SHANDON ROSEWOOD PHASE 2 DRAINAGE STUDY

FOR

CITY OF COLUMBIA CIP#SD8325

PROJECT #2088

PREPARED BY:

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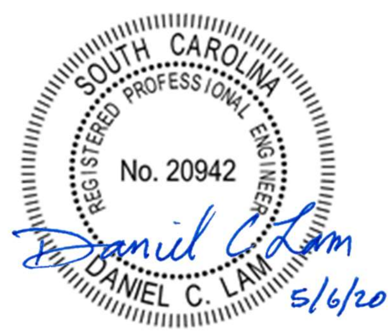

COX AND DINKINS

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DESCRIPTION:

EXECUTIVE SUMMARY:

Cox and Dinkins, Inc. has been requested to perform further storm drainage analysis under the Shandon Rosewood Phase 2 Drainage Study, (City of Columbia CIP Project Number SD8325) to recommend improvements to alleviate existing flooding problems in the Shandon neighborhood south of Devine Street and north of Rosewood Drive. As a part of this study, the storm drainage system downstream south of Rosewood Drive was also analyzed to determine the effects of improvements upstream in the Shandon neighborhood.

Cox and Dinkins, Inc. performed civil engineering and land surveying services for the Shandon/Rosewood Drainage Basin in 2009 and 2010 under the City of Columbia CIP Project Number SD8325 (original project, Phase 1). In addition to providing a database of existing drainage structures in the watershed, the original project also included the development of a computer model and engineering analysis of the drainage system. Two models were developed for the Shandon Rosewood watershed, one for each subwatershed that independently outfall to Devils Ditch. They are designated as the **east trunk** and the **west trunk watersheds**. The analysis identified major potential flooding areas in the storm drainage systems and conceptual plans and analyses for improvements were developed to address specific areas of flooding.

As a follow up to the original project, Cox and Dinkins, Inc. performed further drainage study and analysis in 2014, under City of Columbia CIP Project Number SD8392 (CIP#SD8392), to determine the benefit that limited conventional drainage system improvements may have on certain identified flooding areas during the 10-year, 24-hour rainfall event. Specifically, Cox and Dinkins, Inc. was requested to determine what potential benefit(s) conventional drainage improvements costing in the range of one million dollars ($1,000,000.00) may have on critical flooding areas in either the **east trunk watershed** or **west trunk watershed**. The study determined that in order to provide significant relief to identified flooding areas, the opinion of probable costs (OPCC) for improvements was well beyond one million dollars ($1,000,000.00) into the two million dollar ($2,000,000.00) range for either watershed.

For this report, the **west trunk watershed** will be addressed first in this report since the recommended improvements to the **west trunk watershed** are less extensive than the **east trunk watershed**.

The most significant reported flooding occurring in the west watershed is at the intersection of Maple Street and Monroe Street. The topography of that area is bowl-shaped thus trapping water due to inadequate pipe capacity. However, with the improvements north of Rosewood Drive to alleviate the flooding at the intersection of Maple Street and Monroe Street, the computer model predicts flooding along Elm

Avenue and at Harvard Avenue south of Rosewood Drive due to the additional stormwater which will be conveyed by these improvements. The transition from twin 60-inch pipes to a single 96-inch pipe at Harvard Avenue is determined to be a restriction that causes flooding along Elm Avenue.

The recommended improvements on the **west trunk watershed** consists of bypass and parallel piping beginning at Rosewood Drive near S. Holly Street going north to the Maple Street and Monroe Street intersection, and parallel piping from Harvard Avenue extending downstream to the Devils Ditch outfall. The recommended improvements do not eliminate the flooding issues at the intersection of Maple Street and Monroe Street, but the study shows that the flooding at this intersection is significantly reduced. Some flooding may still exist along west trunk storm system south of Rosewood Drive from Kennedy Street to the north of Shamrock Court, but it will less severe than under existing conditions.

The majority of the damage-causing flooding in the **east trunk watershed** is occurring on and around an existing drainage trunk line running through the blocks starting at Wheat Street and flowing southward to Rosewood Drive. This trunk line flows under, near, or behind many houses and structures and is substantially undersized. The recommended improvements to the **east trunk watershed** are significantly more extensive and consist of bypass piping north of Rosewood Drive and parallel piping south of Rosewood Drive to Devils Ditch. In the area north of Rosewood Drive where significant flooding issues are experienced along the trunk line, there is a significant improvement for the smaller more frequent storms. Flooding from larger storm events will still exist but the improvements do provide some level of relief to the system.

For areas south of Rosewood Drive the parallel pipe improvements eliminate flooding for up through the 10-year storm event, except at Tempo Court at the southern end of the system. There are a few areas where improvements likely eliminate flooding through the 25-year storm. However, in areas where flooding still exists, the improvements will provide a significant decrease from the existing flood elevations.

The improvements on both the **east trunk** and **west trunk watersheds** will cause an increase to the peak flow rates at Devils Ditch. The largest increase in depth of flow will occur with the 2-year storm event. The depth of flow is not significantly increased for the 10-year or 25-year storm events.

All of the analyses, recommendations, calculations, modeling, and conceptual drainage designs developed in this report were produced based upon information provided to Cox and Dinkins by others, limited field surveying, limited topographical data, and limited existing utility data. In the next phase of this project, more complete and detailed data will be obtained that may have a significant impact on the recommendations and designs contained herein. It is possible that significant changes must be made once more detailed data has been obtained that could have significant positive or negative impacts on the actual costs of the project. The actual design and costs of the drainage system will not be known until all of the detailed data has been obtained and studied, all final design has been completed, all permits have been obtained, and actual qualified contractor bids have been received for construction of the project.

SECTION 1 – XPSWMM STORMWATER MODEL DEVELOPMENT

INTRODUCTION

Cox and Dinkins, Inc. has been requested to perform further storm drainage analysis under the Shandon Rosewood Phase 2 Drainage Study (City of Columbia CIP Project Number SD8325) to recommend improvements to alleviate existing flood issues in the Shandon neighborhood south of Devine Street and north of Rosewood Drive. As a part of this study, the storm drainage downstream south of Rosewood Drive was also analyzed to determine the effects of improvements upstream in the Shandon neighborhood.

PROJECT HISTORY

Cox and Dinkins, Inc. performed civil engineering and land surveying services for the Shandon/Rosewood Drainage Basin in 2009 and 2010 under the City of Columbia CIP Project Number SD8325 (original project, Phase 1). The original project consisted of field surveying of major drainage structures in the approximate 750-acre drainage basin and mapping of the structures and the extents of the overall drainage basin. The original project also included an engineering analysis of the drainage system and the development of a computer model of the existing drainage system. The original project also included identification of major potential flooding areas through the drainage model analysis and development of a conceptual plan for overall drainage system upgrades within the watershed.

The survey data used for the current study was gathered in the original project (Phase 1). During the original project Cox and Dinkins, Inc. delineated the overall Shandon-Rosewood watershed and further divided the watershed into two primary sub-watersheds, namely the **west trunk watershed** and the **east trunk watershed**. The **west trunk watershed** and the **east trunk watershed** discharge into two separate open channels at the southern end of the watershed. The open channels converge into one open channel, also known as Devils Ditch, at the downstream limits of the original project area.

As a follow-up to the original project, Cox and Dinkins, Inc. performed further drainage study and analysis in 2014, under City of Columbia CIP Project Number SD8392 (CIP#SD8392) to determine the benefit that limited conventional drainage system improvements may have on certain identified flooding areas during the 10-year, 24-hour rainfall event. Specifically, Cox and Dinkins, Inc. was requested to determine what potential benefit(s) conventional drainage improvements costing in the range of one million dollars ($1,000,000.00) may have on critical flooding areas in either the west trunk watershed and the east trunk watershed.

In between the time of the original project and CIP#SD8392, green infrastructure pilot projects were installed in both the **west trunk watershed** and **east trunk watershed** in the upper reaches of the Shandon neighborhood. The scale of the green infrastructure pilot projects compared to the extremely large land area of the entire 750-acre watershed strongly indicates that the green infrastructure projects will not have a significant impact on the overall watershed analysis. For this reason, the current modeling of the watersheds does not incorporate the green infrastructure. Therefore, extremely minor stormwater reductions that may exist from the green infrastructure are not accounted for in this study.

XPSWMM COMPUTER MODEL

An updated version of **XPSWMM**, version 2019.1, was selected to conduct the current study of the Shandon-Rosewood storm drainage network. Since the **west trunk** and the **east trunk watersheds** do not converge until a point downstream of the project area, independent **XPSWMM** models were developed for each watershed during Phase 1. Although the west and east models have been combined into a single model for this study, the west and east watersheds are addressed separately.

MODEL IMPROVEMENTS

For the current study, improvements were made to the model for more accurate simulations:

1) **NOAA Atlas 14 rainfall data:** Runoff has been routed through the models using the SCS Hydrology Routing Method with up to date NOAA Atlas 14 rainfall distributions. The previous studies used SCS Type II 24-hr rainfall distribution data. The NOAA Atlas 14 synthetic rainfall data is able to better simulate the short burst storms.

2) **Added modeling of the 25-year storm event:** Phase 1 and CIP#SD8392 studies only considered the 2-year and 10-year rainfall events. With the current study, the 25-year storm events was also analyzed.

3) **Smaller watershed areas:** The larger watersheds from the Phase 1 study were subdivided into smaller watersheds based on the drainage areas coming to a street intersection that is connected to the storm drainage network.

4) **Representative Curve Numbers:** Representative curve numbers were assessed for each of the distinct neighborhoods and commercial corridors: the Melrose Heights neighborhood, the Millwood Ave commercial corridor, the Old Shandon neighborhood (between Millwood Avenue and Devine Street), the Devine Street commercial corridor, the Shandon neighborhood, the Rosewood Drive commercial corridor, and the Rosewood neighborhood. The representative curve numbers were then applied to the watersheds with the neighborhood or commercial corridor.

5) **NOAA DTM:** A digital terrain model (DTM) surface was added to the model. The DTM was derived from DTM data downloaded from the NOAA website. The DTM allowed for the model to simulate overland flow due to flooding. However aerial topography is not as accurate as ground run topographic field surveying, so this may cause some inaccuracies in the results.

6) **Additional topographic survey data:** Cox and Dinkins conducted limited additional topographic field surveying from the intersection of Maple Street and Monroe Street going south to Heyward Street to have more accurate topography to assess the flooding patterns and flow at the Maple Street and Monroe Street intersection that the NOAA DTM data did not provide.

7) **City-provided field data:** Cox and Dinkins also studied video footage and sketches provided by the City of Columbia to improve the accuracy of the **west trunk watershed** model. There was a significant change to the model network at the intersection of South Holly Street and Rosewood Drive as a result of the information provided by the City. If similar additional information is provided in the future, it could affect the stormwater simulation models.

8) **Overland exchange of flow between watersheds:** Due to the existing undersized systems, flooding occurs at several locations along the boundary between the **west trunk watershed** and the **east trunk watershed.** With the flooding at the boundary, there is an exchange of overland storm flow from one watershed to the next. Since both watersheds are in the same model, the exchange of overland storm flow is accounted for in the model.

9) **Tailwater Conditions:** Tailwater conditions were applied in the model approximately 190’ downstream of the **west trunk** outfall and at locations 500’ and 1260’ downstream of the confluence of the west and east open channels. These locations are referred as cross-sections “H”, “G” and “F” respectively of the Gills Creek Tributary 1A (Devils Ditch) from the Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) last revised December 21, 2017.

MODEL PARAMETERS

The following parameters were applied to the watershed model:

1) **Tailwater Conditions:** The tailwater data in the FEMA FIS provides data only for the 10-year, 50-year, and 100-year storm events. These published FEMA tailwater elevations for the 10-year and 50-year storm events and the associated rainfall were used to interpolate the 2-year and 25-year tailwater elevations. The following are the tailwater conditions that have been applied to the model at cross-section locations “F”, “G”, and “H” of the Gills Creek Tributary 1A:

Storm Event	Rainfall	Water Surface Elevation		
		Cross section “F”	Cross Section “G”	Cross Section “H”
2-year, 24-hour	3.60”	175.5	178.4	185.0
10-year, 24-hour	5.26”	178.1	181.8	187.6
25-year, 24-hour	6.38”	178.5	182.3	188.3

(Note: There is approximately a 0.2’ elevation difference between the NOAA DTM and the FEMA FIS Devils Ditch profile. The tailwater data from the FIS was adjusted -0.2’ in the model to account for the elevation difference. The tailwater elevations shown above are the adjusted values.)

2) **Pipe losses:** All existing reinforced concrete pipe (RCP) and corrugated metal pipe (CMP) are given a Manning's 'n' coefficient of 0.014 and 0.025 respectively. Proposed pipes are given a Manning's 'n' coefficient of 0.013 and 0.012 for RCP and high-performance polypropylene (PP) pipe respectively. Pipe entrance and exit losses are also applied to each pipe. A default loss coefficient of 0.25 is applied to all pipe entrances, while the pipe exit loss coefficient varies from 0.35 to 1.00 depending on the angle that the stormwater flow will have to turn passing through a stormwater structure.

3) **Overland Flow Roughness Coefficient:** An overall Manning's 'n' of 0.050 was applied to both watersheds for overland flow due to flooding. This number was derived from the above-cited FEMA FIS which stated the overbank Manning's 'n' for the City of Columbia community to have a range from 0.050 to 0.150.

4) **Devils Ditch Channel:** Devils Ditch was modeled as an open channel with a Manning's 'n' value of 0.035 for the channel cross-section and 0.050 beyond the channel banks. Topographical information from the Devils Ditch Maintenance Plan prepared for Richland County Public Works and the City of Columbia by Dennis Corporation dated July 2017 and last revised October 11, 2018, is used for the channel cross-sections.

5) **Watershed peak flows:** Peaks for each watershed coming to a street intersection were routed using the SCS Hydrology method using a curvilinear shape factor of 484. The time of concentration was calculated using the TR-55 method. Storm event peaks were applied in the model to the last node/link leaving the street intersection.

6) **Flooding:** For this study, flooding in the streets will be defined as areas where the accumulated storm runoff has a depth of more than 6" above the street surface. In other words, a street will be considered flooded if the depth of stormwater is higher than the typical street curb height. However, in order to graphically represent flooding outside of the streets, the images in Appendices A and D are adjusted to show stormwater depths of more than 1" above the ground.

MODEL LIMITATIONS

1) **Tailwater conditions:** The flood level conditions from the FEMA FIS are used for all improvement scenarios to account for any tailwater effects. According to the FEMA FIS, the tailwater effects of Gills Creek from the 100-year storm event end approximately 6000' downstream of the Devils Ditch confluence. Therefore, flood level effects are dependent on the characteristics of Devils Ditch and the upstream storm systems in the Rosewood and Shandon neighborhoods. The FEMA FIS is based on the HEC-RAS methodology which takes into account land use and channel cross sections, but does not take into account the storm drainage

conveyance system. A separate study using the HEC-RAS methodology will need to be conducted to assess any changes to the flood levels.

2) **Watershed peak flows:** As stated earlier, the modeling was improved with smaller watersheds based on the drainage area coming to each intersection connected to the storm drainage system. Watershed runoff is not modeled as 2D overland flow from rain falling on a watershed area. Instead, the watershed peak flows were applied directly into the storm system at the last downstream node of the intersection. Therefore the catch basin nodes in the intersection do not model the capture of watershed runoff from the surface. If the system is undersized, the model simulates surcharge at the intersection catch basins causing 2D overland flow. Although the model can simulate increased inlet capacities of the catch basin nodes, the nodes are only capturing overland flow due to the surcharging system upstream. Therefore, during the final design, the inlet capacities of the intersection catch basins need to account for capturing both the watershed runoff and the overland flow from upstream flooding.

SECTION 2 – WEST TRUNK WATERSHED FLOODING

OVERALL WATERSHED

The west trunk watershed extends from the Devils Ditch outfall north through the Rosewood neighborhood and into the Shandon neighborhood. At Hope Avenue, one block south of Rosewood Drive, the storm line splits into two branches. Both branches continue north across Rosewood Drive and extend into the Shandon neighborhood. The original Phase 1 study indicated that the storm drainage system north of Rosewood Drive did not have enough capacity to handle the storm runoff in the Shandon neighborhood. Flooding was indicated at the intersection of Wilmot Avenue and Shandon Street, Maple Street and Monroe Street, Woodrow Street and Monroe Street, and the Harden Street, Woodrow Street, and Rosewood Drive intersection.

South of Rosewood Drive in the Rosewood neighborhood, there is some flooding indicated along the trunk line in the blocks between Kennedy Street and Montgomery Avenue for the 25-year storm event.

See Appendix A to view the existing extents of flooding shown by the XPSWMM model for the 2-year through the 25-year storm event.

INTERSECTION OF MAPLE STREET AND MONROE STREET

There has been a history of flooding at the Maple and Monroe Street Intersection. The original Phase 1 study indicated that the storm drainage system did not have enough capacity to handle the storm runoff at that intersection. This problem was confirmed by complaints by residents at a kickoff townhall informational meeting. Residents on the east side of that intersection had experienced significant flood damage to their homes.

They were the most vocal residents in attendance at the town hall meeting. Therefore, Cox and Dinkins focused the effort for a solution towards alleviating the flooding at this intersection.

SECTION 3 – WEST TRUNK IMPROVEMENT CONSIDERATIONS

LOW IMPACT DEVELOPMENT (LID) STRATEGIES

At the beginning of this project, City of Columbia officials requested Cox and Dinkins to investigate incorporating low impact development (LID) strategies into the recommended solution.

POCKET PARK AT INTERSECTION OF MAPLE STREET AND MONROE STREET

Since the houses on the east side of the Maple and Monroe Street Intersection have experienced damage, the homeowners have indicated that they may be willing to sell their property to the City for conversion into a pocket park for stormwater runoff retention and infiltration. After study, Cox and Dinkins determined that a pocket park (or parks) would not have enough capacity to alleviate the flooding at the intersection. The model indicates that the peak flow that is received by the Maple and Monroe Street Intersection for a 2-year storm event is 56.70 cfs. A shallow 2-foot deep, 50-foot wide by a 160-foot long park with a storage area of 16,000 cubic feet will fill up in 4.7 minutes. The low possibility of benefit to the storm system and expense of the property purchase, demolition and construction, and long term maintenance costs, make the use of a pocket park (or parks) not a cost-effective solution for flood control.

STREET DIETING

Street dieting is the occasional practice of reducing the width of existing streets. It has been observed that the streets running east-west in the Shandon neighborhood are very wide compared to the streets running north-south. Cox and Dinkins gave consideration to the impact on the flooding at the Maple and Monroe Street Intersection if all the east-west streets throughout the Shandon neighborhood were decreased from 34' to 26' in pavement width. The representative curve number for the Shandon neighborhood would decrease from 76 to 73. After using the curve number of 73 the impact to alleviate the flooding was not significant. The model indicated a decrease in the flood level of only one or two tenths of a foot (at most) for flood events greater than the 2-year storm. The expense to convert all the roads throughout the neighborhood is too costly for the minimal benefit that it would provide. In addition, limited polling of the residences showed that residents generally were not in favor of losing the on-street parking spaces that would be a result of street dieting.

RAIN BARRELS

Former Councilman Moe Baddourah requested that we investigate the potential benefit of residents of the Shandon area using rain barrels to help alleviate flooding issues. We made the following analysis. Assuming a residential density of approximately four units per acre and a total watershed of approximately 750 acres, the Shandon drainage basin will have an estimated total number of 3000 residential parcels. Assuming 50% participation of residents in capturing and emptying a 55-gallon rain barrel per rainfall event, the total volume of water of 82,500 gallons (3000 residences x 50% x 55 gallons/residence) will be eliminated from the watershed each rainfall event. During a 10-year storm event, the peak flow rate at the Devils Ditch confluence is 1151 cubic feet per second (cfs). 82,500 gallons equals 11,029 cubic feet (cf) of water (7.48 gal/cf). Therefore all of the rain barrels (assuming 50% resident participation) will only remove 10 seconds of peak flow from the watershed. Hence, rain barrels do not provide measurable relief from flooding.

LOWERING OF MAPLE STREET AND HEYWARD STREET INTERSECTION

Consideration was given to providing an overland outlet for the flooding at the Maple Monroe Street Intersection. This could be accomplished by lowering Maple Street from Monroe Street to Heyward Street. With existing conditions, flooding has generally been confined to the Maple and Monroe Street intersection for the less frequent storms. However, lowering Maple Street will, in fact, transfer the flooding to the Maple and Heyward intersection while providing minimal relief to the flooding at the Maple and Monroe intersection.

INCREASED PIPE CAPACITY AND ELEVATION OF ROSEWOOD DRIVE

It was initially assumed that inadequate pipe capacity was the primary reason for the flooding at the Maple and Monroe intersection. However, in the process of providing an oversized conduit to convey the floodwaters from the Maple and Monroe Street intersection, there was little improvement noticed and flooding continued to persist at the intersection. Upon further examination, it was observed that the elevations of the Maple and Monroe intersections and the Maple and Heyward intersection were essentially the same as the elevation of the South Holly Street and Rosewood Drive intersection located about 1,500’ downstream. Thus, the Maple and Monroe Street and Maple and Heyward Street intersections are essentially “bowls” with no overland outlet until Rosewood Drive.

SECTION 4 – WEST TRUNK RECOMMENDED IMPROVEMENTS

BYPASS NETWORK AND INCREASED PIPE CAPACITY TO ROSEWOOD DRIVE

A single existing 30” RCP conveys the stormwater from the Maple / Monroe intersection to Rosewood Drive. Another existing 30” RCP receives runoff at the low point of Heyward Street and traverses through the block between Heyward Street and Burney Drive, joining with the first 30” RCP at the intersection of Burney Drive and Sloan Street. The single 30” RCP does not increase in size until it reaches the 42” RCP at Rosewood Drive. On the southern side of Rosewood Drive, the 42” RCP is increased to 54” with about a 12’ vertical drop between inverts.

Our recommended flood relief method is to provide increased pipe and inlet capacity at the intersection of Maple and Monroe Street and, through a network of existing and new pipes, provide additional pipe capacity from the Maple and Monroe Street intersection to the 42” RCP at Rosewood Drive. The recommended solution will provide a network of three routes of conveyance from the Maple and Heyward Street intersection to South Holly Street. See Appendix B for the proposed plan for improvements from Rosewood Drive to the Maple and Monroe intersection.

This recommendation will not completely solve the flooding at the Maple and Monroe intersection. See the next section of this report for the improvement results. Since the elevations of the Maple and Monroe intersection and Rosewood Drive are essentially the same, the existing pipe run has very little slope. The size of the new pipes that can be installed is also limited due to ground cover. Additional pipe capacity can only be achieved by adding multiple parallel pipes which would eventually become cost-prohibitive.

Starting at Rosewood Drive, Cox and Dinkins proposes the installation of a 30” RCP parallel to the existing 30” RCP from the 42” RCP to South Holly Street. At South Holly Street, while the existing 30” RCP continues through the block between South Holly Street and Sloan Street, the new 48” RCP will continue north along South Holly Street to the intersection of South Holly Street and Heyward Street, then turning west along Heyward Street. At the low point of Heyward Street, the 48” RCP will join with the existing 30” RCP that drains south through the block between Heyward Street and Burney Drive. From the low point of Heyward Street, a 42” RCP will continue west where it will join with the existing 30” RCP at the Maple and Heyward Street intersection. Because there are only two inlets for this block of Heyward Street, Cox and Dinkins proposes four additional inlets along Heyward Street. From the Maple and Heyward intersection, a new 36” RCP will run north parallel to the existing 30” RCP to the first set of inlets in Maple Street. From there, the pipe run will continue with a new 30” RCP parallel to the existing 30” RCP. The model indicates that the majority of overland flow to the Maple and Monroe intersection comes from the flooding upstream at the Woodrow Street and Monroe Street intersection to the west. Therefore, additional inlets and an increased 30” pipe are recommended for installation on the west side of the Maple and Monroe intersection.

See Appendix A to view the reduction in the extents of flooding after the storm drainage improvements are completed.

EASEMENTS NORTH OF ROSEWOOD DRIVE

The City of Columbia will be responsible for obtaining additional easements for the parallel 30” RCP to be installed through the parking lot (TMS# R11314-07-09) from Rosewood Drive to South Holly Street. See Appendix B for the sketch plans to see other properties that may be impacted by the storm drainage improvements.

FLOODING SOUTH OF ROSEWOOD DRIVE

Under existing conditions, the model indicates that there is flooding along the trunk line between Kennedy Street and South Bonham Road during the 25-year storm event. With the proposed improvements north of Rosewood, the increased stormwater flow also causes increased instances of flooding north of Harvard Avenue also during the 10-year storm event.

Upon further study, Cox and Dinkins determined that the 96” CMP at Harvard Avenue is inadequate to handle the additional flow from the improvements north of Rosewood. This, in turn, is causing the additional instances of flooding north of Harvard Avenue.

Cox and Dinkins proposes the installation of a 48” pipe parallel to the existing 96” CMP starting at Harvard Avenue going to Devils Ditch. This route will pass through the middle of the block bordered by Harvard Avenue to the north, Montgomery Avenue to the south, Wando Street to the east, and Elm Avenue to the west. Beyond Montgomery Avenue, the route goes through Lester Bates Park to where it crosses South Bohnam Road. From there it traverses the northern end of Owens Field Park to South Ott Road. At South Ott Road, the existing 96” CMP increases to a 108” CMP. The outfall of the 108” CMP is into an approximate 75’ long concrete trapezoidal channel. Cox and Dinkins proposes that the proposed 48” pipe bypass the existing outfall and concrete channel and be discharged into Devils Ditch approximately 40’ downstream of the concrete channel.

However, even with the 48” parallel pipe, the model shows increased localized flooding during the 25-year storm event in Elm Avenue just north of Harvard Avenue. From Prentice Avenue to Harvard Avenue, the trunk line consists of twin 60” RCPs that appear to function independently of each other until they reach the 96” CMP. The model shows the HGL is higher in the western 60” RCP due to a larger watershed area that it receives. The localized increased flooding is related to the storm structures connected to the western 60” RCP. Cox and Dinkins proposes to install a box that connects the twin 60” pipes at one of the storm structures on Elm Avenue. This will help equalize the HGL between the twin 60” RCPs and help reduce the localized flooding for the 25-year storm event. This does not eliminate the localized flooding but reduces it from being worse than existing conditions.

See Appendix A to view the reduction in the extents of flooding after the storm drainage improvements are completed. See Appendix B for the improvement sketch plans. At the intersection of Montgomery Avenue and Wando Street, and near the intersection of South Bonham Road and Elm Avenue, the trunk line runs through the block between existing houses. Because of the size and necessary configuration of the pipes to be installed, the City of Columbia may have to purchase properties that will be impacted by the construction. There are also areas where the City will need to obtain new drainage easements through private properties. See Appendix G for a list of possible properties that may be impacted by the storm drainage improvements

SECTION 5 – WEST TRUNK IMPROVEMENT RESULTS

MAPLE STREET AND MONROE STREET INTERSECTION

The model shows that flooding up to the 2-year storm event is eliminated. The 10-year storm event is decreased from a flooding depth of 3.34' to 1.88'. The 25-year storm flood elevation is decreased almost a foot, from 3.6' to 2.7'. With improvements, flooding is confined to the Maple Street and Monroe Street intersection up through the 25-year storm event whereas under existing conditions, flooding was transferred downstream to the Maple Street and Heyward Street intersection during the 25-year storm event. In order to completely eliminate flooding, additional multiple parallel pipes would have to be installed due to the shallowness of the existing system. This would be cost and space prohibitive.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH Maple Street and Monroe Street Intersection (Lowest grate = 266.82)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above lowest catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	269.35	2.53	267.00	NA*	-2.35
10- Year	270.16	3.34	268.70	1.88	-1.48
25- Year	270.42	3.60	269.54	2.72	-0.88

*NA means that the flooding is 0.5' or less (at or below the curb).

MAPLE STREET AND HEYWARD STREET INTERSECTION

With the installation of the new RCP and new inlets in Heyward Street the potential for flooding is removed for up to the 25-year storm event, whereas flooding currently exists for the 10-year and greater storm events under existing conditions.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH Near Maple Street and Heyward Street Intersection (Lowest grate = 267.70)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above lowest catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	268.41	0.71	264.78	NA*	-3.63
10- Year	269.42	1.72	267.09	NA*	-2.33
25- Year	270.35	2.65	268.12	NA*	-2.22

*NA means that the flooding is 0.5' or less (at or below the curb).

See Appendix A to view the comparison of the existing extents of flooding to flooding after improvements.

ROSEWOOD NEIGHBORHOOD DOWNSTREAM

The model indicates that under existing conditions, there is flooding in the Rosewood neighborhood along the trunk line from Kennedy Street to Montgomery Avenue during the 25-year storm. However, with improvements, flooding elevations are reduced or eliminated along the trunk line. Flooding is confined to the area from Kennedy Street to Harvard Avenue.

See Appendix A to view the comparison of existing flooding extents to flooding after improvements.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH					
Elm Avenue between Kennedy Street and Superior Street (Grate = 222.86)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above catch basin throat (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	220.18	NA*	220.32	NA*	0.14
10- Year	220.31	NA*	221.69	NA*	1.38
25- Year	225.14	2.27	225.01	2.15	-0.13
Elm Avenue between Kennedy Street and Superior Street (Grate = 222.83)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above catch basin throat (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	220.63	NA*	220.96	NA*	0.32
10- Year	222.09	NA*	222.78	NA*	0.69
25- Year	225.27	2.44	225.05	2.22	-0.21
Harvard Avenue (Throat = 220.43)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above catch basin throat (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	216.41	NA*	216.86	NA*	0.44
10- Year	221.15	0.72	221.15	0.72	0.00
25- Year	223.61	3.18	221.40	0.97	-2.21
Between Elm Avenue and Wando Street near Huron Street (Grate = 219.63)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	214.01	NA*	214.42	NA*	0.41
10- Year	220.27	0.64	220.27	0.64	0.00
25- Year	221.52	1.89	220.32	0.69	-1.20
East of Shamrock Court cul-de-sac (Grate = 216.55)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	210.83	NA*	211.20	NA*	0.37
10- Year	213.29	NA*	212.53	NA*	-0.76
25- Year	219.39	2.84	216.94	NA*	-2.45

Montgomery Avenue and Wando Street intersection (Grate = 217.21)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	209.63	NA*	210.07	NA*	0.44
10- Year	212.35	NA*	211.42	NA*	-0.93
25- Year	218.10	0.89	215.96	NA*	-2.14

*NA means that the flooding is 0.5' or less (at or below the curb).

LESTER BATES PARK

The model indicates that under existing conditions, there is flooding in Lester Bates Park during the 25-year storm. However, with the proposed improvements, flood elevations are reduced or eliminated. Flooding remains at the lower end of Lester Bates Park near South Bonham Road for the 25-year storm event. However, it is significantly less than the existing conditions.

See Appendix A to view the comparison of the existing flooding extents to flooding after improvements.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH					
Catch Basin at the upstream end of Lester Bates Park (Throat = 214.65)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin throat (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	206.66	NA*	206.86	NA*	0.20
10- Year	209.95	NA*	208.31	NA*	-1.64
25- Year	215.16	0.51	213.26	NA*	-1.89
Catch Basin in middle of Lester Bates Park near Lanier Avenue (Throat = 203.93)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin throat (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	197.05	NA*	197.08	NA*	0.03
10- Year	201.05	NA*	199.03	NA*	-2.03
25- Year	204.56	0.63	203.47	NA*	-1.09
Catch Basin at the downstream end of Lester Bates Park near S Bonham Rd (Throat = 196.43)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin throat (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	191.71	NA*	191.29	NA*	-0.41
10- Year	195.45	NA*	193.95	NA*	-1.50
25- Year	197.95	1.52	197.00	0.57	-0.95

*NA means that the flooding is 0.5' or less (at or below the top of the throat).

SOUTH BONHAM ROAD AND SOUTH OTT ROAD CROSSINGS

The model indicates existing flooding for the 25-year storm event at the South Ott Road crossing. However, with improvements, flood elevations are eliminated through the 25-year storm event.

See Appendix A to view the comparison of the existing flooding extents to flooding after improvements.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH					
Catch Basin on the downstream side of S Bonham Road (Grate = 196.99)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	193.89	NA*	193.89	NA*	0.00
10- Year	193.89	NA*	193.89	NA*	0.00
25- Year	195.97	NA*	195.14	NA*	-0.83
Catch Basin on the upstream side of S Ott Road (Grate = 191.00)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	188.59	NA*	188.28	NA*	-0.31
10- Year	190.48	NA*	189.93	NA*	-0.55
25- Year	191.70	0.70	191.38	NA*	-0.32
Catch Basin on the downstream side of S Ott Road (Grate = 190.97)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	187.80	NA*	187.63	NA*	-0.17
10- Year	189.02	NA*	188.73	NA*	-0.28
25- Year	189.85	NA*	189.72	NA*	-0.13

*NA means that the flooding is 0.5' or less (at or below the top of the curb).

DEVILS DITCH OUTFALL NEAR S. OTT ROAD

As expected in the model, due to the proposed upstream improvements, there is an increase in peak flow rates and depth of flow at the Devils Ditch Outfall near S. Ott Road. The tables below show the existing and post improvement peak flow rates, peak time, peak elevations and depths at the existing outfall for the 108" CMP and the proposed outfall location of the 48" pipe.

EXISTING 108" PIPE OUTFALL NEAR S. OTT ROAD (Channel Bottom = 178.70)					
Flood Peaks and Peak Times					
Storm Event	**Existing Peak (cfs)**	**Existing Peak Time (hr.)**	**Post Improvement Peak (cfs)**	**Post Improvement Peak Time (hr.)**	**∆ (cfs)**
2-Year	286.89	12.33	252.53	12.43	-34.36
10- Year	429.70	12.28	382.60	12.32	-47.10
25- Year	479.11	12.23	456.45	12.27	-22.67
Flood Elevations					
Storm Event	**Existing Flood Elevation**	**Existing Channel Flood Depth (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Channel Flood Depth (ft.)**	**∆ (ft.)**
2-Year	187.41	8.71	187.32	8.62	-0.09
10- Year	188.21	9.51	188.10	9.40	-0.11
25- Year	188.91	10.21	188.86	10.16	-0.05

PROPOSED 48" PIPE OUTFALL NEAR S. OTT ROAD (Channel Bottom = 178.30)					
Flood Peaks and Peak Times					
Storm Event	**Existing Peak (cfs)**	**Existing Peak Time (hr.)**	**Post Improvement Peak (cfs)**	**Post Improvement Peak Time (hr.)**	**Δ (cfs)**
2-Year	**NA**	**NA**	**56.92**	**12.43**	**56.92**
10- Year	**NA**	**NA**	**108.03**	**12.33**	**108.03**
25- Year	**NA**	**NA**	**125.85**	**12.27**	**125.85**
Flood Elevations					
Storm Event	**Existing Flood Elevation**	**Existing Channel Flood Depth (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Channel Flood Depth (ft.)**	**Δ (ft.)**
2-Year	**183.20**	**4.90**	**184.52**	**6.22**	**1.32**
10- Year	**185.83**	**7.53**	**186.46**	**8.16**	**0.63**
25- Year	**186.29**	**7.99**	**186.70**	**8.40**	**0.41**

DEVILS DITCH EAST AND WEST CONFLUENCE

See the end of Section 9 for improvement results at the Devils Ditch confluence where the east and west watersheds meet.

WEST TRUNK IMPROVEMENTS CONCEPTUAL OPINION OF PROBABLE COST AND SCHEDULE REPORT (COPC)

The COPC for the west trunk improvements is approximately $7.7 million. The cost of installing the storm drainage improvements also includes contingencies and costs for additional sanitary sewer mains and services, curbing, asphalt patching and repair, and other services that will be impacted by the storm drainage improvements. The west trunk COPC can be found in Appendix C. Costs for the water system relocations necessary for the project are not included in the COPC.

SECTION 6 – EAST TRUNK WATERSHED FLOODING

OVERALL WATERSHED

The east trunk watershed extends from the Devils Ditch outfall, north through the Rosewood and Shandon neighborhoods, to Millwood Avenue and into the Melrose Heights neighborhood. Unlike the west trunk, there is a single main trunk line that extends through the entire watershed to Millwood Avenue which receives the storm runoff from the Melrose Heights neighborhood. The original Phase 1 study indicated that the storm drainage system as a whole is severely undersized and does not have enough capacity to handle even storm runoff from the 10-year storm event. Flooding was indicated along Millwood Avenue, at the intersection of Sims Avenue and Kirkwood Road, and along the trunk line in the Shandon neighborhood from Wheat Street down to Rosewood Drive. The model also indicated the flooding to continue in the Rosewood neighborhood along the trunk line to the Devils Ditch outfall.

See Appendix D to view the existing extents of flooding in the east trunk watershed shown by the XPSWMM model for the 2-year, 10-year, and 25-year storm events.

MAIN STORM DRAINAGE TRUNK LINE NORTH OF ROSEWOOD DRIVE

There has been a history of flooding along the storm drainage trunk line from the intersection of Wheat Street and Amherst Avenue to Rosewood Drive. The trunk line follows along a “valley” through the middle of the blocks between Walker Street and Ravenel Street passing through yards and in places running under structures. Areas of reported significant flooding have been at the intersection of Monroe Street and Ravenel Street, and the low points of Monroe Street and Heyward Street. At the kickoff town hall meeting, residents verified the flooding issues along the trunk line and also reported flooding at the intersection of Wilmot Avenue and Ravenel Street.

The model concurs with the reports from the residents indicating overland flooding through the intersection of Wilmot Ave and Ravenel Street and the intersection of Monroe Street and Ravenel Street. It also indicates flooding at the low points of Monroe Street and Heyward Street and the intersection of Cannon Street and Ravenel Street and the low point in Rosewood Drive in front of Rosewood Elementary.

The primary effort of this study of the east trunk was to provide a recommendation towards alleviating the flooding north of Rosewood Drive up to Wheat Street especially along the trunk line.

SECTION 7 – EAST TRUNK IMPROVEMENT CONSIDERATIONS

DETENTION AT KIRKWOOD ROAD AND SIMS AVENUE

There is existing flooding at the intersection of Kirkwood Road and Sims Avenue. Consideration was given to using the open area of the Epworth Children's Home as detention to help relieve the load on the downstream system. However, since the system immediately downstream is already undersized, this area is essentially already functioning as a detention pond. Any detention improvements would have little impact on the problems in the Shandon neighborhood. Furthermore, increasing pipe sizes that far up in the watershed will cause increased flooding in Shandon.

LOW IMPACT DEVELOPMENT SOLUTIONS

From the experience gained in considering low impact development strategies for the west trunk watershed, Cox and Dinkins did not consider the options of street dieting and pocket parks in the east watershed. The watershed upstream of the Wheat Street and Amherst Avenue intersection is over 145 acres, almost 2.5 times larger than the upstream watershed area received by the Monroe Street and Maple Street intersection in the west trunk watershed. The large size of the upstream watershed indicates that street diets and pocket parks will have an even less beneficial impact on the east watershed than anticipated in the west watershed.

A small pilot green infrastructure project that involved pervious pavement, underground storage, and infiltration was installed around 2014. Due to the very limited size of the project, this study does not account for stormwater captured and removed from the system through this pilot project.

DETENTION AT ROSEWOOD DRIVE

There were two locations considered for detention at Rosewood Drive. One location was the block north between Cannon Street and Rosewood Drive and between S. Ravenel Street and S. Ott Road. This would require the City of Columbia to purchase a majority of the properties in the block and installing a detention pond adjacent to Rosewood Drive. This would not be aesthetically pleasing and with the large upstream watershed, the pond would be full in very little time thus have essentially no impact on flooding.

The alternate location considered was the Rosewood Elementary school playground for underground detention. Although the depth of the existing 72" RCP at Ott Road would allow for the pond to have the depth to provide significant volume, the cost for such a large underground installation would be cost-prohibitive compared to conventional installation of a pipe network, and it would have minimal impact on flooding.

BYPASS LINES EAST AND WEST OF THE TRUNK LINE

Various bypass scenarios were studied to receive runoff west of Walker Street and east of Ravenel Street to attempt to relieve the load on the existing trunk line.

Walker Street Bypass

Running a bypass line west from the Cannon Street and Ravenel Street intersection, then running north up Walker to Wheat Street did not relieve the trunk line significantly since the watershed area to the west is approximately 56 acres compared to the 145 acres upstream. To relieve the trunk line, the bypass would need to continue north up Capitol Place to intercept the trunk line in Devine Street. This introduced large volumes of water that would increase the potential for flooding along Walker Street. Due to topography, the run of pipe through the Heyward Street intersection would be over 10' deep. Consideration was given to crossing the bypass line east to Monroe Street where the pipe depth would not be as deep. It was determined that the long pipe length, the depth of pipe, the crossing of Devine Street, and the potential for worse flooding along Walker Street would be cost-prohibitive and produce undesirable results.

Ravenel Street Bypass

A second bypass line going north on Ravenel Street from Cannon Street to Wheat Street was considered to relieve the trunk line from some stormwater coming from the east. This bypass line would be able to divert approximately 72 acres away from the trunk line. It would also address reported flooding problems at intersections along Ravenel Street. Therefore, the Ravenel Street Bypass is a part of the recommended improvements.

SECTION 8 – EAST TRUNK RECOMMENDED IMPROVEMENTS

EAST BYPASS LINE – RAVENEL STREET FROM WHEAT STREET

The recommended improvements to alleviate the flooding issues in the east trunk watershed of the Shandon neighborhood has two parts. The first part is a 60" bypass storm line starting at Cannon Street running north on Ravenel Street and tapering down to 30" at Wheat Street to provide relief to the trunk line. Also, a 60" pipe from the low point of Monroe Street will run east towards Ravenel Street and connect to the bypass line to provide relief from the flooding at the Monroe Street low point. The bypass pipe provides capacity for captured runoff at each of the intersections going north on Ravenel Street which will provide relief to the trunk line and address reported intersection flooding in certain areas.

PARALLEL STORM DRAINAGE PIPES FROM CANNON STREET TO DEVILS DITCH

All of the storm runoff converges at the intersection of Cannon Street and Ravenel Street. Increasing the pipe size for volume and capacity brings some relief to the areas of flooding upstream, but transfers the flooding potential downstream. The second portion of the recommended improvements is to install parallel drainage pipes from the intersection of Cannon Street and Ravenel Street to the Devils Ditch outfall to alleviate flooding in the Shandon neighborhood and to minimize the potential for flooding in the downstream Rosewood neighborhood.

The existing trunk line from Cannon Street going south under Rosewood Drive to Ott Road is a 48" RCP. The trunk line from Ott Road to S. Bonham Road is a 72" RCP. From there the system changes to triple 48" RCPs to the Devils Ditch outfall. The outfall for the triple 48" RCPs is in poor condition with sections of the 48" RCPs separating and settling.

The recommendation is to install a 72" RCP that will run parallel to the existing 48" pipe from Cannon Street to Ott Road. From Ott Road to Montgomery Avenue, a 60" pipe will run parallel with the existing 72" pipe. From Montgomery Avenue to S. Bonham Road, the parallel pipe will be a 72" RCP, then from Bonham, the 72" RCP will continue to run parallel to the triple 48" pipes to Live Oak Street. At Live Oak Street, the triple 48" RCPs will be replaced with two 72" RCPs continuing south of Live Oak Street to the Devils Ditch confluence of the east and west watersheds.

See Appendix E for the improvement sketch plans. Between Ott Road and Capers Avenue and between S. Bonham and Live Oak Street, the trunk line runs through the block between houses. Because of the size and necessary configuration of the pipes to be installed, the City of Columbia will need to purchase properties that will be impacted by the construction. There are also areas where the City will need to obtain new drainage easements over private property. See Appendix G for properties to be impacted by the storm drainage improvements.

An alternative to the installation of large parallel pipes is an open ditch from Capers Avenue to Montgomery Avenue and from Manor Avenue to Lanier Avenue. There is an open area west of Tyler Street that would allow for an open ditch. There are pros and cons to open ditches. The overall construction budget would likely be reduced with the open ditch concept as outlined in the OPCC. However the long term maintenance costs will be higher, and there is an increased liability with open ditches. It is also highly unlikely that the open channels will look aesthetically pleasing due to excessive depth and limited area.

SECTION 9 – EAST TRUNK IMPROVEMENT RESULTS

ALONG THE TRUNK LINE – FROM WHEAT STREET TO CANNON STREET

The model shows that for the 2-year storm event flooding is eliminated along the trunk line from Monroe Street to Rosewood Drive. Flooding continues to exist for the larger storms. However, the flood elevations all show a decrease over existing conditions. The Ravenel Street bypass storm line has limited positive impact along the trunk line from Wheat Street to Duncan Street. The positive impact is more significant on the downstream low points because of the amount of storm runoff (approximately 125 cfs for the 25-year storm) that is being diverted from the trunk line.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH					
Wheat Street and Amherst Street Intersection (Lowest grate = 267.99)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**Δ (ft.)**
2-Year	**269.43**	**1.44**	**269.36**	**1.37**	**-0.07**
10- Year	**269.69**	**1.70**	**269.65**	**1.66**	**-0.04**
25- Year	**269.84**	**1.85**	**269.82**	**1.82**	**-0.03**
Wilmot Avenue Low Point (Lowest grate = 261.05)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**Δ (ft.)**
2-Year	**262.93**	**1.88**	**262.69**	**1.63**	**-0.25**
10- Year	**263.25**	**2.19**	**263.12**	**2.07**	**-0.13**
25- Year	**263.43**	**2.38**	**263.32**	**2.27**	**-0.11**
Duncan Street Low Point (Lowest grate = 255.27)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**Δ (ft.)**
2-Year	**257.24**	**1.97**	**256.78**	**1.51**	**-0.46**
10- Year	**257.59**	**2.32**	**257.27**	**2.00**	**-0.32**
25- Year	**257.79**	**2.52**	**257.50**	**2.23**	**-0.29**
Monroe Street Low Point (Lowest grate = 247.80)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**Δ (ft.)**
2-Year	**249.37**	**1.57**	**244.86**	**NA***	**-4.51**
10- Year	**249.74**	**1.94**	**249.20**	**1.40**	**-0.54**
25- Year	**249.94**	**2.14**	**249.59**	**1.79**	**-0.35**
Heyward Street Low Point (Lowest grate = 244.29)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**Δ (ft.)**
2-Year	**246.58**	**2.29**	**241.66**	**NA***	**-4.91**
10- Year	**246.93**	**2.64**	**246.32**	**2.03**	**-0.61**
25- Year	**247.13**	**2.84**	**246.67**	**2.38**	**-0.46**

*NA means that the flooding is 0.5’ or less (at or below the curb).

ALONG THE RAVENEL STREET BYPASS – FROM WHEAT STREET TO MONROE STREET

The bypass pipe on Ravenel Street is sized to accept the overland runoff and pipe flow being received at each intersection up through the 25-year storm without causing flooding in the intersection except for the Monroe Street intersection.

The model indicates that the Wilmot Avenue intersection receives significant overland flow, which residents have confirmed to flow through the intersection. The model shows that the bypass line is adequate to handle all of the overland flow captured at all intersections along Ravenel from Wheat Street to Monroe Street. There is still flooding indicated at the Monroe intersection for the 25-year storm. However, the model shows that it is significantly less than existing conditions, and the flooding is confined to the intersection, i.e. the floodwaters are not conveyed overland to the Monroe Street low point.

The Duncan Street and Heyward Street intersections are not listed in the table below because they are both high points along Ravenel Street where no flooding is reported to exist.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH					
Ravenel Street and Wheat Street Intersection (Lowest grate = 275.16)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	275.44	NA*	268.47	NA*	-6.97
10- Year	275.64	NA*	268.68	NA*	-6.96
25- Year	275.76	0.60	271.02	NA*	-4.74
Ravenel Street and Wilmot Avenue Intersection (Lowest grate = 264.19)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	264.96	0.77	262.34	NA*	-2.62
10- Year	265.22	1.03	263.20	NA*	-2.02
25- Year	265.33	1.14	264.21	NA*	-1.12
Ravenel Street and Monroe Street Intersection (Lowest grate = 248.24)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	250.28	2.04	244.37	NA*	-5.91
10- Year	250.47	2.23	246.87	NA*	-3.60
25- Year	250.57	2.33	249.88	1.64	-0.69

*NA means that the flooding is 0.5' or less (at or below the curb).

ALONG THE ROSEWOOD DRIVE CROSSING – FROM CANNON STREET TO OTT ROAD

Flood elevations are eliminated for the 2-year storm from the Cannon Street intersection to the Ott Road low point. Flooding for the 10-year storm event is eliminated from the Rosewood Drive low point to the Ott Road low point. Any flooding indicated for storms larger than the 2-year storm event is less than the existing conditions.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH					
Ravenel Street and Cannon Street Intersection (Lowest throat inlet = 239.23)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	240.82	1.59	237.59	NA*	-3.23
10- Year	241.29	2.06	240.41	1.18	-0.87
25- Year	241.58	2.35	241.33	2.10	-0.25
Rosewood Drive Low Point (Throat inlet = 236.36)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	239.81	3.45	234.33	NA*	-5.48
10- Year	240.42	4.06	235.81	NA*	-4.61
25- Year	240.71	4.35	239.67	3.31	-1.04
Ott Road Low Point (Grate = 232.52)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above lowest catch basin grate (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	233.90	1.38	228.70	NA*	-5.20
10- Year	234.44	1.92	229.28	NA*	-5.16
25- Year	234.75	2.23	233.89	1.37	-0.86

*NA means that the flooding is 0.5' or less (at or below the curb).

ROSEWOOD NEIGHBORHOOD DOWNSTREAM WITH PARALLEL PIPES

The model indicates that the proposed parallel storm drainage pipe along the existing 72" RCP helps to relieve existing flooding to the outfall south of Live Oak Street up through the 10-year storm event, except for Tempo Court which is a low lying area. Except for the low point at Prentice Avenue and the intersection of Capers Avenue and Tyler Street, flooding continues for the 25-year storm event. However, any flooding that is indicated is significantly less than for the existing conditions.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH WITH PARALLEL PIPES					
Moss Avenue Low Point (Lowest grate = 226.20)					
Storm Event	**Existing Flood Elevation**	**Existing Flood Depth above catch basin throat (ft.)**	**Post Improvement Flood Elevation**	**Post Improvement Flood Depth (ft.)**	**∆ (ft.)**
2-Year	228.53	2.33	222.04	NA*	-6.49
10- Year	229.44	3.24	223.72	NA*	-5.72
25- Year	229.87	3.67	228.74	2.54	-1.13

Prentice Avenue Low Point (Lowest grate = 222.91)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	219.77	NA*	218.31	NA*	-1.47
10- Year	225.72	2.81	219.44	NA*	-6.28
25- Year	226.20	3.29	223.03	NA*	-3.17
Capers Avenue near Tyler Street (Lowest grate = 219.78)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	213.62	NA*	212.80	NA*	-0.81
10- Year	221.51	1.73	213.71	NA*	-7.80
25- Year	222.14	2.36	217.35	NA*	-4.79
Harvard Avenue (Lowest grate = 211.01)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	208.13	NA*	205.52	NA*	-2.62
10- Year	214.58	3.57	207.44	NA*	-7.14
25- Year	215.08	4.07	213.01	2.00	-2.07
Montgomery Avenue (Lowest grate = 207.72)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	205.60	NA*	201.44	NA*	-4.16
10- Year	210.85	3.13	204.29	NA*	-6.56
25- Year	211.35	3.63	208.36	0.64	-2.99
Lanier Avenue (Lowest throat elevation = 200.79)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	199.85	NA*	196.96	NA*	-2.89
10- Year	202.76	1.97	199.23	NA*	-3.53
25- Year	203.20	2.41	202.09	1.30	-1.11
S. Bonham Road (Throat = 196.96)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	196.52	NA*	195.69	NA*	-0.83
10- Year	199.72	2.76	196.19	NA*	-3.53
25- Year	200.30	3.34	198.73	1.77	-1.57
Tempo Court (Lowest grate = 190.33)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	191.62	1.29	190.30	NA*	-1.32
10- Year	192.84	2.51	191.53	1.20	-1.31
25- Year	193.60	3.27	192.66	2.33	-0.94

Live Oak Street (Pipe Invert in ditch = 190.68)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	190.68	NA*	190.68	NA*	0.00
10- Year	192.79	2.11	190.68	NA*	-2.11
25- Year	193.46	2.78	192.60	1.92	-0.86

*NA means that the flooding is 0.5' or less (at or below the curb).

See Appendix D to view the comparison of the existing extents of flooding to flooding after improvements.

ROSEWOOD NEIGHBORHOOD DOWNSTREAM WITH OPEN DITCH

The model indicates that the additional effects of the open ditch starting at Capers Avenue and Tyler Street begin to have a significant effect on the upstream system starting at the Ott Street low point. Flooding is eliminated along the trunk line through the 25-year storm event from Prentice Avenue to Lanier Avenue, except at the Harvard Avenue crossing. However, any flooding indicated elsewhere for any of the storm events is significantly less than existing conditions.

EXISTING AND POST IMPROVEMENT FLOOD ELEVATIONS AND DEPTH WITH OPEN DITCH					
Ott Road Low Point (Grate = 232.52)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin throat (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	233.90	1.38	228.70	NA*	-5.20
10- Year	234.44	1.92	229.28	NA*	-5.16
25- Year	234.75	2.23	233.75	1.23	-1.00
Moss Avenue Low Point (Lowest grate = 226.20)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin throat (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	228.53	2.33	222.04	NA*	-6.49
10- Year	229.44	3.24	223.63	NA*	-5.81
25- Year	229.87	3.67	228.27	2.07	-1.60
Prentice Avenue Low Point (Lowest grate = 222.91)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	219.77	NA*	218.30	NA*	-1.48
10- Year	225.72	2.81	219.36	NA*	-6.36
25- Year	226.20	3.29	221.08	NA*	-5.12
Capers Avenue near Tyler Street (Lowest grate = 219.78)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	213.62	NA*	212.27	NA*	-1.35
10- Year	221.51	1.73	212.81	NA*	-8.70
25- Year	222.14	2.36	213.11	NA*	-9.03

Harvard Avenue (Lowest grate = 211.01)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	208.13	NA*	204.87	NA*	-3.26
10- Year	214.58	3.57	205.66	NA*	-8.92
25- Year	215.08	4.07	212.64	1.63	-2.44
Montgomery Avenue (Lowest grate = 207.72)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	205.60	NA*	201.33	NA*	-4.27
10- Year	210.85	3.13	202.88	NA*	-7.97
25- Year	211.35	3.63	205.01	NA*	-6.34
Lanier Avenue (Lowest throat elevation = 200.79)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	199.85	NA*	196.93	NA*	-2.93
10- Year	202.76	1.97	198.98	NA*	-3.78
25- Year	203.20	2.41	201.08	NA*	-2.12
S. Bonham Road (Throat elevation = 196.96)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	196.52	NA*	195.69	NA*	-0.83
10- Year	199.72	2.76	196.12	NA*	-3.60
25- Year	200.30	3.34	198.11	1.15	-2.19
Tempo Court (Lowest grate = 190.33)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	191.62	1.29	190.28	NA*	-1.34
10- Year	192.84	2.51	191.39	1.06	-1.45
25- Year	193.60	3.27	192.56	2.23	-1.04
Live Oak Street (Pipe Invert in ditch = 190.68)					
Storm Event	Existing Flood Elevation	Existing Flood Depth above catch basin grate (ft.)	Post Improvement Flood Elevation	Post Improvement Flood Depth (ft.)	∆ (ft.)
2-Year	190.68	NA*	190.68	NA*	0.00
10- Year	192.79	2.11	190.68	NA*	-2.11
25- Year	193.46	2.78	192.52	1.84	-0.94

*NA means that the flooding is 0.5' or less (at or below the curb).

DEVILS DITCH OUTFALL SOUTH OF LIVE OAK STREET

The improvements of the east watershed extends the storm drainage system past the existing outfall at Live Oak Street with twin 72 inch pipes to approximately 50' upstream of the point of the confluence in Devils Ditch. As expected the model shows increased peak flows at the new outfall for 2-year and 10-year storm events. However, the improvements appear to allow more efficient conveyance for the 25-year storm event, and therefore, a significantly lower peak flow rate.

The rise in depth of flow is greatest for the 2-year storm event, and lowest for the 25-year storm event. The tables below show the existing and post improvement peak flow, peak time, peak elevation, and flood depth for the parallel pipe and the open ditch scenarios. The open ditch scenario shows insignificant improvement over the parallel pipe scenario.

DEVILS DITCH OUTFALL south of Live Oak Street (Channel Bottom = 177.08)								
Flood Peaks and Peak Times								
Storm Event	Existing		Post Improvement					
			Parallel Pipes			Open Ditch		
	Peak (cfs)	Peak Time (hr.)	Peak (cfs)	Peak Time (hr.)	Δ (cfs)	Peak (cfs)	Peak Time (hr.)	Δ (cfs)
2-Year	308.18	12.28	416.10	12.30	107.92	411.84	12.33	103.66
10- Year	523.80	12.97	602.42	12.27	78.61	589.81	12.32	66.01
25- Year	744.63	12.73	670.44	12.35	-74.19	649.78	12.43	-94.85

Flood Elevations								
Storm Event	Existing		Post Improvement					
			Parallel Pipes			Open Ditch		
	Flood Elevation	Channel Flood Depth (ft.)	Flood Elevation	Channel Flood Depth (ft.)	Δ (ft.)	Flood Elevation	Channel Flood Depth (ft.)	Δ (ft.)
2-Year	183.02	5.94	184.01	6.93	0.99	184.00	6.92	0.98
10- Year	185.35	8.27	185.58	8.50	0.24	185.56	8.48	0.21
25- Year	185.79	8.72	185.93	8.85	0.14	185.90	8.82	0.11

DEVILS DITCH EAST AND WEST CONFLUENCE

The tables below show the existing and post improvement peak flow, peak time, peak elevation, and flood depth at the confluence of the east and west trunk watersheds for the parallel pipe scenario and the open ditch scenarios. The improvements in both the east and west trunk lines increase the peak flow and the depth of flow at the confluence point for all the storm events. The greatest increase in peak flow occurs with the 10-year storm event. The least increase occurs with the 25-year storm event.

The greatest increase in depth of flow occurs with the 2-year storm event. The least increase in depth occurs with the 25-year storm event. The top of bank at the point of confluence is 186.0, so although there is an increase in the flow depth, the model shows that the flow is still contained within the banks of Devils Ditch. Again, the open ditch scenario shows a insignificantly better performance than the parallel pipe scenario. The effect of the open ditch scenario is insignificant to the west watershed system.

DEVILS DITCH at East and West Trunk Confluence (Channel Bottom = 175.1)								
Flood Peaks and Peak Times								
Storm Event	Existing		Post Improvement					
			Parallel Pipes			Open Ditch		
	Peak (cfs)	Peak Time (hr.)	Peak (cfs)	Peak Time (hr.)	Δ (cfs)	Peak (cfs)	Peak Time (hr.)	Δ (cfs)
2-Year	350.42	12.27	489.64	12.35	139.22	488.45	12.37	138.02
10- Year	658.80	12.88	860.67	12.27	201.87	845.99	12.32	187.19
25- Year	920.03	12.73	980.30	12.35	60.27	954.10	12.43	34.07

Flood Elevations								
Storm Event	Existing		Post Improvement					
			Parallel Pipes			Open Ditch		
	Flood Elevation	Channel Flood Depth (ft.)	Flood Elevation	Channel Flood Depth (ft.)	Δ (ft.)	Flood Elevation	Channel Flood Depth (ft.)	Δ (ft.)
2-Year	182.90	7.80	184.03	8.93	1.14	184.02	8.92	1.13
10- Year	185.24	10.14	185.64	10.54	0.40	185.61	10.51	0.36
25- Year	185.81	10.71	185.99	10.89	0.18	185.96	10.86	0.15

EAST TRUNK IMPROVEMENTS CONCEPTUAL OPINION OF PROBABLE COST AND SCHEDULE REPORT (COPC)

The COPC for the east trunk improvements amount to approximately $17.5 million. In addition to the cost of installing the storm drainage improvements, the COPC also includes cost estimating for additional sanitary sewer mains and services, curbing, asphalt patching and repair, and other services that will be impacted by the storm drainage improvements. The east trunk COPC can be found in Appendix F. Costs for the water system relocations necessary for the project are not included in the COPC.

APPENDICES