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1.0 BACKGROUND

The Raccoon Run watershed is located in the southern tip of Horry County, South Carolina near Surfside Beach. The area has experienced periodic flooding damage, including flooding to many commercial properties in the vicinity of the Highway 17 Bypass during Hurricane Floyd, Hurricane Irene, and a localized storm in October 1986.

Horry County contracted with Watershed Concepts to perform hydrologic and hydraulic analyses of the Raccoon Run watershed in order to investigate various alternatives to lessen the effects of flooding. This report includes the results of the hydrologic and hydraulic analyses. A subsequent report will include an evaluation of alternatives.

The stream reaches that were studied by detailed methods are listed in Table 1.

Table 1
Stream Reaches Studied by Detailed Methods

Stream Name	Downstream Limit	Upstream Limit	Length (mi)
Raccoon Run	Confluence with Intracoastal Waterway	WalMart Access Road upstream of Hwy 544	4.9

2.0 WATERSHED DESCRIPTION

The Raccoon Run watershed is drained by Raccoon Run, which flows into the Intracoastal Waterway. The total area of the watershed is 9.12 square miles. Much of the watershed is undeveloped with a significant amount of wetlands, particularly in the area from the Highway 17 Bypass to Highway 544. The headwaters of the watershed contain several residential neighborhoods and commercial areas. Other commercial areas exist along the Highway 17 Bypass corridor. Stormwater runoff is carried by the stream channels and roadside swales. There are no significant storm drainage systems. There are several small detention basins that serve the commercial and residential areas in the headwaters of the watershed. The predominant soil type is hydrologic group D, mainly due to the presence of wetlands. The topography of the watershed is very flat, with elevations ranging from sea level to 50 feet above sea level.

3.0 HYDROLOGY - HEC-HMS MODELS

3.1 HYDROLOGIC APPROACH

The discharges for the studied streams were calculated using the U.S. Army Corps of Engineers' HEC-HMS Flood Hydrograph Package (Reference 1). HEC-HMS is a computer program designed to simulate the surface runoff response of a river basin to precipitation by representing the basin as an interconnected system of hydrologic and hydraulic components. In order for the model to predict the peak discharges, the following information must be known:

Rainfall Amounts
Drainage Areas
Time of Concentration/Lag Times
Soil Conservation Service (SCS) Curve Numbers
Stream Routings

The SCS dimensionless unit graph is used to calculate the hydrograph for each subbasin. The storage method is used for the routing methodology. The raw data for the drainage areas, curve numbers, and lag and routing times were obtained from topography provided by Horry County and field reconnaissance. The hypothetical storm information was obtained from the National Weather Service Technical Paper 40 (TP-40) (Reference 2). There are no streamflow gages located on any of the detailed study streams, so the hydraulic models were calibrated to historical high water marks obtained from Horry County and field reconnaissance.

3.2 DRAINAGE AREAS

The basin delineations were completed using topographic data provided by Horry County. The basin delineations produced 26 drainage areas ranging in size from 19 to 388 acres. A drainage pipe exists under Hwy 17 upstream of Highway 544. The pipes were determined to have minimal capacity, and for modeling purposes, all drainage area was assumed to go into Raccoon Run under Highway 544. A map of these subbasins is included as Attachment 2.

3.3 CURVE NUMBERS

The SCS Curve Numbers were calculated by using the NRCS soil associations and detailed land uses. The land uses were obtained from the South Carolina Department of Natural Resources website and are derived from satellite imagery. A development plan was obtained from Horry County that contains wetland delineations for the watershed downstream of Highway 544. That wetland coverage was used to append the satellite imagery data for that area. Future land uses were determined by assigning a new land use to all existing undeveloped areas, excluding wetlands. The new land use was assigned a composite curve number based on an analysis of all existing developed areas.

The soil coverages were provided by Horry County. The SCS National Engineering Handbook, Section 4, Table 7.1 (NEH-4, Reference 3) provides a method to cross-reference the various soil names with their hydrologic classification (e.g., Cecil = B, Pacolet = B). According to the soil classifications, the predominant soil type in this area is hydrologic group D. The predominance of the D soil classification is mainly due to the numerous wetland areas in the basin. A map of these soil types is included in Attachment 2. A weighted representative curve number for each subbasin was calculated utilizing Table 9.1 of NEH-4. The land use/soil classification matrix used for this study is shown in Table 2 and a map of the existing land use is in Attachment 2.

Table 2
Weighted Curve Number Matrix

Land Use	SCS Soil Classification					
	A	A/D	B	B/D	C	D
Woods	30	40	55	60	70	77
Open	39	43	61	68	74	80
Water	99	99	99	99	99	99
Wetland/Brush	35	45	56	60	70	77
Streets	98	98	98	98	98	98
Cultivated Agriculture Straight Row - Poor	67	72	78	82	85	89
Institutional	54	62	70	75	80	85
Industrial	81	83	88	90	91	93
Light Residential	51	60	68	72	79	84
Medium Residential	57	65	72	77	81	86
Heavy Residential	77	81	85	87	90	92
Commercial	89	91	92	93	94	95

The calculated SCS curve numbers for the 26 sub-basins are summarized in Table 3.

3.4 LAG TIME

Lag time (T_L), or the time which elapses between the center of mass of the rainfall and the peak of the runoff, was derived from the time of concentration (t_c) based on the empirical relationship of $T_L=0.6*t_c$ documented in the HEC-HMS User's Manual. Times of concentration (t_c) for each sub-basin were determined using a component of the hydrologic/hydraulic model based on land

slope, land surface, travel distance and type of flow. Time of concentration is the time it takes runoff to travel from the hydraulically most distant point to the lowest point in the sub-basin. The time of concentration was calculated as the summation of two components, overland flow time and channel flow time. Overland flow occurs when storm runoff is flowing across the ground in a sheet before it reaches a channel or other drainage improvement. Channel flow occurs once the storm runoff concentrates in a low area and flows in a channel or other drainage improvement.

The TR-55 methodology was used to calculate overland velocities. The length of the overland flow path and the average land slope were determined from the topography provided by Horry County. The locations of the overland flow paths were field verified. The longest overland flow length used was 100 feet.

Channel flow was used when flow entered a drainage improvement. All channel velocities were calculated using Manning's equation with a standard cross section. Flow path length and land slope were determined using the topography provided by Horry County.

Times of concentration for each sub-basin were calculated and the results are shown in Table 3.

Table 3
Hydrologic Calculation Variables Summary

Raccoon Run Watershed			
Basin ID	**Time of Concentration (hours)**	**SCS Existing Curve Number**	**SCS Future Curve Number**
1	3.11	66.24	70.17
2	2.43	69.40	70.56
3	1.21	68.71	68.74
24	1.58	75.32	76.63
28	1.54	72.15	72.69
31	2.30	66.29	70.52
35	2.33	69.54	70.25
36	2.28	63.28	68.78
37	2.77	63.95	72.93
38	2.57	68.21	75.51
39	1.54	69.20	77.96
26	2.31	65.62	72.58
30	2.60	66.38	73.99
34	1.91	66.78	74.40
40	1.31	82.96	83.33
25	2.81	66.49	73.38
32	2.86	70.01	77.03
33	1.34	74.67	81.72
41	1.71	76.98	81.52
22	2.60	67.56	70.22
27	2.63	69.30	77.33
42	1.99	69.59	73.38
43	1.08	69.40	71.15
23	3.20	68.09	71.67
29	1.91	73.33	75.65
44	2.16	67.84	70.02

3.5 STREAM ROUTINGS

Attenuation within the streams was calculated using the Modified Puls Stream Routing. These calculations require the user to input variables that define the relationship of inflow to (1) volume of runoff contained within the channel and (2) the number of sub-reaches within the routing calculation.

A detailed survey of structures on Raccoon Run and a tributary was performed in order to build hydraulic models of the major streams. The Army Corps of Engineers' HEC-RAS computer program was used to build these models. Cross sections were entered into the HEC-RAS model not exceeding 500 feet apart along the stream centerline. Locations for cross sections were determined using a combination of field survey data and the topography provided by Horry County at representative locations. The hydraulic model was run initially using incremental discharges for the purpose of establishing rating curves of storage volume and discharge. The relationships determined by these rating curves were entered into the HEC-HMS models so that stream attenuation calculations could be performed.

The number of sub-reaches used to calculate the attenuation within each stream reach equaled the reach length divided by the average velocity, with this value divided by the calculation time interval, as documented in the HEC-HMS User's Manual. The velocity used for this relationship was determined by solving Manning's equation for normal depth given the 100-year flood discharge, as determined from USGS regional regression equations.

3.6 UNIT HYDROGRAPH

The dimensionless unit hydrograph selected for the computer models was the standard SCS Type II unit hydrograph as presented in NEH-4 (Reference 3). This hydrograph is widely accepted to simulate synthetic storms.

3.7 RAINFALL ACCUMULATION

TP-40 was utilized for determining rainfall amounts. TP-40, developed by the National Weather Service, indicates rainfall amounts of various durations and frequencies. Utilizing the techniques stated in TP-40, the rainfall amounts for a hypothetical 24-hour duration event were determined for return periods of 2-, 5-, 10-, 25-, 50- and 100-years. The rainfall amounts for the synthetic storms are summarized in Table 4.

Table 4
TP-40 Rainfall Amounts (Inches)

Duration	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
5 min	0.55	0.75	0.85	0.95	1.05	1.2
15 min	1.10	1.50	1.70	1.90	2.10	2.40
60 min	2.00	2.55	2.95	3.35	3.75	4.10
2 hrs	2.45	3.10	3.60	4.10	4.55	5.10
3 hrs	2.70	3.50	4.00	4.55	5.05	5.65
6 hrs	3.20	4.20	4.75	5.50	6.20	6.90
12 hrs	3.75	5.00	5.75	6.60	7.30	8.30
24 hrs	4.50	5.75	6.80	8.00	8.70	10.00

3.8 HYDROLOGY RESULTS

All hydrographs were routed using cross sections from the floodplain within the HEC-HMS model. The HEC-HMS output files for existing and future conditions for Raccoon Run Watershed are included in Attachments 3 and 4. Table 5 and Table 6 contain a listing of the finalized discharges for the studied streams. They are listed by stream and basin ID and have summarized discharges for recurrence intervals ranging from the 2-year to the 500-year events. The 500-year discharge was calculated by taking a log year vs. log discharge extrapolation of the 50- and 100-year events. The largest increase in discharges from existing to future conditions is 19 % for the 100-year event and 20% in the 10-year event.

Table 5
Existing Conditions HEC-HMS Model Flows at Selected Locations

Stream Name	HEC-HMS Basin ID	Drainage Area (mi^2)	DISCHARGES (cfs)						
			2-year	5-year	10-year	25-year	50-year	100-year	500-year
Raccoon Run	44C	9.13	767	1249	1603	2003	2323	2705	4062
Raccoon Run	42C	7.81	650	1073	1341	1687	1967	2305	3428
Raccoon Run	40C	5.54	305	488	622	774	893	1063	1638
Raccoon Run	39C	4.27	256	401	504	624	726	892	1396
Raccoon Run	36C	3.24	238	375	474	589	693	813	1162
Raccoon Run	28C	2.16	219	344	438	549	654	773	1218
Raccoon Run	24C	2.06	275	428	537	664	774	910	1317

Table 6
Future Conditions HEC-HMS Model Flows at Selected Locations

Stream Name	HEC-HMS Basin ID	Drainage Area (mi^2)	DISCHARGES (cfs)						
			2-year	5-year	10-year	25-year	50-year	100-year	500-year
Raccoon Run	44C	9.13	969	1510	1869	2267	2587	3008	4497
Raccoon Run	42C	7.81	843	1277	1610	1948	2230	2600	3837
Raccoon Run	40C	5.54	341	535	671	824	1023	1246	2046
Raccoon Run	39C	4.27	284	453	575	717	876	1059	1583
Raccoon Run	36C	3.24	249	387	486	602	709	827	1182
Raccoon Run	28C	2.16	230	355	445	557	674	779	1251
Raccoon Run	24C	2.06	289	445	556	683	794	931	1341

4.0 HYDRAULICS - HEC-RAS MODELS

Water surface elevations for the 2-, 5-, 10-, 25-, 50-, 100-, and 500–year recurrence intervals were computed using the Army Corps of Engineers' HEC-RAS version 3.0 step-backwater computer program (Reference 4). The entire storm drainage system in this study consists of open channels and bridge and culvert crossings. The limits of the hydraulic modeling for Raccoon Run extend from the confluence with the Intracoastal Waterway to a WalMart access road upstream of Highway 544. The computer models were verified using historic high water data collected during field investigations. A flood profile showing the hydraulic results is shown in Attachment 5.

4.1 FIELD SURVEY

Field survey information was collected for Raccoon Run at the following locations:

- Cross section 2441 ft upstream (U/S) of the Intracoastal Waterway confluence
- Highway 707
- Cross section 1747 feet U/S of Highway 707
- Palmetto Point Blvd.
- Cross section 1106 feet U/S of Palmetto Point Blvd.
- Highway 17 Bypass
- Cross section 3004 feet U/S of Highway 17 Bypass
- Cross section 7679 feet U/S of Highway 17 Bypass
- Cross section 2693 feet downstream (D/S) of Highway 544
- Access Road (Chick-Fil-A) D/S of Highway 544
- Highway 544
- Access Road (WalMart) U/S of Highway 544

All field survey information was incorporated into the HEC-RAS modeling.

4.2 STARTING CONDITIONS

The downstream starting water surface elevations for all profiles in the HEC-RAS model were calculated using normal depth method. Tidal influences were investigated, and the mean higher high water elevation at NOAA site at Socastee Bridge (#8660983) is 2.44’. The normal depth starting water surface elevation is 5.93’. The normal depth starting condition was used because it is the higher of the two.

4.3 CROSS SECTION GEOMETRIES

The floodplain cross sections were placed at representative locations, approximately 500 feet apart along the stream centerline. Cross section geometries were obtained from a combination of field survey and cross section takeoffs based on topographic data provided by Horry County. All bridge and culvert crossings were field surveyed, as well as six cross sections. Surveyed channel sections were propagated upstream and downstream to nonsurveyed cross sections and blended

with the Horry County topographic sources.

4.4 MANNING'S N-VALUES

Roughness coefficients were estimated based on field inspection of stream channels and floodplain areas for Raccoon Run. A GIS coverage of floodplain and channel n-values was developed. This GIS coverage consists of "bands" of Manning's n-values. These bands were developed using the field reconnaissance and the orthophotos (2-foot pixel resolution) provided by Horry County. The purpose of the n-value "band" coverage is to allow the consistent application of Manning's n-value estimates. Additional cross sections can be added to the models based on the same n-value assessments. The n-value bands also allow for the global increase or decrease of n-values for a stream reach or entire stream for historical calibration and verification. Ineffective flow areas (e.g., extremely dense trees and underbrush, dense residential areas, large buildings, fenced areas) were modeled in HEC-RAS by using a high Manning's n-value to account for the ineffective area.

4.5 HISTORICAL HIGH WATER MARK VALIDATION

Several historical high-water marks were obtained from Horry County and the field reconnaissance. A majority of the marks were obtained in the vicinity of the Highway 17 Bypass. These marks indicate that the major flooding events that occurred on Raccoon Run were Hurricane Floyd (September 1999), Hurricane Irene (October 1999), and a localized event in October 1986. Interviews with several business owners in the area indicated that there have been several additional less severe flood events that have caused property damage; however, no substantial documentation was provided regarding the date or flood heights for these events.

The marks were field surveyed to obtain vertical elevations, with the exception of the mark at 828 Shem Creek Road. The resident indicated that flooding from Hurricane Floyd came to the edge of pavement in front of the house. The high water mark elevation was then taken from topography. The following photos illustrate the high water marks obtained by Horry County.

Photo 1: October 1986 – Highway 17 Bypass

Photo 2: October 1986 – Beaman Construction

Photo 3: Hurricane Floyd – Highway 17 Bypass

Photo 4: Hurricane Floyd – Highway 17 Bypass

Rainfall information was used to estimate the storm recurrence intervals for the high water mark data. Rainfall information was obtained from the South Carolina DNR website (Reference 5). Hurricane Floyd produced 16 inches of rain in 24 hours, which is approximately a 500-year flood. Hurricane Irene produced 4.7 inches of rain in a 12-24 hour period, which correlates to a 2-5 year recurrence interval per TP-40 rainfall charts. Data on the 1986 storm was not available; engineering judgment was used to assume a 5-10 year event because the high water marks were slightly higher than Hurricane Irene. Table 7 is a summary of the calibration to high water mark data.

Table 7: Summary of Historical High Water Mark Validation – Raccoon Run Horry County, SC

Location	HEC-RAS Station	HWM ELEV. (FT) NAVD 88	HWM Event	Estimated Return Period	HEC-RAS Flood Elev. (ft) NAVD 88
828 Shem Creek Rd.	2000	8.5	Floyd	500-year	9.7 (500-yr)
U/S Face Highway 17 Bypass	11607	15.1	Floyd	500-year	15.7 (500-yr)
U/S Face Highway 17 Bypass	11607	13.8	Oct 1986	5-10-year	14.0 (5-yr) 14.4 (10-yr)
U/S Face Highway 17 Bypass	11607	13.1	Irene	2-5 -year	12.3 (2-yr) 14.0 (5-yr)

4.6 HYDRAULIC RESULTS

The hydraulic model indicated a change in the water surface elevation between the existing and future land use conditions. Attachment 5 contains existing and future conditions flood profiles and a comparison of discharge and water surface elevation between existing and future land use for the 10- 25- and 100-year events. The flood boundaries for existing and future conditions are contained in Attachment 6.

5.0 FLOOD MITIGATION ALTERNATIVES – HIGHWAY 17 BY-PASS

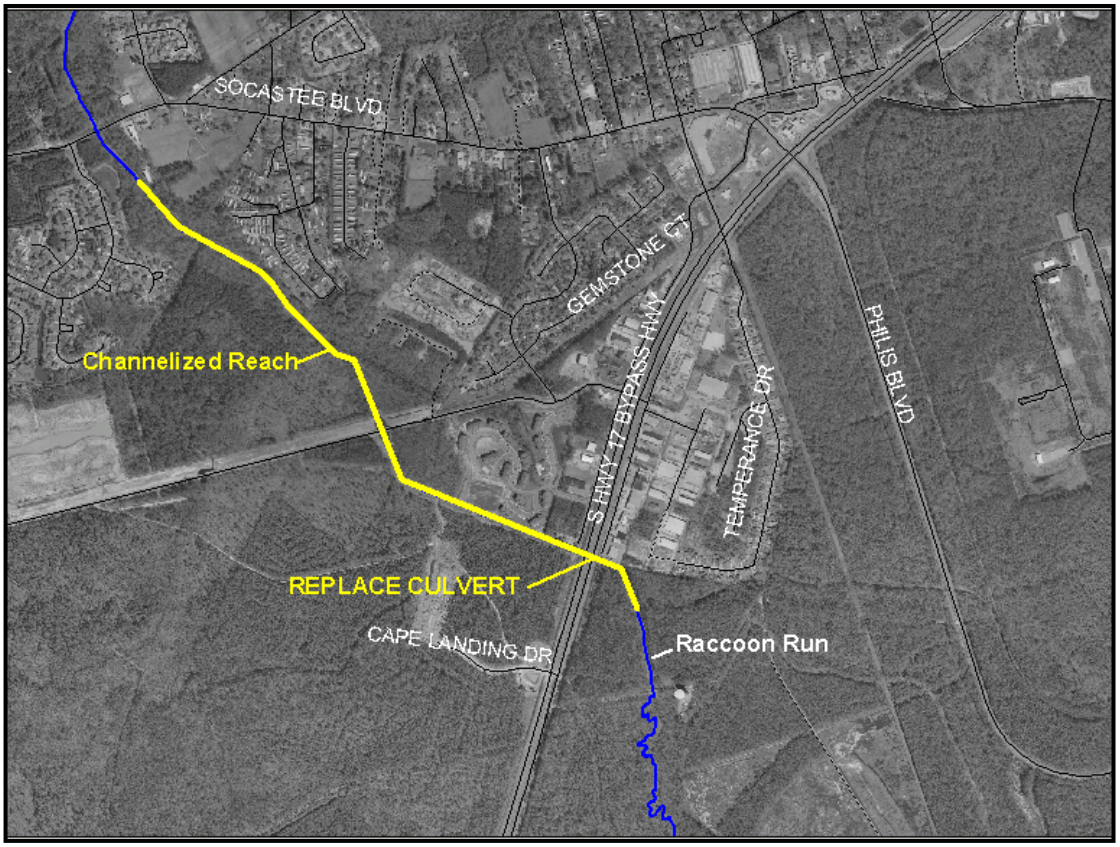
Watershed Concepts has analyzed four alternatives. The alternatives have been analyzed to reduce flooding impacts for the 25-year event. Each alternative is summarized below.

Option 1 – Channelization and Highway 17 By-pass Bridge Replacement

Option 1 consists of channelizing a reach of Raccoon Run from 500' upstream of Highway 707 to 1150' upstream of Highway 17 By-pass. Option 1 also includes the replacement of the existing two 9' by 5' box culverts under Highway 17 with a bridge similar to the bridge on Highway 707. The location of the proposed channelization is shown in figure 1 below:

Figure 1

Flood Mitigation Option 1 – Channelization and Bridge Replacement Location



The proposed channel has a topwidth of 90' with 2:1 side slopes. The depth of the existing channel will be retained. Different channel sizes were investigated, however the 90' topwidth is the minimum width that will protect the properties upstream of Highway 17 from flooding during a 25-year event. The proposed bridge for Highway 17 By-pass will consist of 3 – 30' spans with sloped abutments. The opening area for the proposed bridge is 665 square feet. The existing top of road elevation will be retained. Bridge replacement is proposed for Highway 17 By-pass because the existing culvert for Highway 17 By-pass causes 2-3' of backwater with the channelization option. This is due to the reduction in the tailwater elevations. The current opening area for the existing culverts under Highway 17 By-pass is 90 square feet, which appears to be undersized when compared to adjacent crossings. The opening area for the downstream bridge at Palmetto Point Boulevard is 777 square feet, and the opening area of the upstream bridge at Highway 544 is 128 square feet.

The benefits of option 1 are as follows. The commercial buildings upstream of Highway 17 By-Pass will be protected from the existing 25-year flood, specifically Beaman Construction, which has a first floor elevation of approximately 12'. The 25-year flood elevation for option 1 at the upstream face of Highway 17 By-pass is 12.0'. The commercial buildings upstream of Highway 17 By-pass would also see less damage due to flooding for major events. The 100-year flood elevation is reduced under option 1 by 1.7' at the upstream face of Highway 17 By-pass.

Another benefit is that Highway 17 By-pass, which is a major thoroughfare for Horry County, would not be overtopped by the 100-year event. The apartment complex and homes downstream of Highway 17 By-pass would also be significantly impacted by Option 1. The 25-year flood elevations would be reduced by 1.5' – 2.0' in this area. The results of Option 1 are summarized in table 8 below. A cost estimate of Option 1 is included in Table 9. A flood profile of Option 1 is included in Attachment 5, and the flood boundary mapping is included in Attachment 6.

The negatives of option 1 consist mainly of permitting obstacles and long-term maintenance. It has become increasingly difficult to obtain permits for channel modifications in the current climate of environmental regulations. In some cases, it can result in a project becoming cost prohibitive. Also, construction of Option 1 will result in a channel that has a reduced sediment transport capacity which will likely lead to excessive deposition in the bed of the channel. In order to maintain the design flow conveyance a program of regular maintenance will need to be implemented involving dredging of accumulated sediment, removal of brush, and frequent mowing of bank vegetation.

A possible alternative to this option that may be easier to permit is creating additional conveyance areas by cutting the overbanks down so that the channel is at a more natural size. Raccoon Run has been dredged out through the years, and is currently much deeper than it would exist naturally. If the overbanks were cut down so that the channel depth is 3', this would create an initial floodplain for smaller events to use for conveyance. In order to obtain the same impact as the channelization mentioned above, the floodplain would have to be cut out approximately 60-90' on each side of the channel. This option is prohibitive because of property acquisition.

Table 8

Flood Mitigation Option 1 – Channelization and Bridge Replacement WSEL Comparison for the 25-yr Event

River Sta	Description	Existing WSEL (ft)	Channelization & Hwy 17 Bridge Replace WSEL (ft)	Diff. (ft)
5,087	U/S Face Hwy 707	10.62	10.61	-0.01
5,543	Begin Channelization	10.77	10.75	-0.02
5,997		11.09	10.79	-0.30
6,671		11.57	10.84	-0.73
7,070		11.84	10.88	-0.96
7,528		12.17	10.93	-1.24
8,038		12.56	10.99	-1.57
8,373		12.66	11.04	-1.62
8,879	D/S Face Palmetto Point Blvd	12.87	11.00	-1.87
8,939	U/S Face Palmetto Point Blvd	12.90	11.25	-1.65
9,141		12.88	11.56	-1.32
9,599		13.16	11.63	-1.53
10,015		13.47	11.71	-1.76
10,498		13.70	11.80	-1.90
10,863		13.92	11.93	-1.99
11,247	D/S Face Highway 17 By-pass	13.98	11.96	-2.02
11,421	U/S Face Highway 17 By-pass	14.57	11.99	-2.58
11,607		14.57	12.00	-2.57
11,998		14.59	12.02	-2.57
12,497	End Channelization	14.61	12.06	-2.55
13,071		14.73	11.61	-3.12
13,893		15.50	15.45	-0.05
14,338		15.78	15.75	-0.03
14,940		15.66	15.66	0.00

Table 9

Flood Mitigation Option 1 – Cost Estimate

Assumptions: Existing channel completely within new channel limits.

Existing Channel Dimensions

Top width - 25' (avg)
Depth - 8.5' (avg)
0.5:1 Side Slopes
Linear feet - 7000'
Avg area - 176 sq ft

Proposed Channel Dimensions

Top width - 90'

Depth - 8.5' (avg)
2:1 Side Slopes
Linear feet - 7000'
Avg area - 620 sq ft

Proposed Bridge (Dual Structures)

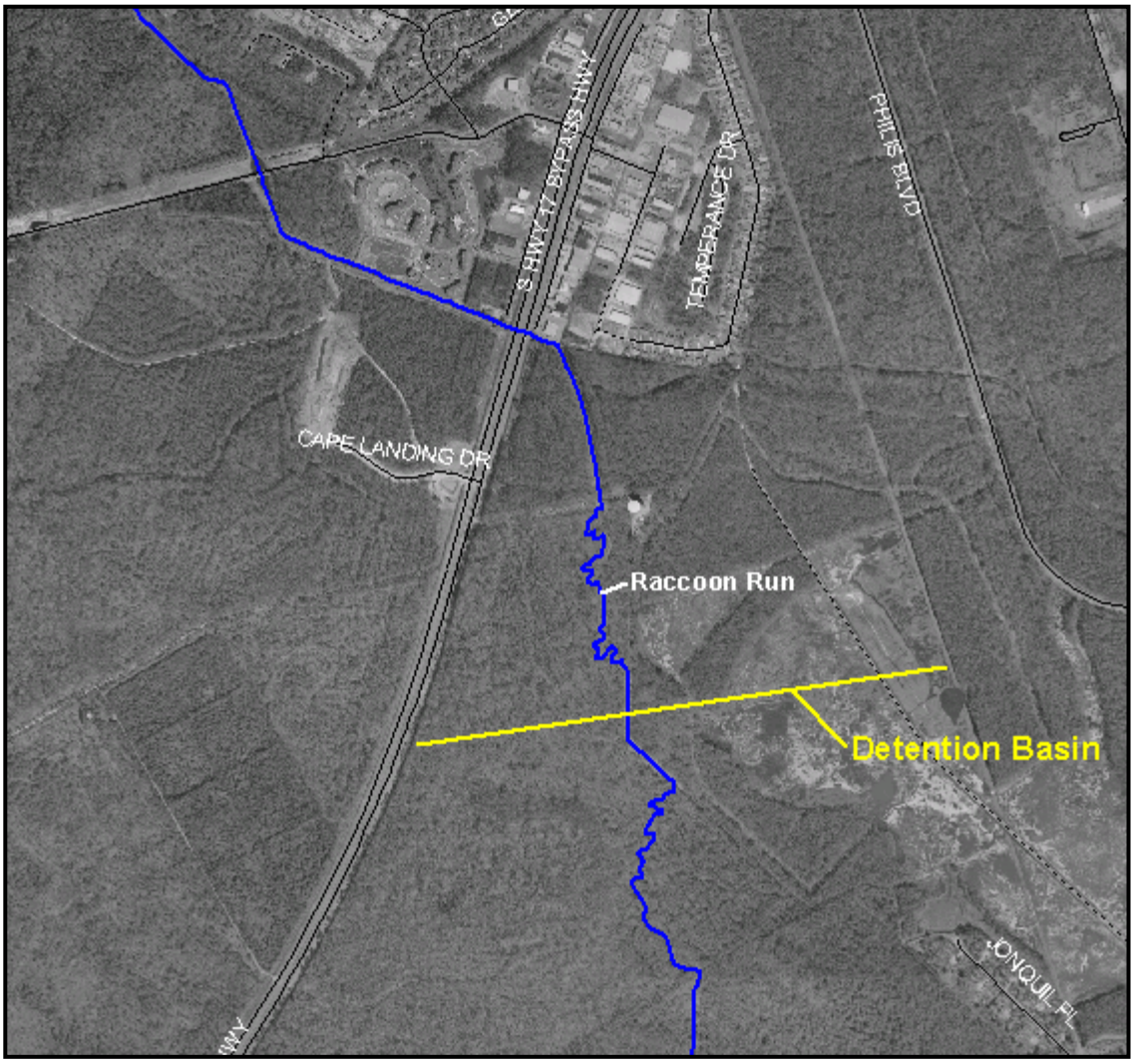
4 Lane Divided highway
2 - 12' Lanes, 2 - 10', 2 - 1'-5" Bridge Rails (per structure)
3 - 30' spans

Total cut:	115,294 cubic yards
Cost per cubic yard:	$6.25 / cubic yard
Land Area:	7000' linear feet, 250' topwidth = 40 acres
Land Acquisition:	40 acres * $15,000/acre = $600,000
Channel cost:	$1,320,000
Remove 2 – 5'x 9' box culverts:	$100,000
Traffic Control:	$50,000
Detour Bridge & Roadway: (Assumes available R/W & no bldg. conflicts)	$250,000
Erosion Control:	$20,000
Approach Work:	$100,000
Total bridge square footage:	8,460 square feet
Cost per square foot:	$68.00 / square foot
Bridge cost:	$575,000
Total:	$2,415,000
Mobilization (15%):	$360,000
Contingency (15%):	$416,000
Option 1 total cost:	**$3,191,000 SAY $3,200,000**

Option 2 – Detention Basin Between Highway 17-By-pass and Highway 544

Option 2 is a detention basin located between Highway 17 By-pass and Highway 544. The goal of the detention basin sizing was to produce a 25-year discharge at the upstream face of Highway 17 By-pass that would cause no flooding to the commercial properties along Highway 17. In order to produce enough storage to attenuate the flow, the detention basin needs to have a main weir elevation of 20'. To place a weir at that elevation, the detention basin had to be located at station 14,940 along Raccoon Run to obtain the necessary relief. This produces a main weir length of approximately 4000'. A smaller, 3' long weir was located at elevation 15' to pass smaller events. The storage volume was increased from a current floodplain storage volume of 140 acre-feet to 650 acre-feet with the detention basin. The result is a 25-yr discharge of 420 cfs at the upstream face of Highway 17 By-pass, or a net reduction of 45%. The location of the modeled detention basin is shown in figure 2 below.

Figure 2
Flood Mitigation Option 2 – Detention Basin Location



The resulting impacts in the hydraulic model is a 0.4' decrease in the 25-year flood elevation, mainly because the tailwater elevation at Highway 17 by-pass is not significantly reduced. The 25-year tailwater elevation at the Highway 17 by-pass culvert is 13.6', which is well above the commercial properties upstream of Highway 17 by-pass first floor elevation of 12.0'. The main reason for the high tailwater elevation is the drainage ditches and added discharge on the downstream face of Highway 17 by-pass, which contribute 1.2 square miles of drainage area. A second detention basin, to be used in combination with the larger detention basin upstream of Highway 17 By-pass, was investigated on the drainage ditch to the west of Highway 17 By-pass. The double detention option decreases the 25-year flood elevations downstream of Highway 17 By-pass to 12.7', which is higher than the first floor elevations of the commercial properties on the upstream face of Highway 17 By-pass. The detention basin option would be an effective alternative if it were used in combination with channelization, which would help reduce the tailwater elevation at Highway 17 By-pass. The obstacles associated with obtaining a permit for Option 2 may prove to be prohibitive since construction of the detention basin could result in alterations to the hydrology and functions of the stream and adjacent wetlands. The results of the detention basin analysis are shown in table 9 below. A cost estimate of Option 2 is included in Table 11. The flood profile for Option 2 is shown in Attachment 5, and the flood boundary mapping is included in Attachment 6.

Table 10

Flood Mitigation Option 2 – Detention Basin WSEL Comparison for the 25-yr Event

River Sta	Description	Existing WSEL (ft)	Detention Basin WSEL (ft)	Diff. (ft)
5,087	U/S Face Hwy 707	10.62	10.27	-0.35
5,543		10.77	10.42	-0.35
5,997		11.09	10.72	-0.37
6,671		11.57	11.23	-0.34
7,070		11.84	11.49	-0.35
7,528		12.17	11.81	-0.36
8,038		12.56	12.18	-0.38
8,373		12.66	12.28	-0.38
8,879	D/S Face Palmetto Point Blvd	12.87	12.49	-0.38
8,939	U/S Face Palmetto Point Blvd	12.90	12.64	-0.26
9,141		12.88	12.71	-0.17
9,599		13.16	12.94	-0.22
10,015		13.47	13.21	-0.26
10,498		13.70	13.41	-0.29
10,863		13.92	13.62	-0.30
11,247	D/S Face Highway 17 By-pass	13.98	13.64	-0.34
11,421	U/S Face Highway 17 By-pass	14.57	14.21	-0.36
11,607		14.57	14.22	-0.35
11,998		14.59	14.23	-0.36
12,497		14.61	14.24	-0.37
13,071		14.73	14.25	-0.48
13,893		15.50	14.41	-1.09
14,338		15.78	14.59	-1.19
14,940		15.66	14.91	-0.75

Table 11
Flood Mitigation Option 2 – Cost Estimate

Assumptions: Main Weir

Length - 4000' (elevation 20')
Avg Height - 2.4'
Top width - 5'
Side slopes - 3:1
Remove 1' depth of existing material

Spillway

Length - 3'
Depth - 5' (elevation 15')

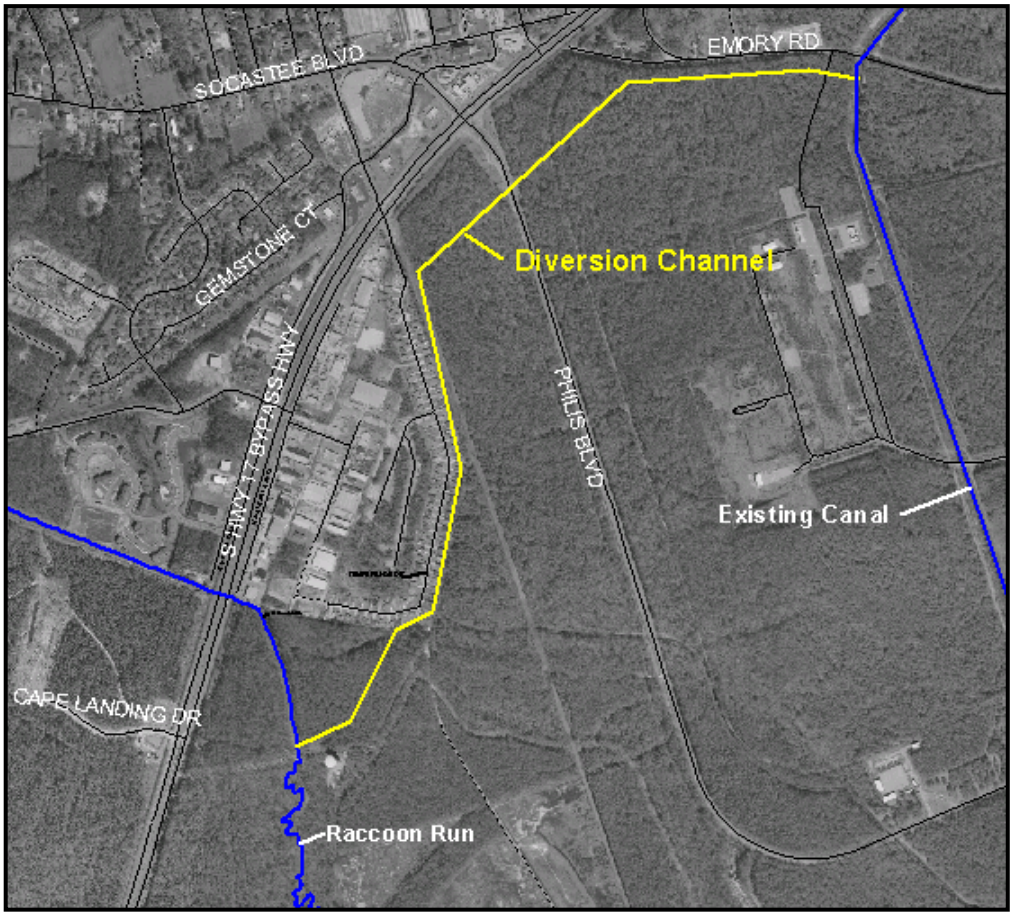
Total cut:	3,158 cubic yards
Cost per cubic yard:	$9.50 / cubic yard
Excavation cost:	$30,000
Land Area:	150 acres (at low water elevations)
Land Acquisition:	150 acres * $15,000/acre = $2,250,000
Total fill:	7,368 cubic yards
Cost per cubic yard:	$9.50 / cubic yard
Fill cost:	$70,000
Spillway cost:	$10,000
Traffic Control:	$10,000
Erosion Control:	$20,000
Total:	$2,390,000
Mobilization (15%):	$359,000
Contingency (20%):	$412,000
Option 2 total cost:	**$3,161,000 SAY $3,200,000**

Option 3 – Flow Diversion

Option 3 is the diversion of flow from Raccoon Run to the existing canal located in the Watershed to the East of the Raccoon Run Watershed. The figure below illustrates the diversion canal location.

Figure 3

Flood Mitigation Option 3 – Flow Diversion Canal Location



As a test to determine if flow diversion is a viable alternative, all basins 3000' upstream of the Highway 17-By-pass were removed from the HEC-HMS model. This resulted in a reduction of 5.1 square miles of drainage area. The result is a 25-yr discharge of 416 cfs at the upstream face of Highway 17 By-pass, or a net reduction of 45%. The result downstream of Highway 17 By-pass is a reduction in discharge of 17%. In order to carry the diverted flow for the 25-year event in the channel, the diversion canal would have a topwidth of 90' and an average depth of 3-4' with 2:1 side slopes. A diversion structure would have to be constructed that allows the discharge for the 1-2 year event pass down Raccoon Run, while diverting all other flow to the diversion canal. This structure could be similar to a culvert, with an opening large enough to

pass the 1-2 year flood. Also, the right overbank would have to be cut down for a certain distance upstream to allow all flow in the floodplain to spill over into the diversion canal. The diversion canal would flow under two road crossings, for which bridges would have to be constructed to carry the flow. The diversion canal would flow under two road crossings, for which bridges would have to be constructed to carry the flow. The diversion canal would also require regular mowing to maintain the design flow conveyance.

The resulting impacts in the hydraulic model is a 0.4' decrease in the 25-year flood elevation, mainly because the tailwater elevation at Highway 17 by-pass is not significantly reduced. The 25-year tailwater elevation at the Highway 17 by-pass culvert is 13.6', which is well above the commercial properties upstream of Highway 17 by-pass first floor elevation of 12.0'. The flow diversion option would be an effective alternative if it were used in combination with channelization, which would help reduce the tailwater elevation at Highway 17 By-pass. The results of the flow diversion are almost identical to the results from the detention basin above, which illustrates the fact that both options effectively remove all upstream discharge from the upstream face of the Highway 17 culvert. The results of the flow diversion analysis are shown in table 10 below. A cost estimate of Option 3 is included in Table 13. The flood profile for Option 3 is shown in Attachment 5, and the flood boundary mapping is included in Attachment 6.

Table 12

Flood Mitigation Option 3 – Flow Diversion WSEL Comparison for the 25-yr Event

River Sta	Description	Existing WSEL (ft)	Flow Diversion WSEL (ft)	Diff. (ft)
5,087	U/S Face Hwy 707	10.62	10.27	-0.35
5,543		10.77	10.42	-0.35
5,997		11.09	10.72	-0.37
6,671		11.57	11.22	-0.35
7,070		11.84	11.49	-0.35
7,528		12.17	11.80	-0.37
8,038		12.56	12.17	-0.39
8,373		12.66	12.28	-0.38
8,879	D/S Face Palmetto Point Blvd	12.87	12.49	-0.38
8,939	U/S Face Palmetto Point Blvd	12.90	12.63	-0.27
9,141		12.88	12.70	-0.18
9,599		13.16	12.93	-0.23
10,015		13.47	13.19	-0.28
10,498		13.70	13.40	-0.30
10,863		13.92	13.60	-0.32
11,247	D/S Face Highway 17 By-pass	13.98	13.63	-0.35
11,421	U/S Face Highway 17 By-pass	14.57	14.20	-0.37
11,607		14.57	14.21	-0.36
11,998		14.59	14.22	-0.37
12,497		14.61	14.23	-0.38

Table 13
Flood Mitigation Option 3 – Cost Estimate

Assumptions: Diversion Channel Dimensions

Top width - 90'
Depth - 4' (avg)
2:1 Side Slopes
Linear feet - 8300'
Avg area - 330 sq ft

Proposed Bridge (2 Structures)

2 Lane Road
2 - 12’ Lanes, 1 - 10’ & 1 - 4’ Shoulder, 2 - 1’-5” Bridge Rails (per structure)
3 - 30' spans

Total cut:	101,176 cubic yards	
Cost per cubic yard:	$6.25 / cubic yard	
Land Area:	8300’ linear feet, 250’ topwidth = 48 acres	
Land Acquisition:	48 acres * $15,000/acre = $720,000	
Excavation cost:	$1,350,000	
Traffic Control:	$50,000	
Detour:	(Assumes road can be closed & detoured to other roads, if not, need $250,000 for each on site detour)	
Erosion Control:	$20,000	
Approach Work:	$100,000	
Total bridge square footage:	7,350 square feet	
Cost per square foot:	$68.00 / square foot	
Bridge cost:	$500,000	
Total:	$2,020,000	
Mobilization (15%):	$303,000	
Contingency (15%):	$349,000	
Option 3 total cost:	**$2,670,000**	**SAY $2,700,000**

Option 4 – Property Buyout

Option 4 is to acquire all flood prone properties. Several properties have been identified for buyout based on the mapped existing 100-ye flood boundary. The included properties are selected only because they are included in the 100-year floodplain boundary. Some structures may have first floor elevations above the 100-year elevations. The properties are shown in figure 4 below, and their acquisition values are summarized in the table 14 below. The acquisition value is the tax value of the property plus 25%.

Figure 4
Flood Mitigation Option 4 – Buyout Locations

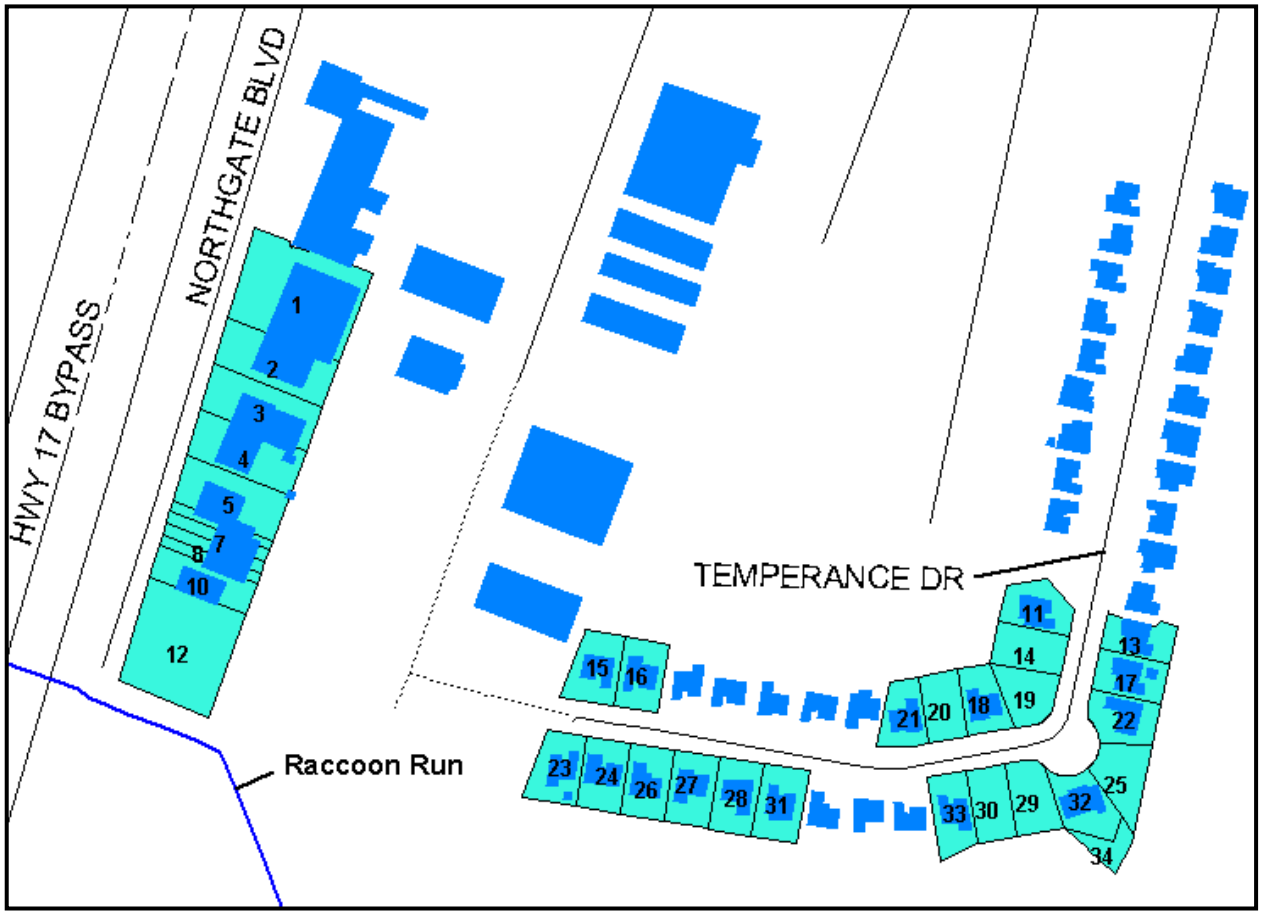


Table 14
Flood Mitigation Option 4 – Buyout Summary

Map ID	Tax Value
1	$373,875
2	$159,625
3	$115,250
4	$156,875
5	$210,750
6	$49,125
7	$30,000
8	$30,000
9	$30,625
10	$123,500
11	$121,875
12	$31,250
13	$109,500
15	$122,125
16	$118,625
17	$111,125
18	$113,500
20	$103,000
21	$115,000
22	$117,375
23	$108,875
24	$112,000
26	$115,000
27	$117,125
28	$125,375
30	$117,000
31	$119,500
32	$121,125
33	$119,750
34	$113,500

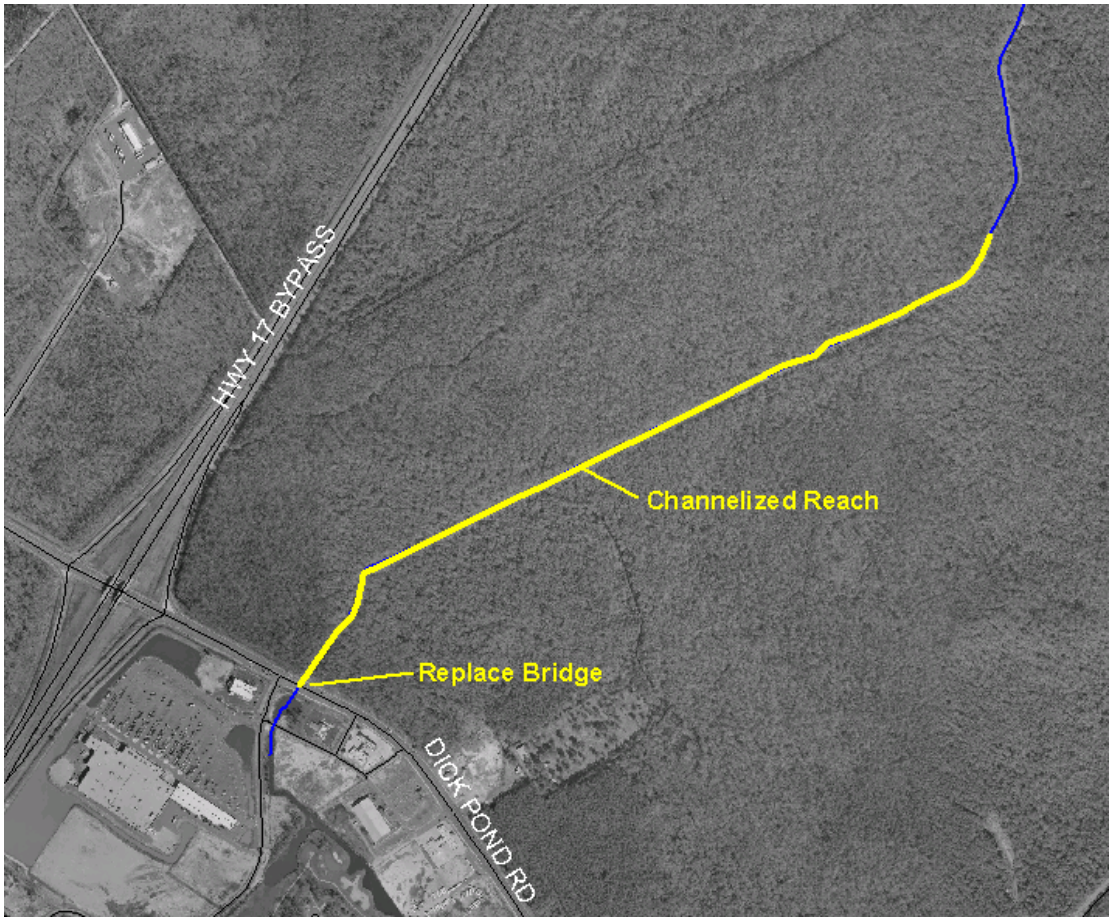
Total $3,512,250

6.0 FLOOD MITIGATION ALTERNATIVES – HIGHWAY 544

Channelization and Highway 544 Bridge Replacement

The option investigated consists of channelizing a reach of Raccoon Run from Highway 544 to a point 5248' downstream. The option also includes the replacement of the existing bridge at Highway 544 with a larger, 120' span bridge and raising the road grade by 1 foot. This option also includes replacing the Chick-Fil-a access Road with a larger 90' bridge. The location of the proposed channelization is shown in figure 1 below:

Figure 5
Channelization and Bridge Replacement Location



The proposed channel has a topwidth of 90' with 2:1 side slopes. The depth of the existing channel will be retained. Different channel sizes were investigated, however the 90' topwidth is the minimum width that will lower the tailwater elevation of the Chick-Fil-a Access Road and Highway 544 below an elevation that does not overtop the Access Road upstream of Highway 544. The proposed bridge for the Chick Fil-a Access Road has and opening area of approximately 450 square feet, compared to the existing bridge opening area of 105 square feet. The proposed bridge for Highway 544 has and opening area of approximately 650 square feet, compared to the existing bridge opening area of 130 square feet. The existing top of road

elevation will be retained on both bridges.

As large of a scale as the proposed option is, it does not accomplish the goal of not overtopping the Access Road upstream of Highway 544. The proposed alternative does lower flood elevations in the area by 1.5' – 2.0', but the Access Road remains overtopped. A comparison table is shown below comparing existing conditions to proposed conditions for the 25-year event. A cost estimate of this option is included in Table 16.

Another alternative is to simply raise the grade of the Access Road upstream of Highway 544 to an elevation above the 25-yr flood, which in this case would be 22 feet. The problem with this alternative is that the road would not be overtopped, but the adjacent parking lot areas would be, making the road inaccessible. If this option is explored, the parking lot grade would have to be raised to an elevation of 22 feet as well.

Table 15

Channelization and Bridge Replacement WSEL Comparison for the 25-yr Event

River Sta	Description	Existing WSEL (ft)	Channelization & Hwy 17 Bridge Replace WSEL (ft)	Diff. (ft)
20134	Begin Channelization	19.3	19.2	-0.1
20740		19.6	19.2	-0.4
21241		20.0	19.2	-0.8
22002		20.8	19.3	-1.5
22689.2		21.1	19.3	-1.8
23327		21.1	19.4	-1.7
23968		21.3	19.5	-1.8
24513		21.4	19.6	-1.8
24894	End Channelization	21.5	19.7	-1.8
25273.2	D/S Face Chick-Fil-a Access	21.6	19.7	-1.9
25327.2	U/S Face Chick-Fil-a Access	21.6	19.8	-1.8
25327.7	D/S Face Hwy 544	21.5	19.8	-1.7
25437.7	U/S Face Hwy 544	21.8	19.9	-1.9
25455.5		22.0	20.0	-2.0
25478.5		22.0	20.2	-1.8
25533		22.0	20.4	-1.6
25671.9	D/S Face Access Road	22.0	20.5	-1.5
25723.9	U/S Face Access Road	22.0	20.7	-1.3
25849		22.1	20.8	-1.3

Table 16
Hwy 544 Flood Mitigation – Cost Estimate

Assumptions: Existing channel completely within new channel limits. Assume additional 100’ wide R/W will be needed.

Existing Channel Dimensions

Top width - 17' (avg)
Depth - 5' (avg)
0.5:1 Side Slopes
Linear feet - 5200'
Avg area – 72.5 sq ft

Proposed Channel Dimensions

Top width - 90'
Depth - 5' (avg)
2:1 Side Slopes
Linear feet - 5200'
Avg area - 400 sq ft

Clearing Additional R/W

5200’ x 100’/43560 = 12 acres

Maintenance Roads

20’ x 2’ x 5200’/27 = 7,700 CY each road

Proposed Bridge @ Access Road

2 Lane Road
2 - 12’ Lanes, 2 - 10’ Shoulders, 2 - 1’-5” Bridge Rails
3 - 30' spans

Proposed Bridge @ Hwy 544

4 Lane Road w/center turn lane
5 - 12’ Lanes, 2 - 10’ Shoulders, 2 - 1’-5” Bridge Rails
4 - 30' spans

Total cut:	63,075 cubic yards
Cost per cubic yard:	$5.25 / cubic yard
Disposal fee:	$1.00/cubic yard
Total Unit cost per cubic yard	$6.25/cubic yard
Land Area:	5200’ linear feet, 250’ topwidth = 30 acres
Land Acquisition:	30 acres * $15,000/acre = $450,000
Channel cost:	$ 845,000
Clearing: - 12 acres x $5,000/acre	$60,000
Maintenance Roads	
2 each x 7,700 cy/road	15,400 cy
Cost per cubic yard:	$4.00/cy
Maintenance Road Cost	$62,000
Remove 2 – Existing Bridges:	$75,000
Traffic Control:	$50,000
2 - Detour Bridges & Roadway: (Assumes available R/W & no bldg. conflicts)	$500,000
Erosion Control:	$20,000
Approach Work for 2 Bridges:	$100,000
Total bridge square footage @ Access Rd:	4,215 square feet
Cost per square foot:	$68.00 / square foot
Bridge cost:	$287,000
Total bridge square footage @ Hwy 544:	9,940 square feet
Cost per square foot:	$68.00 / square foot
Bridge cost:	$676,000
Total:	$ 2,613,000
Mobilization (15%):	$ 391,000
Contingency (15%):	$ 451,000
Option 4 total cost:	**$ 3,455,000 SAY $ 3,500,000**

7.0 SUMMARY

The Raccoon Run Watershed has experienced periodic flooding damage, including flooding to many commercial properties in the vicinity of the Highway 17 Bypass during Hurricane Floyd, Hurricane Irene, and a localized storm in October 1986. Horry County contracted with Watershed Concepts to perform hydrologic and hydraulic analyses of the Raccoon Run watershed in order to investigate various alternatives to lessen the effects of flooding. Existing conditions hydrologic and hydraulic models were created a baseline to determine where flooding occurs. These models were calibrated to known historical high-water marks. Three structural flooding alternatives were investigated to determine what impacts they have on the modeled water surface elevations, and one non-structural alternative was investigated as a cost comparison to the structural alternatives. The structural alternatives include: Channelization and Highway 17 By-pass culvert replacement, a detention basin upstream of Highway 17 By-pass, and a flow diversion canal upstream of Highway 17 By-pass.

The channelization and Highway 17 By-pass culvert replacement is the structural alternative that has the greatest impact on water surface elevations at the flood prone properties. The negatives of this option are mainly with permitting and maintenance. A channelization project may be costly to permit if mitigation is required. The large channel may also encourage excessive deposition due to a reduction in the sediment transport capacity requiring periodic dredging.

The detention basin and flow diversion options effectively reduce discharges at the upstream face of the Highway 17 By-pass culvert, but don't decrease the tailwater elevations enough at Highway 17 By-pass to significantly reduce flooding. The negatives of the diversion canal are that it would require regular maintenance such as frequent mowing. The detention basin option may be difficult to permit due to the alterations to the hydrology and functions of an existing wetland.

As the County moves forward with a decision on a structural alternative, the permitting issues should be investigated in more detail. The costs for each alternative are summarized in Table 15 below.

Table 17
Flood Mitigation Alternatives Cost Estimates

Alternative	Description	Total Cost
Option 1	Channelization and Culvert Replacement	$3,200,000
Option 2	Detention Basin	$3,200,000
Option 3	Flow Diversion	$2,700,000
Option 4	Property Buy-out	$3,512,250
Hwy 544 Option	Channelization and Bridge Replacement	$3,500,000

8.0 RECOMMENDATION

In order to address the problem associated with flooding along Raccoon Run, consideration must be given to both the flooding of roads and public right of ways as well as flooding of private property including commercial and residential structures. Of the alternatives presented, none of the alternatives eliminates all possible flooding for all of the areas of concern. While acquisition and demolition of specific properties addresses much of the private property flooding, it does not address flooding of roads, which pose a significant hazard to the general public.

In order to provide a balanced solution that provides some relief from both private property flooding and the flooding of public roads, Option 1 – Channelization and Highway 17 By-pass Bridge Replacement is recommended. This alternative has the following benefits:

- Reduces water surface elevations upstream of Highway 17 By-Pass 3.0 feet during a 25-year storm
- Highway 17 does not overtop during a 100-yr storm (500-yr overtops)
- Reduces water surface elevations for residential and commercial structures by up to 3.0' feet during a 25-year storm. These properties currently flood during the 2 to 5-year flood events. The improvements will provide protection from flooding up to a 25-year storm.
- Reduces water surface elevations for residential and commercial structures by up to 2.0' feet for a 100-year event. Even though some structures may be inundated during the 100-year flood, damages will be significantly less because of the reduction in flooding depth.

REFERENCES

1. U.S. Army Corps of Engineers, *HEC-HMS Flood Hydrograph Package*. Davis, California; 2001.

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4. U.S. Army Corps of Engineers, Hydrologic Engineering Center, *HEC-RAS River Analysis System, Version 2.1*. Davis, California; October 1997.

5. South Carolina DNR website: http://www.dnr.state.sc.us/climate/sercc/products/tropical/1999/1999_tropical.html#floyd