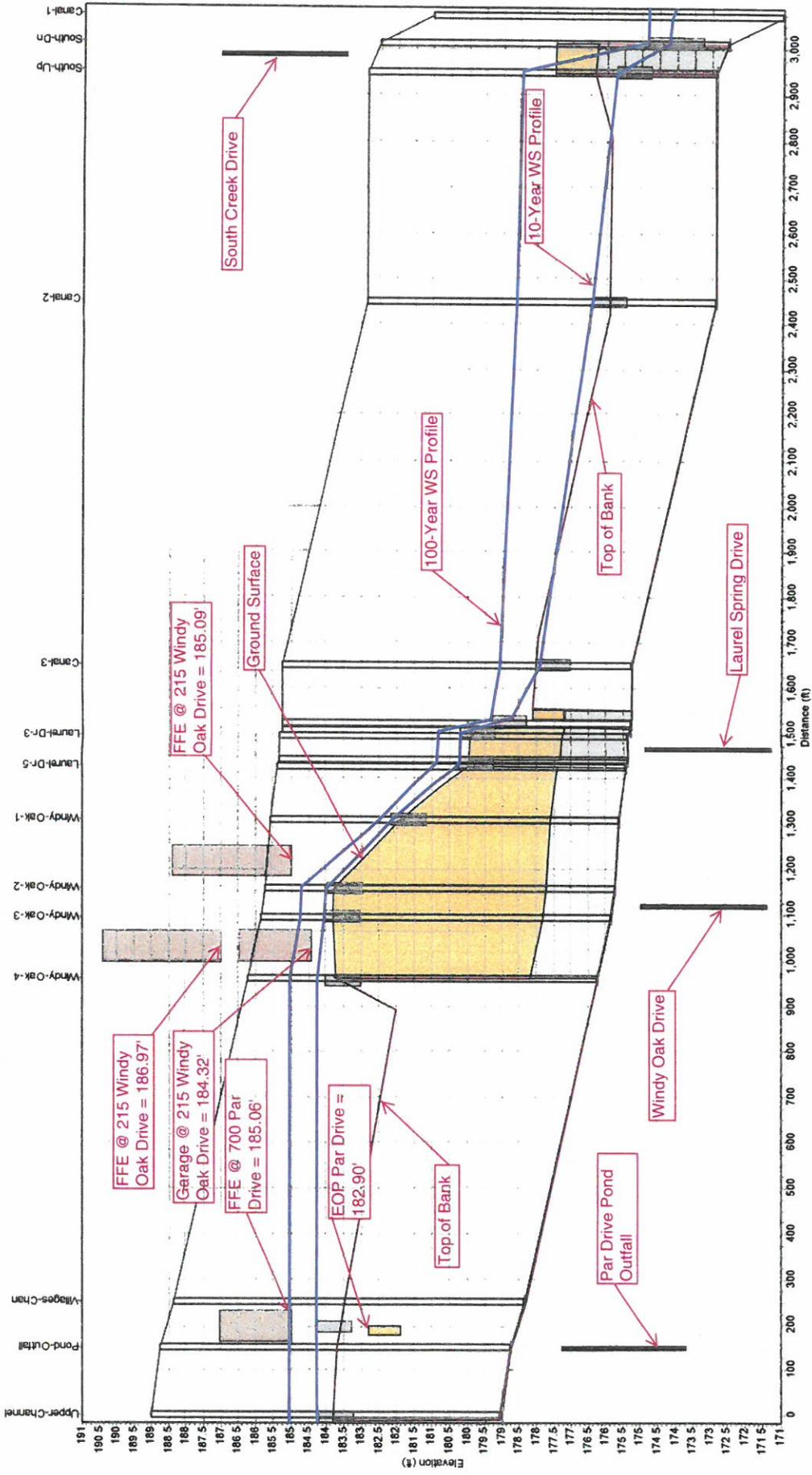
-  Estimated ROW

Woodland



# Exhibit 2

Existing Conditions Water Surface Profile - South Creek Flood Study



Flood Elevations Upstream of 215 Windy Oak Drive - Resultant Flood Depth at Par Drive									
Alt#	Windy Oak Drive Proposed Pipe	Laurel Spring Proposed Pipe	Overtopping Elevation at Windy Oak Drive (ft. NAVD '88)	5-Year WSEL (ft. NAVD '88)	5-Year Flood Depth (ft)	10-Year WSEL (ft. NAVD '88)	10-Year Flood Depth (ft)	100-Year WSEL (ft. NAVD '88)	100-Year Flood Depth (ft)
Existing	24-inch RCP	Twin 24-inch RCPs	183.79	183.66	0.52	184.28	1.14	185.09	1.95
1	24-inch RCP	No changes	182.16	182.92	-0.22	183.19	0.05	184.21	1.07
2	48-inch RCP	No changes	182.16	182.14	-1.00	182.74	-0.4	183.97	0.83
3	Twin 48-inch RCPs +	No changes	182.16	182.02	-1.12	182.38	-0.76	183.78	0.64
4	Twin 48-inch RCPs + Open Channel	Triple 36" RCPs	182.16	180.34	-2.8	180.90	-2.24	183.08	-0.06
5	Twin 48-inch RCPs	Triple 36" RCPs	183.79 (No changes)	180.81	-2.33	181.40	-1.74	184.02	0.88

Par Drive sag is at elevation 183.14 feet (NAVD'88); Flood depths presented in Exhibit 3 are for the sag in Par Drive

Flood Elevations Upstream of 215 Windy Oak Drive - Resultant Flood Depth at Par Drive									
Alt#	Windy Oak Drive Proposed Pipe	Laurel Spring Proposed Pipe	Overtopping Elevation at Windy Oak Drive (ft. NAVD '88)	Windy Oak Drive Overflow			Laurel Spring Drive Overflow		
				5-yr Peak Flow (cfs)	10-yr Peak Flow (cfs)	100-yr Peak Flow (cfs)	5-yr Peak Flow (cfs)	10-yr Peak Flow (cfs)	100-yr Peak Flow (cfs)
Existing	24-inch RCP	Twin 24-inch RCPs	183.79	0	26	200	0	0	165
1	24-inch RCP	No changes	182.16	42	74	285	3	33	249
2	48-inch RCP	No changes	182.16	0	30	230	15	28	216
3	Twin 48-inch RCPs	No changes	182.16	0	0	184	43	58	206
4	Twin 48-inch RCPs + Open Channel	Triple 36" RCPs	182.16	0	0	109	0	0	110
5	Twin 48-inch RCPs	Triple 36" RCPs	183.79 (No changes)	0	0	1	0	0	32



**OPINION OF PROBABLE CONSTRUCTION COST**

Project: South Creek Drive Drainage Study - Nashville, NC  
 Date: 14-Sep-20

Alternative #1					
LINE #	ITEM	QUANT.	UNIT	UNIT PRICE	AMOUNT
1	Mobilization (@ 5% of Construction Cost)	1	LS	\$3,105	3,105.37
2	Construction Staking	1	LS	\$4,000	4,000.00
3	Relocate Utilities	1	LS	\$5,000	5,000.00
4	Demolition Asphalt at Windy Oak Drive including Haul Off/Waste	1122	SY	\$8	8,775.78
5	Waste Subbase Excess Material from Windy Oak Drive	49	TN	\$40	1,963.89
6	Furnish and Install Asphalt Surface Course (SF-9.5A) for Pavement	177	TON	\$125	22,093.75
7	Furnish and Install Aggregate Base Course (ABC) for Pavement	262	TON	\$40	10,474.07
8	Concrete Driveway	32	SY	\$100	3,200.00
9	Reset Stormwater Catch Basin	3	EA	\$800	2,400.00
10	Silt fence	300	LF	\$4	\$1,200
11	Seeding and Mulching	1	AC	\$3,000	\$3,000
				<b>Subtotal</b>	<b>\$65,213</b>
				<b>5% Contractor Profit and Overhead</b>	<b>\$3,261</b>
				<b>Subtotal</b>	<b>\$68,474</b>
				<b>10% Contingency</b>	<b>\$6,850</b>
				<b>Total Construction Cost</b>	<b>\$75,324</b>
Permitting & Design					
12	Permitting	1	LS	\$6,000	\$6,000
13	Design	1	LS	\$14,000	\$14,000
				<b>Total Permitting and Design Cost</b>	<b>\$20,000</b>
	<b>Total</b>			<b>Total Opinion of Probable Construction Cost</b>	<b>\$95,324</b>



**OPINION OF PROBABLE CONSTRUCTION COST**

Project: South Creek Drive Drainage Study - Nashville, NC  
 Date: 14-Sep-20

Alternative #2					
LINE #	ITEM	QUANT.	UNIT	UNIT PRICE	AMOUNT
1	Mobilization	1	LS	\$13,047	\$13,047
2	Construction Staking	1	LS	\$4,000	\$4,000
3	Dewatering	1	LS	\$12,000	\$12,000
4	Relocate Utilities	1	LS	\$5,000	\$5,000
5	Demolition Asphalt at Windy Oak Drive including Haul Off/Waste	1122	SY	\$8	8,775.78
6	Waste Subbase Excess Material from Windy Oak Drive	49	TN	\$40	1,963.89
7	Demolition 24" RCP	466	LF	\$58	\$27,028
8	48" diameter reinforced concrete pipe, Type III	466	LF	\$250	\$116,500
9	Furnish and Install 6' Diameter Stormwater Manhole (COR Std. SW-10.05)	3	EA	\$8,500	\$25,500
10	Grade grass-lined trapezoidal swale +haul off and waste excess material	404	LF	\$50	\$20,200
11	Furnish and Install Asphalt Surface Course (SF-9.5A) for Pavement	177	TON	\$125	\$22,094
12	Furnish and Install Aggregate Base Course (ABC) for Pavement	262	TON	\$40	\$10,474
13	Concrete Driveway	32	SY	\$100	3,200.00
14	Silt fence	300	LF	\$4	\$1,200
15	Seeding and Mulching	1	AC	\$3,000	\$3,000
<b>Subtotal</b>					<b>\$273,982</b>
5% Contractor Profit and Overhead					\$13,699
<b>Subtotal</b>					<b>\$287,681</b>
10% Contingency					\$28,770
<b>Total Construction Cost</b>					<b>\$316,451</b>
Permitting & Design					
15	Permitting	1	LS	\$5,000	\$5,000
16	Design	1	LS	\$17,000	\$17,000
<b>Total Permitting and Design Cost</b>					<b>\$22,000</b>
Total					
<b>Total Opinion of Probable Construction Cost</b>					<b>\$338,451</b>

Lower Windy Oak Dr. & Install Twin 466 LF of 48" RCP (No Pipe Changes @ Laurel Springs Dr.)



Exhibit 8 - Alternative #3

**OPINION OF PROBABLE CONSTRUCTION COST**

Project: South Creek Drive Drainage Study - Nashville, NC  
 Date: 14-Sep-20

Alternative #3					
LINE #	ITEM	QUANT.	UNIT	UNIT PRICE	AMOUNT
1	Mobilization (@ 5% of Construction Cost)	1	LS	\$18,117	\$18,117
2	Construction Staking	1	LS	\$4,000	\$4,000
3	Dewatering	1	LS	\$17,000	\$17,000
4	Relocate Utilities	1	LS	\$5,000	\$5,000
5	Demolition Asphalt at Windy Oak Drive including Haul Off/Waste	1122	SY	\$8	8,775.78
6	Waste Subbase Excess Material from Windy Oak Drive	49	TN	\$40	1,963.89
7	Demolition 24" RCP	466	LF	\$58	\$27,028
8	48" diameter reinforced concrete pipe, Type III	932	LF	\$200	\$186,400
9	Concrete headwall	2	EA	\$9,500	\$19,000
10	Furnish and Install Custom Concrete Junction Boxes	3	EA	\$11,000	\$33,000
11	Grade grass-lined trapezoidal swale	404	LF	\$50	\$20,200
12	Furnish and Install Asphalt Surface Course (SF-9.5A) for Pavement	177	TON	\$125	\$22,094
13	Furnish and Install Aggregate Base Course (ABC) for Pavement	262	TON	\$40	\$10,474
14	Concrete Driveway	32	SY	\$100	3,200.00
15	Silt fence	300	LF	\$4	\$1,200
16	Seeding and Mulching	1	AC	\$3,000	\$3,000
				<b>Subtotal</b>	<b>\$380,452</b>
				<b>5% Contractor Profit and Overhead</b>	<b>\$19,023</b>
				<b>Subtotal</b>	<b>\$399,475</b>
				<b>10% Contingency</b>	<b>\$39,950</b>
				<b>Total Construction Cost</b>	<b>\$439,425</b>
Permitting & Design					
16	Permitting	1	LS	\$5,000	\$5,000
17	Design	1	LS	\$17,000	\$17,000
				<b>Total Permitting and Design Cost</b>	<b>\$22,000</b>
Total					

Lower Windy Oak Dr. & Install Twin 48" RCPs at Windy Oak & Triple 36 RCPs at Laurel Springs Dr. + grade open channel between culverts)



Exhibit 10 - Alternative #4

**OPINION OF PROBABLE CONSTRUCTION COST**

Project: South Creek Drive Drainage Study - Nashville, NC  
Date: 14-Sep-20

Alternative #4					
LINE #	ITEM	QUANT.	UNIT	UNIT PRICE	AMOUNT
1	Mobilization (@ 5% of Construction Cost)	1	LS	\$15,228	\$15,228
2	Construction Staking	1	LS	\$4,000	\$4,000
3	Dewatering	1	LS	\$17,000	\$17,000
4	Relocate Utilities	1	LS	\$5,000	\$5,000
5	Demolition Asphalt at Windy Oak Drive including Haul Off/Waste	1122	SY	\$8	\$8,776
6	Waste Subbase Excess Material from Windy Oak Drive	49	TN	\$40	1,963.89
7	Demolition 24" RCP	466	LF	\$58	\$27,028
8	36" diameter reinforced concrete pipe, Type III	216	LF	\$270	\$58,320
9	48" diameter reinforced concrete pipe, Type III	124	LF	\$250	\$31,000
10	Concrete headwall	6	EA	\$9,500	\$57,000
11	Grade Trapezoidal Open Channel	1	LS	\$50,000	\$50,000
12	Class I Rip-Rap	75	TN	\$60	\$4,500
13	Furnish and Install Asphalt Surface Course (SF-9.5A) for Pavement	177	TON	\$125	\$22,094
14	Furnish and Install Aggregate Base Course (ABC) for Pavement	262	TON	\$40	\$10,474
15	Concrete Driveway	32	SY	\$100	3,200.00
16	Silt fence	300	LF	\$4	\$1,200
17	Seeding and Mulching	1	AC	\$3,000	\$3,000
				<b>Subtotal</b>	<b>\$319,783</b>
				<b>5% Contractor Profit and Overhead</b>	<b>\$15,989</b>
				<b>Subtotal</b>	<b>\$335,772</b>
				<b>10% Contingency</b>	<b>\$33,580</b>
				<b>Total Construction Cost</b>	<b>\$369,352</b>
Permitting & Design					
18	Permitting	1	LS	\$5,000	\$5,000
19	Design	1	LS	\$17,000	\$17,000
				<b>Total Permitting and Design Cost</b>	<b>\$22,000</b>

Install Twin 48" RCPS at Windy Oak & Triple 36 RCPS at Laurel Springs Dr. (No lowering of Windy Oak Dr or yards)



Exhibit 12 - Alternative #5

**OPINION OF PROBABLE CONSTRUCTION COST**

Project: South Creek Drive Drainage Study - Nashville, NC  
Date: 14-Sep-20

Alternative #5					
LINE #	ITEM	QUANT.	UNIT	UNIT PRICE	AMOUNT
1	Mobilization (@ 5% of Construction Cost)	1	LS	\$23,190	\$23,190
2	Construction Staking	1	LS	\$4,000	\$4,000
3	Dewatering	1	LS	\$17,000	\$17,000
4	Relocate Utilities	1	LS	\$5,000	\$5,000
5	Demolition Asphalt at Windy Oak Drive including Haul Off/Waste	1122	SY	\$8	\$8,776
6	Waste Subbase Excess Material from Windy Oak Drive	49	TN	\$40	1,963.89
7	Demolition 24" RCP	466	LF	\$58	\$27,028
8	36" diameter reinforced concrete pipe, Type III	216	LF	\$210	\$45,360
9	48" diameter reinforced concrete pipe, Type III	932	LF	\$200	\$186,400
10	Concrete headwall	6	EA	\$9,500	\$57,000
11	Furnish and Install Custom Concrete Junction Boxes	5	EA	\$14,000	\$70,000
12	Class I Rip-Rap	75	TN	\$60	\$4,500
13	Furnish and Install Asphalt Surface Course (SF-9.5A) for Pavement	177	TON	\$125	\$22,094
14	Furnish and Install Aggregate Base Course (ABC) for Pavement	262	TON	\$40	\$10,474
15	Silt fence	300	LF	\$4	\$1,200
16	Seeding and Mulching	1	AC	\$3,000	\$3,000
				<b>Subtotal</b>	<b>\$486,985</b>
				<b>5% Contractor Profit and Overhead</b>	<b>\$24,349</b>
				<b>Subtotal</b>	<b>\$511,335</b>
				<b>10% Contingency</b>	<b>\$51,130</b>
				<b>Total Construction Cost</b>	<b>\$562,465</b>
Permitting & Design					
17	Permitting	1	LS	\$5,000	\$5,000
18	Design	1	LS	\$17,000	\$17,000
				<b>Total Permitting and Design Cost</b>	<b>\$22,000</b>