AECOM

Draft DuWap Watershed Master Plan

City of Charleston

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Table of Contents

Appendices

Figures

Tables

Acronyms

AMC	Antecedent Moisture Condition
CN	Curve Number
DEM	Digital Elevation Model
DuWap	Dupont-Wappoo
EWL	Extreme Water Level
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GPS	Global Positioning System
HSG	Hydrologic Soil Group
ICPR	Interconnected Pond Routing Model
LiDAR	Light Detection and Ranging
LOS	Level of Service
MACP	Manhole Assessment Certification Program
NASSCO	National Association of Sewer Service Companies
NAVD	North American Vertical Datum
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
O&M	Operations and Maintenance
PACP	Pipeline Assessment Certification Program
QA	Quality Assurance
QC	Quality Control
RFA	Request for Action
SCDOT	South Carolina Department of Transportation
SOP	Standard Operating Procedure
SWEL	Stillwater Elevation
UHG	Unit Hydrograph
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WSS	Web Soil Survey

1. Executive Summary

The City of Charleston (City) and Charleston County (County) retained AECOM to evaluate the Dupont-Wappoo (DuWap) watershed within the City and unincorporated areas of the County and develop a Watershed Master Plan (Plan). The DuWap watershed comprises portions of the Dupont and Wappoo watersheds located in the West Ashley area of Charleston County and encompasses an area of approximately 1,600 acres. The primary purpose of the Plan is to provide an overall assessment of the existing stormwater infrastructure and make recommendations for improvements to the DuWap watershed with regard to surface water management.

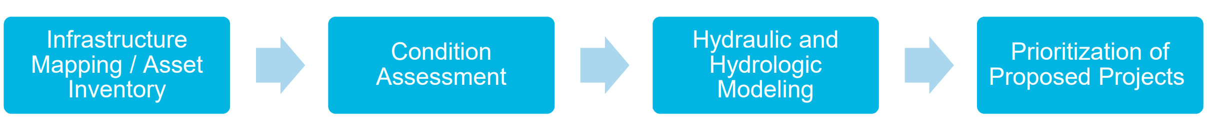
The Plan documents the analysis of the DuWap watershed and identifies the extent of potential flooding during major design storm events. Conceptual improvement alternatives are proposed for flood-prone areas based on the acceptable levels of service (LOS) defined in Chapter 8. The project team developed a hydrologic and hydraulic model with the impacts of tide water levels, surge, wave, and sea level rise using information obtained from sources listed in Section 4.5 and data collected by AECOM. The results of the modeling will be incorporated into City and County stormwater master planning and development.

The Plan presents water quantity concerns, including recommendations for maintenance, and provides a schedule for upgrading and replacing infrastructure within the system based on a condition assessment and cost-benefit analyses for the proposed projects. The proposed projects include replacing culverts, installing additional culverts, raising roadway elevations, regrading and widening ditches or swales, installing check valves, and adding storage facilities (e.g., ponds and impoundments). Chapter 9 presents details on the process of selecting the proposed projects. The estimate of probable costs for the improvements is approximately $6,768,000.

Proposed projects are configured to meet the LOS criteria or to lessen flooding. Some of the projects do not completely alleviate flooding relative to LOS criteria, but have an overall benefit to the watershed. In addition to the recommended projects, other improvements were also identified in the evaluation process to meet the LOS criteria in some of the locations. However, these improvements are not recommended because the cost of implementation of these improvements is prohibitively high compared to the benefits obtained from completing these projects.

Proposed projects address key areas of flooding in the watershed. As each project moves forward, it is recommended that a detailed study be conducted to develop a comprehensive design solution. Recommended improvements to the primary conveyance system are necessary before neighborhood deficiencies can be examined. Implementation of the improvements should provide a secondary benefit of relieving some neighborhood-level flooding.

The Plan includes 10 chapters that address the four main components of the scope of work:



2. Introduction and Project Objectives

Stormwater drainage is a major challenge in the City. The existing stormwater system is inadequate in a large portion of the City. Numerous incidents of surface flooding during periods of moderate to heavy rainfall have occurred and have been exacerbated by high tide water levels and storm surge. The severity of flooding varies by location based on the intensity and duration of the rain. Consequently, the City of Charleston prepared the *Master Drainage and Floodplain Management Plan* in 1984 to outline a comprehensive program to identify and correct deficiencies in the existing systems and accommodate a practical LOS with the available resources.

The 1984 Master Plan included all areas within the City boundaries. That work included portions of the DuWap watershed but not in its entirety. The recommended improvements consisted of increasing the cross-sectional area of the channels and culverts/pipes in their existing alignment and installing pipes/culverts either adjacent to or following the same route as the existing pipes/culverts or along an alternate route. Stormwater pump stations were also evaluated as alternatives when gravity systems became impractically large for some locations.

Subsequent to the 1984 Master Plan, the City has experienced significant population and development growth, resulting in changes to topography, drainage patterns, and impervious areas. The City identified a need to update the Plan given the changes in the watershed.

The purpose of the current Plan is to identify and map the existing stormwater collection, detention, and conveyance structures and to evaluate their capacity within the DuWap watershed for both major and minor storm events. With ongoing and future redevelopment in the Citadel Mall area, the City requested that redevelopment plans for the area be considered when stormwater improvement is recommended for the area. Another layer of the study included identification of flood-prone areas and recommendations for conceptual improvements to reduce roadway flooding to acceptable levels. A portion of the current Plan effort involves identifying the status of capital improvement projects presented in the 1984 Master Plan.

The Plan includes the following components:

- Data Collection and Review
- Infrastructure Mapping/Asset Inventory
- Hydraulic and Hydrologic Modeling
- Condition Assessment
- Level of Service Determination
- Prioritization of Proposed Projects

Based on the results of the modeling, stormwater system deficiencies were identified for further detailed studies involving flood mitigation solutions. The Plan should be used as a planning tool to identify projects and additional areas of study for further detailed analysis.

3. Study Area

The DuWap watershed is located in West Ashley, near the Citadel Mall, in Charleston County as shown on **Figure 3-1**. The study area comprises portions of the Dupont and Wappoo watersheds and encompasses an area of approximately 1,600 acres. The study area is bounded by Savage Road to the west, Paul Cantrell Boulevard to the north, Ashley Hall Road (US 61) to the east, and Clayton Drive to the south. The primary drainage feature of the DuWap watershed is a large drainage channel conveying runoff from the Citadel Mall area to a tidal creek flowing under Ashley Town Center Drive and discharging into the Stono River. The study area is made up of a mix of high-density commercial development, including several shopping centers. The Citadel Mall and Ashley Town Center are two examples of large commercial developments that anchor development in the center portion of the watershed along major roadways. The watershed also includes older residential areas around the perimeter. Most of the watershed consists of curb and gutter drainage through commercial areas, and a network of small roadside drainage ditches in the older residential areas. **Figure 3-2** shows the DuWap watershed study area.

3.1 Topography

The DuWap watershed is about 2.5 miles long and 2.0 miles wide. LiDAR terrain imagery shows that the watershed is generally flat with elevations ranging from 25 feet NAVD at the most upstream end of the watershed to 2 feet NAVD at the downstream end near the Stono River. The watershed slope is approximately 0.1 percent. The drainage network is also flat with very low elevation and therefore, LiDAR terrain imagery shows that overall the drainage network is very flat and low elevation, which results in flooding during storm events. More severe flooding occurs when storm events coincide with high tide in the Stono River, resulting in ponding and backwater effects. **Figure 3-3** shows the topography of the study area used for the model.

3.2 Land Use

The land use/land cover map obtained from the City and County comprises five land use categories, including the following:

- Residential
- Commercial and industrial
- Impervious surfaces such as paved parking lots and driveways
- Woods/Grass
- Open space

About 75 percent of the DuWap watershed falls under the land use category of residential and commercial development. The land use/land cover map was used for the development of curve numbers for modeling. **Figure 3-4** presents the land use map of the study area.

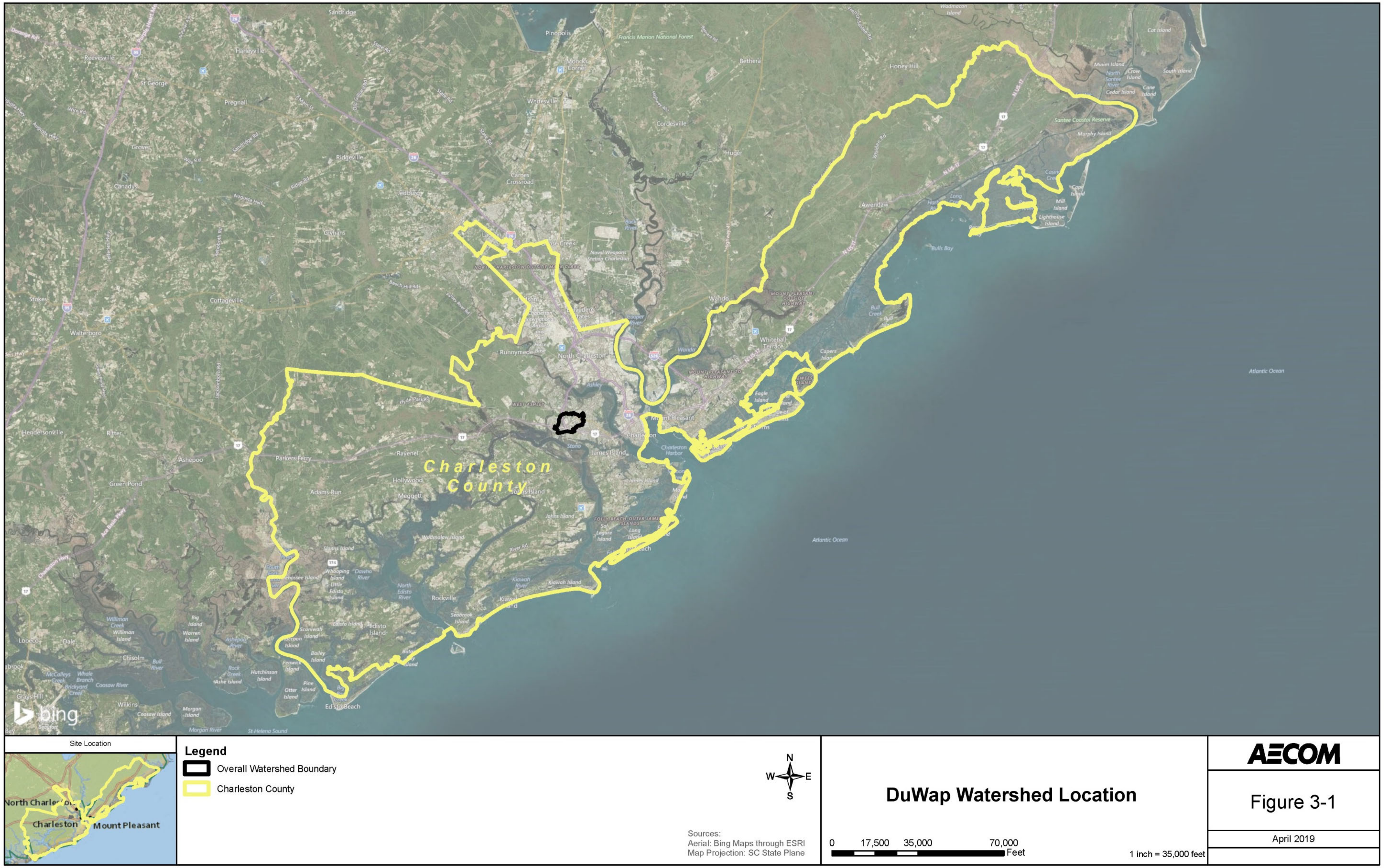


Figure 3-1. DuWap Watershed Location

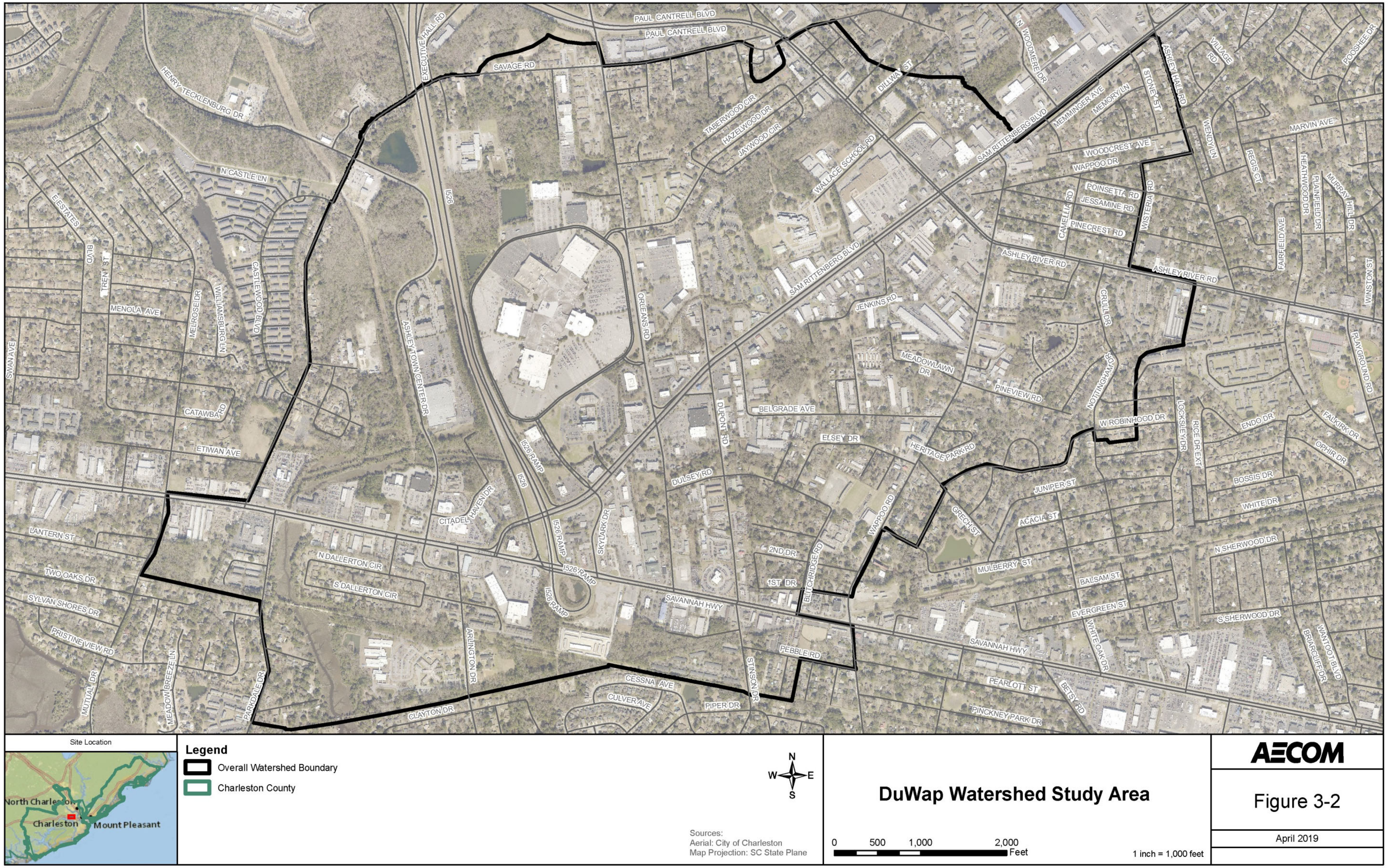


Figure 3-2. DuWap Watershed Study Area

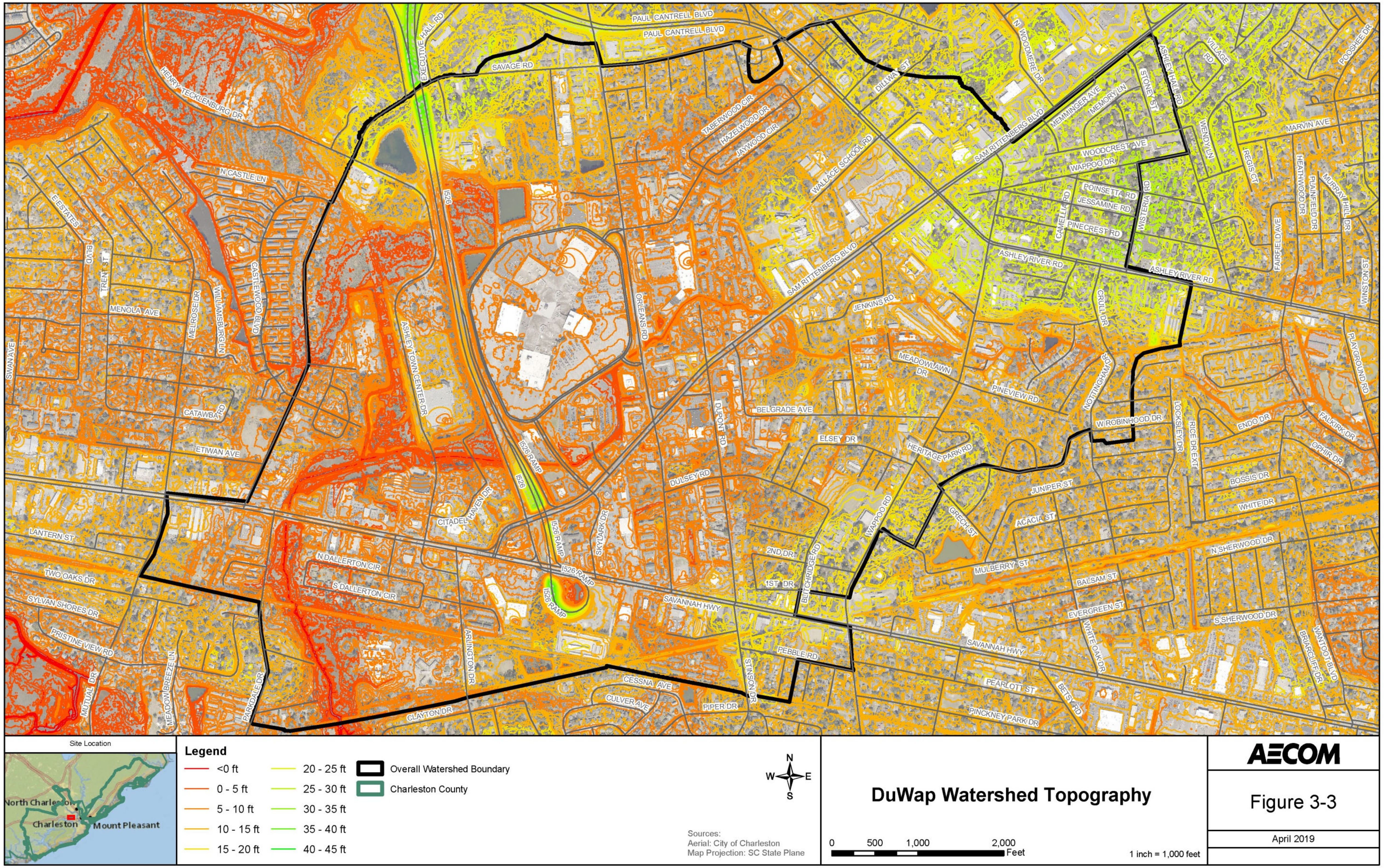


Figure 3-3. DuWap Watershed Topography

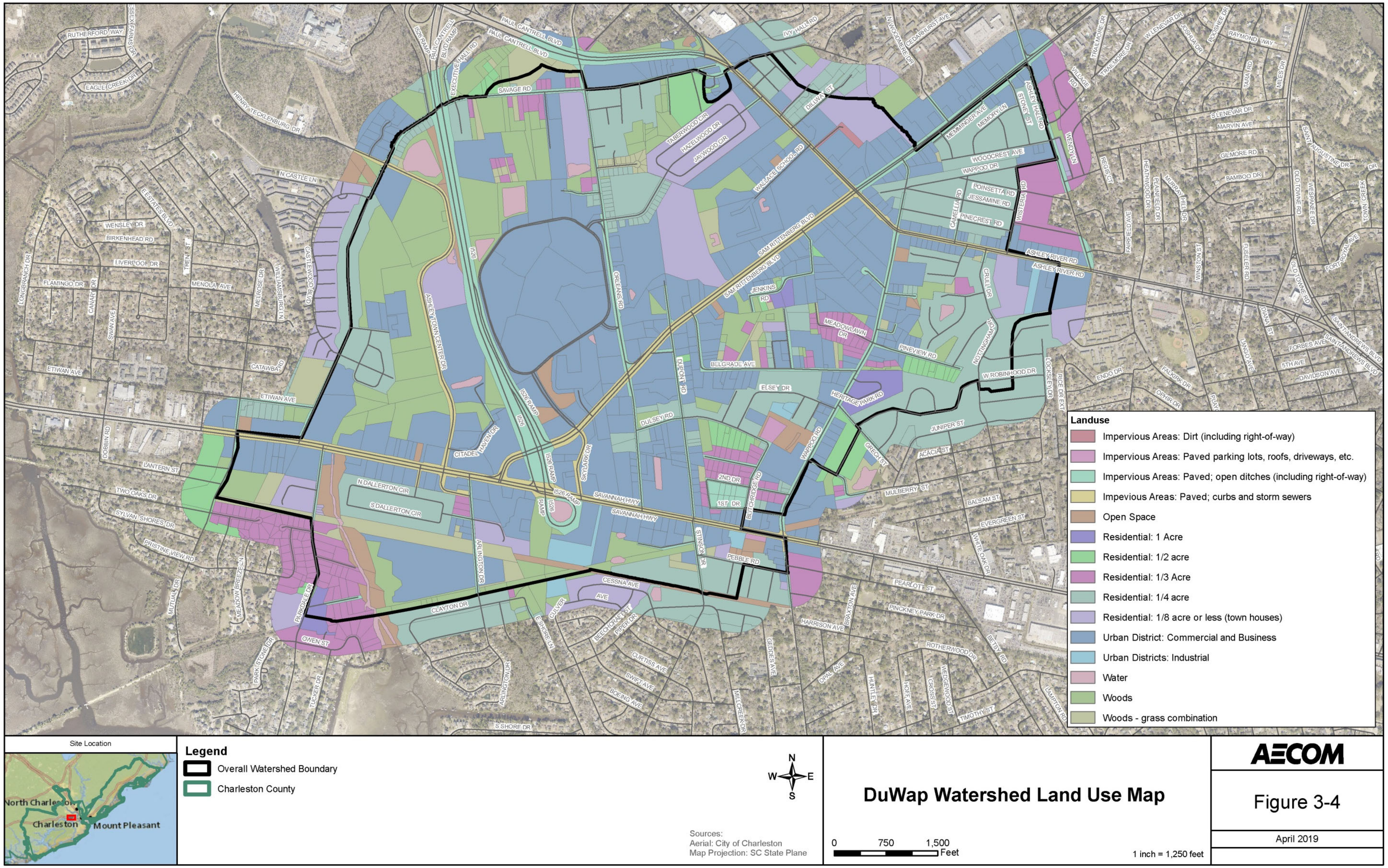


Figure 3-4. DuWap Watershed Land Use Map

3.3 Soils

Soil information for the DuWap watershed was obtained from the Web Soil Survey (WSS) developed by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). **Figure 3-5** shows the soil classifications within the study area. The soil types range from fine sandy loam to silty clay loam. About 50 percent of the DuWap watershed falls within the Stono fine sandy loam, Wadmalaw fine sandy loam, and yonges loamy fine sand soil types. The soils are poorly drained with less infiltration rate and very high runoff potential. All the soil types fall under the Hydrologic Soil Group (HSG) of A/D. The soil resource report for the DuWap watershed is provided in **Appendix A**.

3.4 Rainfall

The mean annual rainfall in the City of Charleston is approximately 50 to 52 inches (South Carolina Climatology Office) and varies due to natural geographic boundaries, such as the extensive river systems. The National Oceanic and Atmospheric Administration (NOAA) estimates the mean annual rainfall to be 51.03 inches at the Charleston International Airport, whereas the mean annual rainfall on the peninsula (downtown Charleston) is 44.42 inches. Mean annual rainfall is shown in **Table 3-1**.

Table 3-1. Mean Annual Rainfall for Charleston, South Carolina

Mean Annual Rainfall (inches)	Data Source and Date
50-52	South Carolina State Climatology Office. Accessed 2019
51.06	US Climate Data, 2019
44.42 – Downtown Charleston	National Oceanic and Atmospheric Administration, 2010
51.03 – Charleston Airport	National Oceanic and Atmospheric Administration, 2010

Rainfall data used for design and calibration of stormwater management systems were obtained from NOAA. Pre- and post-development hydrology was analyzed for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year frequency and 24-hour duration storm events.

The 24-hour precipitation depths corresponding to various return periods used for the analysis are shown in **Table 3-2**.

Table 3-2. Design Storm Precipitation Data for Charleston, South Carolina

Storm Event	Precipitation (inches)
2-year, 24-hour	4.16
5-year, 24-hour	5.38
10-year, 24-hour	6.36
25-year, 24-hour	7.75
50-year, 24-hour	8.88
100-year, 24-hour	10.1

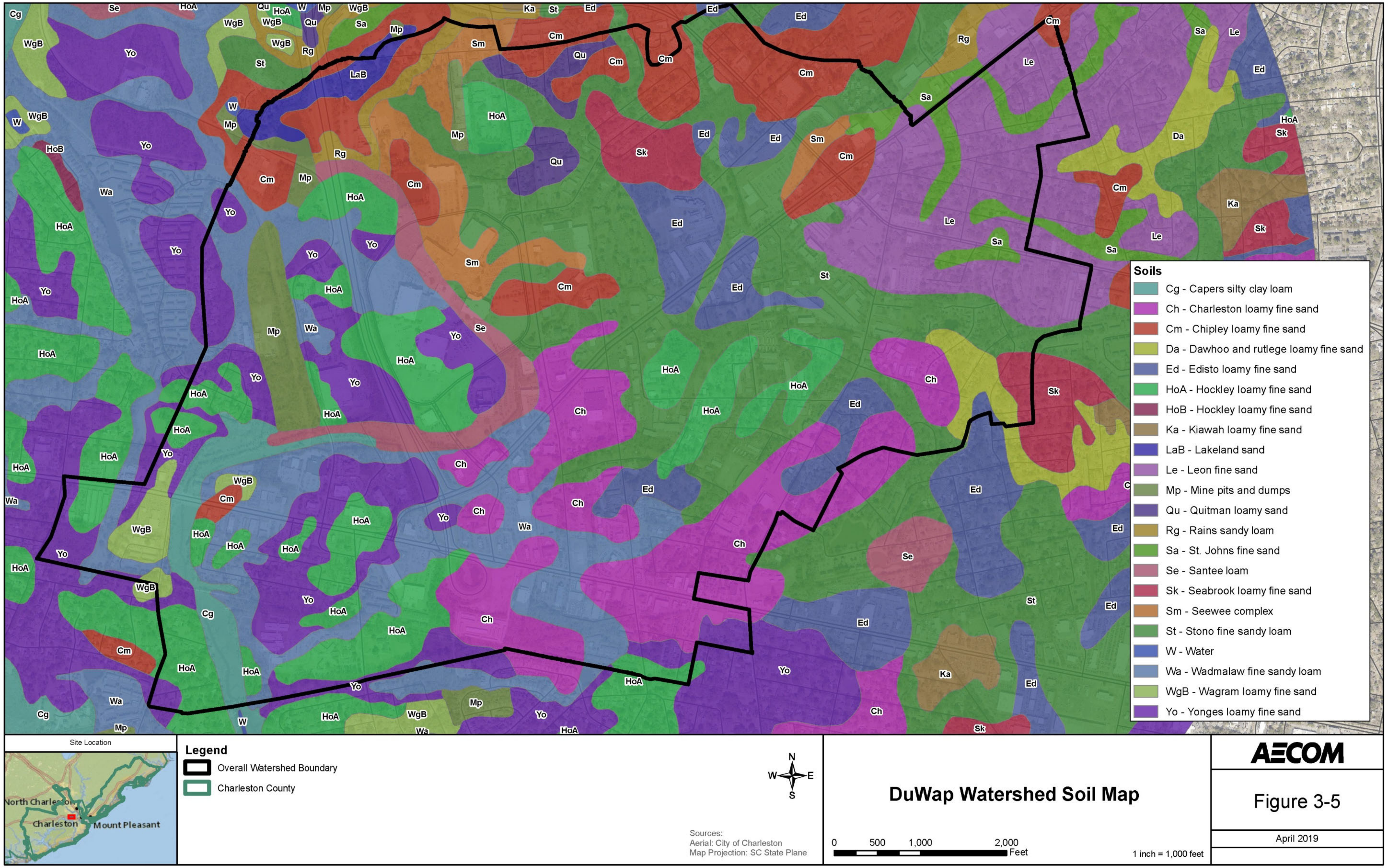


Figure 3-5. DuWap Watershed Soil Map

3.5 Tidal Conditions

The DuWap watershed's final point of discharge is to the Stono River, which is tidally influenced. A NOAA weather station (ID 8665530) is located in the vicinity of the DuWap watershed at the mouth of Cooper River. Station 8665530 was established in 1899 and is currently operational. Data obtained from Station 8665530 show that it recorded a maximum water level of 6.76 feet MHHW on September 21, 1989, and a minimum water level of −4.09 feet MLLW on March 13, 1993, with a mean range of 5.22 feet and diurnal range of 5.76 feet.

4. Baseline Data

This chapter discusses efforts to collect data needed to develop the Plan, which included information on the existing stormwater infrastructure, prior models, and reports/studies.

4.1 General Data Collection and Review

Information and data collection included the review of existing relevant drainage studies and master plans prepared over several decades, as well as numerous reference materials from regulatory and governmental agencies and other technical sources. Data collection and review allows for a thorough understanding of the work that has been previously performed, work that is ongoing, and areas that need to be improved.

The baseline data chapter is divided into following four sections:

- Existing Drainage Studies, Manuals, Reports, and Stormwater Master Plans
- Geographic Information System (GIS) Data Collection and Review
- Field Survey and Organization
- Other Relevant Sources

Each section describes the type of data collected, and how the data were used.

4.2 Existing Drainage Studies, Manuals, Reports, and Stormwater Master Plans

Table 4-1 lists the existing drainage studies, stormwater master plans, stormwater manuals, and other similar data sources used to assess and evaluate how the City has been managing stormwater infrastructure. The studies were examined first for relevancy to existing stormwater issues facing the City, and then relevant documents were reviewed to provide a comprehensive understanding of the current state of the City's stormwater management system and areas that may be upgraded. This Plan continues from the conclusions of the 1984 Master Plan and concentrates on changes that have since occurred in the DuWap watershed.

Table 4-1. List of Previous Master Plans, Drainage Studies, and Manuals

Year	Title of Document	By
1984	Master Drainage and Floodplain Management Plan	Davis and Floyd, Inc.
2001	Church Creek Watershed Storm Water Master Plan	Woolpert,LLP
2007	City of Charleston Stormwater Management Ordinance	City of Charleston
2013	Stormwater Design Standards Manual	City of Charleston
2014, Rev. 2016	Charleston County Stormwater Management Plan	URS Corporation
2015	2015 Church Creek Watershed ICPR Model Addition/Revision	Woolpert, LLP
2016	City of Charleston Redevelopment Standards for Stormwater	AECOM

4.3 GIS Data Collection and Review

The City of Charleston maintains its stormwater data in a GIS database. The majority of stormwater GIS data in the current database were acquired from as-built plans, aerial imagery, and previously scanned stormwater plans and reports such as the 1984 Master Plan and South Carolina Department of Transportation (SCDOT) record drawings. The stormwater system data from the scanned record drawings were converted into GIS format as geodatabase features. The data are currently available for download and use as shapefiles and as comma delimited values, or .CSV files.

The City's current GIS database contains limited data regarding areas in the DuWap watershed. The DuWap watershed has experienced significant redevelopment and growth in recent years and the current GIS database has information gaps or missing data for the stormwater infrastructure within the DuWap watershed. Therefore, development of a more comprehensive stormwater geodatabase model that includes an inventory of all stormwater assets was necessary as part of this Plan. A high level of GIS integration and a robust stormwater data model will enable the City to understand operating conditions of the existing stormwater network and assets, prioritize stormwater infrastructure and drainage maintenance, track water quality data, and assist with watershed modeling and master planning.

AECOM assisted the City in developing a detailed geodatabase for the City's stormwater infrastructure using ESRI ArcGIS, version 10.4.0 by conducting infrastructure mapping and a field survey within the study area. Data collection efforts during the field investigation were limited to the infrastructure near existing roadways and City-owned/maintained infrastructure.

4.4 Field Survey and Organization

AECOM conducted field reconnaissance of the study area. The following items were assessed for use in the development of input parameters for the development of hydrologic and hydraulic model:

- Existing conditions, material, and type of drainage ditches, channels, culverts, and other control structures
- Extent of vegetative growth in the channels to determine the roughness coefficient ranges to be used in the model
- Condition of the pipes and culverts, including the degree of sedimentation that could reduce the conveyance
- Sizes and inverts of the pipes, culverts, and channel dimensions for structures that were not surveyed and for which no data were available from other sources

Additionally, data related to stormwater best management practices (BMPs) such as outfall pipes, dam crest, normal water surface elevations, and outlet control structures were collected.

4.4.1 Standard Operating Procedure

An important step in the development of the Plan was to prepare standardized procedures and consistent methods for the mapping and modeling analysis. AECOM developed a standard operating procedure (SOP) to enable production of quality results and avoid introduction of errors (**Appendix B**). The SOP outlines procedures for data collection, storage, processing, and analyses as well as a framework for quality assurance (QA)/quality control (QC) procedures.

The SOP was provided to the City for review and approval prior to initiating the field investigation. The SOP is intended to serve as a comprehensive guide for future watershed management plans within the City and County.

After the City approved the SOP, AECOM field staff collected and reviewed stormwater infrastructure data within the study area. Prior to initiating field activities, it was determined that encroachment permits were required to complete the field investigation. AECOM worked with the City to coordinate with the South Carolina Department of Transportation (SCDOT) to obtain encroachment permits.

The field data collection effort was composed of two layers as described in the following sections.

4.4.2 Infrastructure Mapping and Asset Inventory

Each stormwater infrastructure asset or feature within the study area was mapped and assigned a unique identification code. This was achieved by conducting field investigation as described below and reviewing existing data, record drawings, and aerial imagery. The field investigation was completed in two passes:

- Pass 1 comprised using existing data and information to verify stormwater infrastructure assets and locations, mapping new assets and collecting attribute data for all assets. As each asset was mapped and inventoried, AECOM staff assessed the condition of the asset for structural defects and operation and maintenance (O&M) defects. The process involved visual observations and a mapping grade Global positioning system (GPS) to complete a condition assessment of the stormwater system.
- Pass 2 comprised capturing horizontal and vertical coordinates of all assets identified during Pass 1. This process used survey grade GPS to collect data.

Asset and attribute information including, but not limited to, those listed in **Table 4-2** was collected during the field investigation

Table 4-2. Stormwater System Inventory and Mapping

Asset Type	Attribute
Pipe	Material
	Depth
	Invert elevations
	Flow direction
Manhole, catch basins, curb inlets	Rim elevations
	Invert elevations
	Size
Culverts	Material
	Invert elevations
	Size
Channels	Material
	Invert elevations
	Size

Asset Type	Attribute
BMPs	Water surface elevations
	Outlet structure

4.4.3 Condition Assessment

The second layer of field data collection was a condition assessment. As each asset was mapped and inventoried, the survey crew evaluated each component of the stormwater system for structural defects, and O&M defects. Within each of these categories, several defects are possible. Each defect was identified and evaluated for its severity of damage. The SOP in **Appendix B** outlines the methodology for conducting the condition assessment.

The updated GIS database was then used in the development of the hydrologic and hydraulic model for the DuWap watershed (Chapter 5).

4.5 Other Relevant Sources

Additional key reference sources were obtained from several federal, state, and local governmental agencies, including the following:

- U.S. Geological Survey (USGS) – Topographic maps, rain gage data, stream flow data
- NOAA - Precipitation data, tidal gage data, Unit Hydrograph (UHG) Technical Manual
- SCDOT - Drainage maps, SCDOT Requirements for Hydraulic Design Studies
- USDA NRCS
  - *Urban Hydrology for Small Watersheds*
  - WSS maps
- South Carolina Department of Natural Resources LiDAR data
- Aerial imagery - City of Charleston
- Easement records – City of Charleston.

In addition to the field data collection, AECOM staff contacted the City and County’s Stormwater Operations and Maintenance staff to discuss existing surface water management issues and concerns. Information obtained from these meetings aided in the development of the surface water management model and contributed to the documentation of the observed drainage conditions in the DuWap watershed. AECOM also reviewed maintenance and flood records and conducted field visits with the City staff to identify issues of specific concern.

4.5.1 Public Involvement

AECOM held one public meeting in May 2017 specifically for the DuWap watershed and attended the first West Ashley Master Plan public meeting in May 2017, where an update was provided on the DuWap watershed project. Residential, commercial, and industrial stakeholders were invited to these public meetings. The purpose of the meetings was to inform the public about the project, the timeline, and expected outcomes; to seek their input regarding issues of concern; and to obtain contact information for interviews with residents and business owners.

4.5.2 Flooding Hot Spots Map

Flooding hot spot maps identify areas or zones that experience chronic flooding. A flooding hotspot map was developed using data collected from the SCDOT Request for Action (RFA) Complaint database and information obtained from Operations and Maintenance personnel and business owners within the study area.

The process for developing the flooding hotspot map included the following:

- Step 1: The entire County database was queried for flooding complaints to generate a flooding complaints database. The accuracy of the storm-related complaints was verified during the first public workshop meeting.
- Step 2: The flooding complaints database was exported as a database file.
- Step 3: The flooding complaints database file was imported into GIS using XY coordinates provided within the database.
- Step 4: A hot spot map was created in GIS by isolating flooding complaints within the study area to create a new flooding hot spot map.

Appendix C shows the compiled flooding hotspot map for the study area. This map was used as a reference for evaluating the model and aided in the determination of proposed improvements. The red dots on the map represent locations from the SCDOT RFA complaint database.

5. Watershed Stormwater Modeling

This chapter discusses the development of input parameters such as the curve numbers, time of concentration, and other elements needed to construct the existing conditions hydrologic and hydraulic model of the DuWap watershed. The chapter also details the calibration and validation of the model along with the summary of calibration results.

5.1 Delineation of Sub-Basins

A watershed must be delineated into drainage sub-basins to evaluate the stormwater management features that collect and convey stormwater throughout the watershed to the basin outfalls. The sub-basins define the contributing drainage area for each of the major conveyance elements in the watershed.

The sub-basins for the DuWap watershed were delineated using ESRI© ArcHydro tools version 10.6. The delineation was initially performed using 2007 LiDAR and further refined using the stormwater network and information gathered via field investigation and the City's input. Basins were mainly delineated based on natural hydrologic boundaries such as ridges, channels, and other waterways, as well as constructed boundaries such as roadways. A total of 125 sub-basins were delineated for a total contributing area of approximately 1,500 acres. Sub-basins include 105 basins representing land areas that contribute runoff and 20 sub-basins representing the ponds incorporated into the DuWap model. The ponds receive runoff from their respective contributing sub-basins as well as from precipitation that falls directly on the pond. Therefore, each pond must have an associated basin that represents the pond area itself. The sub-basins delineated using the 2007 LiDAR were compared to the drainage features and the stormwater network within the DuWap basin and were modified to account for flow redirection that was not obvious from the LiDAR assessment. The sub-basins within the watershed, as shown on **Figure 5-1**, vary in size from approximately 0.04 acre to 73.86 acres. Sub-basin names and their corresponding areas are listed in **Water quantity** can impact the community if the capacity of the existing stormwater infrastructure is inadequate to convey the runoff generated by the watershed and can consequently cause flooding. Flooding occurs when the stormwater management system does not have enough capacity to convey the stormwater quickly enough or store the stormwater in stormwater-designated areas (ponds, lakes, or swales) for certain storm events. Water quantity issues are, therefore, often studied with the aid of hydraulic and hydrologic modeling, a thorough review of area topography, and complaint information.

Table 5-1**.**

5.2 Modeling Software

The combined hydrologic and hydraulic model for the DuWap watershed was developed using Interconnected Pond Routing Model (ICPR), Version 4. The model can perform both 1-D and 2-D modeling. For this analysis, one-dimensional (1D) modeling capabilities of the software were used. The software generated runoff hydrographs from delineated sub-basins within the DuWap watershed and applied those hydrographs as inputs to the hydraulic network.

5.3 Water Quantity Model – Hydrology

Water quantity is calculated as the volume of stormwater runoff produced by a rainfall event from a watershed. A hydrologic analysis was performed to determine stormwater runoff rates for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year frequency and 24-hour duration storm events using the TR-20 curve number (CN) approach originally developed by the USDA Soil Conservation Service (SCS) (1986). The shape of the hydrograph is dependent on the sub-basin time of concentration, which is a representation of how long it takes for the runoff to go from the most distant point in the sub-basin to the sub-basin outfall.

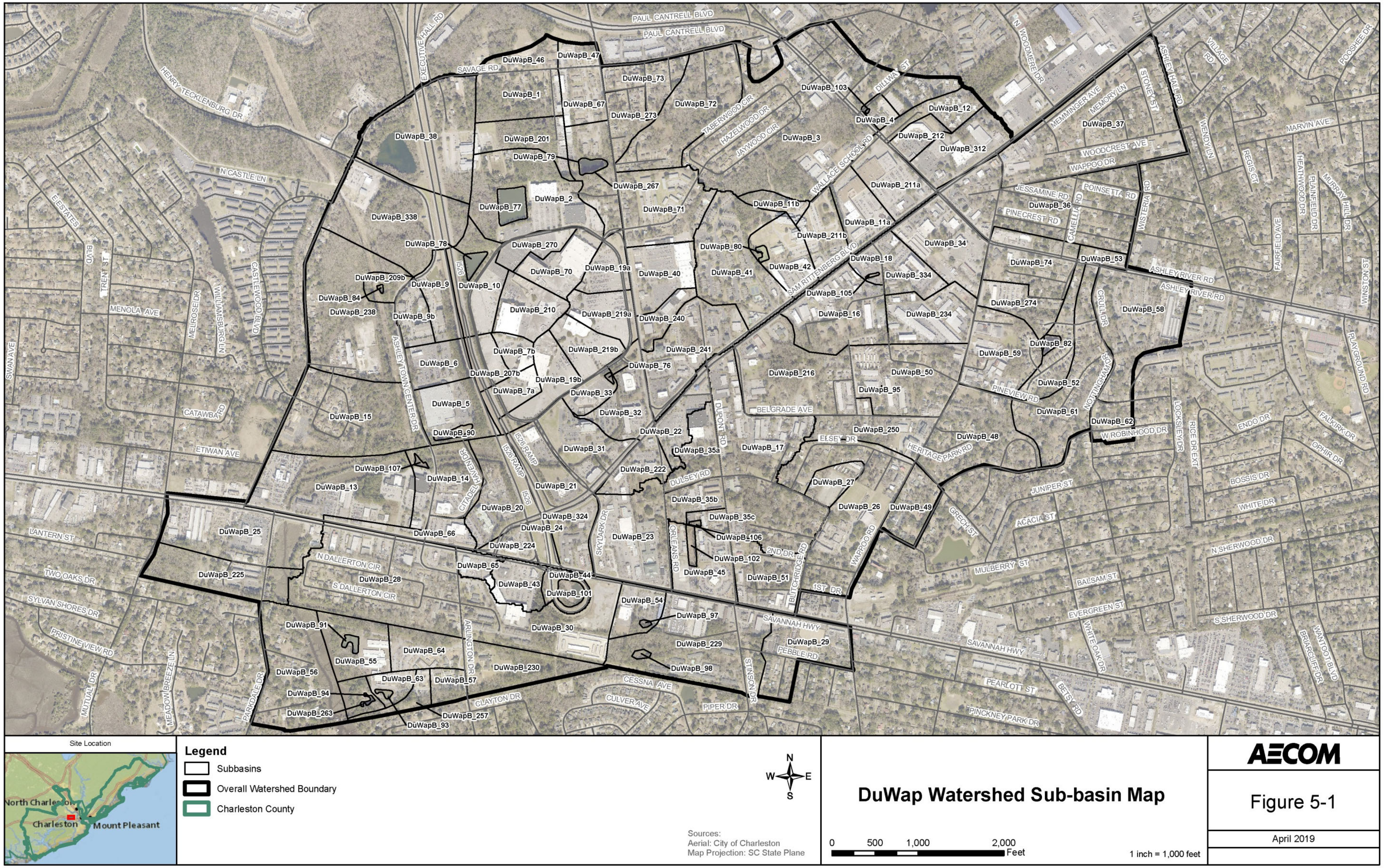


Figure 5-1. DuWap Watershed Sub-basin Map

Water quantity can impact the community if the capacity of the existing stormwater infrastructure is inadequate to convey the runoff generated by the watershed and can consequently cause flooding. Flooding occurs when the stormwater management system does not have enough capacity to convey the stormwater quickly enough or store the stormwater in stormwater-designated areas (ponds, lakes, or swales) for certain storm events. Water quantity issues are, therefore, often studied with the aid of hydraulic and hydrologic modeling, a thorough review of area topography, and complaint information.

Table 5-1. DuWap Watershed Sub-Basins

Sub-Basin Name	Area (acres)	Sub-Basin Type
DuWapB_1	12.68	Basin
DuWapB_10	13.06	Basin
DuWapB_101	1.84	Pond
DuWapB_102	1.03	Pond
DuWapB_103	0.04	Pond
DuWapB_105	0.12	Pond
DuWapB_106	0.16	Pond
DuWapB_107	0.26	Pond
DuWapB_11a	9.49	Basin
DuWapB_11b	3.41	Basin
DuWapB_12	6.96	Basin
DuWapB_13	31.07	Basin
DuWapB_14	14.95	Basin
DuWapB_15	31.79	Basin
DuWapB_16	20.43	Basin
DuWapB_17	39.83	Basin
DuWapB_18	2.83	Basin
DuWapB_19a	6.66	Basin
DuWapB_19b	9.55	Basin
DuWapB_2	24.72	Basin
DuWapB_20	15.66	Basin
DuWapB_201	10.02	Basin
DuWapB_207b	5.17	Basin
DuWapB_209b	3.25	Basin
DuWapB_21	11.40	Basin
DuWapB_210	10.18	Basin
DuWapB_211a	11.89	Basin
DuWapB_211b	8.91	Basin
DuWapB_212	4.46	Basin

Sub-Basin Name	Area (acres)	Sub-Basin Type
DuWapB_216	27.37	Basin
DuWapB_219a	8.57	Basin
DuWapB_219b	8.09	Basin
DuWapB_22	7.68	Basin
DuWapB_222	7.46	Basin
DuWapB_224	4.18	Basin
DuWapB_225	15.70	Basin
DuWapB_229	33.89	Basin
DuWapB_23	22.07	Basin
DuWapB_230	13.33	Basin
DuWapB_234	13.98	Basin
DuWapB_238	35.84	Basin
DuWapB_24	3.15	Basin
DuWapB_240	4.74	Basin
DuWapB_241	19.57	Basin
DuWapB_25	26.04	Basin
DuWapB_250	11.97	Basin
DuWapB_257	3.66	Basin
DuWapB_26	33.02	Basin
DuWapB_263	3.50	Basin
DuWapB_267	11.55	Basin
DuWapB_27	4.79	Basin
DuWapB_270	5.30	Basin
DuWapB_273	6.74	Basin
DuWapB_274	7.91	Basin
DuWapB_28	43.01	Basin
DuWapB_29	15.54	Basin
DuWapB_3	73.86	Basin
DuWapB_30	26.50	Basin
DuWapB_31	14.07	Basin
DuWapB_312	12.84	Basin
DuWapB_32	11.68	Basin
DuWapB_324	8.11	Basin
DuWapB_33	4.37	Basin
DuWapB_334	8.38	Basin
DuWapB_338	30.69	Basin
DuWapB_34	16.62	Basin

Sub-Basin Name	Area (acres)	Sub-Basin Type
DuWapB_35a	8.62	Basin
DuWapB_35b	5.71	Basin
DuWapB_35c	2.34	Basin
DuWapB_36	37.17	Basin
DuWapB_37	46.22	Basin
DuWapB_38	32.32	Basin
DuWapB_4	2.27	Basin
DuWapB_40	11.79	Basin
DuWapB_41	25.02	Basin
DuWapB_42	10.22	Basin
DuWapB_43	7.03	Basin
DuWapB_44	3.32	Basin
DuWapB_45	12.43	Basin
DuWapB_46	5.39	Basin
DuWapB_47	3.11	Basin
DuWapB_48	23.27	Basin
DuWapB_49	8.28	Basin
DuWapB_5	11.41	Basin
DuWapB_50	22.18	Basin
DuWapB_51	12.91	Basin
DuWapB_52	9.42	Basin
DuWapB_53	2.38	Basin
DuWapB_54	6.73	Basin
DuWapB_55	11.06	Basin
DuWapB_56	26.84	Basin
DuWapB_57	3.74	Basin
DuWapB_58	25.88	Basin
DuWapB_59	16.47	Basin
DuWapB_6	7.94	Basin
DuWapB_61	22.87	Basin
DuWapB_62	5.24	Basin
DuWapB_63	3.57	Basin
DuWapB_64	8.73	Basin
DuWapB_65	3.33	Basin
DuWapB_66	6.78	Basin
DuWapB_67	7.63	Basin
DuWapB_70	9.28	Basin

Sub-Basin Name	Area (acres)	Sub-Basin Type
DuWapB_71	19.24	Basin
DuWapB_72	23.82	Basin
DuWapB_73	8.70	Basin
DuWapB_74	15.16	Basin
DuWapB_76	0.17	Pond
DuWapB_77	2.93	Pond
DuWapB_78	1.11	Pond
DuWapB_79	1.08	Pond
DuWapB_7a	5.72	Basin
DuWapB_7b	3.60	Basin
DuWapB_80	0.40	Pond
DuWapB_82	0.74	Pond
DuWapB_84	0.11	Pond
DuWapB_9	7.79	Basin
DuWapB_90	0.97	Pond
DuWapB_91	0.57	Pond
DuWapB_93	0.26	Pond
DuWapB_94	0.20	Pond
DuWapB_95	0.08	Pond
DuWapB_97	0.21	Pond
DuWapB_98	0.40	Pond
DuWapB_9b	5.87	Basin

As described in Section 5.1, the watershed was divided into 125 sub-basins. To develop the hydrologic model, the following parameters were determined for each sub-basin within the DuWap watershed and then incorporated into the model:

- Runoff CN derived from land use and soil type
- Time of concentration
- Assignment of unit hydrograph peaking factor
- Assignment of rainfall depths and distribution

5.3.1 Runoff Curve Number Determination

The NRCS CN methodology estimates precipitation excess as a function of cumulative precipitation, soil cover, land use, and antecedent moisture conditions.

CNs were calculated based on the soil group and land use. The soil group and land use were categorized based on the following:

5.3.1.1 Soils

Soil types in the DuWap watershed were obtained from the NRCS via WSS. WSS provides soil data and information produced by the National Cooperative Soil Survey.

Approximately 53 percent of the watershed contains soils with dual hydrologic soil groups (HSG) of A/D. Based on discussions with the City and the general characteristics of soil conditions, undrained conditions were considered appropriate and therefore soils with dual HSG used D for the modeling analysis. The different types of soils and their distribution can be found in **Appendix A**.

5.3.1.2 Land Use

Land use and land cover maps within the watershed boundary were created using the latest zoning data obtained from the City and the County, as discussed in Section 3.2. For the purpose of the hydrologic model, the land use file was generated based on existing conditions. For example, if a parcel was zoned Single Family Residential, but was currently undeveloped, it was assumed undeveloped to more accurately represent land cover.

Table 5-2 lists the land uses within the DuWap watershed that were used for developing CNs.

Table 5-2. DuWap Watershed Land Use

DuWap Watershed Land Use
Impervious Areas: Dirt (including right-of-way)
Impervious Areas: Paved parking lots, roofs, driveways, etc.
Impervious Areas: Paved with open ditches (including right-of-way)
Impervious Areas: Paved with curbs and storm sewers
Open Space: Good Condition (grass cover >75%)
Residential: 1 Acre
Residential: 1/2 acre
Residential: 1/3 Acre
Residential: 1/4 acre
Residential: 1/8 acre or less (town houses)
Urban District: Commercial and Business
Urban Districts: Industrial
Water
Woods - grass combination
Woods: Good

5.3.1.3 Curve Numbers and Antecedent Moisture Condition

Antecedent Moisture Condition (AMC) is defined as the moisture content in soils before a precipitation event. AMC affects the ability of soils to absorb and infiltrate surface runoff. The nature of soils and frequency of rainfall events in the DuWap watershed indicated a need to adjust the AMC to more accurately reflect existing conditions.

Typical soil CN values published in the NRCS Urban Hydrology for Small Watersheds TR-55 are classified under the AMC II category, which reflects the average antecedent moisture condition. Soils that do not retain moisture (dry soils) are classified under AMC I category and soils that retain moisture (wet soils) are classified under the AMC III category. Soils in the DuWap watershed retain moisture and are best described as AMC III. Additionally, recent studies in the proximity of the DuWap watershed, such as the Church Creek Drainage Project (Weston and Sampson), used AMC III for CN determination. Therefore, AMC III was selected to best represent the existing soil conditions, which have a decreased infiltration capacity and high stormwater runoff potential.

The original CN values for the average soil moisture conditions (AMC II) are taken from NRCS published values for TR-55 methodology for Urban Hydrology and Agricultural land uses, Tables 2-2a through 2-2d (**Appendix D**). The CN values were adjusted from the average AMC II conditions to wet soil moisture conditions (AMC III).

Table 5-3 shows conversion factors used to compute adjusted CNs for soils classified under AMC I and AMC III categories.

Table 5-3. Conversion Factors for AMC I and AMC III

Curve Numbers (AMC II)	AMC I (Dry)	AMC III (Wet)
10	0.4	2.22
20	0.45	1.85
30	0.5	1.67
40	0.55	1.5
50	0.62	1.4
60	0.67	1.3
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07

Source: Ward, Andy D.; Trimble, Stanley W. (2004). Environmental Hydrology. Boca Raton, Florida 33431: CRC Press LLC.

Table 5-4 presents the proposed CN values for each soil classification and land use category present in the DuWap watershed used in the hydrologic analysis.

Table 5-4. Curve Numbers for AMC III

Land Use	Soil Classification			
	A	B	C	D
Impervious Areas: Dirt (including right-of-way)	86	92	95	96
Impervious Areas: Paved parking lots, roofs, driveways, etc.	99	99	99	99
Impervious Areas: Paved with open ditches (including right-of-way)	93	96	97	98
Impervious Areas: Paved with curbs and storm sewers	99	99	99	99
Open Space: Good Condition (grass cover >75%)	59	79	87	91

Land Use	Soil Classification			
	A	B	C	D
Residential: 1 Acre	71	84	91	93
Residential: 1/2 acre	73	85	91	94
Residential: 1/3 Acre	76	86	92	94
Residential: 1/4 acre	79	88	93	95
Residential: 1/8 acre or less (town houses)	89	94	96	97
Urban District: Commercial and Business	96	97	98	98
Urban Districts: Industrial	92	95	97	98
Water	100	100	100	100
Woods - grass combination [a]	52	77	86	91
Woods [b]: Good	56	78	87	91

[a] CNs were computed for areas with 50% woods and 50% grass cover.

[b] Woods are protected from grazing, and litter and brush adequately cover the soil.

Sub-basin, soil data, and land use data were imported into the model as georeferenced ESRI shape files. The program then overlaid the three sets of information and calculated a CN for each unique combination of soil type and land use within the sub-basin along with their respective areas. Each sub-basin was further divided into several areas with different CNs. The composite CN for the sub-basin is calculated as a weighted average of all the CNs within the sub-basin.

5.3.2 Time of Concentration Determination

Time of concentration is defined as the time required for a drop of water to travel from the most hydraulically distant part of a watershed to the point of discharge or outfall. In order to determine the time of concentration, the longest flow path was generated using ArcHydro 10.6. and modified according to the latest available information on the sub-basin.

Surface runoff initially flows through a watershed as sheet flow for the first 100 feet after which it starts to concentrate and flow as shallow concentrated flow for the next 1,200 feet. Any flow beyond that is referred to as open channel/pipe flow. The type of surface flow that occurs in a watershed is a function of surface cover. Time of concentration for surface flow was calculated for each sub-basin using the TR-55 methodology.

The maximum sheet flow length recommended in the TR-55 publication was 300 feet; however, recent studies and publications (**Appendix E**) recommend a maximum flow length of 100 feet for sheet flow. Therefore, in the current model, a maximum sheet flow length of 100 feet and a 2-year, 24-hour rainfall depth of 4.16 inches was used for sheet flow travel time calculations. The Manning's roughness (n) coefficients for sheet flow for various surface conditions as provided in the TR-55 methodology are shown in **Table 5-5**.

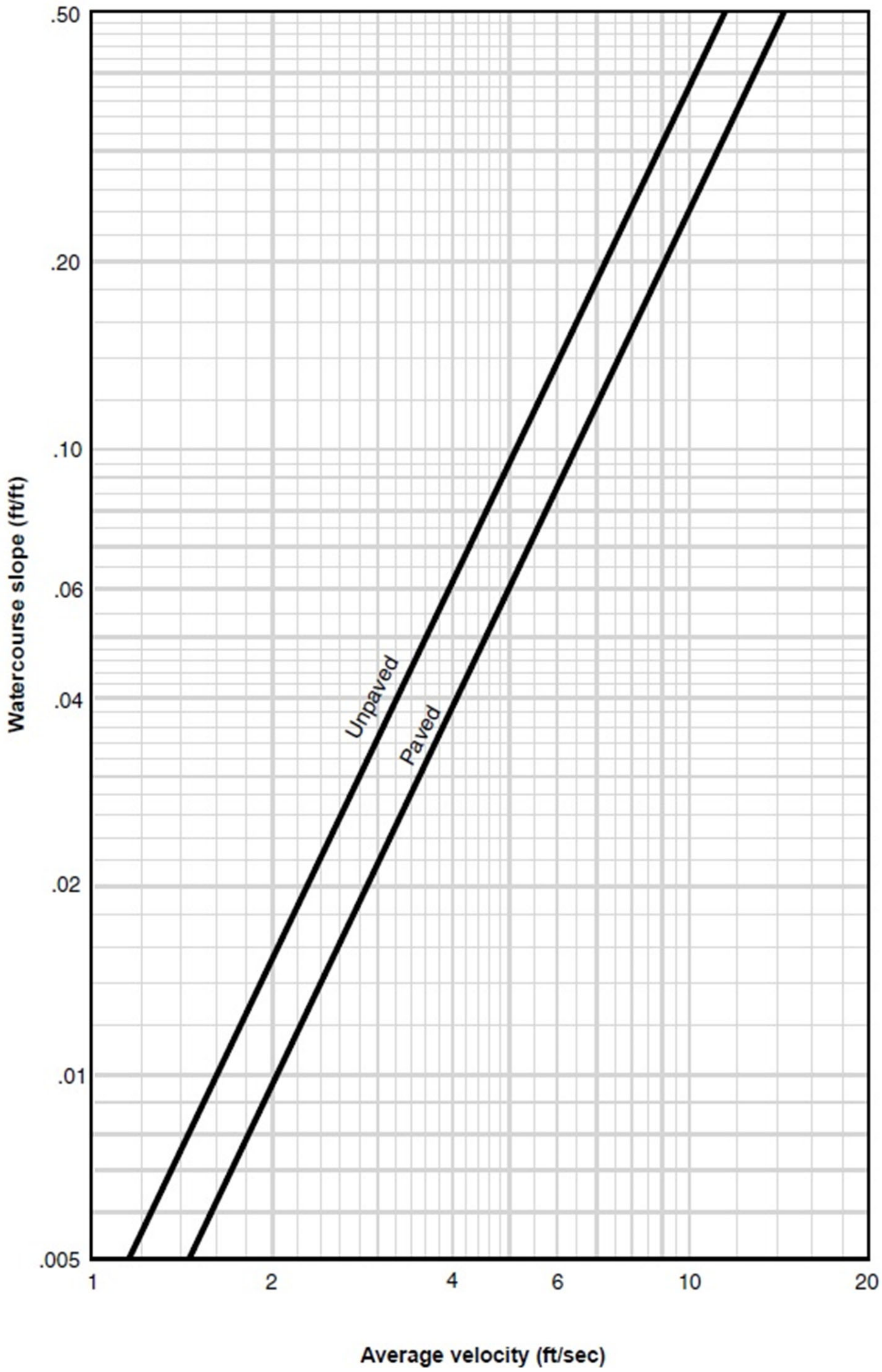
Table 5-5. Manning's Roughness Coefficient for Sheet Flow

Surface Description	Manning's n
Smooth surface (pavement, gravel or bare soil)	0.01
Fallow (no residue)	0.05
Cultivated soils, residue cover <20%	0.06
Cultivated soils, residue cover >20%	0.17
Short grass prairie	0.15
Dense grasses	0.24
Bermudagrass	0.41
Range (nature)	0.13
Light underbrush woods	0.40
Dense underbrush woods	0.80

The shallow concentrated flow length was divided by the average velocity determined to get the travel time for shallow concentrated flow. The maximum shallow concentrated length considered was 1,200 feet. The time of travel for shallow concentrated flow is calculated using flow length and flow velocity. Flow length is measured directly from the map. The flow velocity is calculated as a function of the watercourse slope and the surface cover type. **Figure 5-2** is taken from the original TR-55 publication that provides the estimate for flow velocity using the slope and surface cover of the watershed.

For open channel flow travel time, the flow velocity was calculated based on the physical parameters of the conveyance such as dimensions of the pipe or channel, roughness coefficient, bottom slope, and hydraulic radius. The calculated flow velocity was then used with the open channel flow length to determine the travel time component for open channel flow for each sub-basin. The Manning's roughness coefficient used for channel flow calculations is shown in **Table 5-6**.

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow



Source: USDA NRCS 1986.

Figure 5-2. Shallow Concentrated Flow Average Velocity

Table 5-6. Manning's Coefficient (n) for Channels and Pipes

Item	Conduit Material	Manning’s n		Average n
1	Asbestos-cement pipe	0.011	0.015	0.013
2	Brick	0.013	0.017	0.015
3	Cement lined and seal coated cast iron pipe	0.011	0.015	0.013
4	Concrete (monolithic)	0.012	0.014	0.013
5	Concrete pipe	0.011	0.015	0.013
6	Plain corrugated metal pipe	0.022	0.026	0.024
7	Paved invert corrugated metal pipe	0.018	0.022	0.020
8	Spun asphalt lines corrugated metal pipe	0.011	0.015	0.013
9	Plastic pipe (smooth)	0.011	0.015	0.013
10	Vitrified clay pipes	0.011	0.015	0.013
11	Vitrified clay liner plates	0.013	0.017	0.015
12	Line channel with asphalt	0.013	0.017	0.015
13	Line channel with concrete	0.012	0.018	0.015
14	Lined channel with rubble or riprap	0.011	0.020	0.016
15	Lined channel with vegetal	0.020	0.035	0.028
16	Earth, straight and uniform open channel	0.020	0.030	0.025
17	Earth, winding, fairly uniform open channel	0.025	0.040	0.033
18	Excavated or dredged – Rock	0.030	0.045	0.038
19	Excavated or dredged - Unmaintained	0.050	0.140	0.095
20	Fairly regular section natural channel	0.030	0.070	0.050
21	Irregular section natural channel with pools	0.040	0.100	0.070

The total time of concentration for each sub-basin was calculated as the sum of travel times for the three flow components, namely sheet flow, shallow concentrated flow, and open channel flow. Time of concentration was calculated for each of the 125 sub-basins and varies from 10 minutes to 60 minutes. Since a majority of the DuWap watershed is highly urbanized with a large percentage of paved areas, some of the sub-basins had a time of concentration of less than 10 minutes. For all such sub-basins the time of concentration was set at a minimum of 10 minutes.

The time of concentration for each sub-basin is included in **Appendix F**.

5.3.3 Unit Hydrograph Peaking Factor

Peaking factor is the ability of the watershed to retain and delay flow. Steep terrain and urban areas tend to produce higher early peaks and thus values of the peaking factor may tend towards 600. Likewise, flat swampy regions tend to retain and store the water, causing a delayed lower peak. In these circumstances’ values may tend towards 300 or lower. The City of Charleston *Stormwater Design Standards Manual* recommends a unit hydrograph peaking factor of 323. However, considering the specific character of the DuWap watershed, which is predominantly urbanized, a typical SCS peaking factor of 484 was used for the hydrologic model development.

For additional information, refer to the NOAA *Unit Hydrograph Technical Manual* provided in **Appendix G**.

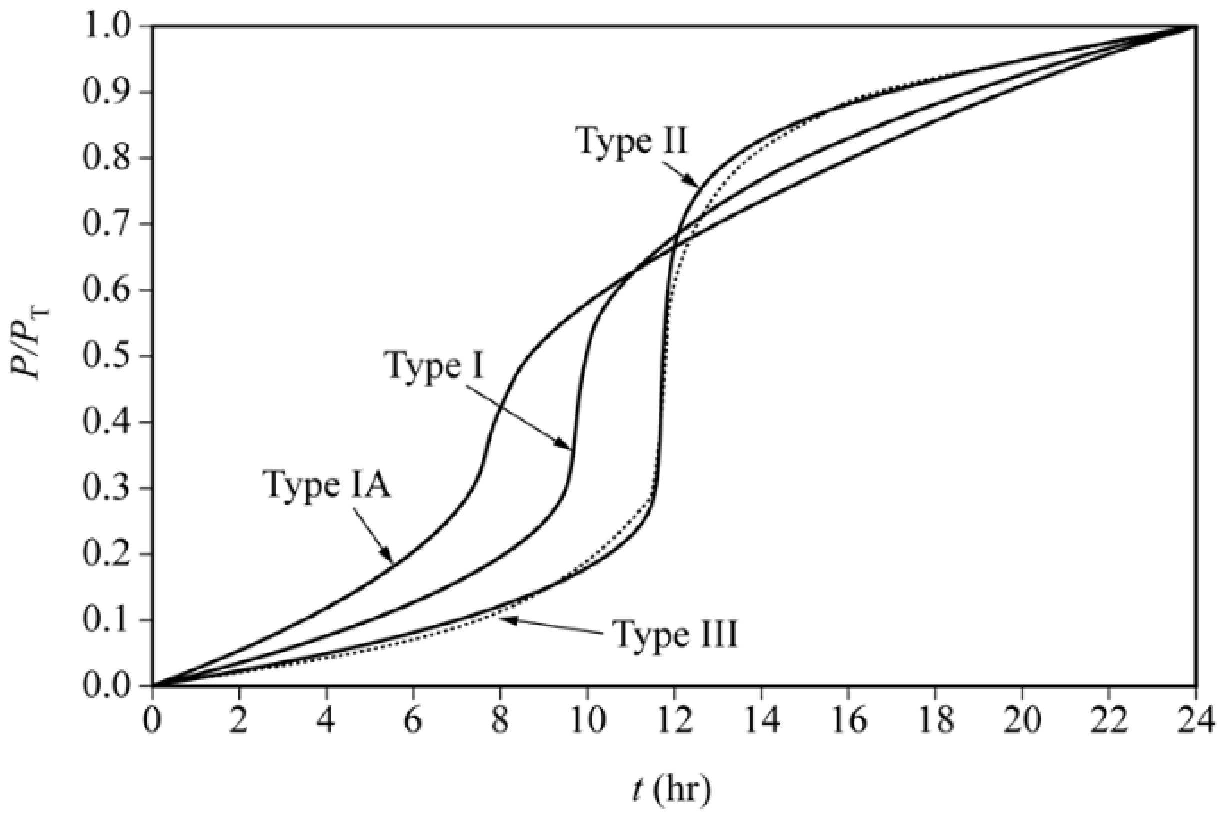
5.3.4 Rainfall Depths and Distribution

The City of Charleston *Stormwater Design Standards Manual* references three types of data sources for design storms that may be used in any stormwater-related design in the City. After meeting with City staff, it was agreed that the storm data developed by NOAA would be used for the DuWap watershed model. The 24-hour duration precipitation depths corresponding to various return periods are shown in **Table 5-7**.

Table 5-7. Storm Return Period and Precipitation Depths

Return Period	24-hour Precipitation Depth (inches)
2-year	4.16
5-year	5.38
10-year	6.36
25-year	7.75
50-year	8.88
100-year	10.1

NRCS Rainfall distribution types for continental United States are shown in **Figure 5-3**. Charleston lies in the coastal region of South Carolina, which falls under the NRCS Type III rainfall distribution as shown on **Figure 5-4**. Therefore, for all the design storm simulations, the NRCS Type III rainfall distribution was used.



Source: USDA NRCS 1986.

Figure 5-3. NRCS Rainfall Distribution

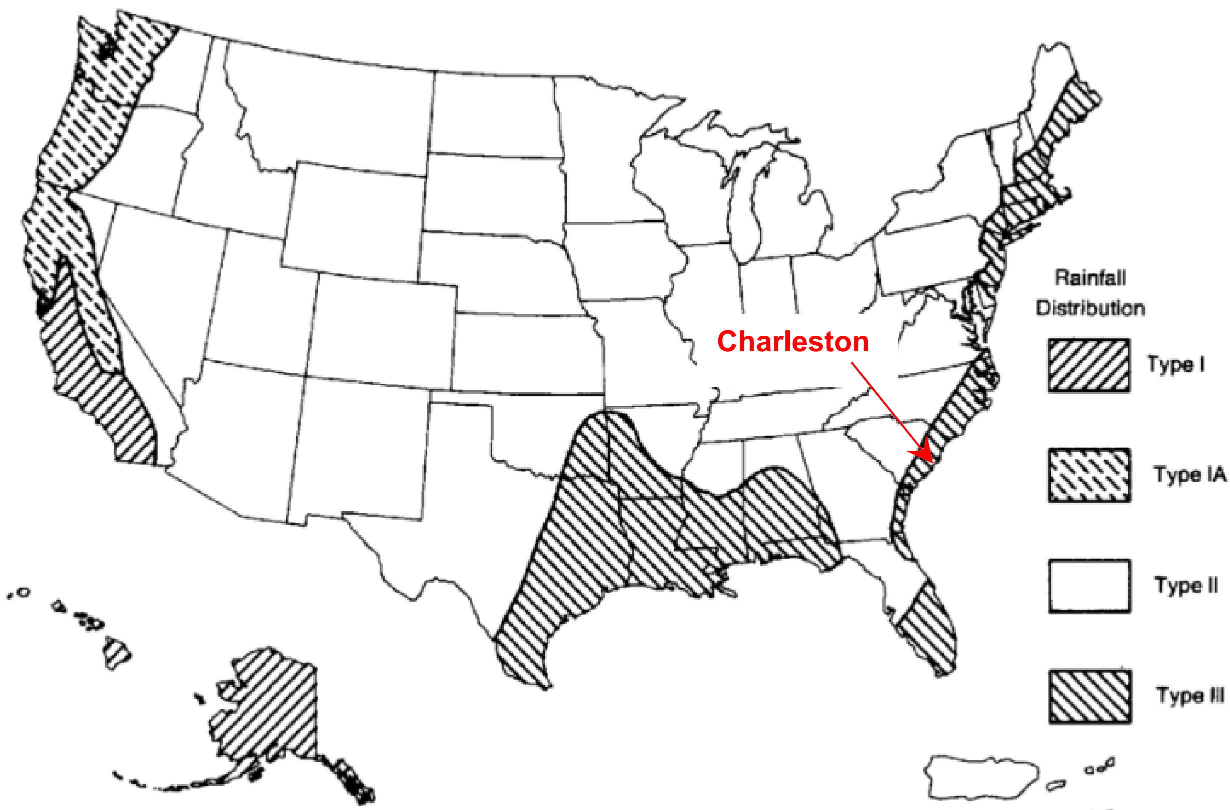


Figure 5-4. Rainfall Distribution Boundaries

5.4 Water Quantity Model – Hydraulics

The objective of the water quantity modeling effort was to determine flows and flood levels in the main drainage features of the DuWap watershed for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year frequency and 24-hour duration storm events. Information needed to develop the hydraulic model includes the node-link configuration, channel cross-sections, Manning's roughness coefficients, initial stages, stage-area determination, and boundary conditions. The current DuWap watershed model was developed as a 1D model. A 1D model can be used effectively to determine the capacity and performance of linear features in a stormwater management system such as pipes, culverts, and channels. However, a 1D model has only limited capability in predicting the amount of overland flooding in a watershed.

5.4.1 Development of Stormwater Network

The DuWap watershed stormwater network was developed from the information acquired from as-built drawings and field survey data. A connected network of all the stormwater assets was created using their spatial locations. Flow directions were determined based on invert elevation and slopes. In some cases, such as locations where pipes had adverse slopes, sound engineering judgement was used to assume flow directions. The network was initially developed for pipes with diameters equal to or larger than 24 inches. Some of the sub-basins, especially the ones near the outer boundary of the watershed, did not have drainage pipes with diameters equal to or larger than 24 inches. In such areas, pipes smaller than 24 inches in diameter were included in the model to maintain connectivity in all the contributing areas.

The DuWap watershed contains 34 ponds, of which 14 ponds were deemed to not have significant impact on the runoff based on discussions with the City. These ponds were therefore excluded from the model and only the remaining 20 ponds were included in the model.

For stormwater pipes in the model network that lack geometric information such as pipe/culvert diameters and inverts, a step-by-step approach was followed to fill in the missing information. The approach was applied on a case-by-case basis and is described in detail below.

While creating the hydraulic network for the DuWap watershed basin, the highest priority was given to survey data. In cases where reasonable field survey data were available, it was used as is in the model. In cases where some inverts from the field survey were available in the upstream and downstream sections of a flow path but inverts were missing in the intermediate sections of the flow path, the inverts were calculated with interpolation using the known upstream and downstream inverts as well as the length of the asset with missing invert information. Some flow paths in the DuWap stormwater network only had a downstream invert available, and therefore, it was not possible to calculate the inverts of the upstream assets using interpolation. In such cases the upstream inverts were calculated using the known downstream invert, the length of the asset, and an assumed 0.3 percent slope. Where connectivity information was missing altogether, appropriate assumptions were made based on upstream and downstream pipe data and sound engineering judgement to build a complete network.

For channels, missing inverts and channel cross-sections were determined based on the 2007 Digital Elevation Model (DEM) that was used for the initial delineation of the DuWap watershed. The DEM was incorporated into the model as a surface, allowing channel cross sections to be created within the ICPR model itself rather than developing cross sections externally and importing them into the model. To describe each channel, one representative cross section was cut at a point near the middle of the channel run and applied to the entire length of the channel.

Drop/control structures from the ponds were also built into the model based on information obtained from survey data. In cases where sufficient information was not available, a standard drop structure template was used to build the complete network.

Appendix H shows the hydraulic network in the DuWap watershed.

5.4.2 Development of Surface Storage

ArcHydro 10.6 was used to calculate the surface storage in the form of an elevation-area table for each sub-basin in the watershed. A portion of each basin’s storage was applied to the first node of each sub-basin where the sub-basin is assumed to drain. The portion of the storage applied to the first drainage node depends on the elevation of the node. The remaining storage was applied to subsequent downstream nodes based on their respective ground elevation.

5.4.3 Inclusion of Condition Assessment Parameters in the Network

Once the model was built with the existing network, the condition assessment data, described in Section 4.4.3, were incorporated into the model. The condition assessment data mostly included severe defects in pipe or blockages of different degrees. The condition assessment data from GIS were spatially joined with the model network to identify the pipes and culverts with blockages. The blockages were created in pipes within the model by adding appropriate bottom clips. This model is considered the existing conditions model. The existing conditions model was simulated for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year design storm events. Any validation issues or warnings encountered during the simulation were addressed and the resulting model was then used for model calibration as discussed in Section 5.5.

5.4.4 Development of Boundary/Tailwater Conditions

Tailwater conditions for the watershed are influenced by daily diurnal tide water levels. Tailwater elevation for the existing conditions model was determined at the final outfall of the DuWap watershed, which is the Stono River. Since there was no tidal gage data available for the Stono River, the tidal gage weather station (ID 8665530) located at the mouth of Cooper River was used for the analysis. Station 8665530 was established in 1899 and remains operational. To accurately model the actual performance of the stormwater management system for the DuWap watershed, 36-hour dynamic tailwater conditions were developed for each design storm event. For the base model, the tailwater elevation based on normal tide water levels was used for the analysis. Storm surge, wave effects, and sea level rise were added after the existing conditions model was calibrated and verified for future analysis. **Figure 5-5** shows the tailwater condition for the base model.

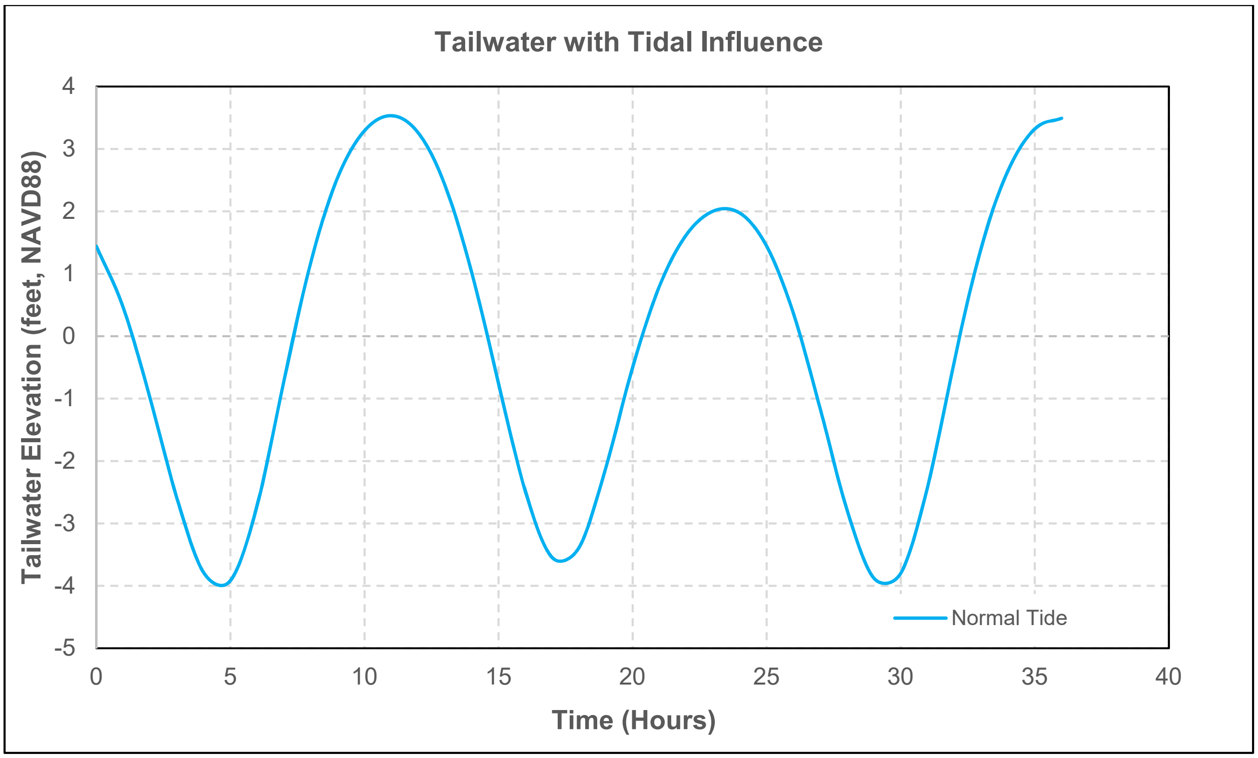


Figure 5-5. Tailwater Condition with Tidal Influence

5.5 Model Calibration and Validation

All models must be calibrated and validated to ascertain that they represent the observed/measured data. The calibration process involves collecting field data from a known event and trying to replicate the results in the model. For stormwater models, calibration presents some challenges due to several factors that can introduce uncertainty in the results. These factors include the following:

- Non-uniform precipitation over the watershed. This is especially true for large watersheds.
- Availability of accurate time scale precipitation data for the entire watershed.
- Assumptions made in the model for soil and surface cover types.
- Irregular cross sections of natural channels and waterways.
- Dynamic tailwater conditions.
- Unknown blockages in the pipes.
- Assumptions made for roughness/entrance loss/exit loss coefficients for the pipes, culverts, channels, and waterways.

5.5.1 Model Calibration Storm Event Selection

Selection of the appropriate storm event is critical to achieving a tight calibration of a stormwater model. The storm event should be selected such that spatial distribution of precipitation is relatively uniform across the watershed and accurate information is available for the intensity and duration of the storm. Data such as flowrates or stages in conveyance systems and high water mark elevations should also be available for the selected storm. Based on review of the rainfall data over the past few years, Hurricane Irma was the chosen one since it had the best available/relevant data needed for calibration.

Precipitation data for Hurricane Irma were obtained in custom binary format from the Earth Observing Laboratory website affiliated with NOAA. The data were obtained for the NEXRAD 4Km x 4Km grids that covered the watershed. The precipitation was assumed to be uniform within a grid. The binary precipitation data were processed using the following tools and steps to the desired ICPR format as detailed below:

1. Grid files downloaded from National Weather Service (NWS) were used to convert the raw binary data into ASCII format.
2. A script was created to convert the binary data with each hour, 6-hour, or as desired. The output values were written into a text file.
3. Data were converted into the ICPR format.

The shapefile and the precipitation data were brought into the model and converted to a raster. The DuWap watershed spreads across three NEXRAD grids. The model extracted the precipitation data from the shapefile for each grid and applied it to all the sub-basins located within that grid.

After entering the precipitation data, the model was simulated for 192 hours from September 7 to 14, 2017, and the water surface elevations predicted by the model were compared to the surveyed high water marks as shown on **Figure 5-6**.

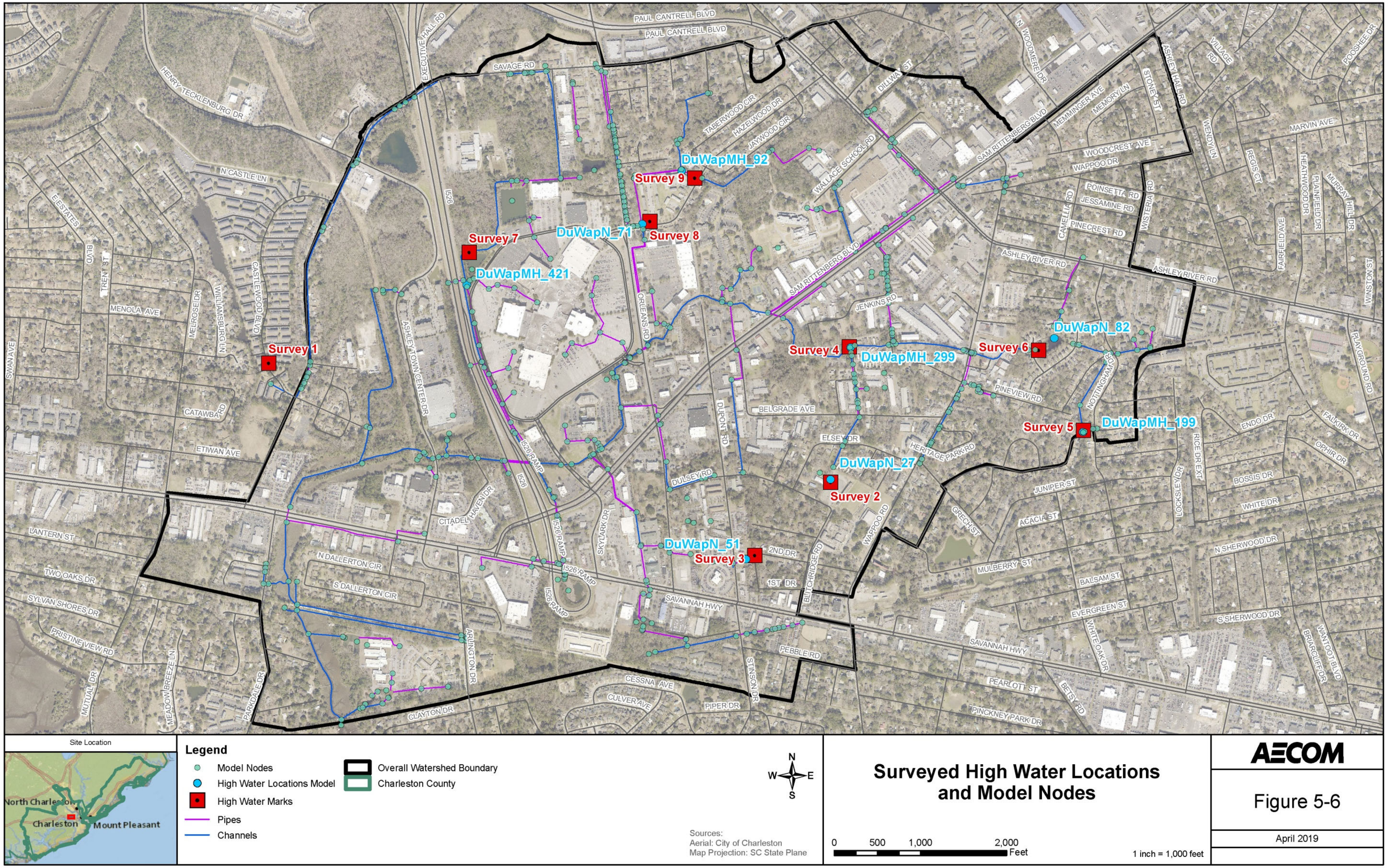


Figure 5-6. Surveyed High Water Locations and Model Nodes

Based on the results, several parameters were adjusted to bring the high water elevations predicted by the model in line with the surveyed high water marks and to match modeled flooding locations with the known location of flooding from the flooding hotspots map.

5.5.2 Calibration Parameter Adjustments

The parameters that were adjusted to bring the modeled maximum water level elevations in line with the observed high water level marks are as follows:

- **Adjustments to the condition assessment data**. The condition assessment quantified the blockage in the pipes in wide ranges. For example, pipe blockages were divided into the following ranges:
  - 0–25 percent
  - 25–50 percent
  - 50–75 percent

  To be conservative, initially the higher blockage percentage was used in the model. During calibration some of these blockages were adjusted between the upper and lower limits of the range.
- **Pipe entrance and exit loss coefficients**. Initially all pipes were assigned an entrance loss coefficient of 0.5 and an exit loss coefficient of 0.45. Loss coefficients were adjusted for a few selected pipes during calibration.
- **Channel Manning's roughness coefficient "n."** All the channels in the network were initially assigned a roughness coefficient of 0.035. During calibration, some of the roughness coefficients were reduced as needed.
- **Addition of stage area**. Some of the nodes showed a higher maximum stage than observed high water marks. Small amounts of surface storage were either added to those nodes or to the nodes near those nodes to reduce the maximum stage elevation.

Appendix I provides the log of all modifications made to the model during the calibration process.

5.5.3 Model Calibration Results Summary

The high water marks at the eight surveyed locations were compared to the modeled results from nodes located at or near those locations to check the accuracy of the model against the surveyed data. The results are shown in **Table 5-8**.

Table 5-8. Surveyed High Water Marks Compared to Model Results

Surveyed Location	Model Nodes Corresponding to Surveyed Locations	High Water Mark Surveyed Locations	High Water Elevation Model Results	Difference Survey versus Model
Survey-2	DuWapN_27	10.14	10.52	0.38
Survey-3	DuWapN_51	10.91	11.36	0.45
Survey-4	DuWapMH_299	8.01	8.47	0.46
Survey-5	DuWapMH_199	11.44	11.45	0.01

Surveyed Location	Model Nodes Corresponding to Surveyed Locations	High Water Mark Surveyed Locations	High Water Elevation Model Results	Difference Survey versus Model
Survey-6	DuWapN_82	11.35	11.01	−0.34
Survey-7	DuWapMH_421	7.57	8.10	0.53
Survey-8	DuWapN_71	8.51	8.15	−0.36
Survey-9	DuWapMH_92	9.14	9.57	0.44

The modeled results show that after calibration, at seven of the eight locations, the modeled high water elevations are within 0.50 feet of the surveyed high water elevations. At one location the surveyed high water elevation was 0.53 feet lower than the modeled high water elevation. **Figure 5-7** shows the locations listed in **Table 5-8** with departure of model data from the observed data.

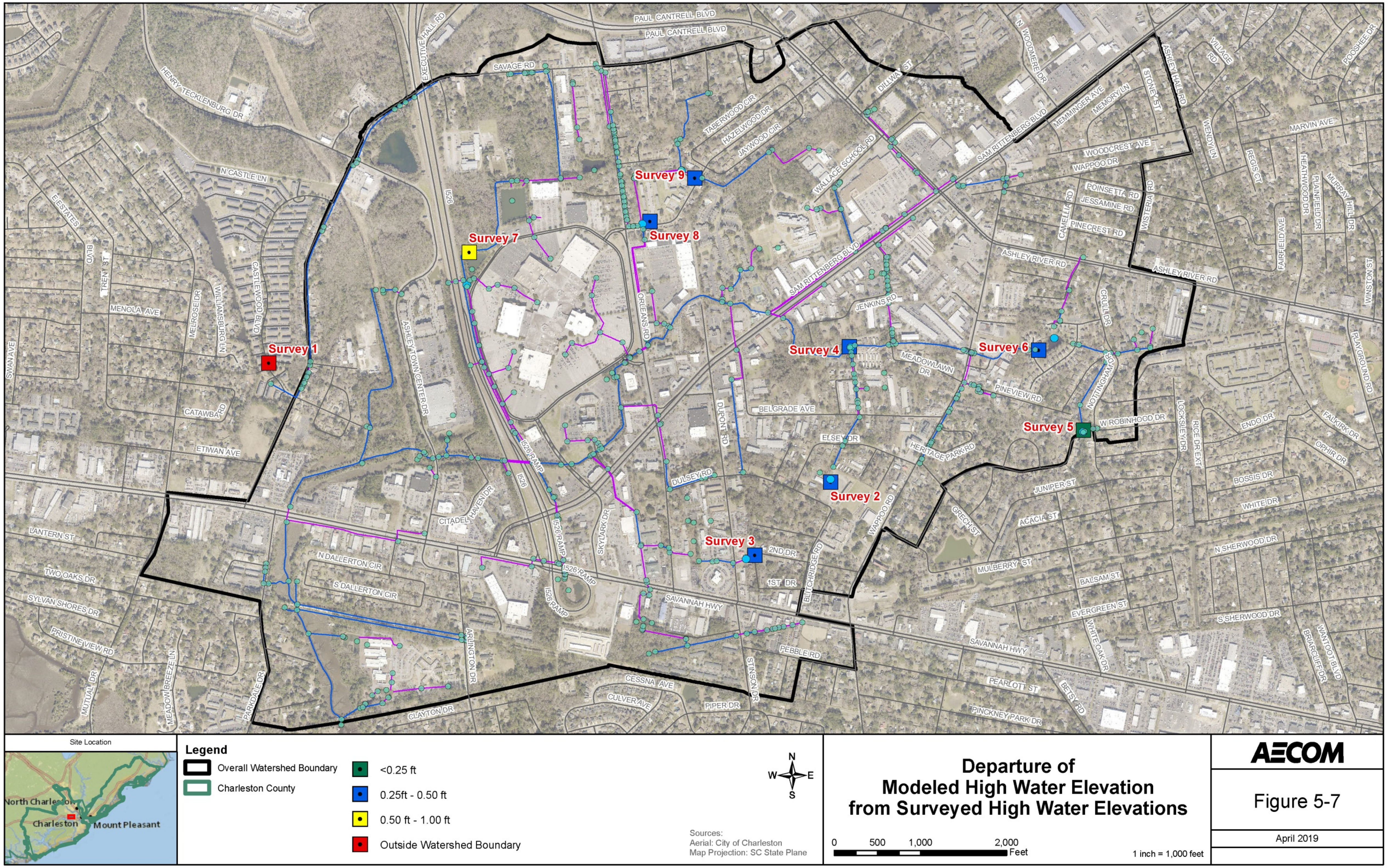


Figure 5-7. Departure of Modeled High Water Elevation from Surveyed High Water Elevations

6. Sea Level Rise and Storm Surge Considerations

Dynamic tailwater conditions were developed for the DuWap watershed to account for potential storm surge and sea level rise impacts. These dynamic boundary conditions were necessary to evaluate the response of the City's stormwater infrastructure (or system) to varying water levels and storm scenarios over a 24-hour ICPR simulation. The modeling results were used to identify problems in the drainage system, make recommendations for proposed drainage improvements, evaluate the performance of drainage improvements, and evaluate the response of the stormwater system to potential future conditions.

6.1 Sea Level Rise Determination

Three sea level rise predictions were estimated using NOAA equations (2017) employed within the USACE Sea-Level Change Curve Calculator (2017). The three predictions included a range covering "low," "intermediate," and "high" predictions for 25-year, 50-year, and 100-year horizons. **Table 6-1** summarizes the NOAA computed sea level rise values for each of the horizons. **Figure 6-1** depicts the NOAA computed sea level rise over the 100-year period.

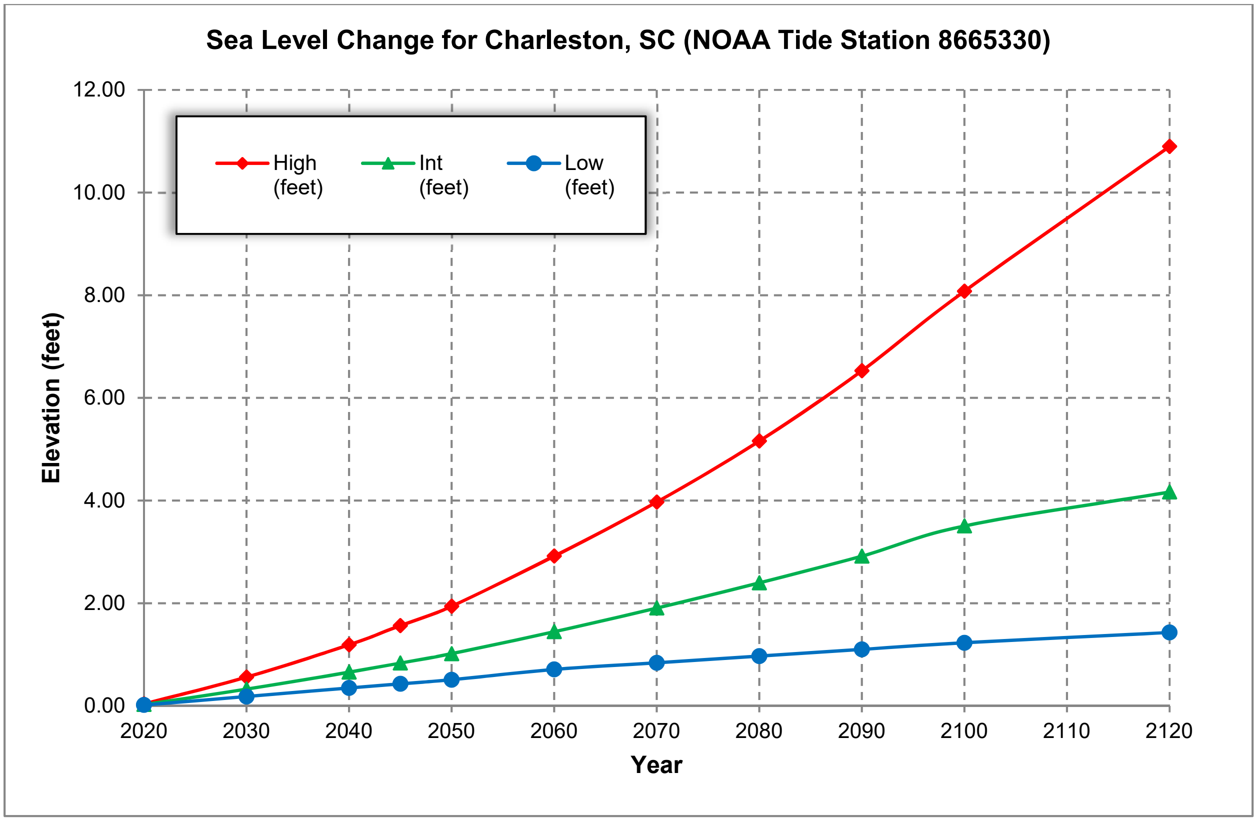
Table 6-1. Estimated Sea Level Rise for Charleston, South Carolina

DuWap Watershed Sea Level Change for Charleston, SC (NOAA Tide Station 8665330)			
Year	**Low (feet)**	**Intermediate (feet)**	**High (feet)**
2019	0.00	0.00	0.00
2020	0.02	0.03	0.04
2030	0.18	0.33	0.56
2040	0.35	0.66	1.19
2045	0.43	0.84	1.57
2050	0.51	1.02	1.94
2060	0.71	1.45	2.92
2070	0.84	1.91	3.97
2080	0.97	2.40	5.16
2090	1.10	2.92	6.53
2100	1.23	3.51	8.08
2120	1.43	4.17	10.90

Source: NOAA 2017.

Note: NOAA2017 VLM: 0.00417 feet/year

Three sea level rise predictions were added to each of the storm surge time series and a 24-hour tide water level prediction was applied to create representative dynamic boundary conditions for the 24-hour rainfall simulations in the ICPR modeling.



Source: NOAA 2017.

Figure 6-1. Estimated Sea Level Rise Projections for Charleston, South Carolina

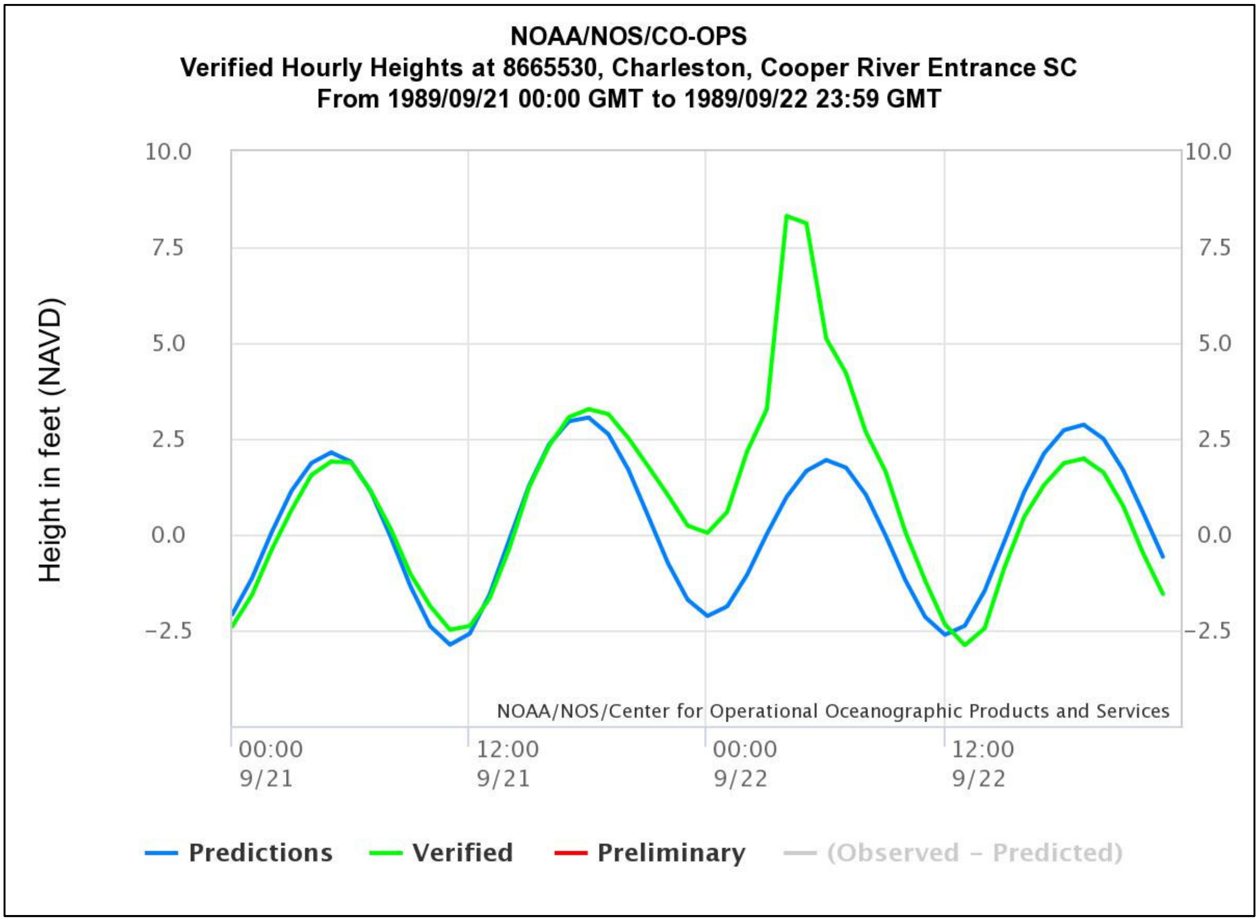
6.2 Storm Surge Determination

Representative storm surge hydrographs were required to provide dynamic boundary conditions for simulations of peak storm surge potentially arriving coincident with high tide for a range of hypothetical storm surge levels (i.e., 2-year to 100-year return periods). The hydrographs were developed to cover a range of "n-year" surge events occurring within the 24-hour rainfall simulation (i.e., worst-case scenarios) modeled within ICPR. Representative surge conditions were also combined with the NOAA sea level rise estimates to include simulations that accounted for surge plus sea level rise scenarios.

Several methods exist to develop storm surge hydrographs ranging from purely synthetic using statistics, using a historic event (e.g., extracting the surge component or residual from measured water levels during Hurricane Hugo), or a hybrid approach (i.e., developing a representative mathematical function or distribution of measured water levels replicating a surge time series) superimposed to fit estimated peak flood levels (i.e., n-year estimates). The hybrid approach was selected for developing the surge hydrographs used for the ICPR model's dynamic boundary conditions.

The overall goal of the hybrid approach was to fit a mathematical distribution to a real-world time series data set of an actual hurricane that impacted the area to provide a flexible means of developing a range of surge hydrographs from minor to extreme levels (i.e., 2-year to 500-year events). To accomplish this, the distribution was scaled to fit various n-year surge peaks to provide 24-hour dynamic boundary condition that included surge with sea level rise (sea level rise was added to surge).

The most notable hurricane with a complete record of measured water levels was Hurricane Hugo measured at NOAA's Cooper River tide station (i.e., 8665330). **Figure 6-2** depicts the measured water levels and the storm surge that occurred during Hurricane Hugo and captured the storm surge peak (versus missing peaks due to damaged or inoperable gages).



Source: NOAA 2017.

Figure 6-2. Hurricane Hugo Measured Water Levels (i.e., actual time series of flood levels)

Although more extensive means to extract the surge residuals from tidally influenced measured water levels exist (e.g., Fourier spectral analysis on time series of water level signals), a simplified approach for this modeling effort involved subtracting the predicted tide water levels from the verified water levels over an approximate 24-hour period to extract a representative surge residual. Using this residual as a proxy to guide the shape of synthetically derived surge hydrographs, the next step was to apply a gamma distribution and fit it to replicate the Hurricane Hugo surge time series water level. Following adjustments (i.e., gamma distribution coefficients and peak-to-peak phasing), a final gamma distribution was developed that aligned reasonably well (in terms of peak, duration, and spread) with the Hugo-derived hydrograph as shown in **Figure 6-3**.

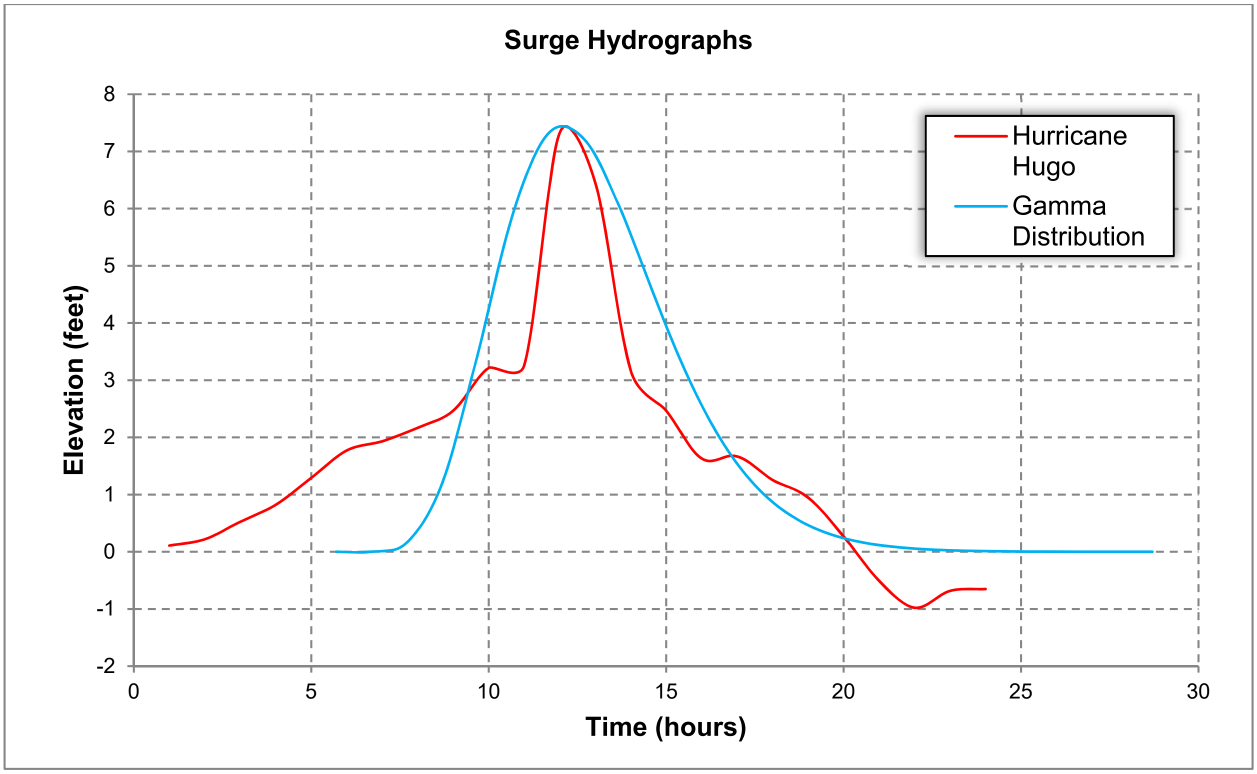


Figure 6-3. Synthetic Derived Hydrograph based on Hurricane Hugo

To scale the gamma-based hydrograph to any probability for any given year, peak values for those years were used to scale the Hugo-based gamma-distribution. These peaks were based on flood frequency elevations estimated from NOAA's Extreme Water Levels (EWL) program FEMA's Flood Insurance Study (2016). The NOAA EWL values estimated at the NOAA Cooper River tide station (i.e., 8665330) provided a reasonable estimate for high frequency distributions; likewise, FEMA's FIS Stillwater elevations (SWEL) provided reasonable estimates for the lower-frequency levels (i.e., 50-year to 500-year return periods). The final values used to scale gamma distributions are based on a combination of NOAA and FEMA estimates as shown in **Table 6-2** and on **Figure 6-4**.

Using the ratio of the peak gamma distribution to the peak "n-year" values, a set of "n-year" gamma distributions was created by multiplying each "n-year" ratio by the gamma distribution. When combined with a representative tide signal (and aligning peak tide water levels with peak surge), the final "n-year" surge hydrographs were developed. A sea level rise value of 0.84 feet (representing the 25-year sea level rise, or in 2045) was added to each of the "n-year" hydrographs to produce the final set of dynamic boundary conditions or time series water levels as shown on **Figure 6-5**. In summary, this set of dynamic boundary conditions for the 24-hour simulations included the elements of (1) surge, (2) sea level rise in 2045, and (3) phase alignment to replicate peak tide water levels coincident with peak surge (i.e., worst-case scenarios). AECOM acknowledges that the boundary conditions developed and graphically represented in Figure 6-5 includes stacking of the astronomical tide, surge, and SLR, which is extremely conservative and used for the purpose of master planning. However, it is recommended that boundary conditions be revisited and revised as needed at the time of entering the design phase for each proposed improvement.

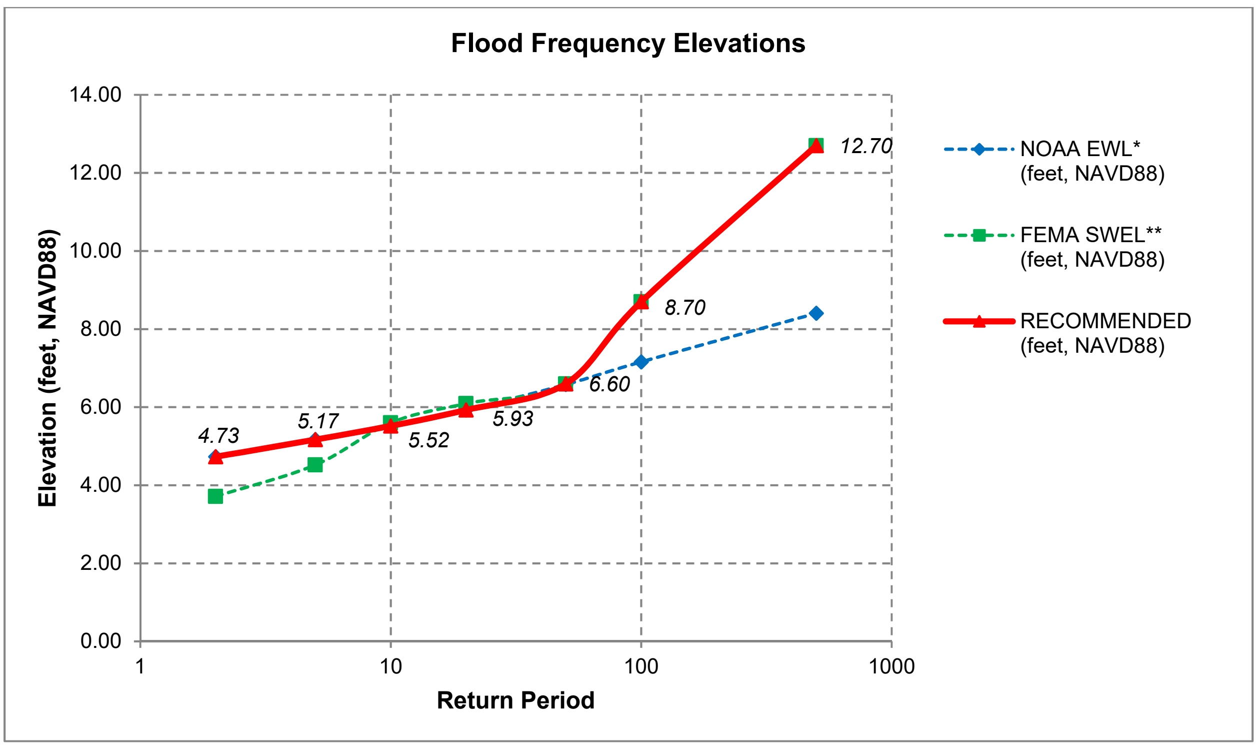
Table 6-2. Frequency Distributions for "n-year" Peak Values

DuWap Watershed NOAA Extreme Water Levels & FEMA Stillwater Elevations			
Return Period (N-Year)	NOAA EWL [a] (feet, NAVD88)	FEMA SWEL [b] (feet, NAVD88)	RECOMMENDED (feet, NAVD88)
2	4.73	3.71	4.73
5	5.17	4.52	5.17
10	5.52	5.60	5.52
20	5.93	6.09	5.93
50	6.58	6.60	6.60
100	7.16	8.70	8.70
500	8.41	12.70	12.70

[a] *NOAA Extreme Water Levels Tide Station 8665330 (Charleston, Cooper River Entrance SC).*

[b] *FEMA Preliminary FIS (Charleston County, SC, September 9, 2016) @Transect 116.*

Note: The combined frequency distribution represents the peak values used for scaling.



Note The combined frequency distribution represents the peak values used for scaling.

Figure 6-4. Frequency Distributions for "n-year" Peak Values

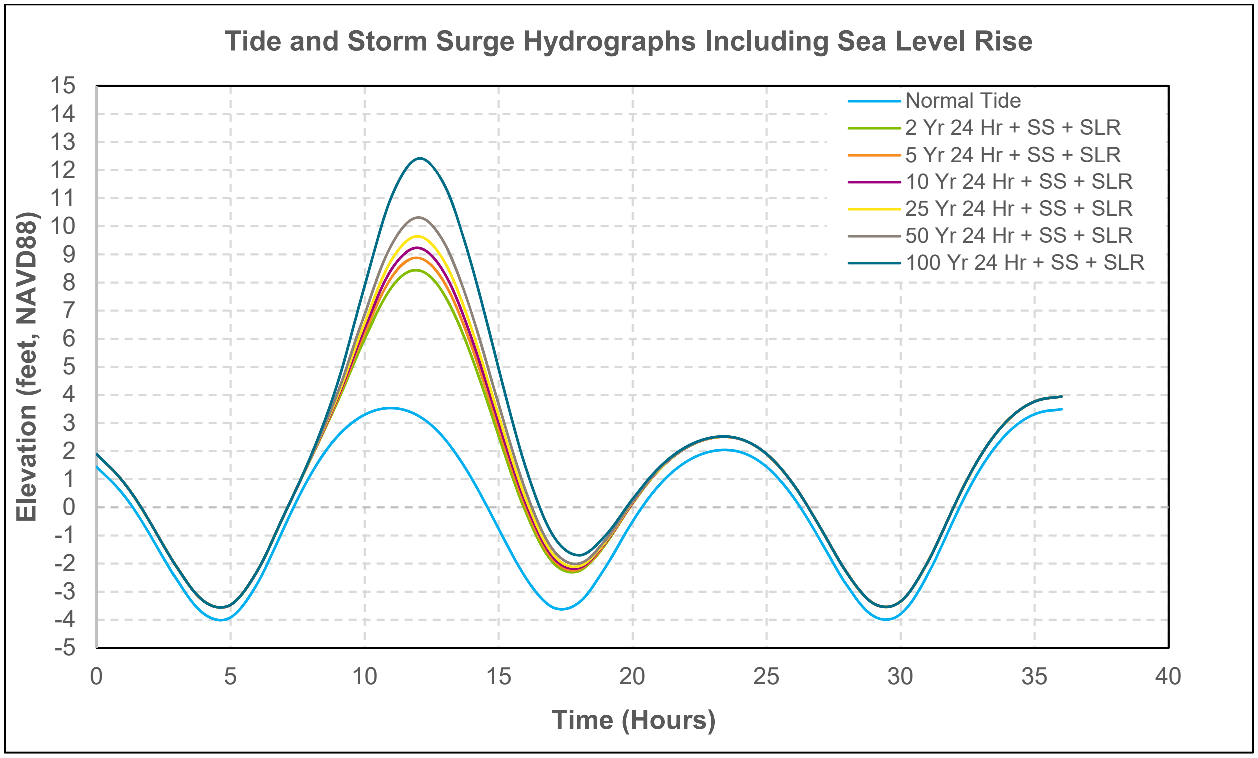


Figure 6-5. Dynamic Boundary Conditions for 24-hour Simulations

6.3 Final Existing Conditions Model Analysis with Sea Level Rise and Storm Surge

The calibrated model was simulated for the design storm events with the inclusion of storm surge and sea level rise and the results are summarized below.

The DuWap watershed is drained by a channel that runs from the eastern corner of the DuWap watershed near the intersection of Wappoo Road and Pineview Road to the basin outfall at the southwestern end of the watershed near Lamb Street. Flooding is exacerbated by the tidal influence in the channel as well as the storm surge. This channel is the principal outlet for the DuWap watershed. Flooding in this channel prevents runoff from the other areas of the watershed from draining freely.

Each node in the model was assigned an initial stage and a warning stage. The initial stage is the water surface elevation at a node before the beginning of the precipitation. The warning stage is the ground surface elevation at the node. The model calculates the elevation of the water surface at each node in the model throughout the selected simulation duration and records the maximum value (maximum stage). If the maximum stage at a node is higher than the warning stage, it indicates that the node is experiencing flooding. The depth of flooding is calculated by subtracting the warning stage, which is also the ground surface elevation at the node, from the maximum stage, which is the highest water surface elevation calculated by the model for that node. When the water level reaches the ground surface for a particular node or above the warning stage, the model determines the maximum/peak water levels by accounting for the stage-area relationship incorporated into the model. The stage-area relationship is provided for each 1-foot increment and the model calculates the storage volume for each incremental depth above the warning stage.

Based on the evaluation of results from the 2-year 24-hour design storm to the 100-year design storm event, the existing conditions model with the incorporated condition assessment data shows that several locations across the DuWap watershed have a high potential for flooding. The degree and depth of flooding varies depending on the type of design storm event selected.

Figure 6-6, **Figure 6-7**, and **Figure 6-8** depict the model nodes that experience flooding during a 2-year 24-hour storm, 25-year 24-hour storm, and 100-year 24-hour storm, respectively. The nodes in the figures are color coded to show the extent of flooding. The flooding extent is broken into five categories (shown on Figures 6.6 through 6.8) ranging from minimal flooding with flooding depth of less than 6 inches to major flooding with flooding depth exceeding 2 feet. The flooding depth calculated by the model includes the effect of the tide and the storm surge in the main drainage channel. All the nodes shown on the figures as flooding may not experience flooding at the same time. **Appendix J** summarizes the initial stage, warning stage, maximum stage, and depth of flooding at each node for each storm event. **Appendix K** includes the maximum flow rate, minimum flow rate, and maximum flow velocity in each link (pipe, culvert, or channel) for each storm event.

The flooding maps along with the assessment of the existing assets are evaluated and analyzed in the next chapter. The analysis scores the assets both in terms of flooding and condition and then flood-prone areas are prioritized in order of importance for system improvements.

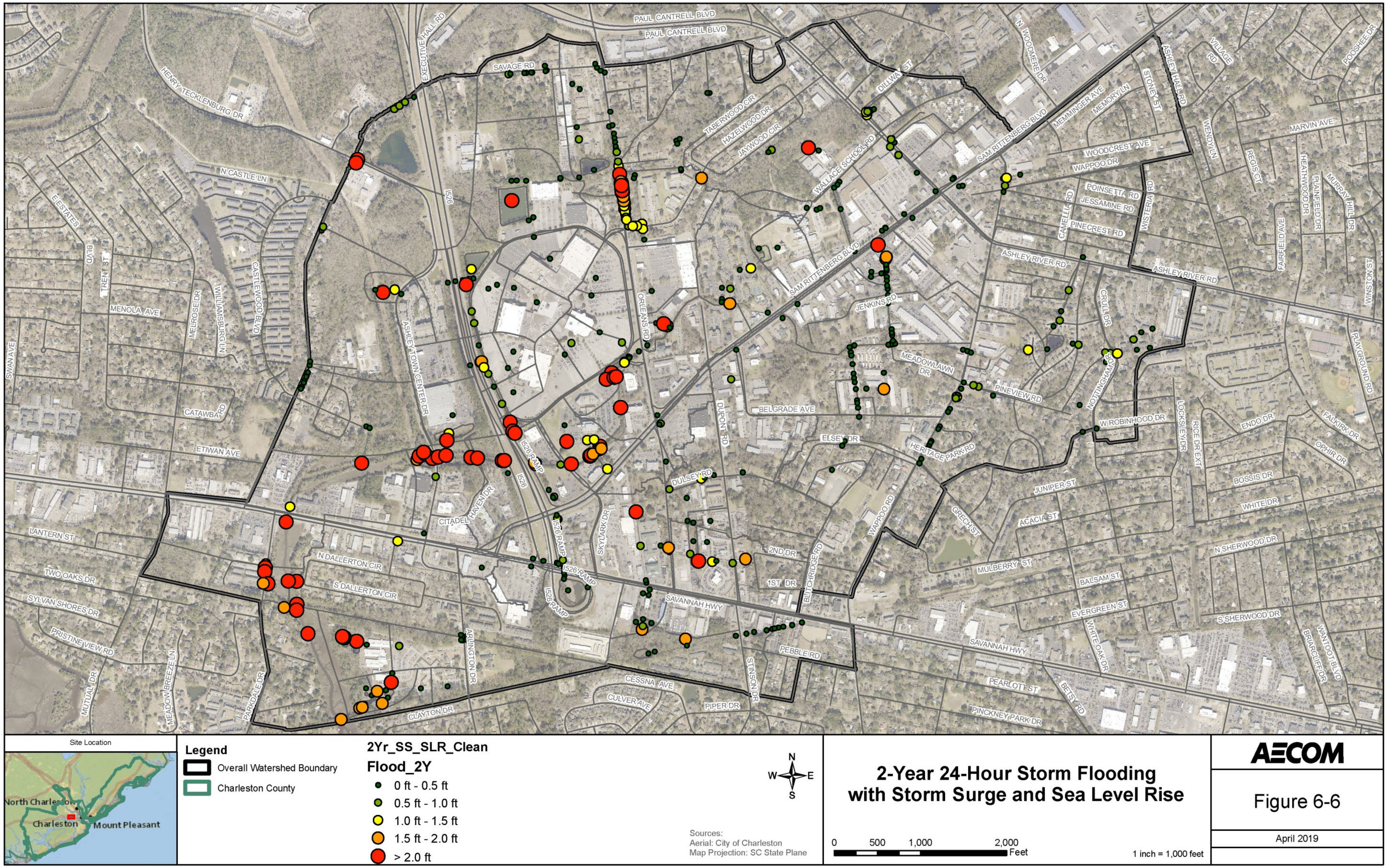


Figure 6-6. 2-Year 24-Hour Storm Flooding with Storm Surge and Sea Level Rise

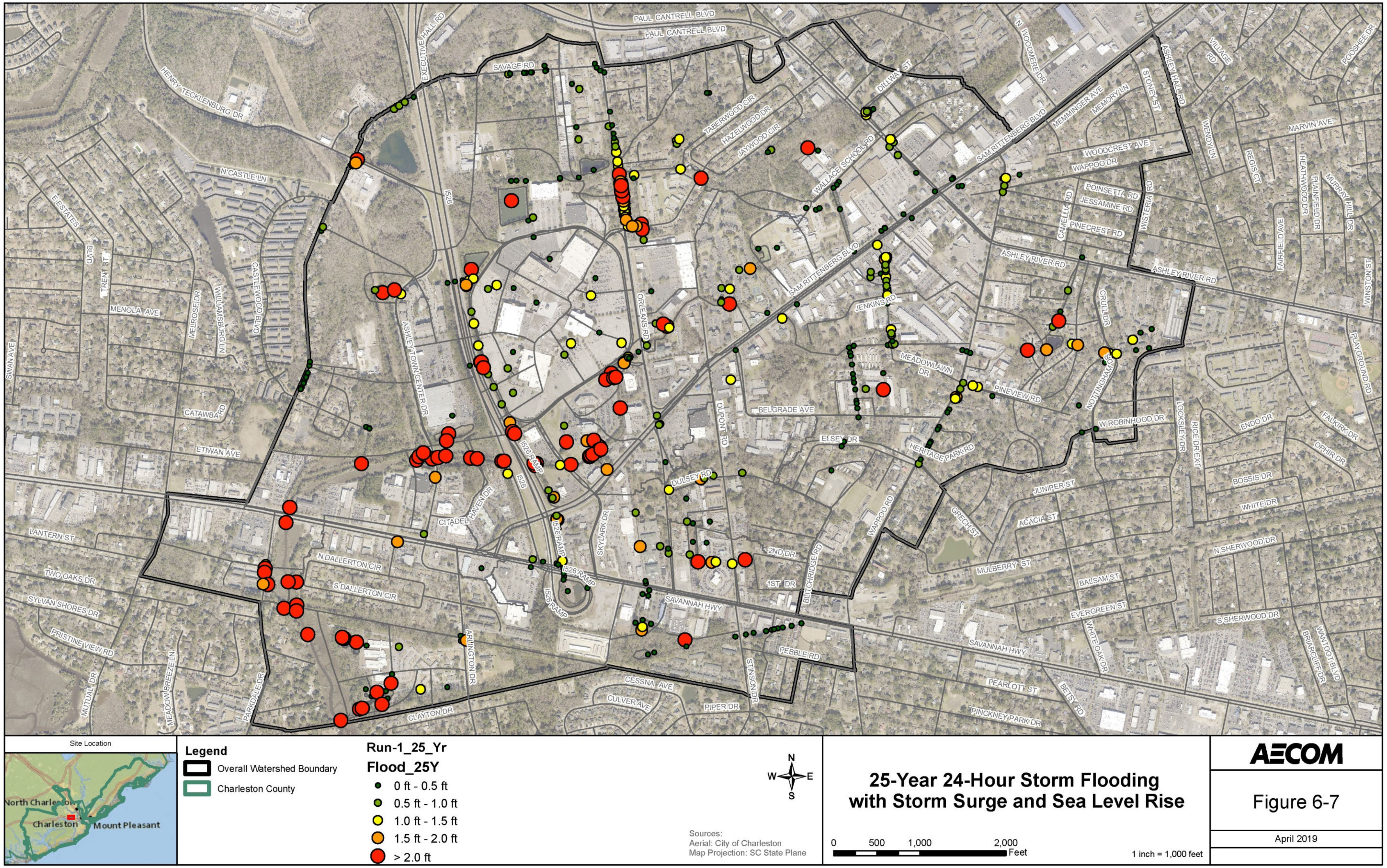


Figure 6-7. 25-Year 24-Hour Storm Flooding with Storm Surge and Sea Level Rise

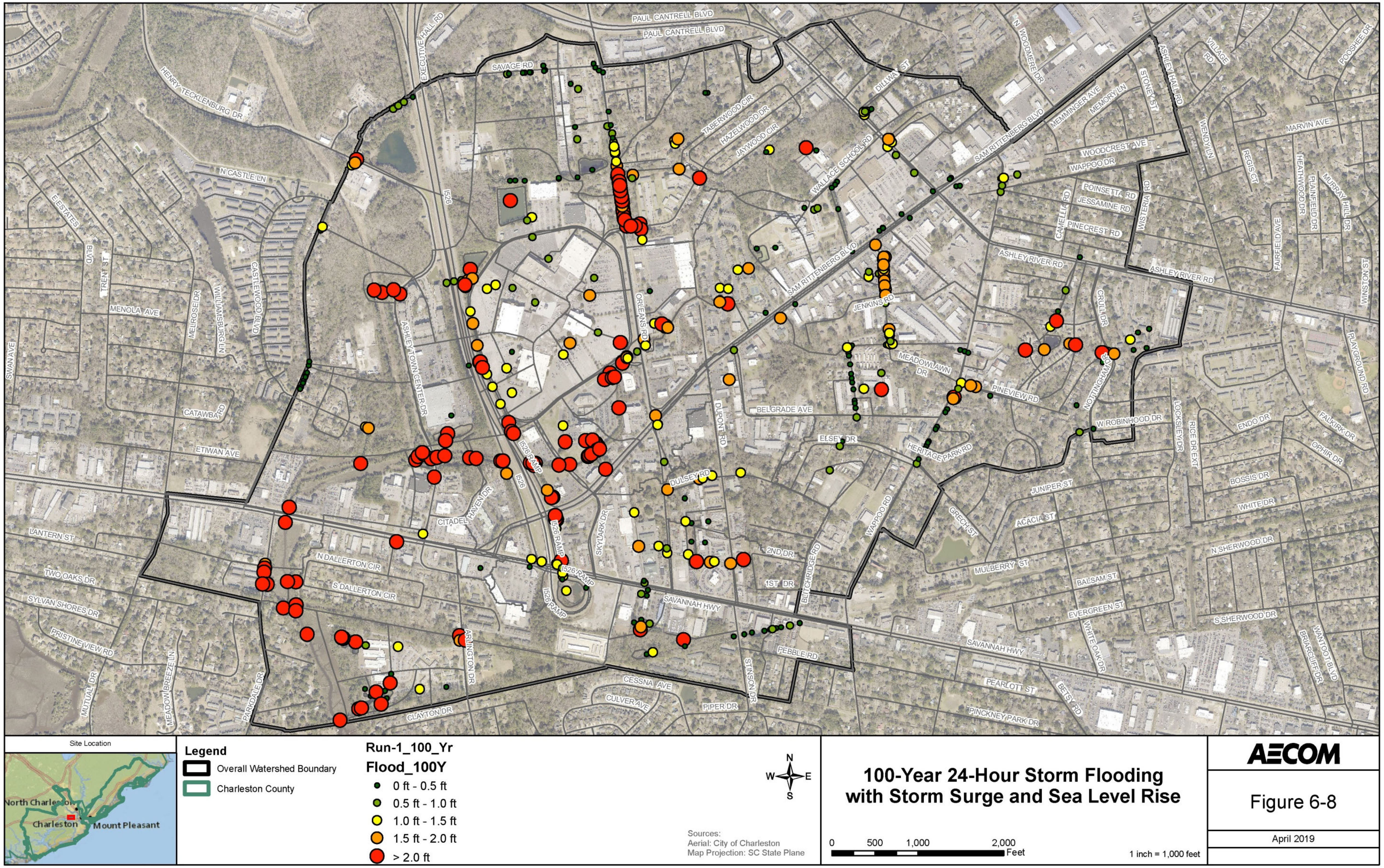


Figure 6-8. 100-Year 24-Hour Storm Flooding with Storm Surge and Sea Level Rise

7. Prioritization of Existing Stormwater Assets

To recommend or propose system improvements based on the desired LOS, it is important to develop a matrix that prioritizes the existing assets both in terms of condition and system capacity/flooding. Prioritizing the key segments for assessment allows the team to review condition data in conjunction with model results to identify proposed projects with multiple benefits that will provide the greatest cost-benefit to the City.

Prioritization and ranking of the assets in terms of condition and flooding was performed by the following steps:

1. Selection of assets
2. Condition assessment metrics and scoring
3. Flood resiliency metrics and scoring
4. Prioritization and ranking of assets for proposed projects/system improvements

7.1 Selection of Stormwater Assets

A detailed stormwater structure inventory of over 3,000 assets was done to document the stormwater system extent and condition. All pipes over 15 inches in diameter were included in the inventory.

For the purpose of this analysis, 1,208 pipes, culverts, and channels (links) and 330 manholes, inlets, and outlets (junctions) across the DuWap watershed were selected from the structure inventory.

The assets selected from the inventory were based on the assets used in the modeling. This included most or almost all the primary and secondary conveyance systems. This amounted to 552 culverts/pipes and 178 structures. For the remaining assets, select tertiary systems were also included based on known locations of flooding from the model results for different design storm events and based on chronic flooding identified by the City. Localized systems that would not have significant impact on the overall system were generally not included in the modeling and were eliminated from the inventory assessment.

A summary of these features is included on **Figure 7-1** and in **Table 7-1**. **Appendix L** includes a list of assets selected for the analysis.

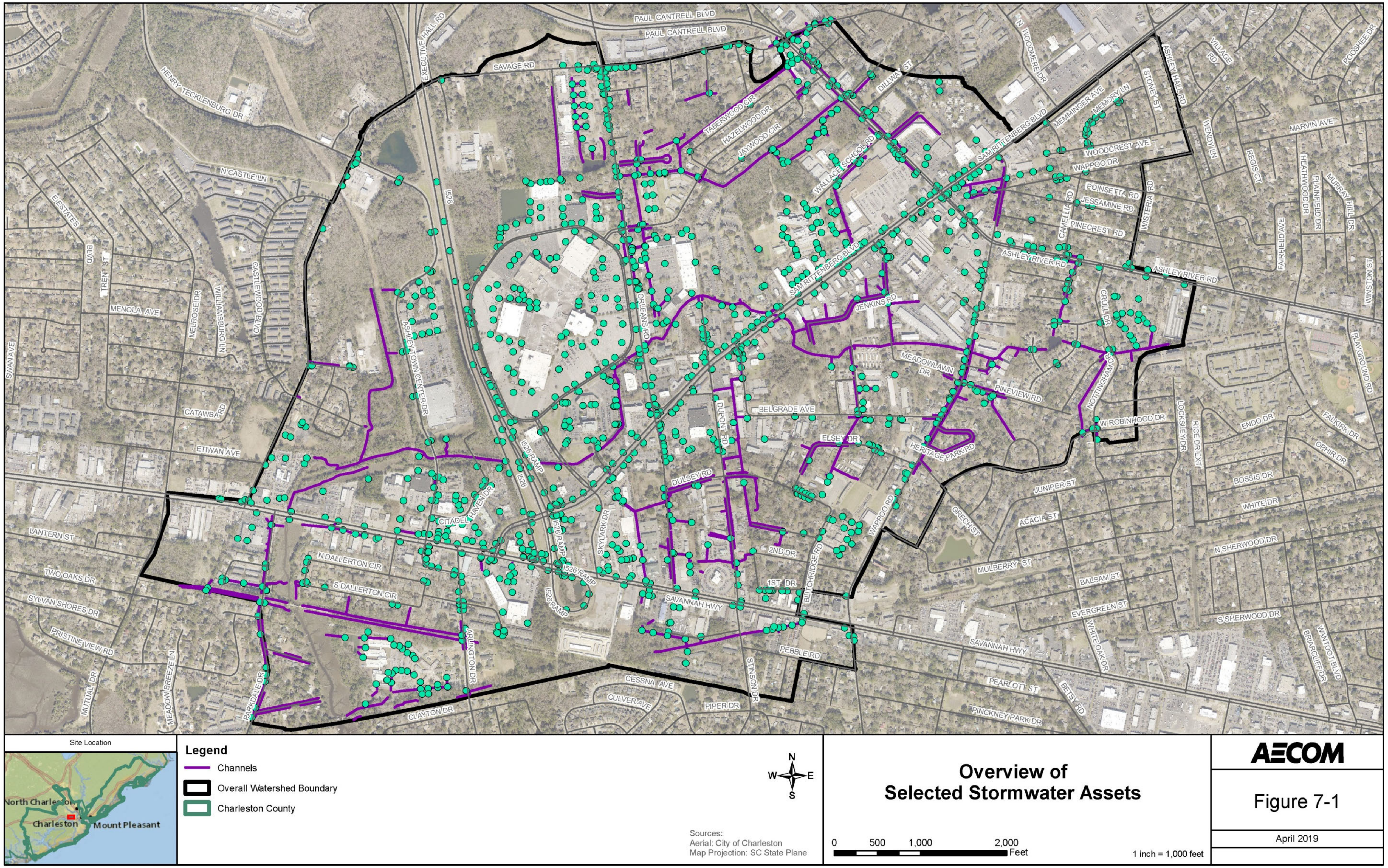


Figure 7-1. Overview of Selected Stormwater Assets

Table 7-1. Stormwater Inventory Overview

Asset	Number Inventoried	Percentage
Inlets	237	15.4%
Manholes	83	5.4%
Outlets	10	0.7%
Pipes	529	34.4%
Culverts	234	15.2%
Channels	445	28.9%
TOTAL	**1,538**	**100%**

7.2 Condition Assessment Metrics and Scoring

The condition assessment metrics followed the procedures outlined in the Dupont-Wappoo Watershed Master Plan SOP (**Appendix B**). The metrics used in the condition assessment were dependent on the types of defects likely encountered during the field visit, as well as the types of repairs likely needed.

The methodology outlined in the SOP for the stormwater infrastructure condition assessment was partially adapted from the National Association of Sewer Service Companies (NASSCO) standards for condition assessment of sanitary sewer systems. Due to the similarities between sanitary sewer and stormwater infrastructure, NASSCO Pipeline Assessment Certification Program (PACP) and Manhole Assessment Certification Program (MACP) standards are applicable to stormwater pipes, culverts, manholes, and junctions. The PACP and MACP (hereinafter NASSCO) standards were simplified and modified in the SOP to better represent the City's goals and use of the stormwater condition assessment data and to represent conditions typically found in stormwater systems.

For each feature class included in the inventory as discussed in Chapter 4, a descriptor or modifier was assigned to detail the pipe condition. Descriptors and modifiers are discussed in more detail in the following sections. Pipe condition was noted for all pipe segments unless prevented by a maintenance, access, or traffic issue. The condition assessment was limited to observations of defects that were visible to the survey crew and could be seen on the pole camera screen or video. The range of the pole camera is approximately 50 feet of zoom inside a pipe, depending on light conditions.

7.2.1 Descriptors

Descriptors provide further description of the problem such as different types of erosion, obstructions, or surface damage. Pipe defects were broken into three categories: structural, O&M, and supplemental stormwater as detailed in **Table 7-2**.

Table 7-2. Stormwater Asset Defects

Feature Class (Asset)	Defect Category	Defect
Inlets Manholes/Junctions Outlets Pipes Culverts Channels BMPs	Structural Defects	Crack Fracture Broken Hole Deformed (≤40% XS area) Collapse (>40% XS area) Joint Surface Damage Brick/Block/Rock Decayed Sag
	O&M Defects	Deposits (≤25% XS area) Obstruction (>25% XS area) Roots Infiltration
	Supplemental Stormwater Defects	Erosion Vegetation Submergence

7.2.2 Modifiers

Modifiers indicate the severity of a defect. Each defect was assigned a single descriptor and a single corresponding modifier where appropriate. For a few defect categories the severity is classified within the descriptor itself and thus a separate modifier was not associated with that defect. For example, the descriptor “deposit” was assigned to areas with less than a 25 percent blockage; blockages greater than 25 percent were considered an obstruction. For pipe segments where multiple similar defects (e.g., multiple cracks) were identified, a higher severity rating of moderate or severe was assigned to the feature. Modifiers used in the condition assessment are defined in **Table 7-3**.

7.2.3 Condition Assessment Scoring

The condition of assets is a key factor in ranking and prioritizing improvements. The stormwater condition assessment data were used for this assessment. As previously noted, defects were identified for every pipe and structure inspected during the data collection task. An asset database was developed that mapped each asset and assigned a defect descriptor (if applicable) and a defect code. This code defines the type and often the source of the defect. The asset codes were translated into the stormwater condition assessment defect categories listed in **Table 7-4**.

Table 7-3. Stormwater Asset Modifier Descriptions

Defect Category	Modifier	GIS Code	Description
Structural (except sag)	Minor	Minor	Few defects visible
	Moderate	Moderate	Multiple defects visible; deterioration may continue
	Severe	Severe	Risk of failure due to defects

Defect Category	Modifier	GIS Code	Description
Structural – Sag	<30%	LT30	< 30% cross-sectional area affected
	30-50%	30to50	30-50% cross-sectional area affected
	>50%	GT50	> 50% cross-sectional area affected
O&M - Obstruction	<50%	LT50	< 50% cross-sectional area affected
	50-75%	50to75	50-75% cross-sectional area affected
	>75%	GT75	> 75% cross-sectional area affected
Supplemental Stormwater - Erosion	Minor	Minor	Rill – very small incision eroded into soil due to runoff; loss of vegetation; point erosion
	Moderate	Moderate	Gully – distinct, narrow incitements, larger and deeper than rills
	Severe	Severe	Potential failure of bank
Supplemental Stormwater – Submergence	Limited	Limited	Few defect areas
	Patchy	Patchy	Multiple defect areas
	Extensive	Extensive	Defect covers most of the area
	<25%	LT25	< 25% cross-sectional area is submerged
	25-50%	20to50	25-50% cross-sectional area is submerged
	>50%	GT50	> 50% cross-sectional area is submerged

Table 7-4. Stormwater Asset GIS Descriptors

Asset Code	Defect Category	Defect, Descriptor
DCON	O&M Defects	Deposit, Concrete
DGAR	O&M Defects	Deposit, Garbage
DGRV	O&M Defects	Deposit, Gravel
DSED	O&M Defects	Deposit, Sediment
DWOD	O&M Defects	Deposit, Woody Debris
DZ	O&M Defects	Deposit, Other
OBB	O&M Defects	Obstruction, Brick or masonry
OBB	O&M Defects	Obstruction, Buried
OBI	O&M Defects	Obstruction, object intruding through wall
OBN	O&M Defects	Obstruction, construction debris
OBP	O&M Defects	Obstruction, external pipe/cable
OBRG	O&M Defects	Obstruction, Gravel/Rocks
OBZ	O&M Defects	Obstruction, Other
OGAR	O&M Defects	Obstruction, Garbage
OSED	O&M Defects	Obstruction, Sediment
OWDD	O&M Defects	Obstruction, Woody Debris
RB	O&M Defects	Roots, Ball

Asset Code	Defect Category	Defect, Descriptor
RF	O&M Defects	Roots, Fine
RT	O&M Defects	Roots, Tap
DB	Structural Defects	Brickwork, displaced
JO	Structural Defects	Joint, Offset
JS	Structural Defects	Joint, Separated
MB	Structural Defects	Brickwork, missing
MM	Structural Defects	Missing Mortar
EBKES	Supplemental Stormwater Defects	Erosion, Bank Erosion/Scour
EBMES	Supplemental Stormwater Defects	Erosion, Bottom Erosion/Scour
SAG	Structural Defects	Sag
SMFW	Supplemental Stormwater Defects	Submergence, Flowing Water
SMSW	Supplemental Stormwater Defects	Submergence, Standing Water
SRC	Supplemental Stormwater Defects	Surface damage, reinforcement corroded
VGS	Supplemental Stormwater Defects	Vegetation, Growth on Structure
VOG	Supplemental Stormwater Defects	Vegetation, Overgrown
VTB	Supplemental Stormwater Defects	Vegetation, Trees/Brush

To help characterize the results of the assets, some common defects identified for pipes/channels and structures are included in **Table 7-5** and

Table 7-6. Defects were not identified for 26 percent of pipes/channels and 36 percent of structures included in the assessment. Of the defects identified, deposits and vegetation were common defects for pipes/channels and deposits and standing water were the most common defects for structures.

Table 7-5. Stormwater Asset Defect Summary – Pipes/Channels

Defect Descriptors	Number	Percentage
Deposit, Garbage	4	0.3%
Deposit, Gravel	3	0.2%
Deposit, Sediment	203	16.6%
Deposit, Woody Debris	60	4.9%
Deposit, Other	1	0.1%
Erosion, Bank Erosion/Scour	29	2.4%
Erosion, Bottom Erosion/Scour	1	0.1%
Joint, Offset	4	0.3%
Joint, Separated	150	12.3%
Obstruction, Buried	37	3.0%
Obstruction, object intruding through wall	12	1.0%
Obstruction, construction debris	2	0.2%

Defect Descriptors	Number	Percentage
Obstruction, external pipe/cable	6	0.5%
Obstruction, Gravel/Rocks	4	0.3%
Obstruction, Other	6	0.5%
Obstruction, Garbage	3	0.2%
Obstruction, Sediment	8	0.7%
Obstruction, Woody Debris	100	8.2%
Roots, Ball	27	2.2%
Roots, Tap	3	0.2%
Sag	1	0.1%
Submergence, Flowing Water	1	0.1%
Submergence, Standing Water	4	0.3%
Vegetation, Growth on Structure	151	12.3%
Vegetation, Overgrown	1	0.1%
Vegetation, Trees/Brush	63	5.2%
Deposit, Garbage	17	1.4%
No Defect	322	26.3%
Grand Total	**1223**	**100%**

Table 7-6. Stormwater Assets Defect Summary – Structures

Defect Descriptors	Number	Percentage
Brickwork, displaced	4	1.2%
Deposit, Concrete	1	0.3%
Deposit, Garbage	5	1.5%
Deposit, Gravel	8	2.4%
Deposit, Sediment	78	23.6%
Deposit, Woody Debris	10	3.0%
Joint Offset	1	0.3%
Brickwork, missing	1	0.3%
Missing Mortar	1	0.3%
Obstruction, Brick or masonry	1	0.3%
Object intruding through wall	2	0.6%
Construction Debris	1	0.3%
Obstruction, Garbage	3	0.9%
Obstruction, Sediment	12	3.6%
Obstruction, Woody Debris	4	1.2%
Roots, Fine	1	0.3%
Submergence, Flowing Water	1	0.3%

Defect Descriptors	Number	Percentage
Submergence, Standing Water	81	24.5%
Surface damage, reinforcement corroded	1	0.3%
No Defect	114	34.5%
Grand Total	**330**	**100%**

To prioritize the repairs/replacements, numeric scoring criteria were used for the assets. The scoring criteria were developed in the SOP and applied to the selected assets. A summary of the assessment scoring criteria is included in **Table 7-7**.

Table 7-7. Stormwater Condition Assessment Scoring

	Defects	Descriptors	Modifiers	Condition Grade			
				No Mod.	Minor	Moderate	Severe
Structural Defects	Crack		Minor, Moderate, Severe		2	3	4
	Fracture		Minor, Moderate, Severe		3	4	5
	Broken		Minor, Moderate, Severe		3	4	5
	Hole		Minor, Moderate, Severe		3	4	5
	Deformed (≤40%)			4			
	Collapse (>40%)			5			
	Joint	Offset	Minor, Moderate, Severe		2	3	4
		Separated	Minor, Moderate, Severe		3	4	5
	Surface Damage	Spalling		2			
		Aggregate Visible		3			
		Rebar Exposed		4			
		Corrosion		5			
		Lining Failure		3			
		Other	Minor, Moderate, Severe		1	3	5
	Brick/Block /Rock	Displaced		3			
		Missing		4			
		Missing Mortar		2			
	Decayed		Minor, Moderate, Severe		2	3	4
				No Mod.	**<30%**	**30-50%**	**>50%**
	Sag		(<30%), (30-50%), (>50%)		2	3	4

	Defects	Descriptors	Modifiers	Condition Grade			
				No Mod.	Minor	Moderate	Severe
Operational & Maintenance (O&M) Defects				No Mod.	<30%	30-50%	>50%
	Deposits (≤25%)	Deposit Sediment		2			
		Deposit Gravel		2			
		Deposit Woody Debris		2			
		Deposit Concrete		2			
		Deposit Garbage		2			
		Deposit Other		2			
				No Mod.	<50%	50-75%	>75%
	Obstruction (>25%)	Sediment	(<50%), (50-75%), (>75%)				
		Gravel/Rocks	(<50%), (50-75%), (>75%)		3	4	5
		Woody Debris	(<50%), (50-75%), (>75%)		3	4	5
		Construction Debris	(<50%), (50-75%), (>75%)		3	4	5
		Garbage	(<50%), (50-75%), (>75%)		3	4	5
		Buried	(<50%), (50-75%), (>75%)	5			
		Object Intruding Through Wall	(<50%), (50-75%), (>75%)		3	4	5
		External Pipe/cable	(<50%), (50-75%), (>75%)		3	4	5
		Other	(<50%), (50-75%), (>75%)		3	4	5
	Roots	Fine		2			
		Tap		3			
		Medium (≤50%)		4			
		Ball (>50%)		5			
	Infiltration	Weeper/Dripper		2			
		Runner		4			

	Defects	Descriptors	Modifiers	Condition Grade			
				No Mod.	Minor	Moderate	Severe
Supplemental Stormwater Defects				No Mod.	Minor	Moderate	Severe
	Erosion	Bottom Erosion/Scour	Minor, Moderate, Severe		2	3	4
		Bank Erosion/Scour	Minor, Moderate, Severe		3	4	5
		Geotextile Visible	Minor, Moderate, Severe		1	2	3
		Tree Roots Exposed	Minor, Moderate, Severe		1	3	5
		Scour Around/Beneath Structure	Minor, Moderate, Severe		3	4	5
				No Mod.	Limited	Patchy	Extensive
	Vegetation	Bare Earth	Limited, Patchy, Extensive		2	3	4
		Aggressive Maintenance	Limited, Patchy, Extensive		2	3	4
		Overgrown Grasses/Weeds		1			
		Trees/Brush	Limited, Patchy, Extensive		3	4	5
		Growth on Structure	Limited, Patchy, Extensive		2	3	4
		Wetland Fringe Distressed	Limited, Patchy, Extensive		1	3	5
				No Mod.	< 25%	25-50%	> 50%
	Submergence	Standing Water	(<25%), (25-50%), (>50%)		1	3	5
		Flowing Water	(<25%), (25-50%), (>50%)		1	3	5

Grades:

5 Failed or failure is imminent - requires immediate attention

4 Severe defects - risk of future failure

3 Moderate defects - deterioration may continue

2 Minor to Moderate defects - low risk of failure

1 Minor defects - failure unlikely in the foreseeable future

For each selected asset, the condition scores were applied based on **Table 7-7**. No assets were identified in the DuWap watershed with multiple defects, so scores ranged from 0 to 5 for each asset. Following is a summary of condition scores.

- 16 percent of assets scored a four or five, indicating severe defects.
- 45 percent of assets scored two or three, indicating minor or moderate defects.
- 11 percent of assets scored a one, indicating minor defects
- 28 percent of assets scored had no noted defects.

The detailed condition assessment scoring and map can be found in **Appendix M**, **Figure 7-2**, and **Figure 7-3**.

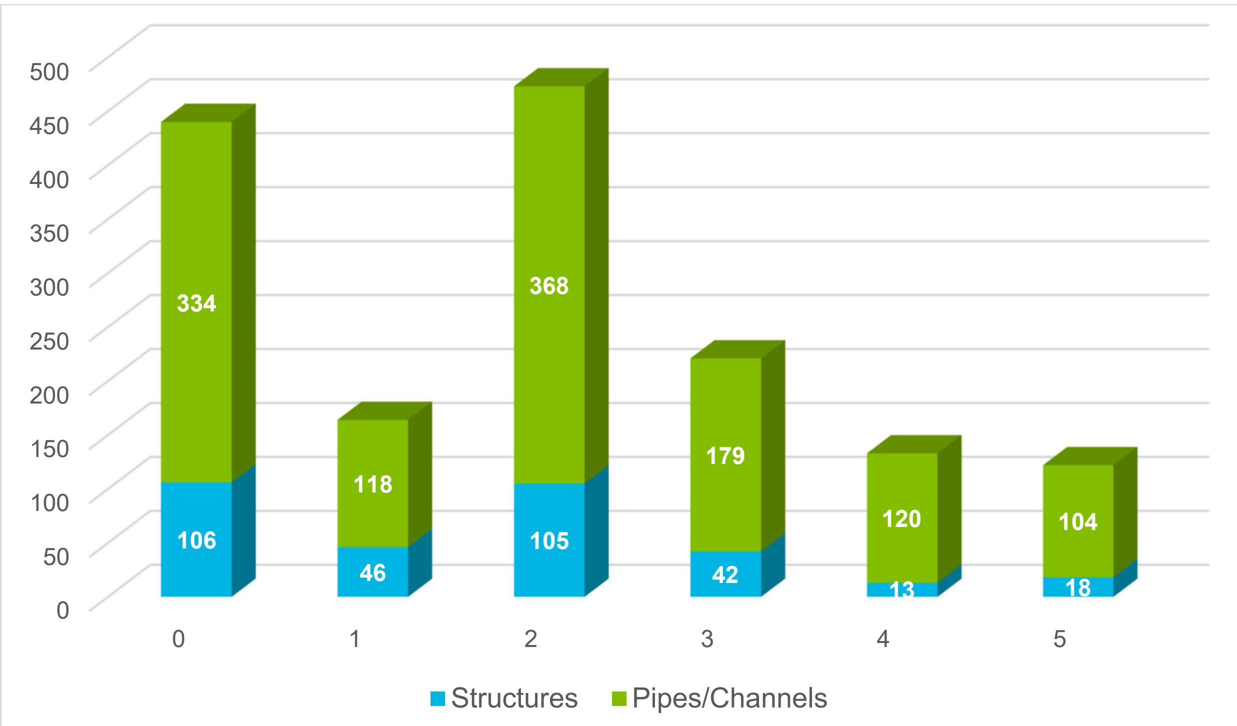


Figure 7-2. Condition Assessment Scores

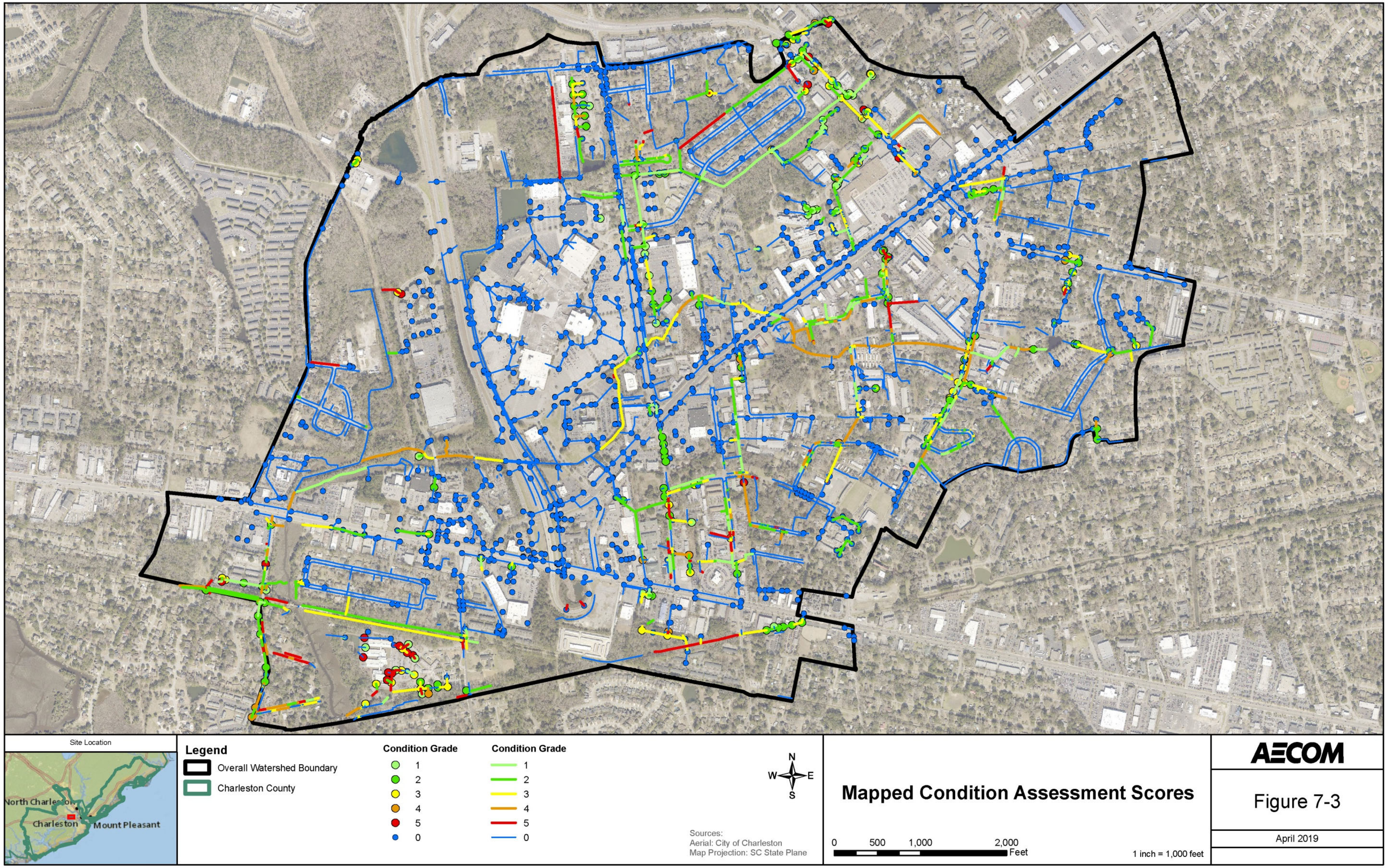


Figure 7-3. Mapped Condition Assessment Scores

7.3 Flood Resiliency Metrics and Scoring

The flood resiliency assessment was based on system modeling for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events.

Flooding is a common issue in the DuWap watershed, as noted in the West Ashley plan and Church Park stormwater study. Key recommendations from these plans include increasing the design storm frequency for pipes, culverts, and other features to alleviate floods, and providing controls for the smaller, more frequent storms, like the 1-2-year event.

Modeling was performed for 456 nodes across the watershed as described in Section 5.2. The results of the model identified the frequency and depth of flooding at each nodal location.

For each modeled node, a flood resiliency assessment was performed. The assessments included the following metrics:

- **Flood Frequency**. Using the model results, flooding was identified at each node during the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year storm events. Assets experiencing flooding during the 2-year event and greater were assigned the highest score given the increased frequency of occurrence.
- **Depth of Flooding**. The LOS of the City of Charleston is the 25-year storm. The depth of flooding at each node was assessed during this design storm event. Flood depths greater than 2 feet during the event were considered highest priority.
- **Major Evacuation Routes Impacted**. If a major evacuation route is impacted during a storm event, it will impact an increased population, so each asset was assessed for proximity to a potential evacuation route. For this assessment, structures located within 50 feet of a state highway or US Highway were considered structures that could impact an evacuation route.
- **Critical Facilities Impacted**. Another flood factor considered was potential critical facility impacts. For this assessment critical facilities were defined as any school, military installation, government office, hospital, or airport within 50 feet of an asset. For the DuWap watershed the only critical facilities identified were educational facilities.

To help rank potential projects based on flood resiliency, a scoring table (**Table 7-8**) was developed using the above categories.

Each modeled junction was assessed in each of the four categories in **Table 7-8** and the appropriate numeric score was assigned based on the model results and the flood resiliency assessment as shown on **Figure 7-4**. Scores were totaled across the four categories for all 456 modeled nodes. Scores ranged from 0 to 35 for all flood criteria.

Table 7-8. Project Scoring – Flood Resiliency

Category	Flood Metrics	Criteria Score
Flood Frequency [a]	2-year	6
	5-year	5
	10-year	4
	25-year	3
	50-year	2
	100-year	1
Depth of flooding during 25-year storm	>2.0 feet	4
	1–2.0 feet	3
	0.5–1.0 feet	2
	0-0.5 foot	1
	No flooding	0
Major Evacuation Routes impacted [b]	Yes	10
	No	0
Critical Facilities impacted [c]	Yes	10
	No	0

[a] *Flood frequency was considered cumulative, a maximum flood frequency score of 21 was assigned to links/junctions with impacts during the 2-year through 100-year storms.*

[b] *Any State or US Highway within 50 feet was considered a potentially impacted evacuation route.*

[c] *Any school, military installation, government office, hospital, or airport within 50 feet was considered potentially impacted.*

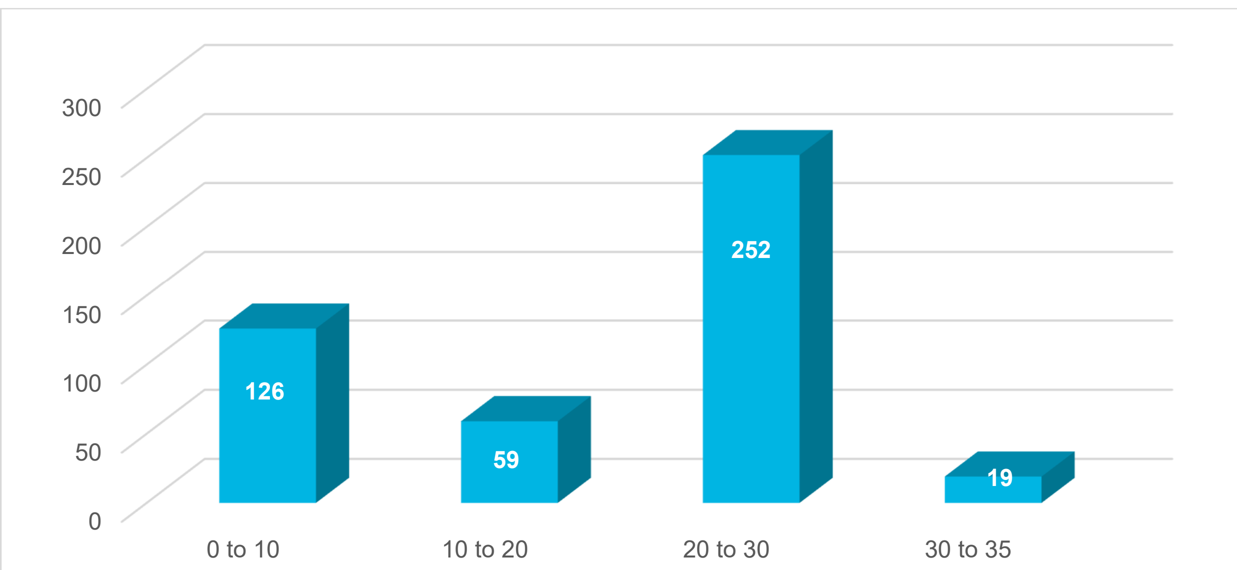


Figure 7-4. Total Flood Resiliency Scores at Model Nodes

Since the flood resiliency assessment was completed for modeled nodes, the data from these nodes were extrapolated to surrounding impacted assets. To combine the datasets, a spatial join was completed in GIS to correlate the modeled nodes to the selected pipes, channels, and structures.

For each selected asset, the condition scores were applied based on **Table 7-8**. No assets were identified in the DuWap watershed with multiple defects, so scores ranged from 0 to 5 for each asset.

- 7 percent of assets scored in the range of 30 to 35, indicating severe flood risk.
- 43 percent of assets scored in the range of 20 to 30, indicating moderate flood risk.
- 13 percent of assets scored in the range of 10 to 20, indicating minor flood risk.
- 37 percent of assets scored in the range of 0 to 10, indicating negligible flood risk.

Detailed flood scoring can be found in **Appendix N**. A summary of the total flood resiliency scores is shown on **Figure 7-5** and **Figure 7-6**.

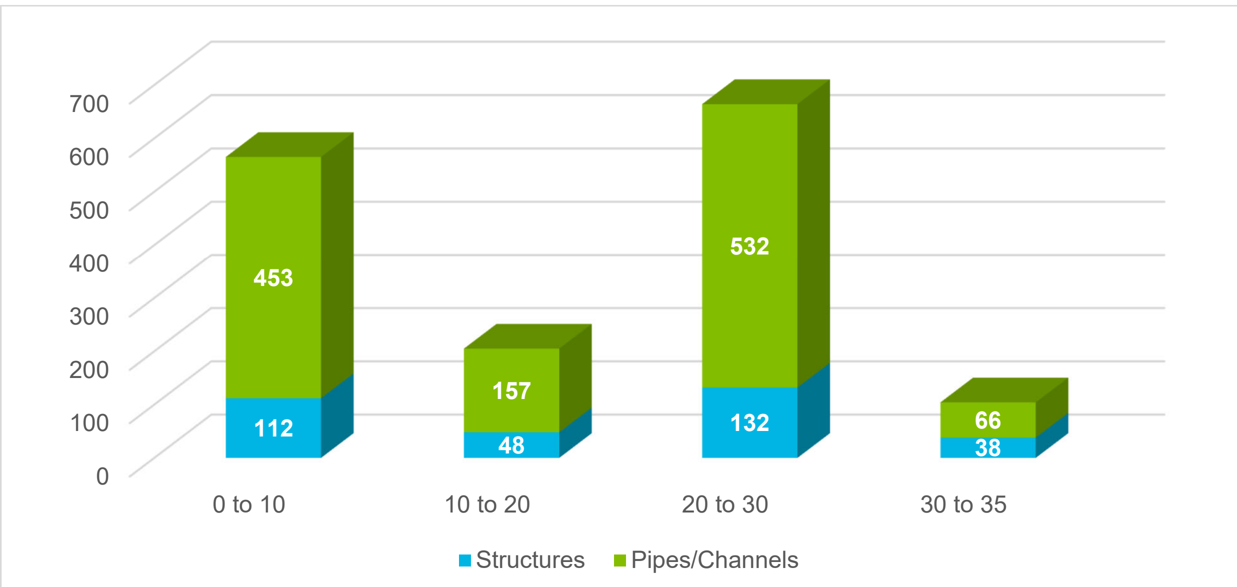


Figure 7-5. Flood Resiliency Scores at Pipes, Channels, and Structures

7.4 Prioritization and Ranking of Assets for Proposed Projects/System Improvements

The results of the flood resiliency assessment and condition assessment were combined to help prioritize problem areas for potential projects.

As previously noted, the flood assessment scores totaled a maximum of 35, while the condition assessment totaled a maximum of 5. Flood resiliency is a key priority for the DuWap watershed, so flood resiliency rankings make up most of the project score. To make the two ranking indexes more equal, the condition assessment scores were multiplied by a factor of three, increasing the maximum value to 15 points. When combined, the maximum total possible score (flood resiliency + condition assessment) is 50 points. Final scoring is included in **Appendix O**, and summary data are presented on **Figure 7-7** and **Figure 7-8**.

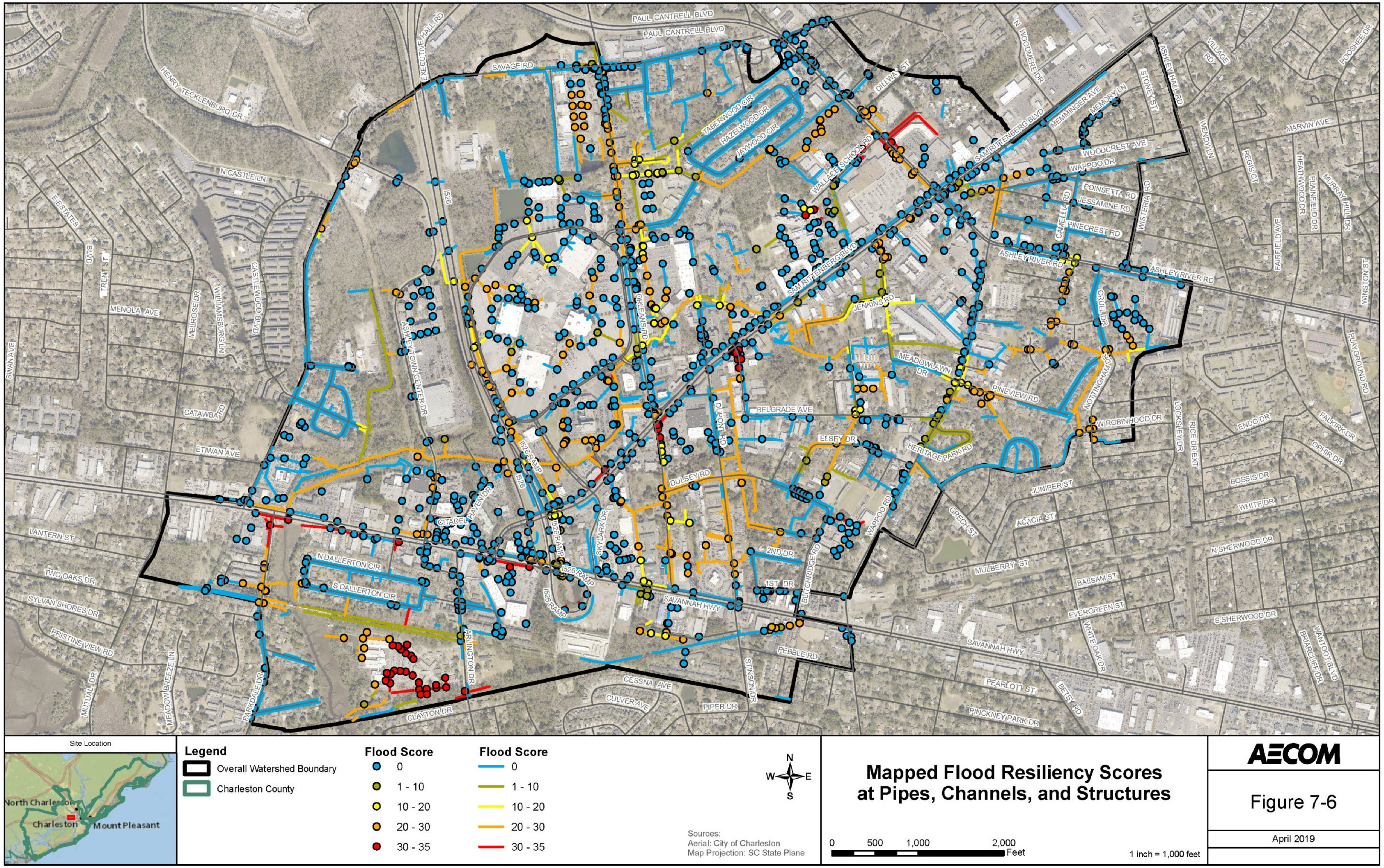


Figure 7-6. Mapped Flood Resiliency Scores at Pipes, Channels, and Structures

Total Score	Number of Assets	Percentage of Assets
0-10	331	27.4%
11-20	218	18.0%
21-30	376	31.1%
31-40	252	20.9%
41-50	31	2.6%

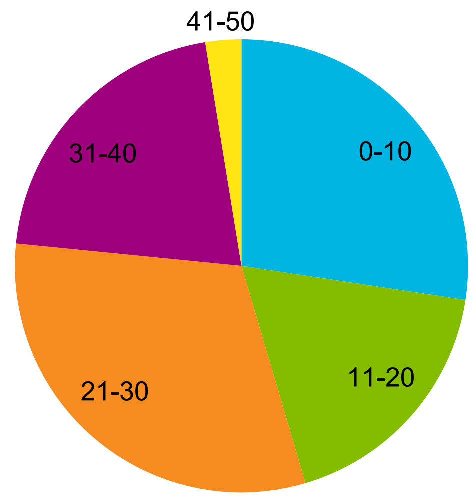


Figure 7-7. Total Ranking Scores – Pipes/Channels

Total Score	Number of Assets	Percentage of Assets
0-10	100	30.3%
11-20	42	12.7%
21-30	112	33.9%
31-40	61	18.5%
41-50	15	4.5%

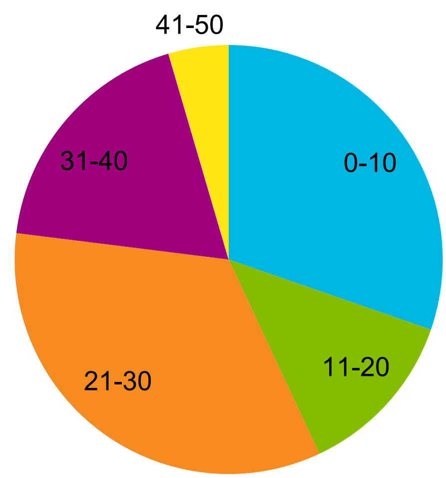


Figure 7-8. Total Ranking Scores – Structures

Project areas were prioritized based on the ranking score of their associated assets. The link and node scoring are combined in the asset scoring summary table, **Table 7-9**, and mapped on **Figure 7-9**.

Table 7-9. Summary of Stormwater Asset Scoring

Total Score	Links	Nodes	Total	Percentage of Assets
41-50	31	15	46	3.0%
31-40	252	61	313	20.4%
21-30	376	112	488	31.7%
11-20	218	42	260	16.9%
0-10	331	100	431	28.0%

Since some known flood areas were not included in the condition assessment, the prioritization results were mapped alongside the model nodes. Since these locations have no condition assessment score, they were mapped using solely the flood resiliency scoring as shown on **Figure 7-10**.

To prioritize areas within the City where stormwater system improvements should be made first, 11 areas with high problem concentrations were identified. These areas were prioritized based on the total of both scores from impacted assets and modeled nodes with flooding; these areas are mapped on **Figure 7-11** and summarized in **Table 7-10**. **Table 7-10** includes the overall impacted scores along with descriptions of these locations.

Table 7-10. Study Area Prioritization

Project Area	Total Impact Score within Area	Project Area Description
1	3318	Intersection of Samuel Grant Place and Orleans Road
2	2745	Area between End Drive and Orleans Road,
3	1030	Areas along the north western corner of the Citadel Mall parking lot
4	1194	Intersection of Sam Rittenberg Boulevard and I-526
5	1732	Intersection of Pratt Street and Nottingham Drive,
6	1809	Intersection of Tomoka Drive and Westover Drive
7	700	Intersection of Jenkins Road and Gardner Road
8	875	Intersection of Ashley River Road and Akers Road
9	799	Intersection of Wappoo Road and Meadowlawn Drive
10	1677	Intersection of Applebee Way and Parkdale Drive
11	415	Area between W Ashley Greenway and Clayton Drive

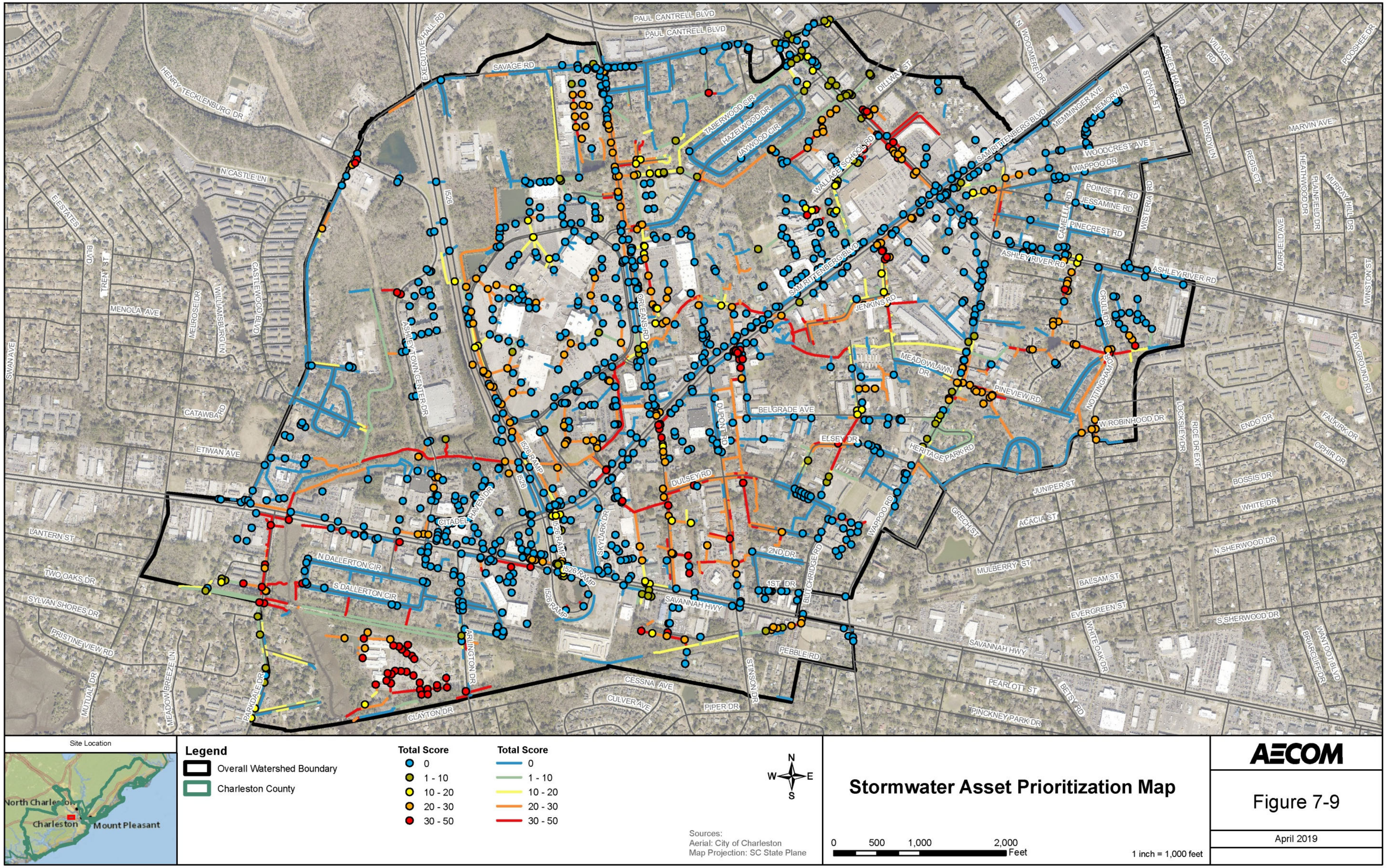


Figure 7-9. Stormwater Asset Prioritization Map

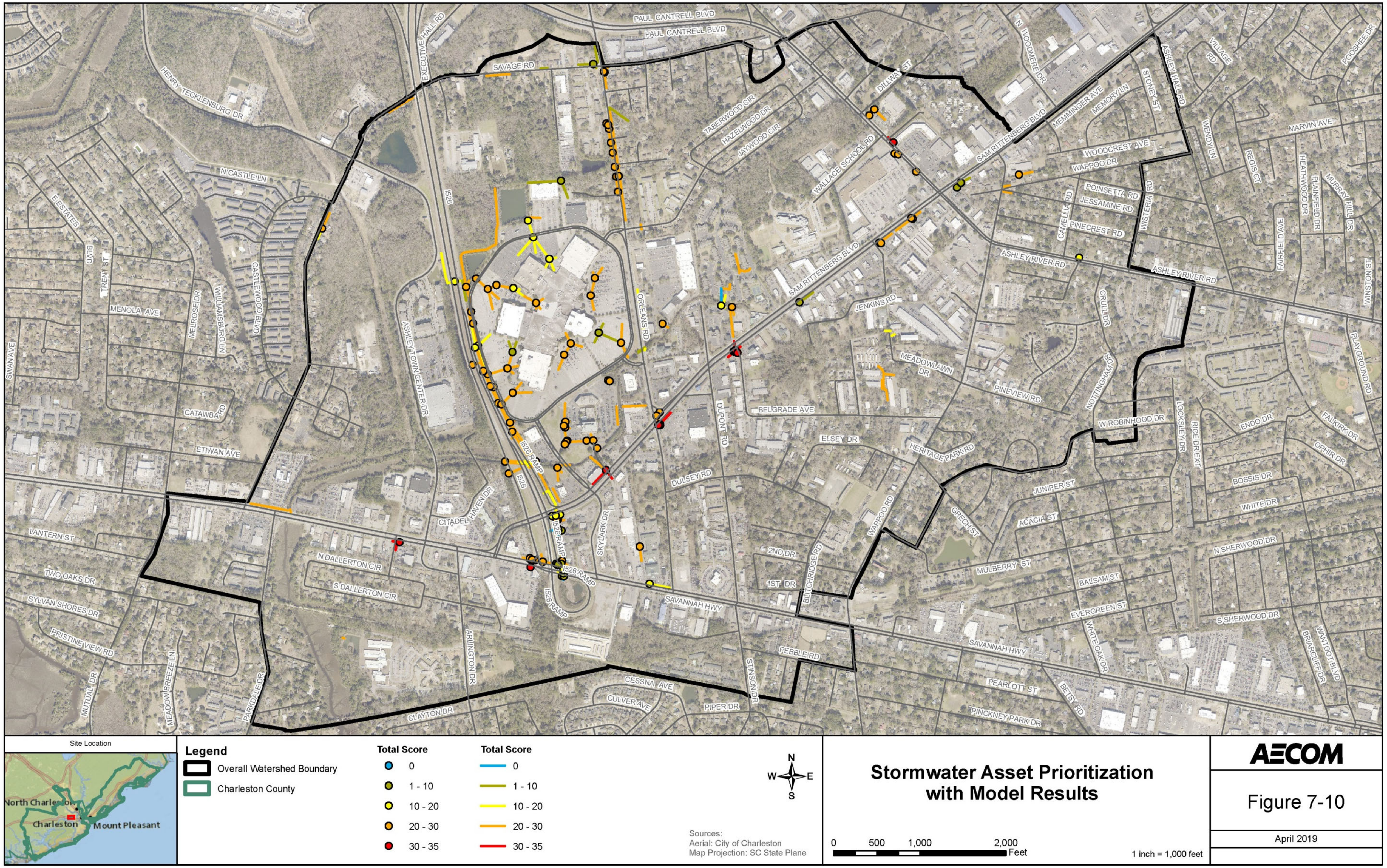


Figure 7-10. Stormwater Asset Prioritization with Model Results

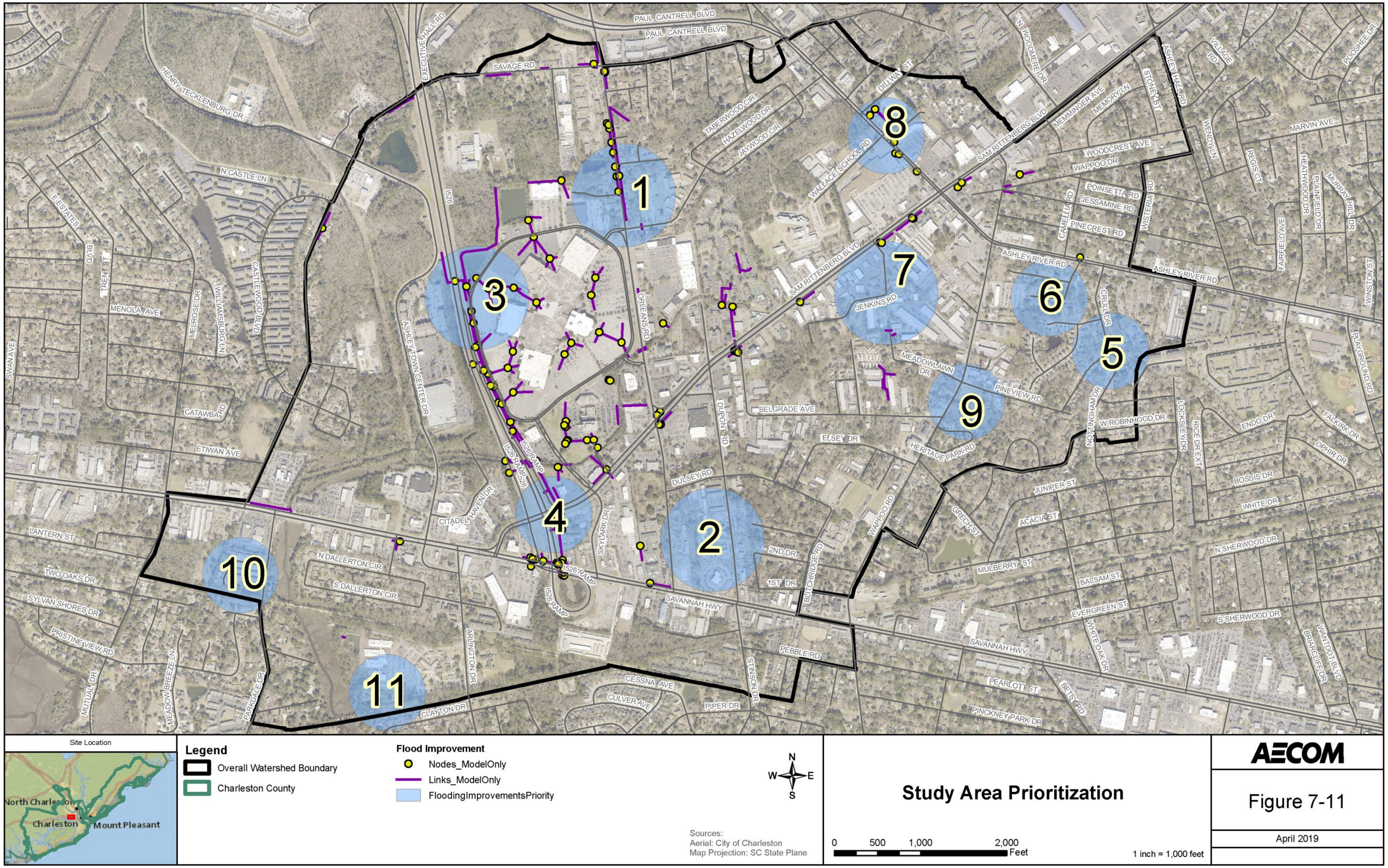


Figure 7-11. Study Area Prioritization

The condition assessment identified 11 areas of focus for implementation of capital improvements for the DuWap watershed. While these areas represent a majority of the flooding problems in the DuWap watershed, other portions of the watershed experience flooding and that will also require flood mitigation measures. The capital improvements recommended for the flooding problems in the 11 selected areas will provide flood mitigation benefits to surrounding areas. The recommended improvements are based on the 25-year storm, so even if the improvements do not completely eliminate the flooding for the 25-year storm, they will eliminate or greatly reduce it for the higher frequency storms (smaller storms). Similarly, the benefits of improvement will apply to lower frequency storms (larger storms) by reducing the severity of flooding during larger storm events.

8. Level of Service and Design Standards Recommendations

8.1 Water Quantity Level of Service

For stormwater management, LOS standards represent degrees of protection for various structures and natural features expressed in terms of storm events anticipated to be accommodated by the applicable drainage facilities. LOS standards apply to both water quantity, in terms of providing an efficient and effective stormwater management system that protects the public and property from flooding, and water quality, in terms of protecting surface waters from erosion and degradation of water quality. For water quantity, LOS standards are used for the design of facilities such as roads, drainage systems such as conveyance and outfalls, and buildings.

Specifying the frequency and duration of rainfall to be handled by a drainage facility establishes the degree of protection that the facility can be expected to provide. That is, the chance of overloading a facility designed to accommodate runoff from a 5-year, 24-hour design storm is one in five, while the chance of satisfactory performance is four in five in any given year for a storm lasting 24 hours. Generally, the greater the potential threat to life and property should a drainage system fail, the more severe or less frequent the design storm used in determining the drainage capacity required for that system.

The LOS analysis and appropriate recommendations for the DuWap watershed were based on a review of the following documents:

- City of Charleston *Stormwater Design Standards Manual*, March 15, 2013
- *City of Charleston Redevelopment Standards for Stormwater (Executive Report)*, September 12, 2016
- City of Charleston, Church Creek Basin Ordinance, Rev. 2018

Based on a detailed review of the above documents, there was no clear definition on the flood protection LOS for roadways and buildings (structural). Due to the lack of clear definition on the LOS standards, LOS for stormwater management was reviewed for several different municipalities and found to be different for each. Each municipality examines its facilities and determines the LOS each facility can achieve and then requires any development or redevelopment to abide by the defined LOS.

Based on the review, the following roadway and structural LOS are recommended for the DuWap watershed (**Table 8-1**).

Table 8-1. LOS Flooding Criteria

Description	5-Year	10-Year	25-Year	100-Year
Roadway: Evacuation	None	None	None	None
Roadway: Collectors	None	None	6 inches	9 inches
Roadway: Neighborhood	None	6 inches	9 inches	12 inches
Structural: Buildings	None	None	None	None

The 11 flood-prone locations were examined and conceptual project solutions were developed with the goal of meeting the desired/recommended LOS where possible. In addition, additional design standards were considered to develop the system improvements, which are detailed in the following section.

8.2 Design Standard Recommendations

In addition to the General Design Standards, additional design standards specific to different regions within DuWap watershed are listed below. These standards should be taken in to consideration when redevelopment occurs within the watershed.

Northwest Region (Enclosed by Savage Rd in the North, Sam Rittenberg Blvd in the South, I526 on the West and middle of Orleans Rd and Ashley River Rd in the East)

- High flood potential
- Densely populated with large impervious areas
- Redevelopment within this area should be required to improve existing stormwater management with additional volume control and water quality infrastructure.
- If redevelopment occurs, the development should consider the use of Green Infrastructure techniques such as the use of porous pavement, green roofs etc. to reduce the amount of runoff
- System improvements within this region should detain the excess runoff at least 12 hrs after the peak of the event and maintain the post development flow rate to be less than the pre-development flow rate
- Regular inspection should be performed on a quarterly basis and any maintenance or repair issues discovered should be rectified.
- No adverse impacts to the downstream portion of the watershed

Northeast Region (Enclosed by Savage Rd in the North, Sam Rittenberg Blvd in the South, middle of Orleans Rd and Ashley River Rd in the West, and Ashley Hall Rd in the East)

- Low to Medium flood potential
- Redevelopment within this area can be considered with appropriate system measures to mitigate flooding. If the area to be developed is determined to be an SPA then regulations pertaining to the SPA shall apply to all future development. If the area of development is not in SPA then the normal stormwater regulations as described in the stormwater design manual shall apply.
- Development should consider the use of Green Infrastructure techniques such as the use of porous pavement, green roofs etc. to reduce the amount of runoff
- System improvements within this region should maintain the post development flow rate to be less than the pre-development flow rate
- Regular inspection should be performed on a semiannual basis and any maintenance or repair issues discovered should be rectified.
- No adverse impacts to the downstream portion of the watershed

Southwest Region (Enclosed by Savannah Hwy/Sam Rittenberg Blvd in the North, Clayton Dr in the South, Melrose Dr in the West, and Dupont Rd in the East)

- High flood potential
- Tidally influenced due to the proximity to the Stono River
- Redevelopment within this area should be required to improve existing stormwater management with additional volume control and water quality infrastructure.
- If redevelopment occurs, the development should consider the use of Green Infrastructure techniques such as the use of porous pavement, green roofs etc. to reduce the amount of impervious areas
- System improvements within this region should detain the excess runoff at least 12 hrs after the peak of the event and maintain the post development flow rate to be less than the pre-development flow rate
- Regular inspection should be performed on a quarterly basis and any maintenance or repair issues discovered should be rectified.
- No adverse impacts to the downstream portion of the watershed

Southeast Region (Enclosed by Sam Rittenberg Blvd in the North, Savannah Hwy in the South, Dupont Rd in the West, and Ashley River Rd in the East)

- Low to Medium flood potential
- Located at the high point in the watershed with good relief
- Redevelopment within this area can be considered with appropriate system measures to mitigate flooding. If the area to be developed is determined to be an SPA then regulations pertaining to the SPA shall apply to all future development. If the area of development is not in SPA then the normal stormwater regulations as described in the stormwater design manual shall apply.
- Development should consider the use of Green Infrastructure techniques such as the use of porous pavement, green roofs etc. to reduce the amount of runoff
- System improvements within this region should maintain the post development flow rate to be less than the pre-development flow rate
- Regular inspection should be performed on a semiannual basis and any maintenance or repair issues discovered should be rectified.
- No adverse impacts to the downstream portion of the watershed

8.3 Other Design Standards

Additional design standards were considered when recommending system improvements to existing drainage and flow characteristics within the watershed. For example, selected water quantity requirements found in the City of Charleston's *Stormwater Design Standards Manual* are excerpted below:

Minimum Requirements for all Projects

- **Runoff Rates**. Post-development discharge rates shall not exceed predevelopment discharge rates for the 2-, 10-, and 25-year frequency, 24-hour duration storm.
- **Recovery Time**. Detained volume from all controls shall be drained from the structure within 72 hours.
- **Ponds**. Runoff is detained above the permanent pool elevation and released at a designed flow rate to reduce the downstream water quantity impacts.
- A 100-year, 24-hour storm event shall be used to check all drainage designs for local flooding and possible flood hazards at adjacent structures and/or property.

Design Standards specific to Church Creek Basin

- **Church Creek Basin**. Systems shall be designed and constructed to maintain the post-development peak flow rates at or below the pre-development peak flow rates, and to detain the excess runoff volume for the 2-, 10-, 25-, 50-, and 100-year frequency storms, with duration of 24 hours. Systems must detain excess runoff for a period of 24 hours, with tolerances for a peak flow rate match for the 25- and 50-year storm events being ±10 percent, with all others matching pre-development conditions. Detention facilities shall detain the excess volume for the 24-hour period, and only discharge at a post-development peak flow rate at or below the predevelopment peak flow rate.

General Design Standards

- Main channels/conveyances should be sized for a 50-year design storm event with 6 inches of freeboard. Main conveyance easements shall allow for a maintenance shelf on one side of the channel. Side slopes shall not be steeper than 2.5H:1V.
- A main conveyance is defined as a large, common facility serving multiple projects or a large area: 100 lots or more or provides drainage for more than one subdivision or community or commercial project greater than 30 acres.
- Release rates from ponds will be controlled to prevent downstream impacts.
- Main culverts along the main channels will be sized for a 50-year design storm event.
- The minimum required easement width for any open conveyance is 24 feet. This easement shall include a 16-foot-wide maintenance shelf accessible to a public right-of-way. For open conveyances greater than 4 feet wide and/or 4 feet deep, the easement width shall be increased by 2 feet for each foot of channel width or depth in addition to 4 feet.
- Channels shall be sized to operate at full capacity with reasonable vegetation growth. A channel opening dimension factor of safety of 1.25 shall be used for conveyance structures to account for normal accumulation of debris and sediment between maintenance cycles. The 1.25 factor of safety shall be based on hydraulic capacity during the 50-year storm conditions.
- Conveyance culverts shall be sized to ensure operation at full required capacity under severe conditions common in the area of installation. Minimum sizes shall be determined to reduce the potential for fouling or clogging due to trapped debris. Culverts shall be sized

with a 1.25 safety factor based on hydraulic capacity during a 50-year event to allow for normally occurring conditions.

- Flooding exists at many locations around the City where development densities have increased to the point that stormwater controls have become overwhelmed. These areas are expected to change with time; however, it is the intent of the Engineering Division that flooding in these areas does not increase. The following design criteria shall be used for projects discharging to receiving waters within these areas:
  - The post-development, peak discharge rate is restricted to one-half the pre-development rate for the 2- and 10-year 24-hour storm event or to the downstream system capacity, whichever is less.
  - The post-development runoff volumes for the 2-year frequency 24-hour duration storm events above the predevelopment level shall be stored for a period of 24 hours on average before release.

9. Surface Water Management Improvement Projects

Selections of flooding locations were determined based on the results of the model and condition of assets within DuWap watershed. The selection process is detailed under Section 7.0 of the report. In addition, a review of the City's complaints database, location of critical facilities, evacuation routes, and FEMA's flood zone maps were also considered during the selection process. **Table 9-1** below shows the list of those project areas.

Table 9-1. List of Project Areas

Project Areas	Project Area Description
1	Intersection of Samuel Grant Place and Orleans Road
2	Area between End Drive and Orleans Road,
3	Areas along the north western corner of the Citadel Mall parking lot
4	Intersection of Sam Rittenberg Boulevard and I-526
5	Intersection of Pratt Street and Nottingham Drive,
6	Intersection of Tomoka Drive and Westover Drive
7	Intersection of Jenkins Road and Gardner Road
8	Intersection of Ashley River Road and Akers Road
9	Intersection of Wappoo Road and Meadowlawn Drive
10	Intersection of Applebee Way and Parkdale Drive
11	Area between W Ashley Greenway and Clayton Drive

Based on these identified areas, surface water management improvement projects to provide corrective measures to meet the recommended Level of Service criterion are proposed. These proposed projects are based on the current land use within the watershed and are categorized as Maintenance Projects, Repair Projects or Capital Improvement Projects (CIPs).

Maintenance projects are defined as the work required for continuous function of a stormwater asset at its design capacity or to prevent decline or failure of that asset.

Repair projects are defined as the work required to restore the function, up to and including replacement, but not including increase of capacity or function beyond the original design of the asset.

CIPs are defined as improvements required to not only restore the function but also solve flooding issues. These projects mainly include increasing the capacity of the system. Some of the proposed projects considered are as listed below:

- Provide storm water storage facilities such as retention/detention systems to capture and detain/retain excess flood waters and reduce downstream peak discharge rates.
- Provide an enhanced conveyance system, through channel and structure improvements, which increases the hydraulic efficiency of the drainage system and reduces peak flood elevations.
- Raise the elevation of the roadway to detain the flood waters upstream thereby limiting the downstream discharge rates and reducing peak flood elevations.

- Add in-line check valves to control the flow direction and limit the back-water effects from the downstream areas.

The proposed improvements may not be adequate to solve all the flooding problems in the DuWap watershed for the 25 year 24 hour storm; however, these improvements will help to alleviate the flooding that is currently experienced in the watershed for the smaller intensity storms.

Constraints, Limitations and Assumptions

To recommend surface water management improvement projects, the following list of constraints, limitations, and assumptions were considered prior to the selection of proposed projects:

- The post-development flowrate at the Stono River is not constrained or is not required to meet the pre-development flowrate since the river is tidally influenced.
- No adverse impacts, either upstream or downstream, should result from the proposed improvements within the watershed.
- No modifications to the main channel within the study area are proposed since it is tidally influenced.
- No projects were proposed within the areas where the stormwater infrastructure is not maintained by the City.

Selection Criteria

In addition to the constraints, limitations and assumptions, the selection of surface water management improvement projects was also based on the following criteria:

- Meeting 25-year LOS criterion for evacuation routes and major collectors/arterials had a higher priority
- Availability of County Owned Lands for storage facilities within the watershed
- Availability of Open/Vacant lands within the watershed for additional storage
- Availability of rights-of-way and drainage easements
- A cost-benefit consideration for the proposed surface water improvements

Capital Improvement Projects Recommendations

Prior to the recommendation of appropriate CIPs for each of the project area, the first step in the process is to use the model to simulate the removal of blockages from the stormwater infrastructure assets as applicable and determine the amount of additional capacity the system will provide Blockage is simulated in the model by reducing the cross sectional area of conveyance features (channels, pipes) and/or reduction in volume associated with storage facilities. To simulate they system without blockage, these artificial reductions are restored in the model to obtain a revised existing conditions model. Maintenance of these stormwater assets is categorized as either Maintenance/Repair projects.

Table 9-2 below provides summary of results with and without blockage for the 25-year-24-hour design storm event.

Table 9-2. Summary of Results With and Without Blockage

Storm	Scenario	Outflow (ft^3)
25 Yr 24 Hr	Model simulation results with blockages	38,730,063
25 Yr 24 Hr	Model simulation results with blockage removed	41,706,120

Results from **Table 9-2** shows that removing the system blockage across the entire watershed increases the system capacity by approximately 7.5%. The difference in depth of flooding at each node between the existing conditions model with and without blockages are graphically represented in **Figure 9-1**. The reductions are minor and do not alleviate flooding at those eleven project locations or meet the desired LOS. Therefore, additional CIPs are needed for each of the project area as detailed below. Revised existing conditions model (with blockage removed) is used for modeling CIPs for each Project Area.

The flood elevations and the ground elevations used in this analysis have been derived from the Digital Elevation Model (DEM) for the City of Charleston which has an accuracy tolerance of +/- 6 inches. Therefore, model results showing the nodes with flooding heights of up to 6 inches can be assumed to have no flooding. In this report, all roadways where the flooding elevations were within 6 inches of the LOS established for that type of road were deemed to be passing the LOS criteria.

Appendix P shows the maximum stage at each node after improvements along with the warning stage. **Appendix Q** shows the maximum flow rate in each link after improvements.

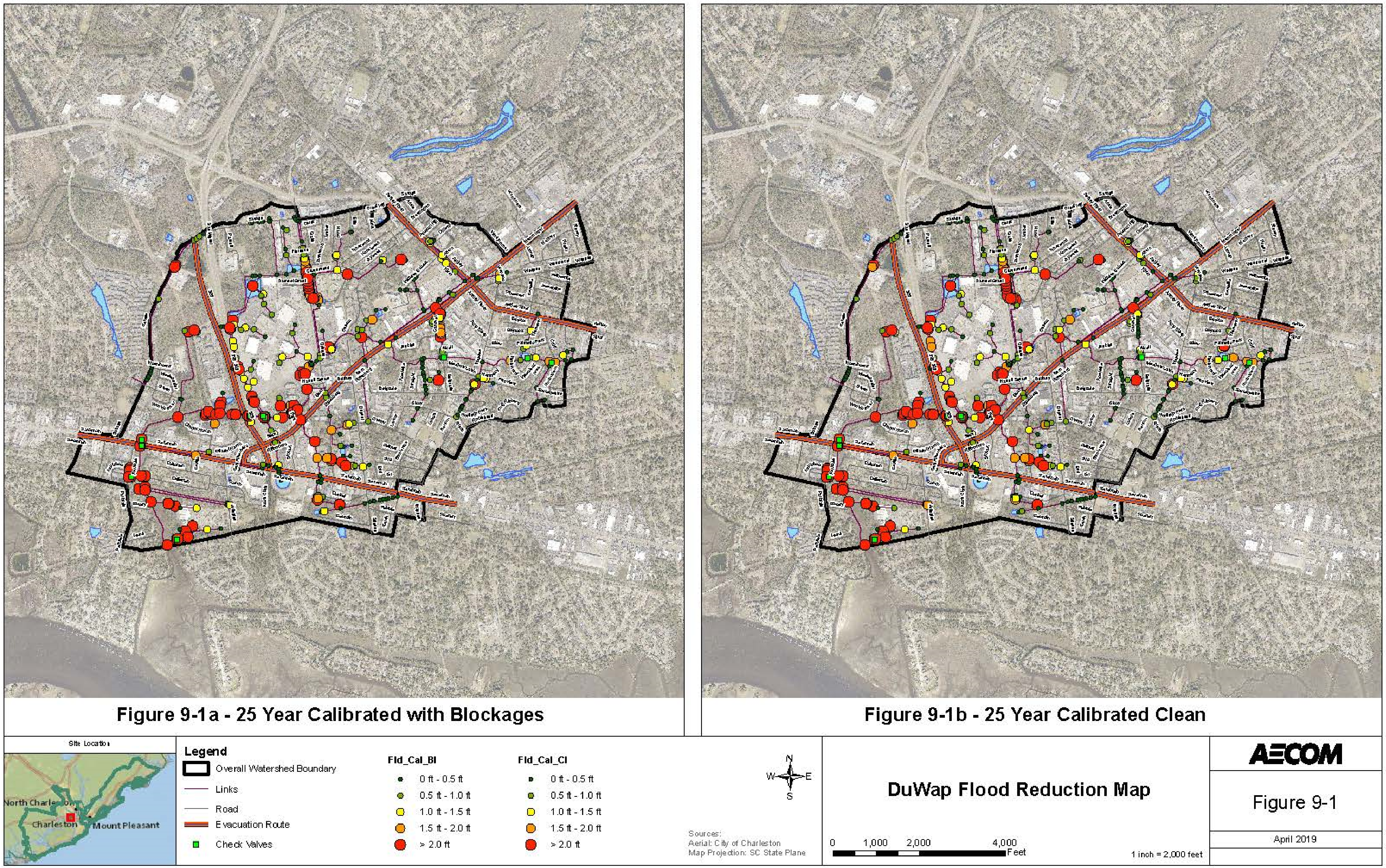


Figure 9-1. DuWap Flood Reduction Map

<u>Project Area # 1 – Intersection of Samuel Grant Place and Orleans Road</u>

Project Area 1 has the highest concentration of impacts with a total impacted score of **3318**. The area is located in the northern part of the DuWap watershed east of Citadel Mall area and bounded by Savage Road on the North, Orleans Road on the West, Main Channel on the South and Ashley River Road on the East. Portions of this area are within the FEMA Flood zone of AE with Base flood elevation of 11ft NGVD.

Table 9-3 provides a comparison of the existing condition model results for the 25-year, 24-hour design storm event with the inclusion of storm surge and SLR and the existing road elevations within that Project area. This table presents a listing of model nodes with road names along the primary drainage system. The third column identifies if the roads are classified as evacuation routes, major arterials/collectors, or minor neighborhood roads for comparison of the roadway's LOS criteria. Columns four to six provides the edge of pavement elevation for the road as determined from DEM, peak stage elevation for the 25-year, 24-hour event for the listed nodes, and the depth of flooding at that location.

Table 9-3. Area-1 Existing Conditions

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
Orleans Rd	DuWapMH_259	Major	11.36	12.92	2.32
Savage Rd	DuWapN_73	Major	15.76	15.57	0.11
Carvewood Ln	DuWapMH_259	Minor	10.86	12.92	2.32
Samuel Grant Pl	DuWapMH_357	Minor	9.83	12.23	3.1
Hazelwood Drive	DuWapMH_221	Minor	7.44	8.97	1.58
Taborwood Cir	DuWapMH_330	Minor	7.44	9.68	0.42

Figure 9-2 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 1 based on the model analysis:

- 643 linear feet of pipe increased in diameter
- 618 linear feet of channels widened
- 70 linear feet of new additional pipe
- Storage added to 1 pond & 1 additional node

Details of the capital improvements listed above are provided in **Appendix R**.

Figure 9-2 (b) graphically represents the location of these improvements.

Figure 9-2 (c) graphically represents the range of flooding depths after the improvements are made. The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-4**.

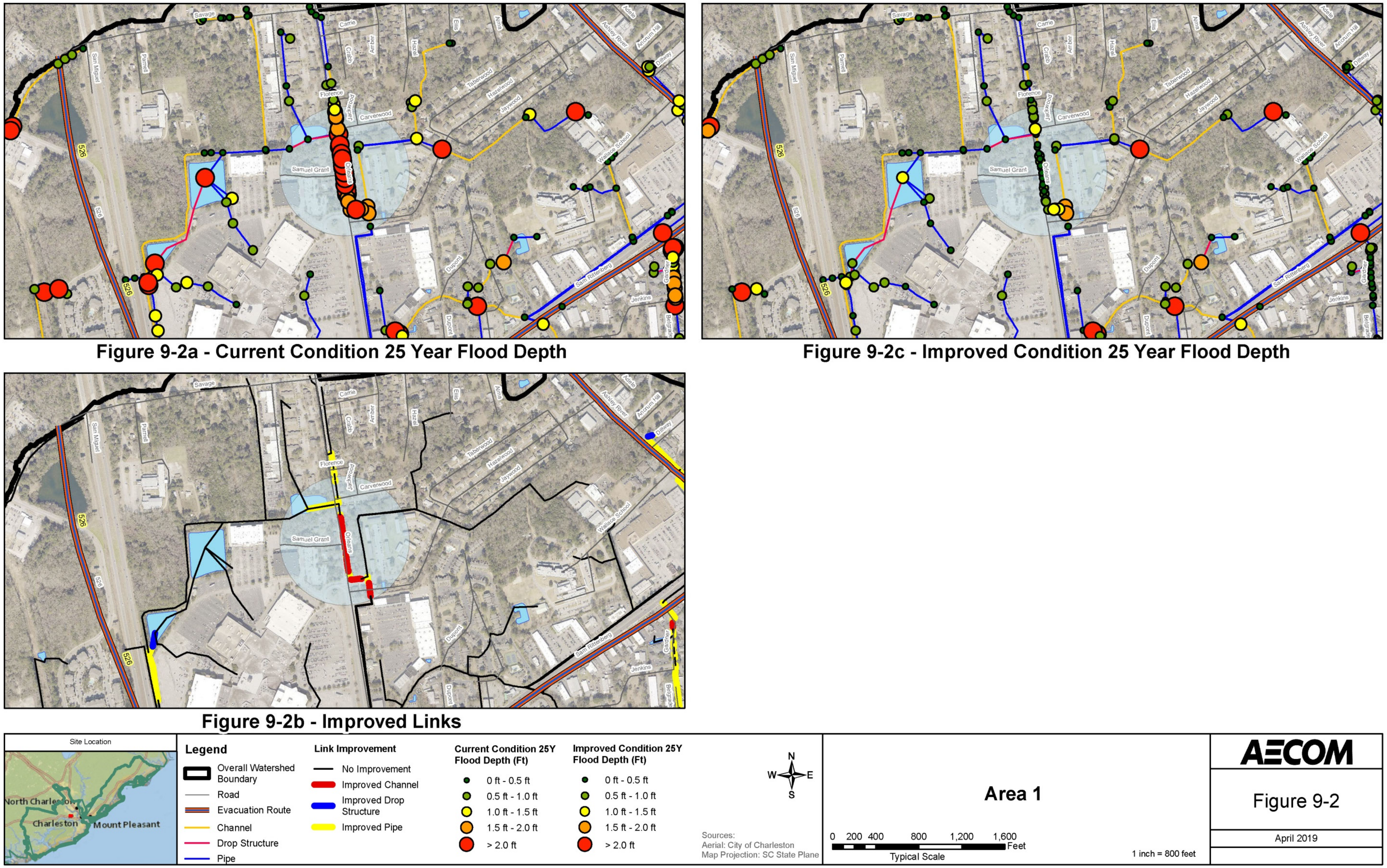


Figure 9-2. Area 1: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

Table 9-4. Area-1 Improved Conditions

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
Orleans Rd	DuWapMH_259	Major	11.36	11.81	0	Yes
Savage Rd	DuWapN_73	Major	15.76	15.57	0.11	Yes
Carvewood Ln	DuWapMH_259	Minor	10.86	11.81	0	Yes
Samuel Grant Pl	DuWapMH_357	Minor	9.83	10.86	0.06	Yes
Hazelwood Drive	DuWapMH_221	Minor	7.44	8.95	0.76	Yes
Taborwood Cir	DuWapMH_330	Minor	7.44	10.25	0.87	Yes

Table 9-4 shows that all the roadways within Project Area 1 meet the intended Level of Service criteria with the proposed improvements. The improvements take the entire Project area 1 out of the flooding and meet the LOS criteria. While these improvements provide the maximum benefits, they significantly increase the cost of the capital improvements.

Table 9-5 provides the total cost of the recommended improvements for Project Area 1.

Table 9-5. Total Cost for Project Area 1

Area-1 Items	Cost
Pipe Improvements	$ 371,000
Channel Improvements	$ 10,000
Addition of Storage	$ 86,000
TOTAL	**$ 467,000**

Details of the capital improvements costs listed above are provided in **Appendix R**.

<u>Project Area # 2 – Area between End Drive and Orleans Road</u>

Project Area 2 has a total impacted score of **2745**. The area is located at the southern part of the DuWap watershed south of Sam Rittenberg Blvd. The area is bounded by skylark road on the West, Dupont road on the East and Savannah Hwy on the South. Portions of this area is within the FEMA Flood zone of AE with Base flood elevation of 11ft NGVD.

Table 9-6 shows the nodes and roadway flooding for the 25-year event within Project Area 2.

Table 9-6. Nodes and Roadway Flooding within Project Area 2

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
Savannah Hwy	DuWapMH_11	Evacuation	8.33	8.64	0.31
Sam Rittenberg Blvd	DuWapMH_74	Evacuation	8.57	8.74	0.17
Orleans Rd	DuWapMH_192	Major	8.62	9.31	0.69
Dupont Rd	DuWapMH_190	Major	10.09	11.84	1.75
Dulsey Rd	DuWapMH_377	Minor	9.01	9.18	0.17
2nd Dr	DuWapN_51	Minor	9.87	12.44	2.57
End Dr	DuWapN_51	Minor	9.87	12.44	2.57

Figure 9-3 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 2 based on the model analysis:

- 1786 linear feet of pipe increased in diameter
- 251 linear feet of pipe relayed to change slope
- 610 linear feet of channel widening
- 2 check valves added to stormwater pipes
- Storage added to 1 pond

Details of the capital improvements listed above are provided in **Appendix R**.

Figure 9-3 (b) visually shows the location of these improvements and **Figure 9-3 (c)** graphically represents the range of flooding depths after the improvements are made.

The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-7**.

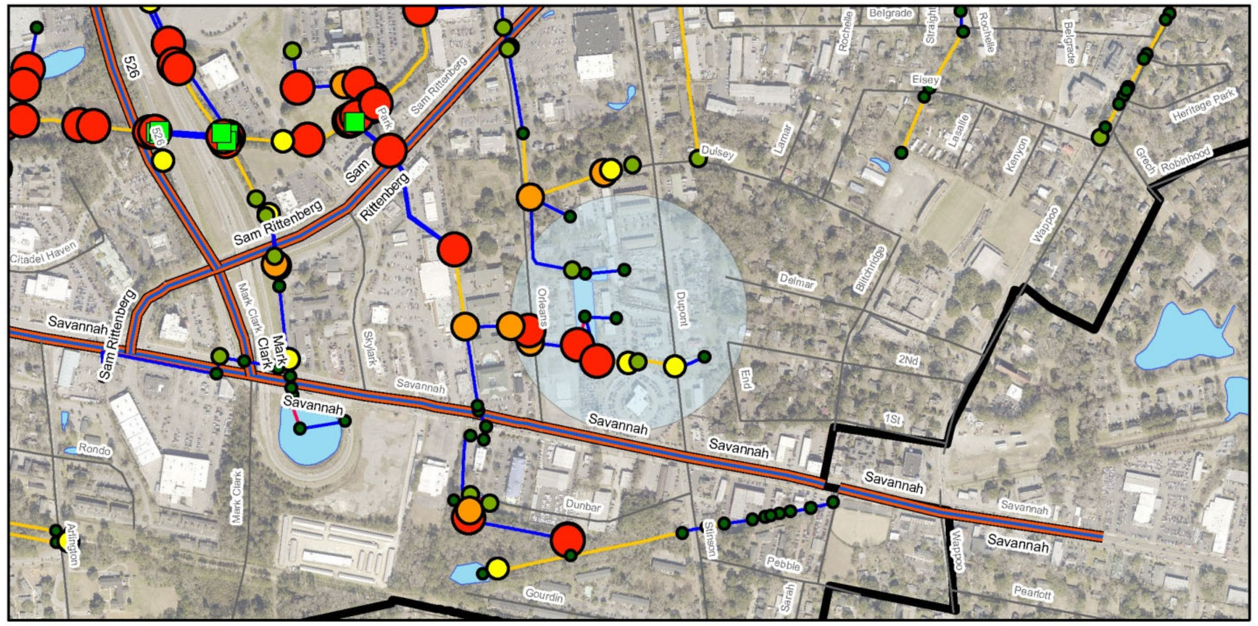


Figure 9-3a - Current Condition 25 Year Flood Depth

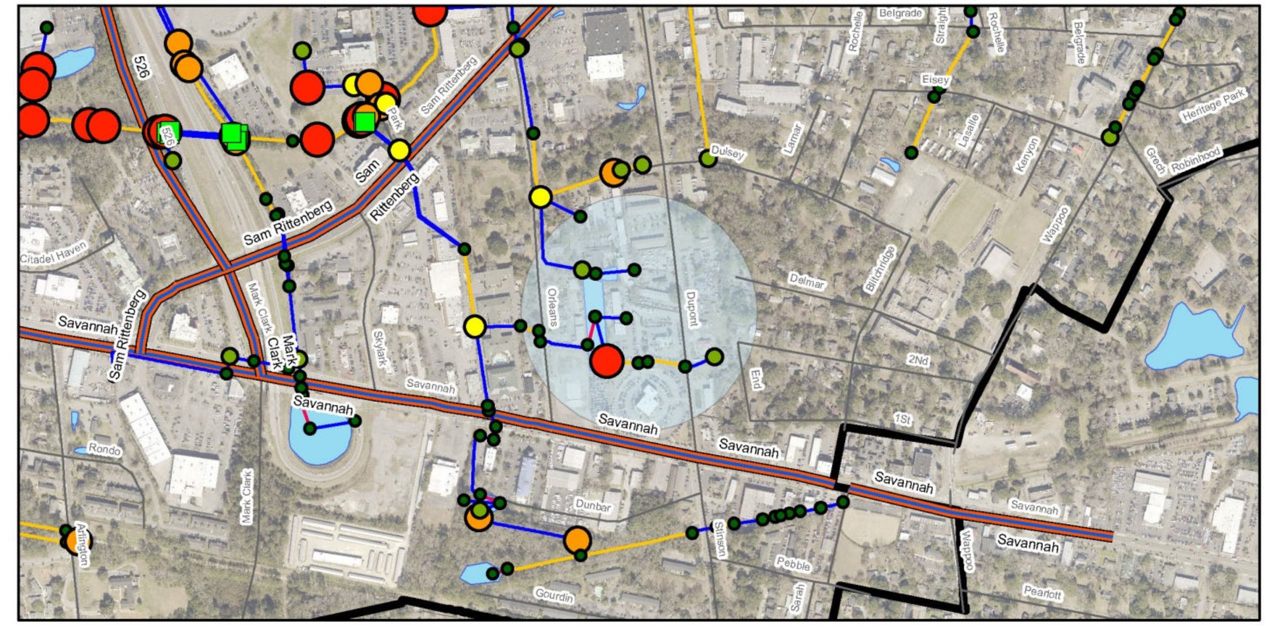


Figure 9-3c - Improved Condition 25 Year Flood Depth

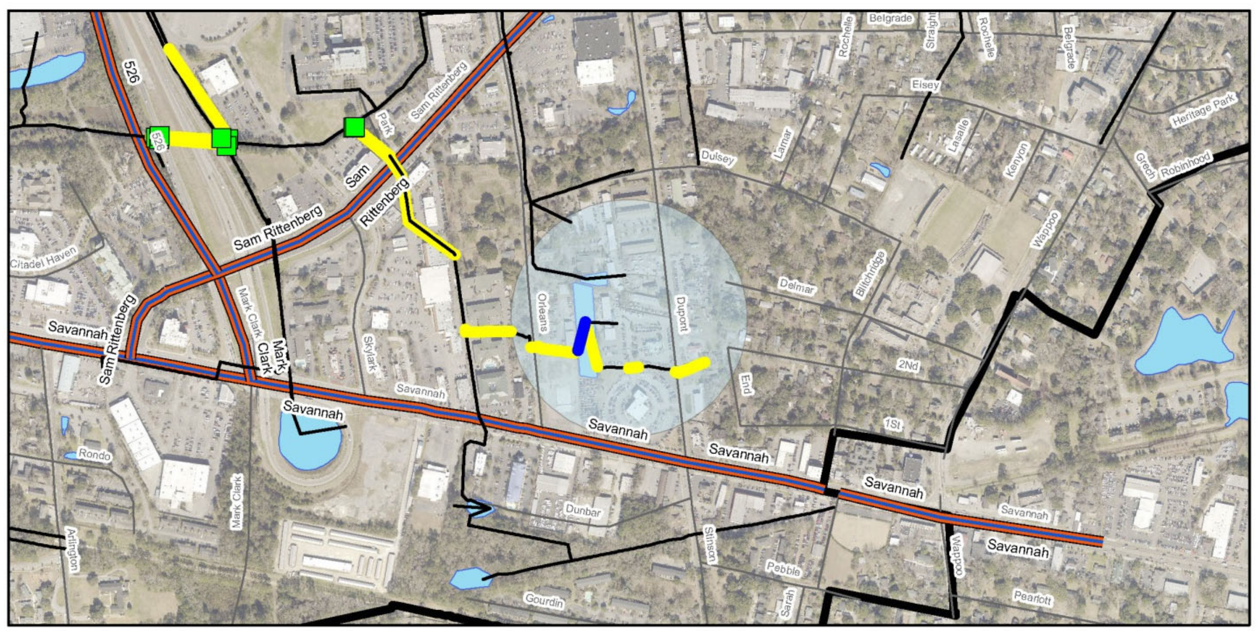


Figure 9-3b - Improved Links

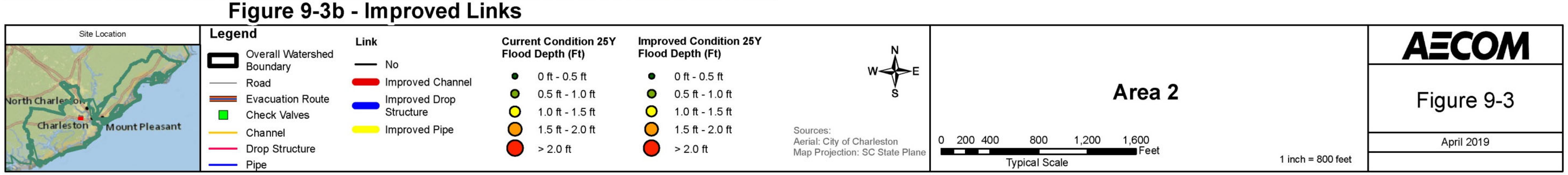


Figure 9-3. Area 2: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

Table 9-7. Levels of Service Criteria

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
Savannah Hwy	DuWapMH_11	Evacuation	8.33	8.16	0	Yes
Sam Rittenberg Blvd	DuWapMH_74	Evacuation	8.57	8.55	0	Yes
Orleans Rd	DuWapMH_192	Major	8.62	8.22	0	Yes
Dupont Rd	DuWapMH_190	Major	10.09	9.8	0	Yes
Dulsey Rd	DuWapMH_377	Minor	9.01	9.06	0.05	Yes
2nd Dr	DuWapN_51	Minor	9.87	10.58	0.71	Yes
End Dr	DuWapN_51	Minor	9.87	10.58	0.71	Yes

Results from the table shows that all roadways within Project Area 2 meet the intended Level of Service criteria.

Additionally, at the City's request, a currently vacant lot at the intersection of Dunbar St. and Stinson Dr. was analyzed for flooding risk. The model results show that after the recommended improvements for Area 2 are implemented, the flooding condition in this area will reduce significantly.

Table 9-8 provides the total cost of the recommended improvements for Project Area 2.

Table 9-8. Total Costs for Project Area 2

Area-2 Items	Cost
Pipe Improvements	$ 476,000
Channel Improvements	$ 11,000
Addition of Storage	$ 30,000
TOTAL	**$ 517,000**

Details of the capital improvements costs listed above are provide in Appendix R.

<u>Project Area # 3 – Areas along the north western corner of the Citadel Mall parking lot</u>

Project Area 3 has a total impacted score of **1030**. The area is mainly located within Citadel Mall area and bounded by Orleans Road on the East and Interstate 526 on the West. Portions of this area are within the FEMA Flood zone of AE with Base flood elevation of 11ft NGVD.

Table 9-9 illustrates the nodes that indicate roadway flooding for the 25-year event within Project Area 3.

Table 9-9. Nodes and Roadway Flooding within Project Area 3

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
I-526	DuWapMH_60	Evacuation	8.05	8.63	0.58

Figure 9-4 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 3 based on the model analysis:

- 1148 linear feet of pipe increased in diameter
- 3 check valves added to stormwater pipes
- Storage added to 1 pond

Details of the capital improvements listed above are provided in **Appendix R**.

Figure 9-4 (b) visually shows the location of these improvements and **Figure 9-4 (c)** graphically represents the range of flooding depths after the improvements are made.

The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-10**.

Table 9-10. Levels of Service Criteria

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
I-526	DuWapMH_60	Evacuation	8.05	7.99	0	Yes

Table 9-10 shows that all the roadways within Project Area 3 meet the intended Level of Service criteria.

Table 9-11 provides the total cost of the recommended improvements for Project Area 3.

Table 9-11. Total Costs for Project Area 3

Area-3 Items	Cost
Pipe Improvements	$838,000
Channel Improvements	$ -
Addition of Storage	$ 8,000
TOTAL	**$ 846,000**

Details of the capital improvements costs listed above are provide in **Appendix R**.

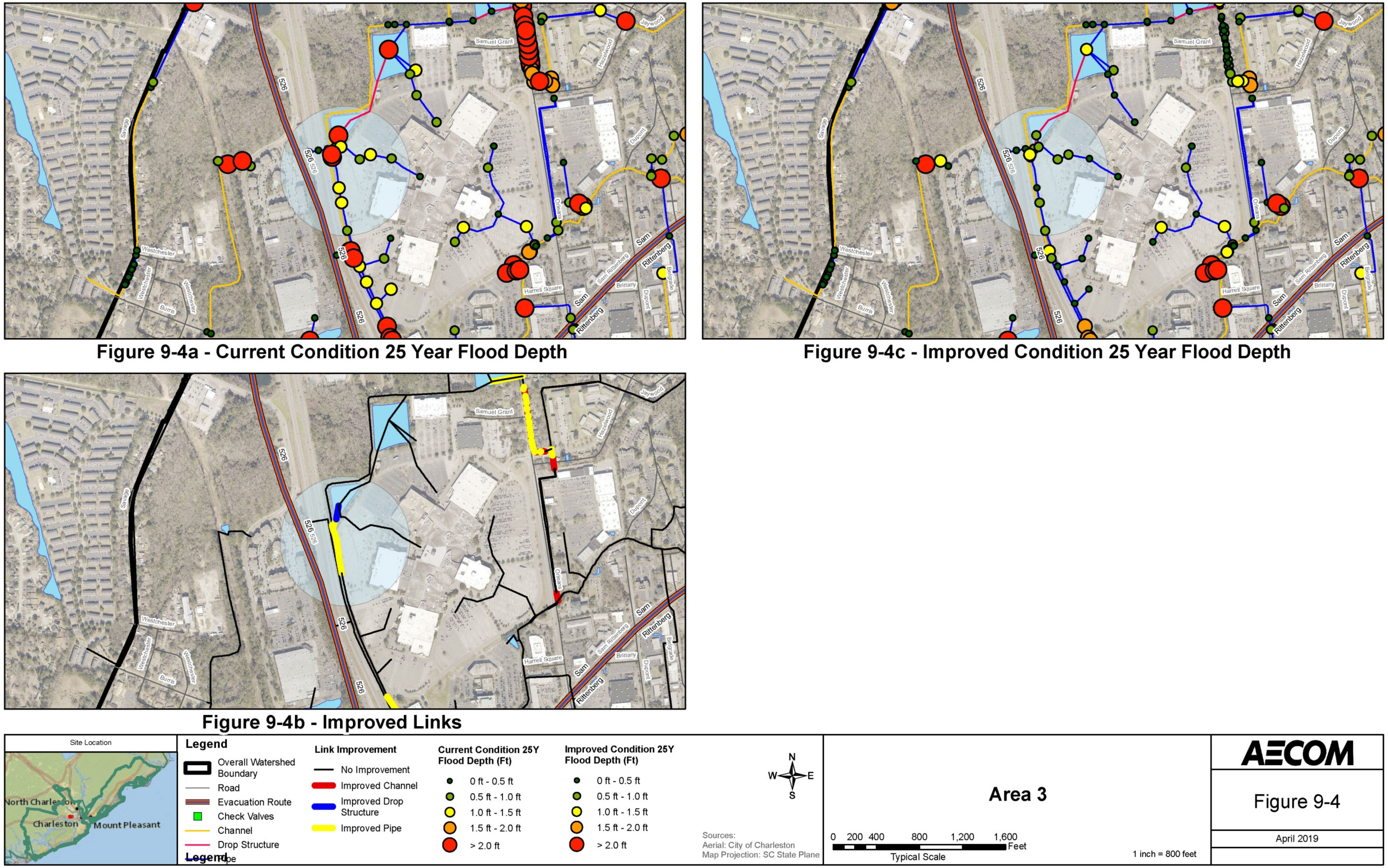


Figure 9-4. Area 3: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

<u>Project Area # 4 – Intersection of Sam Rittenberg Boulevard and I-526</u>

Project Area 4 has a total impacted score of **1194**. The area is located at the southern part of the DuWap watershed near the intersection of Sam Rittenberg Blvd and Savannah Hwy. Portions of this area are within the FEMA Flood zone of AE with Base flood elevation of 11ft NGVD.

Table 9-12 shows the nodes that indicate roadway flooding for the 25-year event within Project Area 4.

Table 9-12. Nodes and Roadway Flooding within Project Area 4

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
Sam Rittenberg Blvd	DuWapMH_84	Evacuation	8.1	8.86	0.76
Savannah Hwy	DuWapMH_81	Evacuation	8.61	8.9	0.29
I-526	DuWapMH_81	Evacuation	8.61	8.9	0.29

Figure 9-5 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 4 based on the model analysis:

- 5 check valves added to stormwater pipes

Details of the capital improvements listed above are provided in **Appendix R**.

Figure 9-5 (b) visually shows the location of these improvements and **Figure 9-5 (c)** graphically represents the range of flooding depths after the improvements are made.

The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-13**.

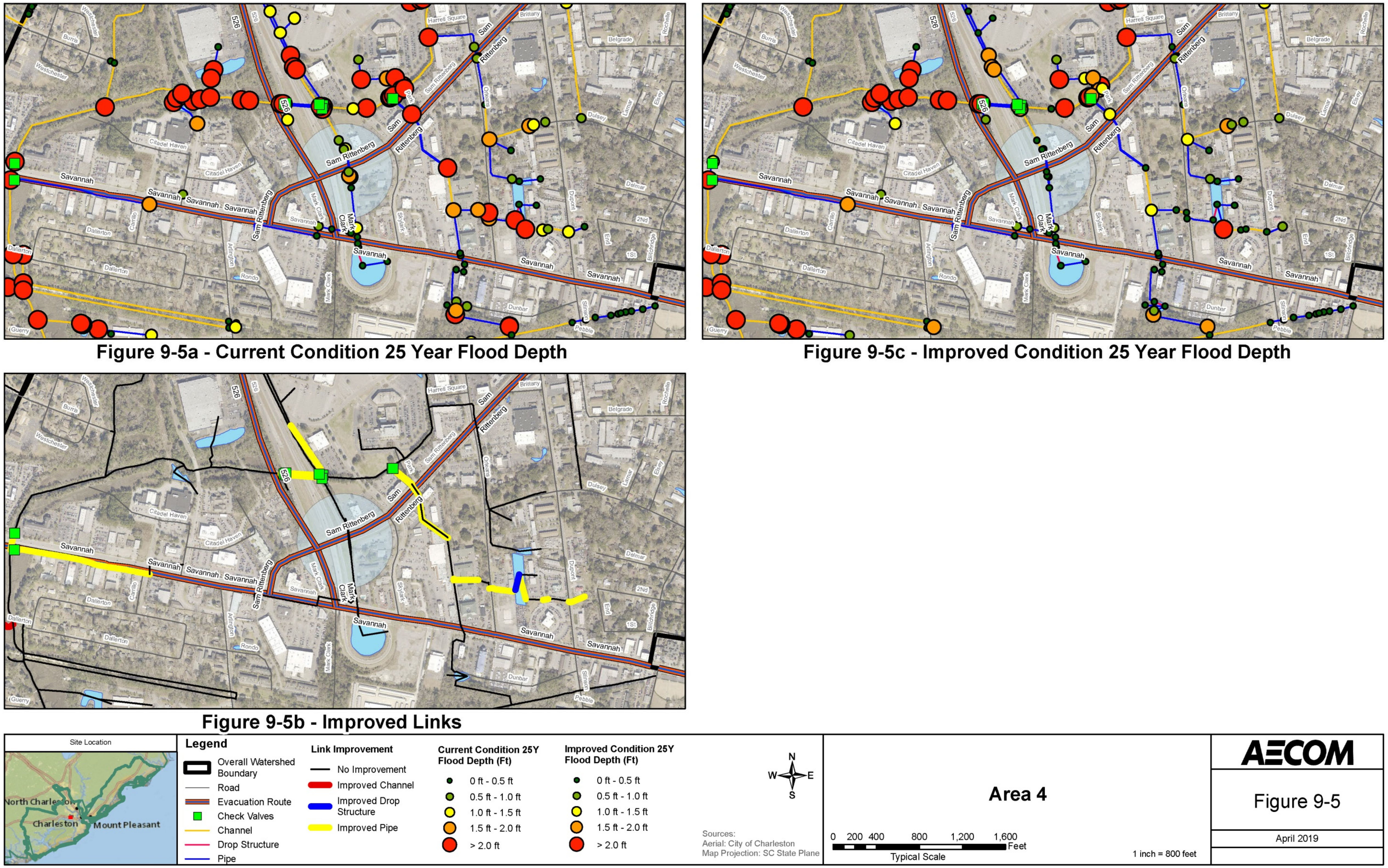


Figure 9-5. Area 4: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

Table 9-13. Levels of Service Criteria

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
Sam Rittenberg Blvd	DuWapMH_84	Evacuation	8.1	7.98	0	Yes
Savannah Hwy	DuWapMH_81	Evacuation	8.61	8.14	0	Yes
I-526	DuWapMH_81	Evacuation	8.61	8.14	0	Yes

Results from the table shows that all roadways within Project Area 4 meet the intended Level of Service criteria.

Table 9-14 provides the total cost of the recommended improvements for Project Area 4.

Table 9-14. Total Costs for Project Area 4

Area-4 Items	Cost
Pipe Improvements	$ 110,000
Channel Improvements	$ -
Addition of Storage	$ -
TOTAL	**$ 110,000**

Details of the capital improvements costs listed above are provide in **Appendix R**.

Project Area # 5 – Intersection of Pratt Street and Nottingham Drive

Project Area 5 has a total impacted score of **1732**. The area is located at the most upstream end of the DuWap watershed and enclosed by Ashley River Rd on the North, W Robinhood Dr on the South, Pine view St on the West and Little John Dr on the East. This area is within the FEMA Flood zone of X.

Table 9-15 shows the nodes that indicate roadway flooding for the 25-year event within Project Area 5.

Table 9-15. Nodes and Roadway Flooding within Project Area 5

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
W Robinhood Dr	DuWapN_62	Minor	11.86	12.53	0.67
Crull Dr	DuWapMH_175	Minor	10.01	11.92	1.91
Nottingham Dr	DuWapN_62	Minor	11.86	12.53	0.67
Pratt St	DuWapMH_175	Minor	10.01	11.92	1.91
Woodleaf Ct	DuWapN_52	Minor	10.45	11.58	1.13

Figure 9-6 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 5 based on the model analysis:

- 671 linear feet of pipe increased in diameter
- 325 linear feet of channels widened
- 3 check valves added to stormwater pipes
- Storage added to 1 pond

Details of the capital improvements listed above are provided in **Appendix R**.

Figure 9-6 (b) visually shows the location of these improvements and **Figure 9-6 (c)** graphically represents the range of flooding depths after the improvements are made.

The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-16**.

Table 9-16. Levels of Service Criteria

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
W Robinhood Dr	DuWapN_62	Minor	11.86	11.57	0	Yes
Crull Dr	DuWapMH_175	Minor	10.01	11.54	1.53	No
Nottingham Dr	DuWapN_62	Minor	11.86	11.57	0	Yes
Pratt St	DuWapMH_175	Minor	10.01	11.54	1.53	No
Woodleaf Ct	DuWapN_52	Minor	10.45	11.52	1.07	

Table 9-16 shows that not all the roadways within Project Area 5 meet the intended Level of Service criteria. Further analysis was performed and additional improvements in combination with other project areas are proposed to have the entire Project area 5 out of the flooding and meet the LOS criteria. The improvements include addition of surface storage to mitigate the peak runoff. Since this is a highly developed residential area, the space is at premium. Addition of surface storage will require the City to buy some of the already developed properties. These additional improvements do not provide proportionate benefits due to the cost of the improvements.

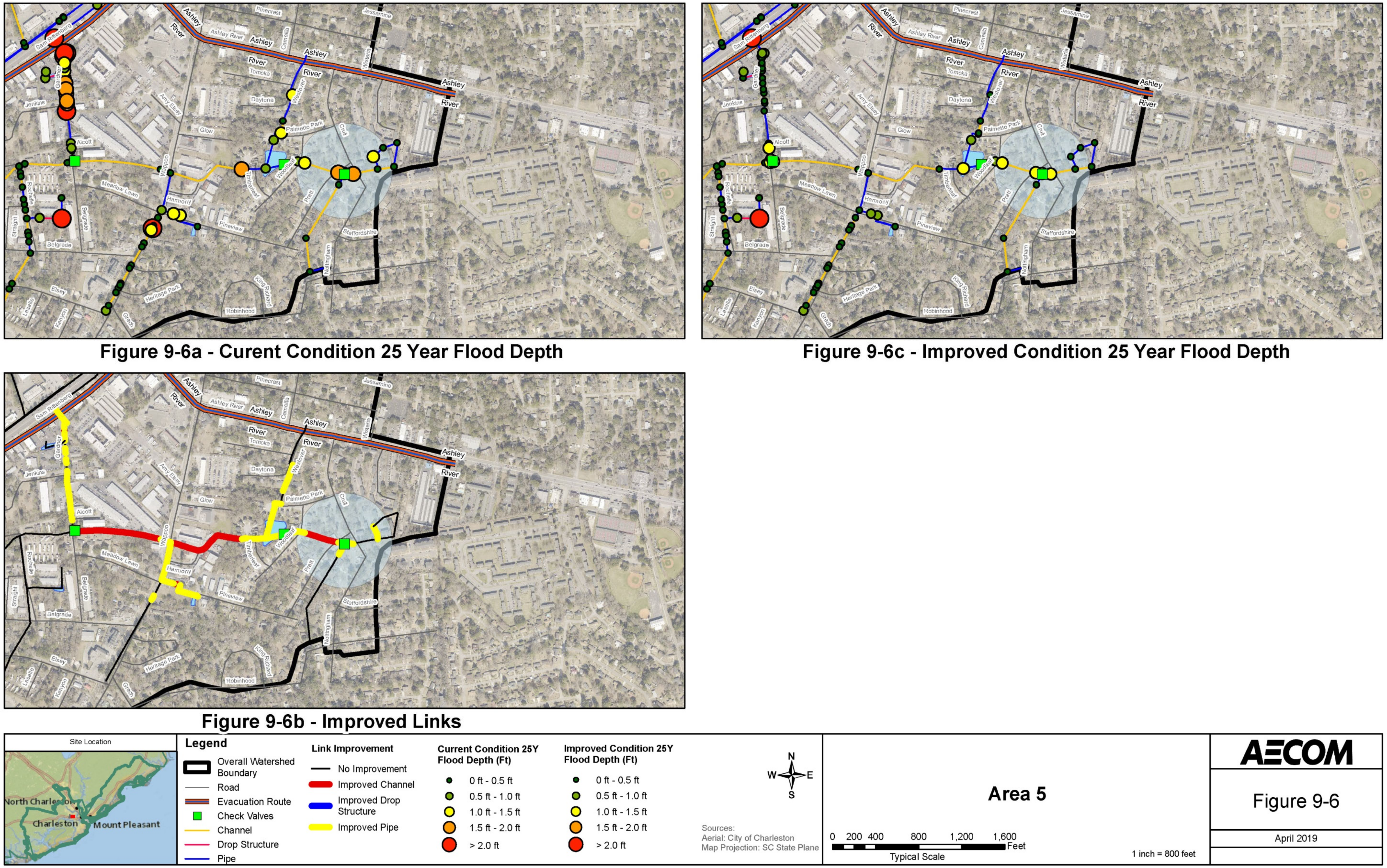


Figure 9-6. Area 5: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

Table 9.17 provides the total cost of the recommended improvements for Project Area 5.

Table 9-17. Total Costs for Project Area 5

Area-5 Items	Cost
Pipe Improvements	$ 339,000
Channel Improvements	$ 8,000
Addition of Storage	$ 8,000
TOTAL	**$ 355,000**

The total cost of additional improvements including purchase of properties and creation of detention pond is approximately $7,596,000.

Details of the capital improvements costs listed above are provide in **Appendix R**.

Project Area # 6 – Intersection of Tomoka Drive and Westover Drive

Project Area 6 has a total impacted score of **1809**. The area is located west of Project area 5 with area bounded by Ashley River Rd on the North, Main Channel on the South, Wappoo Rd on the West and Crull Dr on the East. This area is in the FEMA Flood Zone of X.

Table 9-18 shows the nodes that indicate roadway flooding for the 25-year event within Project Area 6.

Table 9-18. Nodes and Roadway Flooding within Project Area 6

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
Ashley River Rd	DuWapN_53	Evacuation	24.41	24.53	0.12
Tomoka Dr	DuWapN_74	Minor	22.47	23.64	1.17
Westover Dr	DuWapN_74	Minor	22.47	23.64	1.17
Daytona Dr	DuWapN_74	Minor	22.47	23.64	1.17
Palmetto Park Rd	DuWapN_274	Minor	9.6	11.83	2.23

Figure 9-7 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 4 based on the model analysis:

- 794 linear feet of pipe increased in diameter
- 742 linear feet of channels widened
- Storage added to 1 pond

Details of the capital improvements listed above are provided in **Appendix R**.

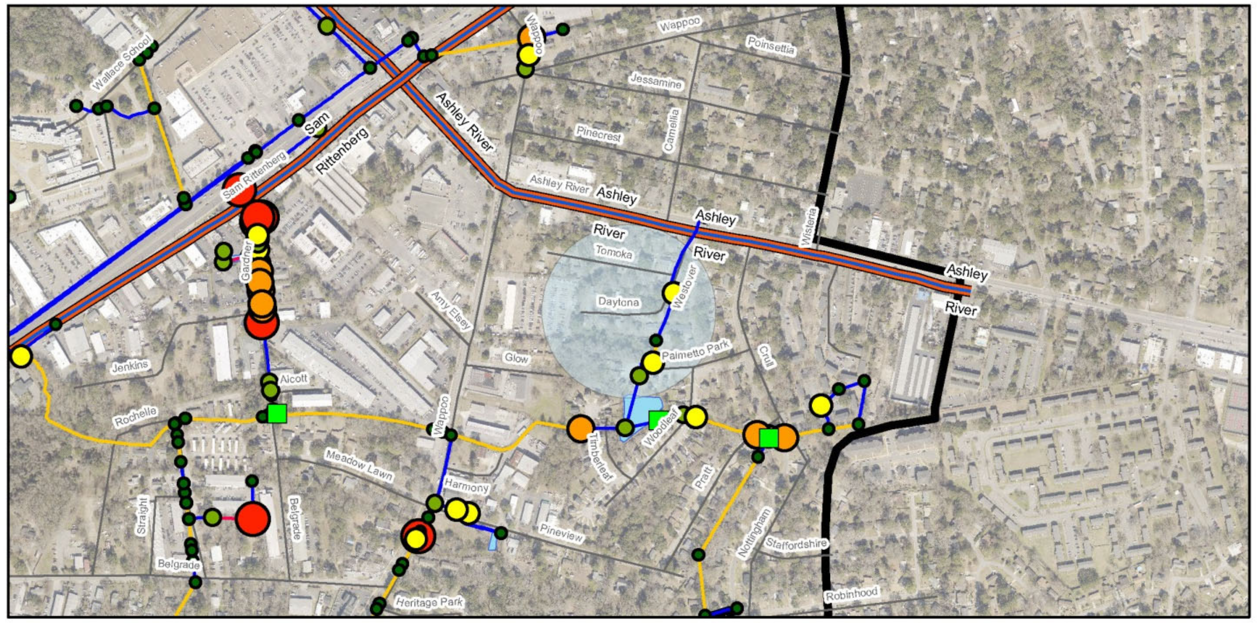


Figure 9-7a - Current Condition 25 Year Flood Depth

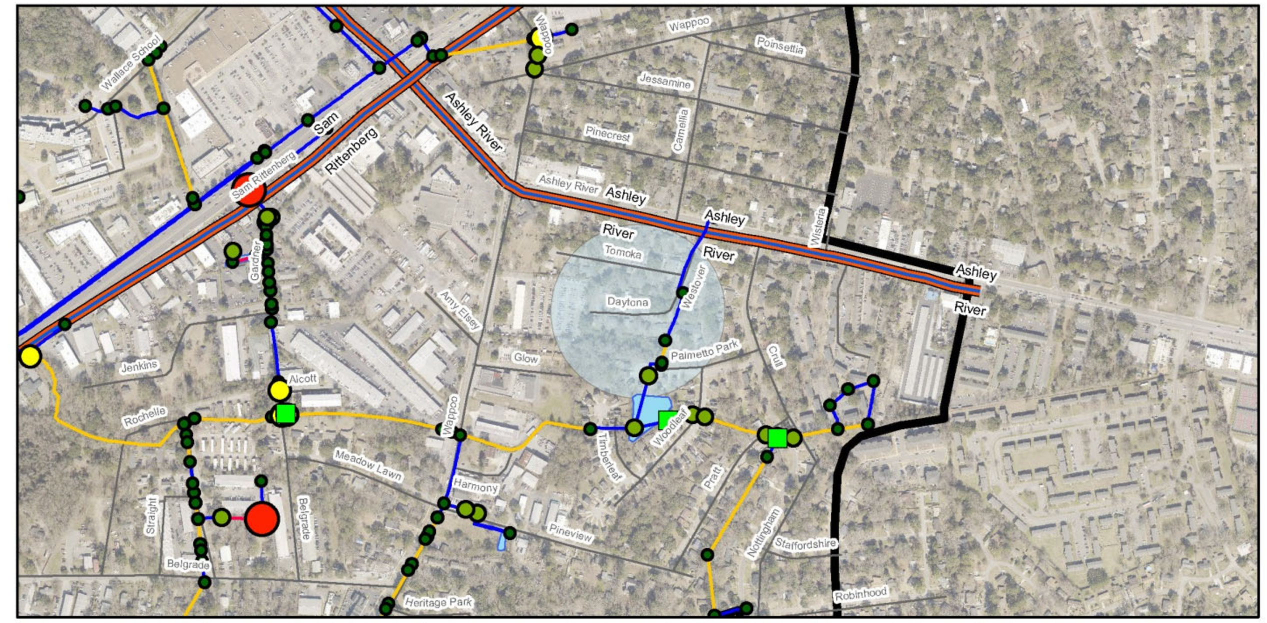


Figure 9-7c - Improved Condition 25 Year Flood Depth

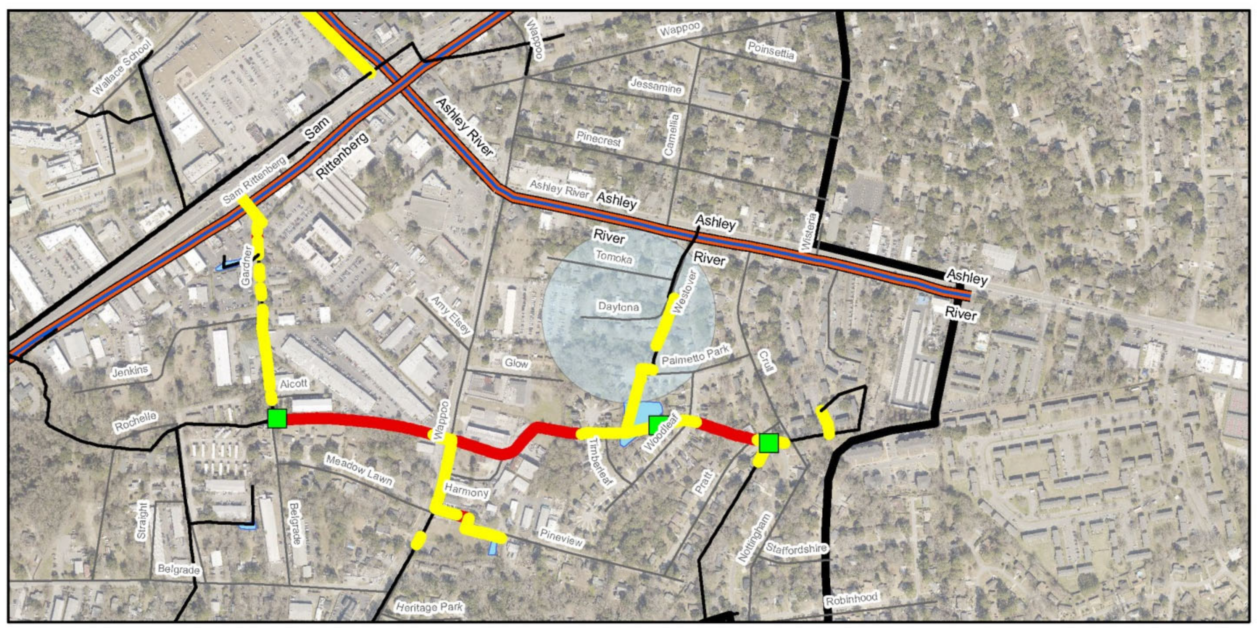


Figure 9-7b - Improved Links

Site Location

Legend

- Overall Watershed Boundary
- Road
- Evacuation Route
- Check Valves
- Channel
- Drop Structure
- Pipe

Link Improvement

- No Improvement
- Improved Channel
- Improved Drop Structure
- Improved Pipe

Current Condition 25Y Flood Depth (Ft)

- 0 ft - 0.5 ft
- 0.5 ft - 1.0 ft
- 1.0 ft - 1.5 ft
- 1.5 ft - 2.0 ft
- > 2.0 ft

Improved Condition 25Y Flood Depth (Ft)

- 0 ft - 0.5 ft
- 0.5 ft - 1.0 ft
- 1.0 ft - 1.5 ft
- 1.5 ft - 2.0 ft
- > 2.0 ft

N W E S

Sources:
Aerial: City of Charleston
Map Projection: SC State Plane

Area 6

0 200 400 800 1,200 1,600 Feet
Typical Scale

1 inch = 800 feet

AECOM

Figure 9-7

April 2019

Figure 9-7. Area 6: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

Figure 9-7 (b) visually shows the location of these improvements and **Figure 9-7 (c)** graphically represents the range of flooding depths after the improvements are made.

The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-19**.

Table 9-19. Levels of Service Criteria

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
Ashley River Rd	DuWapN_53	Evacuation	24.41	24.15	0	Yes
Tomoka Dr	DuWapN_74	Minor	22.47	22.73	0.26	Yes
Westover Dr	DuWapN_74	Minor	22.47	22.73	0.26	Yes
Daytona Dr	DuWapN_74	Minor	22.47	22.73	0.26	Yes
Palmetto Park Rd	DuWapN_274	Minor	9.6	9.8	0.2	Yes

Results from the table shows that all roadways within Project Area 6 meet the intended Level of Service criteria.

Table 9-20 provides the total cost of the recommended improvements for Project Area 6.

Table 9-20. Total Costs for Project Area 6

Area-6 Items	Cost
Pipe Improvements	$ 387,000
Channel Improvements	$ 14,000
Addition of Storage	$ 13,000
TOTAL	**$ 414,000**

Details of the capital improvements costs listed above are provide in **Appendix R**.

<u>Project Area # 7 – Intersection of Jenkins Road and Gardner Road</u>

Project Area 7 has a total impacted score of **700**. The area is surrounded by San Rittenberg Blvd in the North, Main channel in the South, and Ashley River Rd/Wappoo Rd on the East. The area is in FEMA Flood Zone X.

Table 9-21 shows the nodes that indicate roadway flooding for the 25-year event within Project Area 7.

Table 9-21. Nodes and Roadway Flooding within Project Area 7

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
Sam Rittenberg Blvd	DuWapN_34	Evacuation	18.3	19.29	0.99
Gardner Rd	DuWapMH_46	Minor	11.34	13.3	1.96
Jenkins Rd	DuWapMH_46	Minor	11.34	13.3	1.96

Figure 9-8 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 7 based on the model analysis:

- 820 linear feet of pipe increased in diameter
- 886 linear feet of channels widened
- 1 check valves added to stormwater pipes
- Storage added to 1 pond

Details of the capital improvements listed above are provide in Appendix R.

Figure 9-8 (b) visually shows the location of these improvements and **Figure 9-8 (c)** graphically represents the range of flooding depths after the improvements are made.

The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-22**.

Table 9-22. Levels of Service Criteria

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
Sam Rittenberg Blvd	DuWapN_34	Evacuation	18.3	17.48	0	Yes
Gardner Rd	DuWapMH_46	Minor	11.34	11.5	0.16	Yes
Jenkins Rd	DuWapMH_46	Minor	11.34	11.5	0.16	Yes

Results from the table shows that all roadways within Project Area 7 meet the intended Level of Service criteria.

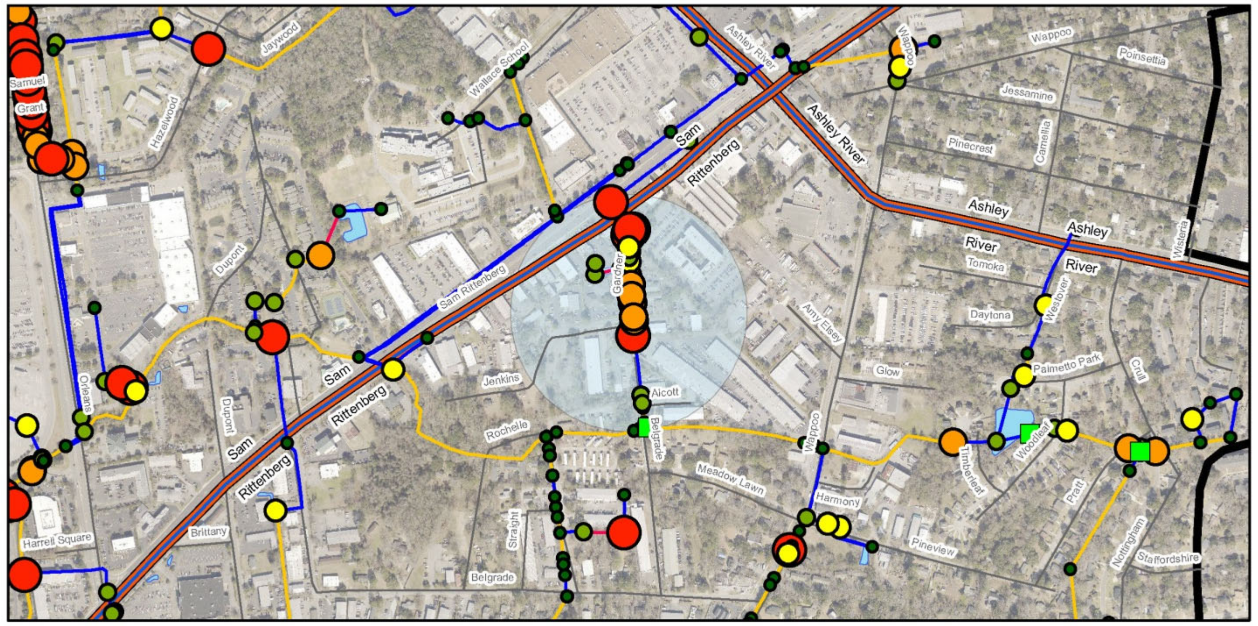


Figure 9-8a - Current Condition 25 Year Flood Depth

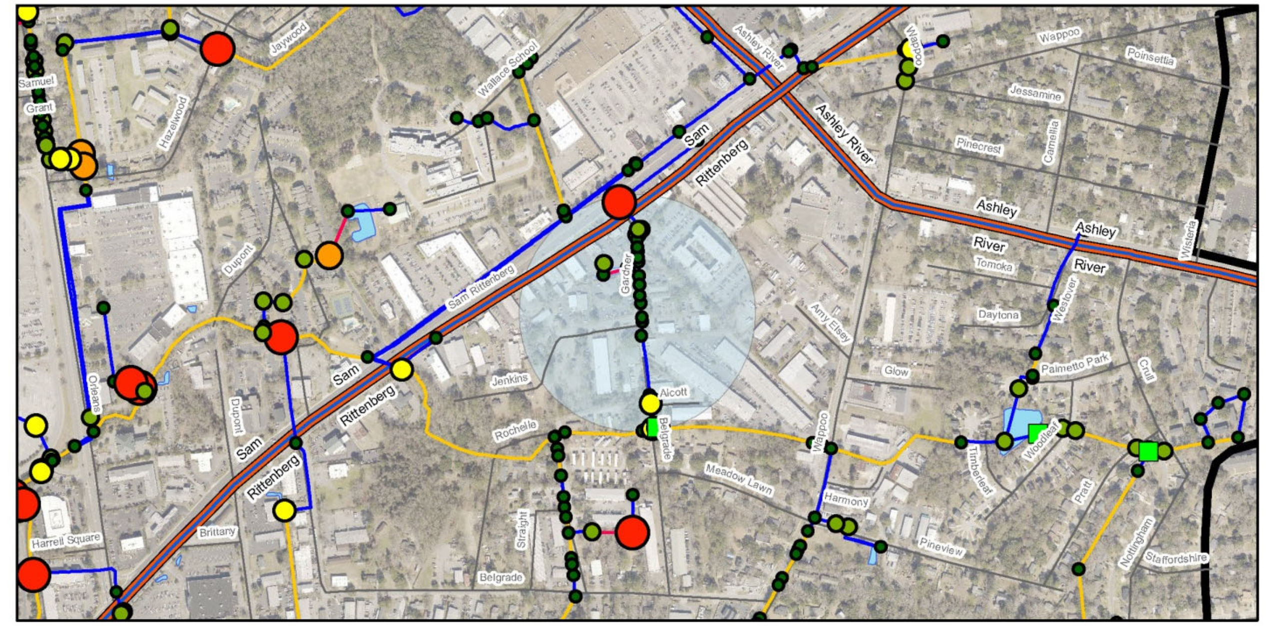


Figure 9-8c - Improved Condition 25 Year Flood Depth

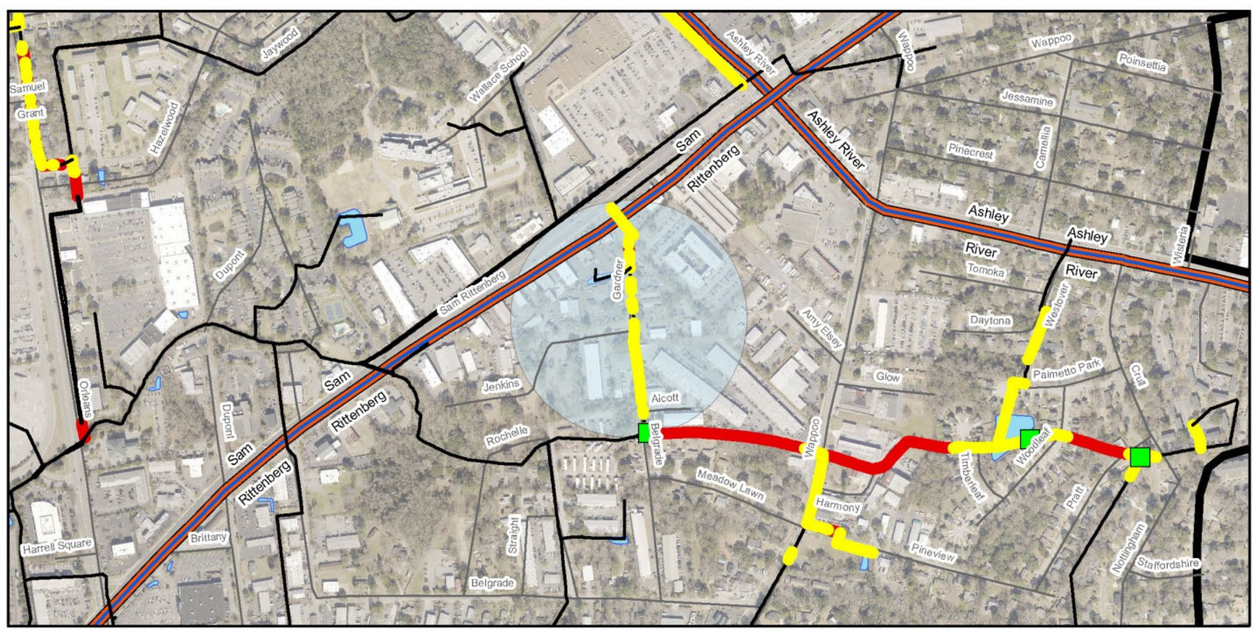


Figure 9-8b - Improved Links

Site Location

Legend

- Overall Watershed Boundary
- Road
- Evacuation Route
- Check Valves
- Channel
- Drop Structure
- Pipe

Link Improvement

- No Improvement
- Improved Channel
- Improved Drop Structure
- Improved Pipe

Current Condition 25Y Flood Depth (Ft)

- 0 ft - 0.5 ft
- 0.5 ft - 1.0 ft
- 1.0 ft - 1.5 ft
- 1.5 ft - 2.0 ft
- > 2.0 ft

Improved Condition 25Y Flood Depth (Ft)

- 0 ft - 0.5 ft
- 0.5 ft - 1.0 ft
- 1.0 ft - 1.5 ft
- 1.5 ft - 2.0 ft
- > 2.0 ft

N W E S

Sources:
Aerial: City of Charleston
Map Projection: SC State Plane

Area 7

0 200 400 800 1,200 1,600 Feet
Typical Scale

1 inch = 800 feet

AECOM

Figure 9-8

April 2019

Figure 9-8. Area 7: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

Table 9-23 provides the total cost of the recommended improvements for Project Area 7.

Table 9-23. Total Costs for Project Area 7

Area-7 Items	Cost
Pipe Improvements	$ 406,000
Channel Improvements	$ 16,000
Addition of Storage	$ 67,000
TOTAL	**$ 489,000**

Details of the capital improvements costs listed above are provide in **Appendix R**.

<u>Project Area # 8 – Intersection of Ashley River Road and Akers Road</u>

Project Area 8 has a total impacted score of **875**. The area is located at the north east corner of the DuWap watershed on the western side of Windjammer Rd on the West. The Project area is within FEMA Flood zone of X.

Table 9-24 shows the nodes that indicate roadway flooding for the 25-year event within Project Area 8.

Table 9-24. Nodes and Roadway Flooding within Project Area 8

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
Sam Rittenberg Blvd	DuWapMH_118	Evacuation	18.7	15.62	0
Ashley River Rd	DuWapMH_27	Evacuation	17.1	18.37	1.27
Akers Rd	DuWapN_12	Minor	17.02	17.93	0.91
Wallace School Rd	DuWapN_12	Minor	17.02	17.93	0.91
Dillway St	DuWapMH_108	Minor	17.18	18.41	1.23

Figure 9-9 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 8 based on the model analysis:

- 1353 linear feet of pipe increased in diameter
- Storage added to 2 ponds

Details of the capital improvements listed above are provided in **Appendix R**.

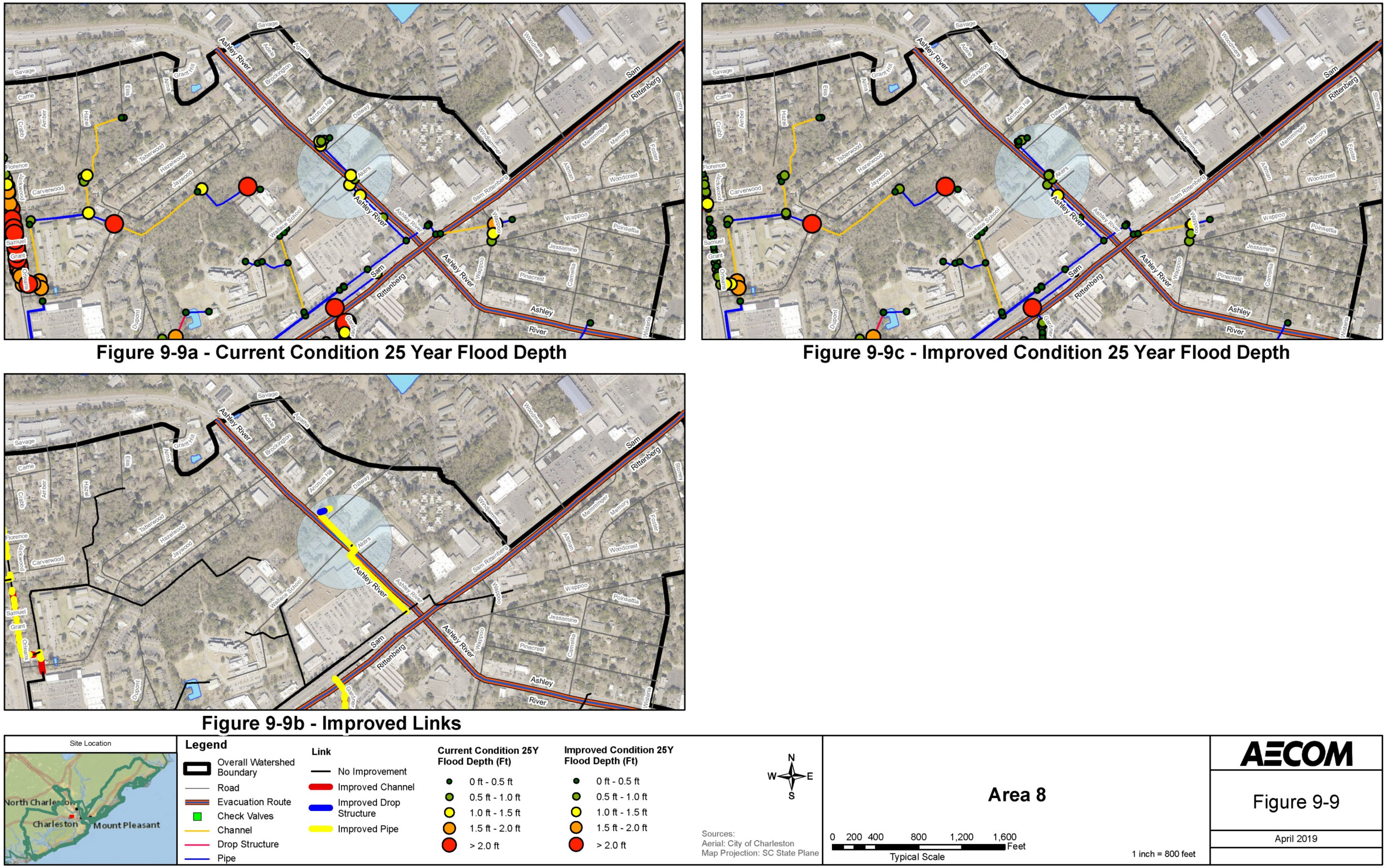


Figure 9-9. Area 8: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

Figure 9-9 (b) visually shows the location of these improvements and **Figure 9-9 (c)** graphically represents the range of flooding depths after the improvements are made.

The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-25**.

Table 9-25. Levels of Service Criteria

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
Sam Rittenberg Blvd	DuWapMH_118	Evacuation	18.7	16.82	0	Yes
Ashley River Rd	DuWapMH_27	Evacuation	17.1	17.44	0.34	Yes
Akers Rd	DuWapN_12	Minor	17.02	17.57	0.55	Yes
Wallace School Rd	DuWapN_12	Minor	17.02	17.57	0.55	Yes
Dillway St	DuWapMH_108	Minor	17.18	17.44	0.26	Yes

Results from the table shows that all roadways within Project Area 8 meet the intended Level of Service criteria.

Table 9-26 provides the total cost of the recommended improvements for Project Area 8.

Table 9-26. Total Costs for Project Area 8

Area-8 Items	Cost
Pipe Improvements	$ 665,000
Channel Improvements	$ -
Addition of Storage	$ 34,000
TOTAL	**$ 699,000**

Details of the capital improvements costs listed above are provide in **Appendix R**.

<u>Project Area # 9 – Intersection of Wappoo Road and Meadowlawn Drive</u>

Project Area 9 has a total impacted score of **799**. The area is surrounded by W Robinhood Dr/Grech St on the South, W Glow Dr on the North, Wappo Rd on the West and Woodleaf Ct on the East. The Project area is located within the FEMA Flood zone X. They are adjacent to Project areas 5 and 6.

Table 9-27 shows the nodes that indicate roadway flooding for the 25-year event within Project Area 9.

Table 9-27. Nodes and Roadway Flooding within Project Area 9

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
Wappoo Rd	DuWapMH_10	Major	12.11	12.69	0.58
Meadowlawn Dr	DuWapMH_10	Minor	12.11	12.69	0.58
Pineview Rd	DuWapMH_10	Minor	12.11	12.69	0.58
Heritage Park Rd	DuWapMH_294	Minor	13.59	13.77	0.18

Figure 9-10 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 9 based on the model analysis:

- 849 linear feet of pipe increased in diameter
- 65 linear feet of channels widened

Details of the capital improvements listed above are provided in **Appendix R**.

Figure 9-10 (b) visually shows the location of these improvements and **Figure 9-10 (c)** graphically represents the range of flooding depths after the improvements are made.

The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-28**.

Table 9-28. Levels of Service Criteria

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
Wappoo Rd	DuWapMH_10	Major	12.11	11.75	0	Yes
Meadowlawn Dr	DuWapMH_10	Minor	12.11	11.75	0	Yes
Pineview Rd	DuWapMH_10	Minor	12.11	11.75	0	Yes
Heritage Park Rd	DuWapMH_294	Minor	13.59	12.91	0	Yes

Results from the table shows that all roadways within Project Area 9 meet the intended Level of Service criteria.

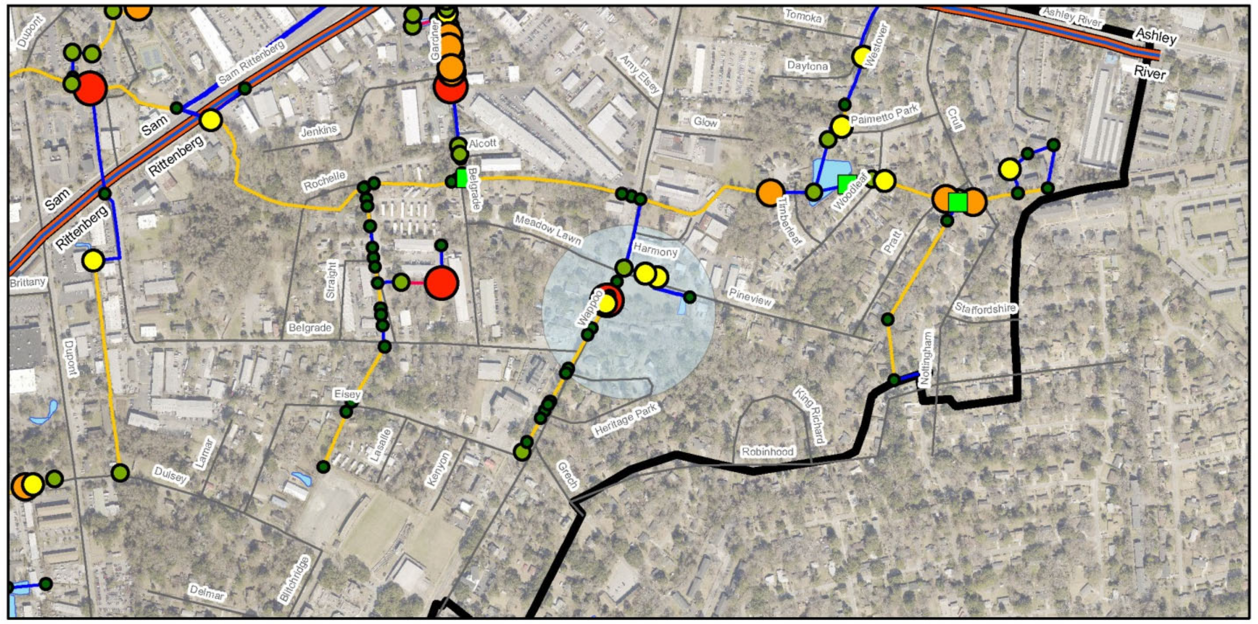


Figure 9-10a - Current Condition 25 Year Flood Depth

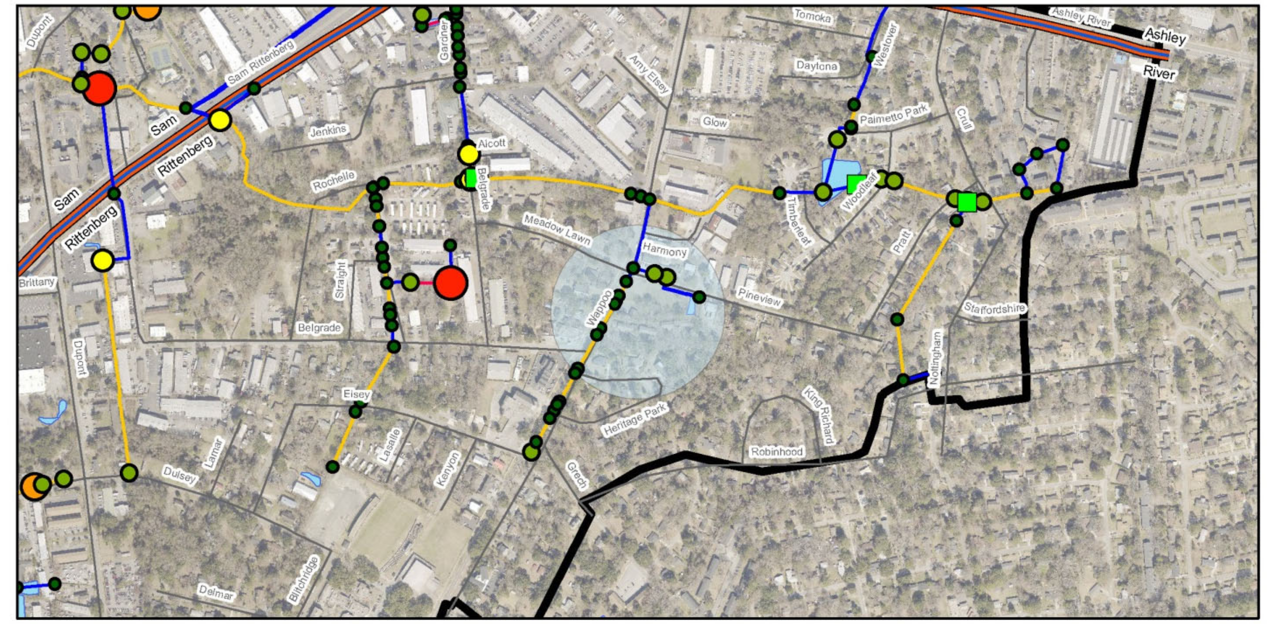


Figure 9-10c - Improved Condition 25 Year Flood Depth

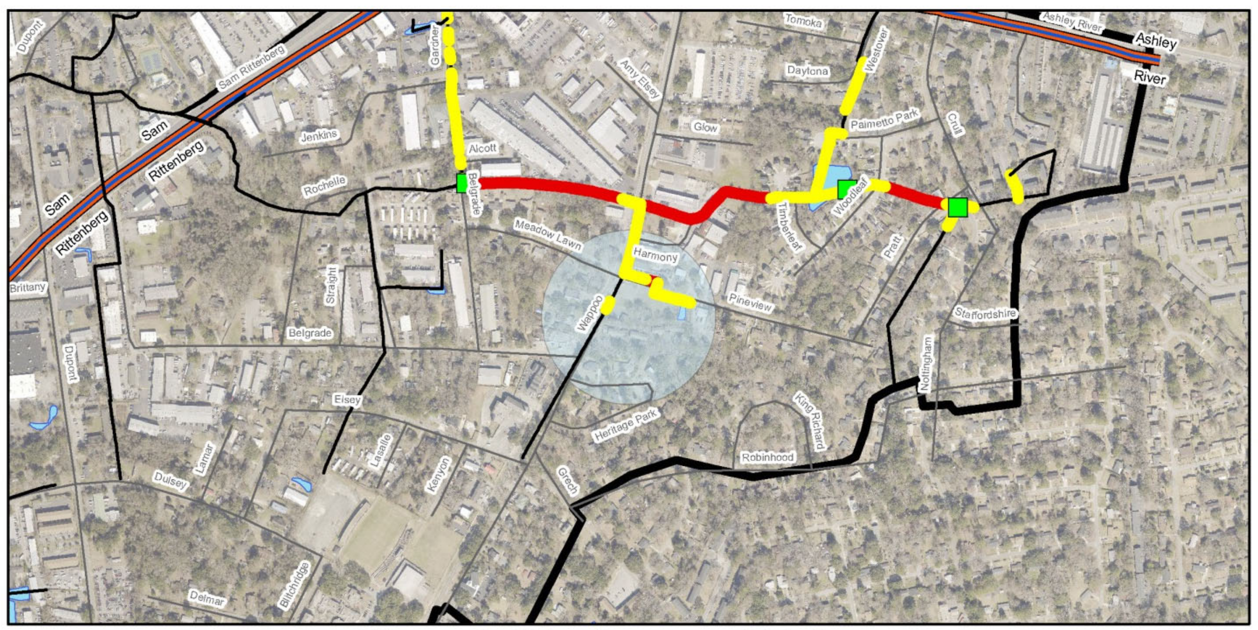


Figure 9-10b - Improved Links

Site Location

Legend

- Overall Watershed Boundary
- Road
- Evacuation Route
- Check Valves
- Channel
- Drop Structure
- Pipe

Link Improvement

- No Improvement
- Improved Channel
- Improved Drop Structure
- Improved Pipe

Current Condition 25Y Flood Depth (Ft)

- 0 ft - 0.5 ft
- 0.5 ft - 1.0 ft
- 1.0 ft - 1.5 ft
- 1.5 ft - 2.0 ft
- > 2.0 ft

Improved Condition 25Y Flood Depth (Ft)

- 0 ft - 0.5 ft
- 0.5 ft - 1.0 ft
- 1.0 ft - 1.5 ft
- 1.5 ft - 2.0 ft
- > 2.0 ft

N W E S

Sources:
Aerial: City of Charleston
Map Projection: SC State Plane

0 200 400 800 1,200 1,600 Feet
Typical Scale

Area 9

1 inch = 800 feet

AECOM

Figure 9-10

April 2019

Figure 9-10. Area 9: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

Table 9-29 provides the total cost of the recommended improvements for Project Area 9.

Table 9-29. Total Costs for Project Area 9

Area-9 Items	Cost
Pipe Improvements	$ 413,000
Channel Improvements	$ 1,000
Addition of Storage	$ -
TOTAL	**$ 414,000**

Details of the capital improvements costs listed above are provided in **Appendix R**.

Project Area # 10 – Intersection of Applebee Way and Parkdale Drive

Project Area 10 has a total impacted score of **1677**. The area is close to the Stono river and is tidally influenced. The area is surrounded by Savannah Hwy on the North, West Ashley Greenway on the South, Mutual Dr on the West and the Main Channel on the East. The area is

Table 9-30 shows the nodes that indicate roadway flooding for the 25-year event within Project Area 10.

Table 9-30. Nodes and Roadway Flooding within Project Area 10

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Existing Conditions Node Max Stage (ft)	Flood Depth (ft)
Savannah Hwy	DuWapMH_191	Evacuation	5.22	9.59	4.37
Applebee Way	DuWapMH_56	Minor	5.23	8.51	3.28
Parkdale Dr	DuWapMH_56	Minor	5.23	8.51	3.28

Figure 9-11 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

To address the flooding and meet the LOS criteria, the following capital improvement projects are suggested for Project Area 10 based on the model analysis:

- Storage added to 4 nodes
- 3 check valves added to stormwater pipes

Details of the capital improvements listed above are provided in **Appendix R**.

Figure 9-11 (b) visually shows the location of these improvements and **Figure 9-11 (c)** graphically represents the range of flooding depths after the improvements are made.

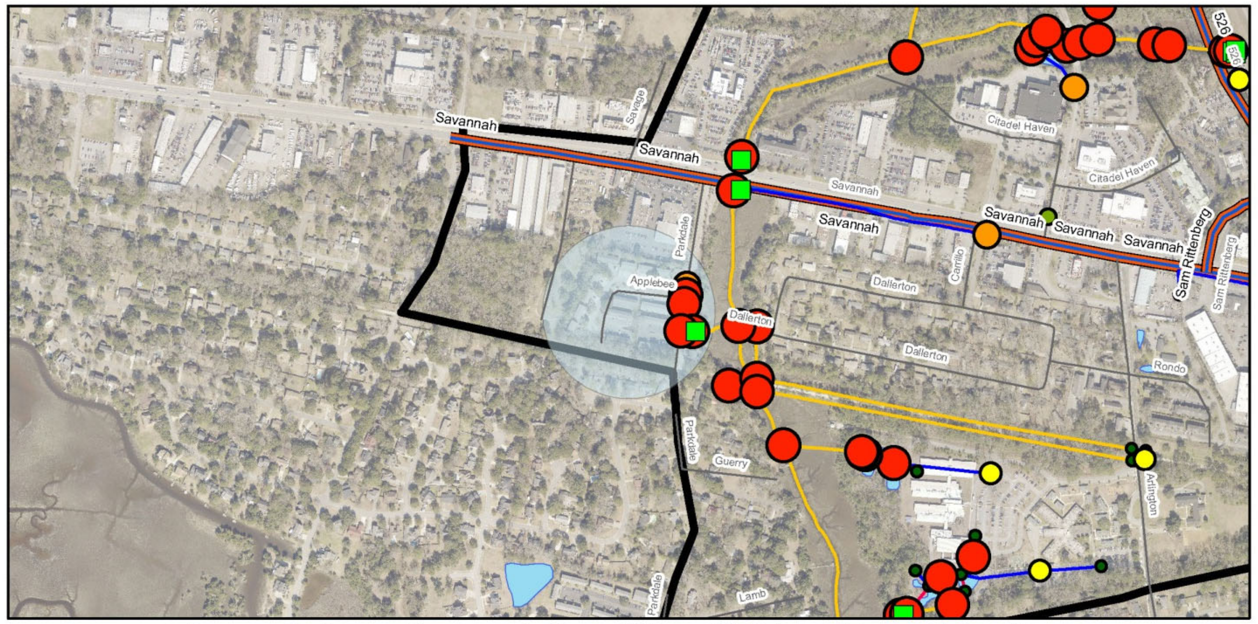


Figure 9-11a - Current Condition 25 Year Flood Depth

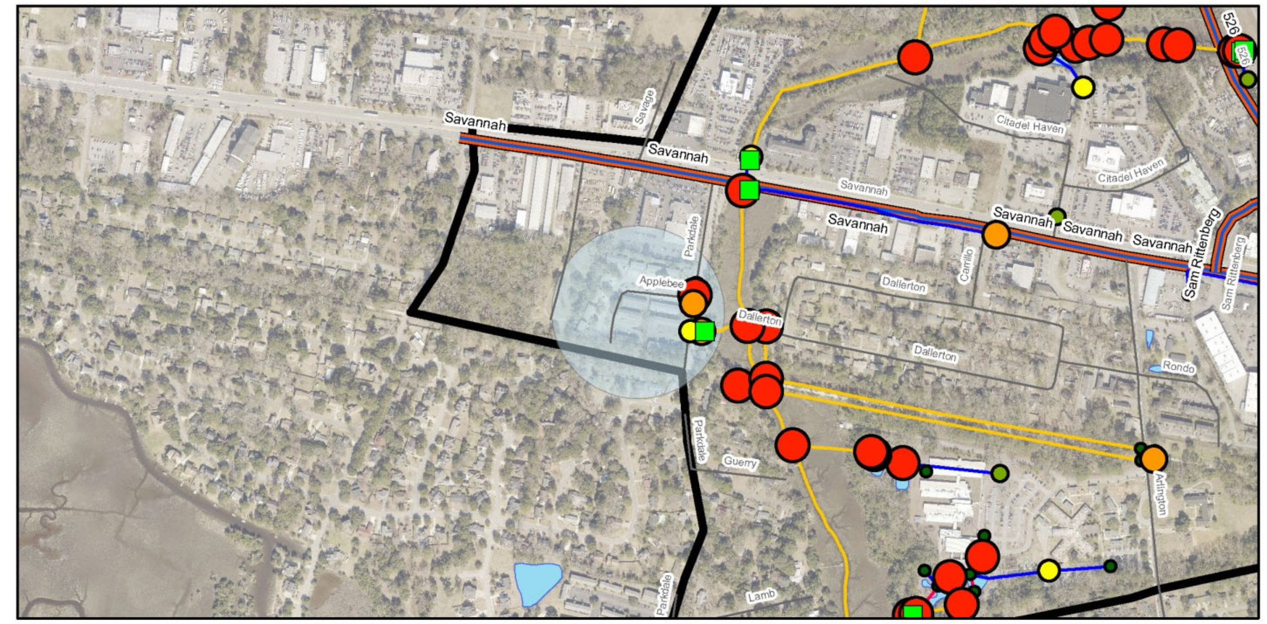


Figure 9-11c - Improved Condition 25 Year Flood Depth

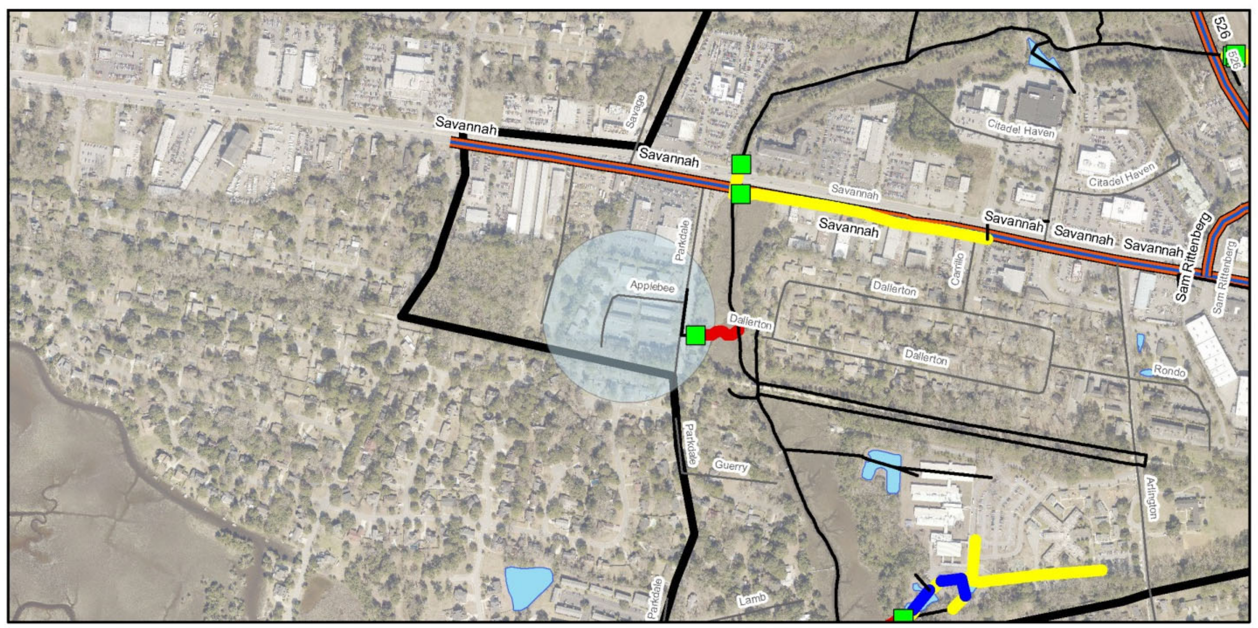


Figure 9-11b - Improved Links

Site Location

Legend

- Overall Watershed Boundary
- Road
- Evacuation Route
- Check Valves
- Channel
- Drop Structure
- Pipe

Link Improvement

- No Improvement
- Improved Channel
- Improved Drop Structure
- Improved Pipe

Current Condition 25Y Flood Depth (Ft)

- 0 ft - 0.5 ft
- 0.5 ft - 1.0 ft
- 1.0 ft - 1.5 ft
- 1.5 ft - 2.0 ft
- > 2.0 ft

Improved Condition 25Y Flood Depth (Ft)

- 0 ft - 0.5 ft
- 0.5 ft - 1.0 ft
- 1.0 ft - 1.5 ft
- 1.5 ft - 2.0 ft
- > 2.0 ft

N W E S

Sources:
Aerial: City of Charleston
Map Projection: SC State Plane

Area 10

0 200 400 800 1,200 1,600 Feet
Typical Scale

1 inch = 800 feet

AECOM

Figure 9-11

April 2019

Figure 9-11. Area 10: Current Condition 25 Year Flood Depth, Improved Condition 25 Year Flood Depth, and Improved Links

The levels of service criteria were compared to the proposed condition model results for each of the road intersections and are summarized in **Table 9-31.**

Table 9-31. Levels of Service Criteria

Road Name	Associated Model ID	Road Classification	Edge of Pavement Elevation (ft)	Proposed Conditions Node Max Stage (ft)	Flood Depth (ft)	Meets LOS
Savannah Hwy	DuWapMH_191	Evacuation	5.22	9.64	4.42	No
Applebee Way	DuWapMH_56	Minor	5.23	7.29	2.06	No
Parkdale Dr	DuWapMH_56	Minor	5.23	7.29	2.06	No

Table 9-31 shows that none of the roadways within Project Area 10 meet the intended Level of Service criteria. This is the result of the area closely located to the Stono River, which is tidally influenced and the effect of storm surge and SLR put the peak value at 9.0’ NAVD for 25-year design storm event. Therefore, to eliminate flooding at this location, it would require a berm with a wall adjacent to the main channel up to the peak WSE and use Pump Station with wet well within the project location to drain the water. Since this is a mixed commercial/residential area, the space is at premium. Addition of a pump station with a wetwell will require the City to buy some of the already developed properties. These additional improvements may not provide proportionate benefits due to the cost of the improvements.

Table 9.32 provides the total cost of the recommended improvements for Project Area 10.

Table 9-32. Total Costs for Project Area 10

Area-10 Items	Cost
Pipe Improvements	$ 52,000
Channel Improvements	$ -
Addition of Storage	$ 148,000
TOTAL	**$ 200,000**

The total cost of additional improvements including purchase of properties, creation of berm, and installation of a stormwater pump station is approximately $31,442,300.

Details of the capital improvements costs listed above are provided in **Appendix R**.

Project Area # 11 – Area between W Ashley Greenway and Clayton Drive

Project Area 11 has a total impacted score of **415**. The area is located at the mouth of Stono river and is impacted by the tidal influence of the river. The area is located between Boardwalk and Clayton Dr.

System infrastructure within Project Area 11 is privately owned and per the assumptions, no improvements have been proposed for Project Area 11.

Figure 9-12 (a) graphically represents the evacuation routes, major arterials/collectors, and local roads along with the range of flooding depths for existing conditions.

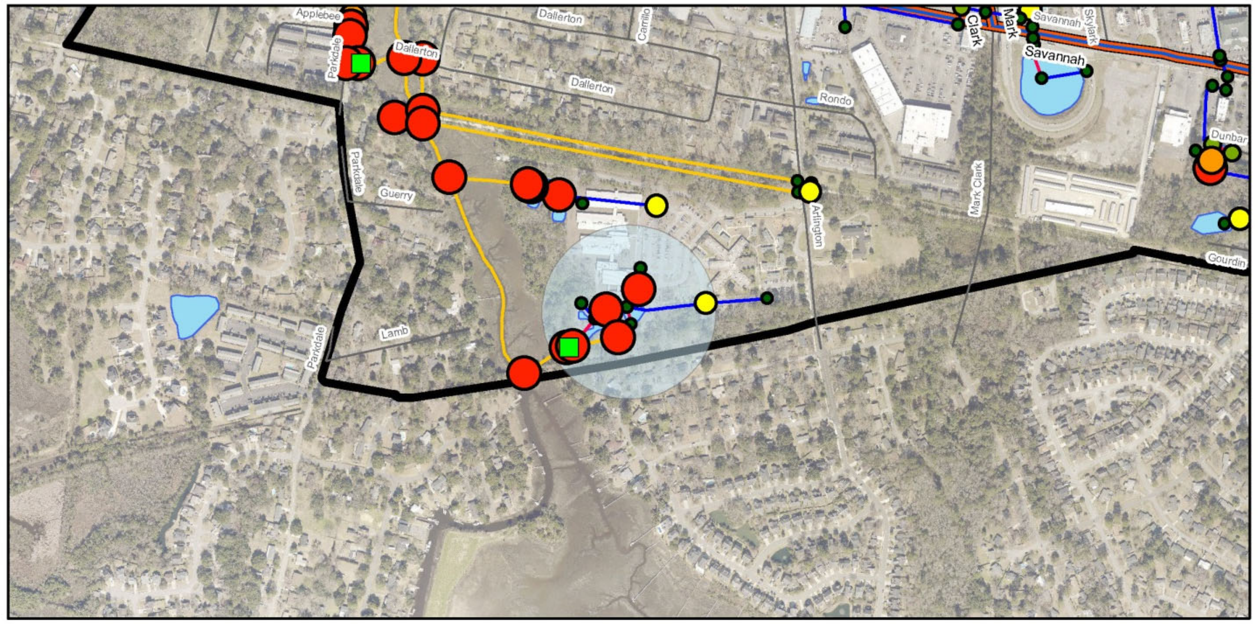


Figure 9-12a - Current Condition 25 Year Flood Depth

Figure 9-12. Area 11: Current Condition 25 Year Flood Depth

9.1 Capital Improvement Projects Summary

Overall summary of improvements for the entire watershed along with the cost of improvements are provided in **Table 9-33** below. All these improvements in individual form or in combination provided significant benefits by alleviating flooding across the entire watershed. In addition, the improvements also provided second benefits in terms of alleviating the neighborhood flooding across the watershed.

Table 9-33. Summary of Cost

Area	Pipes	Channels	Ponds	Total
1	$ 371,000	$ 10,000	$ 86,000	*$ 467,000*
2	$ 476,000	$ 11,000	$ 30,000	*$ 517,000*
3	$ 838,000	$ -	$ 8,000	*$ 846,000*
4	$ 110,000	$ -	$ -	*$ 110,000*
5	$ 339,000	$ 8,000	$ 8,000	*$ 355,000*
6	$ 387,000	$ 14,000	$ 13,000	*$ 414,000*
7	$ 406,000	$ 16,000	$ 67,000	*$ 489,000*
8	$ 665,000	$ -	$ 34,000	*$ 699,000*
9	$ 413,000	$ 1,000	$ -	*$ 414,000*
10	$ 52,000	$ -	$ 148,000	*$ 200,000*
			Construction Total	*$ 4,511,000*
			Preliminary Engineering	**$ 903,000**
			Design & Construction Engineering	**$ 1,354,000**
			Project Total	**$ 6,768,000**

9.2 Water Quality

Stormwater and water quality improvements play an important role in preserving and enhancing the natural environment. Appropriate mix of grey infrastructure improvements with green infrastructure (GI) improvements can improve water quality, mitigate flooding, and improve the aesthetics of the environment. In addition, incorporation of GI in the stormwater plan can provide supplementary benefits like development of recreational areas, revival of distressed communities, and attract new investments. GI elements should be incorporated in the DuWap watershed along with the proposed stormwater improvements at each flooding location.

GI approach is based on four fundamental principles:

- Embrace stormwater as a resource rather than a waste product,
- Preserve and/or re-create natural landscape features and systems,
- Minimize the effects of impervious cover, and
- Implement stormwater systems that rely on natural systems to manage runoff.

Common GI tools include bioswales, bioretention basins, filter marsh systems, tree planters, permeable/porous pavement and green roofs etc.

Proposed improvements within DuWap watershed mainly includes:

- Improvement of culverts (Addition/Upsizing),
- Addition of check valves,
- Addition of Storage as Wet Detention/Dry Detention ponds, and
- Addition/Widening of Swales/Channels.

Improvement of Culverts and Addition of Check Valves: These improvements mainly provide water quantity benefits by conveying the excess stormwater runoff from the watershed and preventing the low lying areas in the watershed from tidal influence. However, addition of mechanical devices such as baffle boxes/downstream defender units inside the structures can remove floatable organics, oils, large particles, and suspended solids. These systems are typically used as pretreatment devices and require maintenance to remove collected debris and sediments.

Wet Retention Ponds: Wet retention systems are permanently wet pools that retain untreated runoff. These systems could be configured as bioretention basins that are designed to collect and filter runoff. Over time, pollutants are removed from the water via nutrient uptake by algae, special soils that filter the water and enhance infiltration, adsorption onto bottom sediments, biological oxidation of organic materials, and sedimentation.

Dry Detention: Dry detention systems collect runoff and slowly release the volume to adjacent surface waters through an outlet structure over a time period until water is drawn down completely. These areas do not permanently hold water and are typically dry. Pollutants settle to the bottom of the dry detention pond as water is drawn out. Dry retention systems collect runoff and release the volume slowly through an engineered outlet structure and by allowing the water to percolate through soils into the shallow aquifer.

Channel/Swale Improvements: These improvements consist of vegetated channels such as bioswales that require shallow slopes and soils that drain well. Bioswales provide filtering function and require less maintenance over time. Runoff collected in these systems drain quickly and is not detained for a long period of time. Pollutants are removed by filtration through the grass and infiltration through the soil. Deeper and longer swales function like a linear retention pond and can reduce the peak flowrate and provide high pollutant removal rates.

As with any stormwater management design, GI practices must be carefully designed to account for existing soil conditions, seasonal high groundwater elevation, and topography.

10. Conclusions and Recommendations

This Stormwater Master Plan update evaluated the current state of stormwater management and the condition of storm sewers within DuWap watershed in City of Charleston, South Carolina. This master plan takes the City into the next age of stormwater management and will give its residents assurances that the City is actively implementing projects and operation and maintenance activities that “manage stormwater in ways to store, improve water quality, and achieve the drainage level of service as recommended, thereby protecting public health, property and the environment.

Hydrologic and Hydraulic modeling using ICPR 4 was performed for the study watershed and approximately 11 locations were identified based on the modeling results and assessed condition of storm sewers. Within these flood prone areas, a total of 42 roadways where the model demonstrated roadway flooding. Of those 42 locations, 36 locations did not meet the 25-year level of service (LOS) criteria as defined in Section 8 of the report.

For each area, the extent of roadway flooding based on the model along with the locations that did not meet the LOS criteria are detailed. After identifying these locations, improvements were proposed to reduce the roadway flooding to desired levels of service (LOS). The proposed improvements consisted of the following types of improvements:

- Provide storm water storage facilities such as retention/detention systems to capture and detain/retain excess flood waters and reduce downstream peak discharge rates.
- Provide an enhanced conveyance system, through channel and structure improvements which increase the hydraulic efficiency of the drainage system and reduces peak flood elevations. These improvements were limited to the use of existing rights-of-ways or easements.
- Included check valves at appropriate locations to isolate sub-areas within the watershed and also reduce the tidal impacts in to the system.

Capital improvement projects worth $6,768,000. were identified and upon implementation of these projects, 30 of the 35 locations met the LOS criteria, with flood areas 5 and 10 requiring additional improvements. Although the LOS was not met, there was a decrease in peak stage at some of these locations. For those areas that did not meet the LOS, additional improvements such as building a flood wall, installation of stormwater pump station, and converting some existing residential properties to detention ponds etc. were considered. While these improvements provide maximum benefits, they significantly increase the cost of the improvements. The cost of these improvements is approximately $39,000,000 and the details are provided in **Appendix R**.

With the completion of the Stormwater Master Plan Update, the County now has a prioritized list of projects to improve storm sewer system capacity and to treat stormwater runoff. Cost estimate for each of the proposed projects were also developed and summarized in the report.

In addition, some areas for future consideration include:

- As each project moves forward, it is recommended that a detailed study be conducted to develop a comprehensive design solution. Implementation of the improvements should provide a secondary benefit of relieving some neighborhood-level flooding.

- Development of a rainfall and runoff monitoring system to provide more robust data for hydrologic models;
- Installation of Flow meters and Stage recorders to monitor and record flow and stage data for model calibration and validation
- Development of a County-wide Green Infrastructure Plan that addresses the programs related to tree canopy, parks, stormwater facilities, and natural resources, examines current connections and conflicts, and develops a unified set of objectives

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Appendix A NRCS Soil Report

United States Department of Agriculture

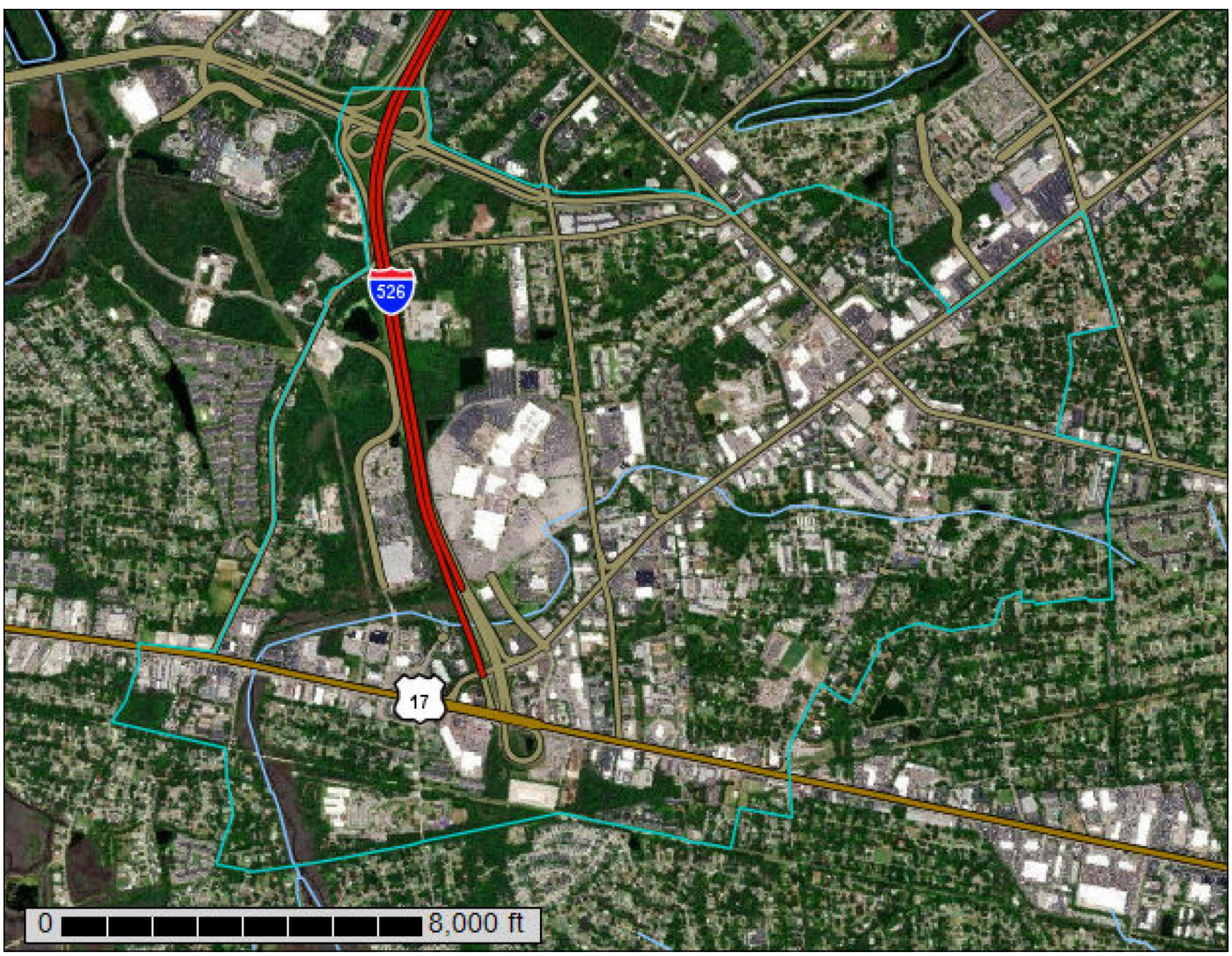
NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for Charleston County Area, South Carolina

Dupont-Wappoo Watershed



January 16, 2019

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

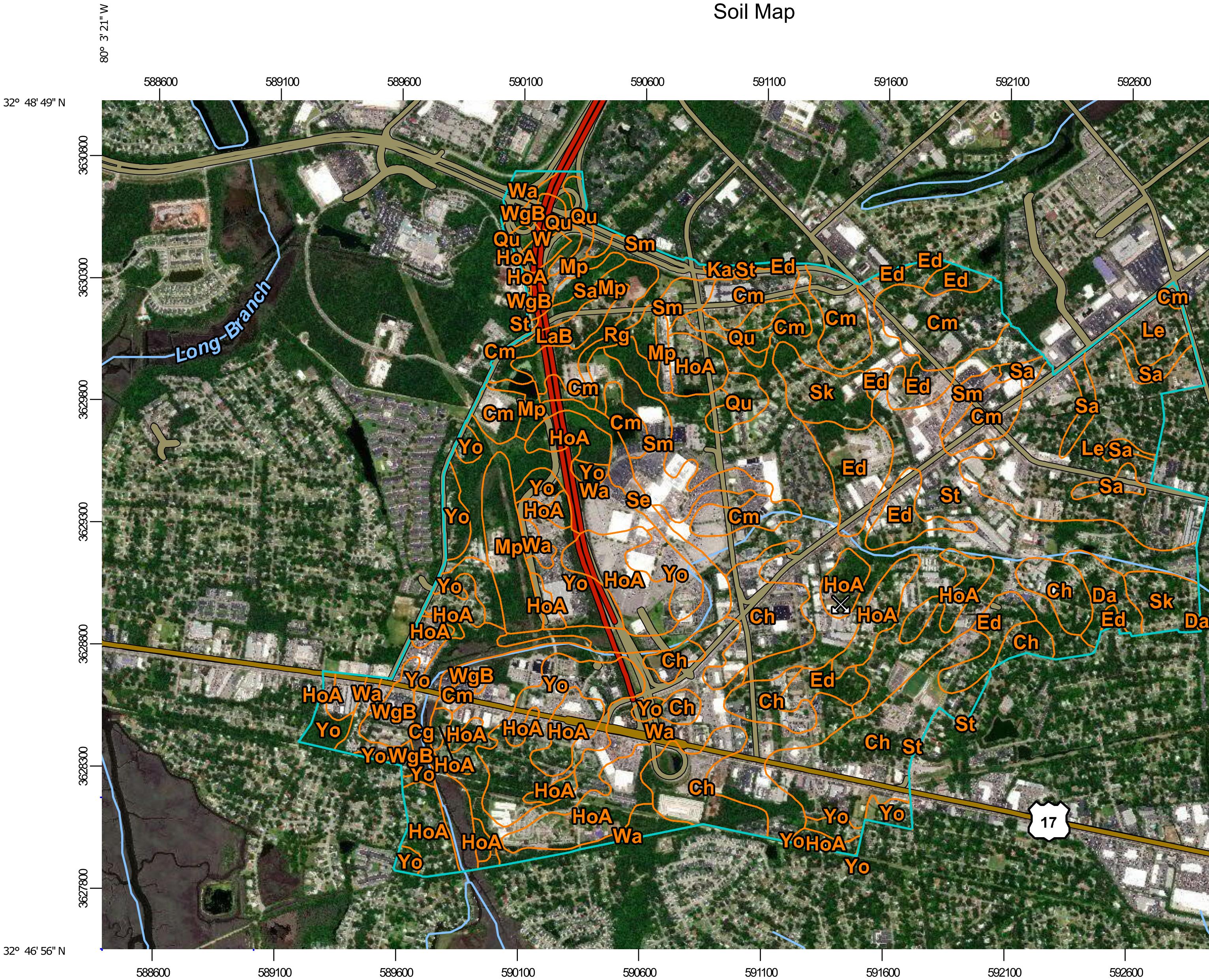
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map



Map Scale: 1:24,500 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 350, 700, 1400, 2100

Feet: 0, 1000, 2000, 4000, 6000

N

Map projection: Web Mercator   Corner coordinates: WGS84   Edge tics: UTM Zone 17N WGS84

MAP LEGEND

Area of Interest (AOI)

Area of Interest (AOI)

Soils

Soil Map Unit Polygons

Soil Map Unit Lines

Soil Map Unit Points

Special Point Features

Blowout

Borrow Pit

Clay Spot

Closed Depression

Gravel Pit

Gravelly Spot

Landfill

Lava Flow

Marsh or swamp

Mine or Quarry

Miscellaneous Water

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Severely Eroded Spot

Sinkhole

Slide or Slip

Sodic Spot

Spoil Area

Stony Spot

Very Stony Spot

Wet Spot

Other

Special Line Features

Water Features

Streams and Canals

Transportation

Rails

Interstate Highways

US Routes

Major Roads

Local Roads

Background

Aerial Photography

MAP INFORMA

The soil surveys that comprise your AOI w
1:20,000.

Please rely on the bar scale on each map
measurements.

Source of Map: Natural Resources Con
Web Soil Survey URL:
Coordinate System: Web Mercator (EPS

Maps from the Web Soil Survey are base
projection, which preserves direction and
distance and area. A projection that prese
Albers equal-area conic projection, should
accurate calculations of distance or area

This product is generated from the USDA
of the version date(s) listed below.

Soil Survey Area: Charleston County Ar
Survey Area Data: Version 15, Sep 15,

Soil map units are labeled (as space allow
1:50,000 or larger.

Date(s) aerial images were photographed
15, 2017

The orthophoto or other base map on wh
compiled and digitized probably differs fro
imagery displayed on these maps. As a r
shifting of map unit boundaries may be ev

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Cg	Capers silty clay loam	31.2	1.9%
Ch	Charleston loamy fine sand	170.1	10.6%
Cm	Chipley loamy fine sand	142.4	8.8%
Da	Dawhoo and rutlege loamy fine sand	13.6	0.8%
Ed	Edisto loamy fine sand	81.0	5.0%
HoA	Hockley loamy fine sand, 0 to 2 percent slopes	182.7	11.3%
Ka	Kiawah loamy fine sand	0.9	0.1%
LaB	Lakeland sand, 0 to 6 percent slopes	14.1	0.9%
Le	Leon fine sand, 0 to 2 percent slopes	121.0	7.5%
Mp	Mine pits and dumps	36.1	2.2%
Qu	Quitman loamy sand	34.0	2.1%
Rg	Rutlege loamy fine sand	24.1	1.5%
Sa	St. Johns fine sand	28.1	1.7%
Se	Santee loam	34.5	2.1%
Sk	Seabrook loamy fine sand	36.4	2.3%
Sm	Seewee complex	48.1	3.0%
St	Stono fine sandy loam	278.0	17.3%
W	Water	5.1	0.3%
Wa	Wadmalaw fine sandy loam	161.0	10.0%
WgB	Wagram loamy fine sand, 0 to 6 percent slopes	24.0	1.5%
Yo	Yonges loamy fine sand	143.8	8.9%
Totals for Area of Interest		**1,610.4**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Charleston County Area, South Carolina

Cg—Capers silty clay loam

Map Unit Setting

National map unit symbol: 4mw8
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Capers and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Capers

Setting

Landform: Marshes
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Clayey fluviomarine deposits

Typical profile

A - 0 to 5 inches: silty clay loam
Cg - 5 to 50 inches: silty clay

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: Very frequent
Frequency of ponding: Frequent
Available water storage in profile: Low (about 5.9 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 8w
Hydrologic Soil Group: C/D
Hydric soil rating: Yes

Ch—Charleston loamy fine sand

Map Unit Setting

National map unit symbol: 4mw9

Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Charleston and similar soils: 97 percent
Minor components: 3 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Charleston

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy fluviomarine deposits

Typical profile

Ap - 0 to 8 inches: loamy fine sand
E - 8 to 16 inches: loamy fine sand
Bt - 16 to 44 inches: fine sandy loam
C - 44 to 52 inches: fine sandy loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 5.95 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 7.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: B
Hydric soil rating: No

Minor Components

Yonges

Percent of map unit: 3 percent
Landform: Depressions, marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

Cm—Chipley loamy fine sand

Map Unit Setting

National map unit symbol: 4mwc
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Pactolus and similar soils: 97 percent
Minor components: 3 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Pactolus

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy marine deposits

Typical profile

Ap - 0 to 6 inches: loamy fine sand
C1 - 6 to 40 inches: loamy fine sand
C2 - 40 to 50 inches: sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: About 18 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 4.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3s
Hydrologic Soil Group: A
Hydric soil rating: No

Minor Components

Rutlege

Percent of map unit: 3 percent
Landform: Depressions, flood plains
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

Da—Dawhoo and rutlege loamy fine sand

Map Unit Setting

National map unit symbol: 4mwh
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Rutlege and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Rutlege

Setting

Landform: Flood plains, depressions
Landform position (three-dimensional): Tread
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Parent material: Sandy fluviomarine deposits

Typical profile

A - 0 to 30 inches: loamy fine sand
Cg - 30 to 60 inches: sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Available water storage in profile: Low (about 5.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 4w
Hydrologic Soil Group: A/D
Hydric soil rating: Yes

Ed—Edisto loamy fine sand

Map Unit Setting

National map unit symbol: 4mwk
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Edisto and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Edisto

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy marine deposits

Typical profile

Ap - 0 to 10 inches: loamy fine sand
E - 10 to 14 inches: loamy fine sand
Bt - 14 to 27 inches: fine sandy loam
E' - 27 to 36 inches: loamy fine sand
B't - 36 to 62 inches: fine sandy loam
B't - 62 to 70 inches: sandy clay loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat poorly drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 5.95 in/hr)
Depth to water table: About 12 to 36 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 7.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: B
Hydric soil rating: No

HoA—Hockley loamy fine sand, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 4mwm
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Yauhannah and similar soils: 94 percent
Minor components: 6 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Yauhannah

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy marine deposits

Typical profile

Ap - 0 to 6 inches: loamy fine sand
E - 6 to 9 inches: loamy fine sand
Bt - 9 to 52 inches: sandy clay loam
BC - 52 to 62 inches: sandy loam
Cg - 62 to 75 inches: loamy sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained
Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 1.98 in/hr)
Depth to water table: About 18 to 30 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 7.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: C
Hydric soil rating: No

Minor Components

Nakina

Percent of map unit: 2 percent
Landform: Marine terraces, depressions
Landform position (three-dimensional): Tread
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Hydric soil rating: Yes

Mouzon

Percent of map unit: 2 percent
Landform: Depressions, flood plains
Landform position (three-dimensional): Tread
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

Yonges

Percent of map unit: 2 percent
Landform: Depressions, marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

Ka—Kiawah loamy fine sand

Map Unit Setting

National map unit symbol: 4mwp
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Kiawah and similar soils: 97 percent
Minor components: 3 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Kiawah

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy marine deposits

Typical profile
Ap - 0 to 8 inches: loamy fine sand
E - 8 to 15 inches: loamy fine sand
Bt - 15 to 48 inches: loamy fine sand
C - 48 to 72 inches: fine sand

Properties and qualities
Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: About 12 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 5.5 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: A/D
Hydric soil rating: No

Minor Components

Rutlege
Percent of map unit: 3 percent
Landform: Depressions, flood plains
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

LaB—Lakeland sand, 0 to 6 percent slopes

Map Unit Setting
National map unit symbol: 4mwq
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition
Foxworth and similar soils: 96 percent
Minor components: 4 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Foxworth

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Sandy marine deposits

Typical profile

A - 0 to 7 inches: sand
C - 7 to 31 inches: sand

Properties and qualities

Slope: 0 to 6 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: About 45 to 72 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Very low (about 2.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3s
Hydrologic Soil Group: A
Hydric soil rating: No

Minor Components

Rutlege

Percent of map unit: 2 percent
Landform: Flood plains, depressions
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Hydric soil rating: Yes

Lynn haven

Percent of map unit: 2 percent
Landform: Depressions, marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

Le—Leon fine sand, 0 to 2 percent slopes

Map Unit Setting

National map unit symbol: 2sxqt
Elevation: 0 to 180 feet
Mean annual precipitation: 45 to 53 inches
Mean annual air temperature: 51 to 81 degrees F
Frost-free period: 190 to 297 days
Farmland classification: Not prime farmland

Map Unit Composition

Leon and similar soils: 94 percent
Minor components: 6 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Leon

Setting

Landform: Flatwoods
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Sandy marine deposits

Typical profile

A - 0 to 7 inches: fine sand
E - 7 to 11 inches: fine sand
Bh - 11 to 26 inches: loamy fine sand
Eg - 26 to 59 inches: loamy fine sand
EBh - 59 to 74 inches: loamy fine sand
B'h - 74 to 80 inches: loamy fine sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.20 to 1.98 in/hr)
Depth to water table: About 0 to 6 inches
Frequency of flooding: None
Frequency of ponding: None
Salinity, maximum in profile: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Sodium adsorption ratio, maximum in profile: 4.0
Available water storage in profile: Low (about 3.8 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4w
Hydrologic Soil Group: A/D

Hydric soil rating: Yes

Minor Components

Mandarin

Percent of map unit: 3 percent
Landform: Rises
Landform position (three-dimensional): Talf, rise
Down-slope shape: Convex, linear
Across-slope shape: Convex, linear
Hydric soil rating: No

Mascotte

Percent of map unit: 3 percent
Landform: Flatwoods
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Hydric soil rating: Yes

Mp—Mine pits and dumps

Map Unit Setting

National map unit symbol: 4mww
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Udorthents and similar soils: 60 percent
Pits: 40 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Udorthents

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy marine deposits

Typical profile

C - 0 to 60 inches: sandy loam

Properties and qualities

Slope: 0 to 6 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Moderately well drained

Runoff class: Low
Capacity of the most limiting layer to transmit water (Ksat): Very low to high (0.00 to 1.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4e
Hydrologic Soil Group: B
Hydric soil rating: No

Description of Pits

Setting

Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy fluviomarine deposits

Qu—Quitman loamy sand

Map Unit Setting

National map unit symbol: 4mx4
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Prime farmland if drained

Map Unit Composition

Yemassee and similar soils: 96 percent
Minor components: 4 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Yemassee

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loamy marine deposits

Typical profile

A - 0 to 8 inches: loamy sand
E - 8 to 13 inches: loamy sand
BE - 13 to 17 inches: fine sandy loam
Btg - 17 to 48 inches: sandy clay loam
BCg - 48 to 56 inches: sandy clay loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 5.95 in/hr)
Depth to water table: About 12 to 18 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: A/D
Hydric soil rating: No

Minor Components

Daleville

Percent of map unit: 2 percent
Landform: Depressions, marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

Rutlege

Percent of map unit: 2 percent
Landform: Depressions, flood plains
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

Rg—Rutlege loamy fine sand

Map Unit Setting

National map unit symbol: 4mx6
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Rutlege and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Rutlege

Setting

Landform: Marine terraces, depressions, flood plains
Landform position (three-dimensional): Tread
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Parent material: Sandy fluviomarine deposits

Typical profile

A - 0 to 20 inches: loamy fine sand
Cg - 20 to 60 inches: sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: About 0 to 6 inches
Frequency of flooding: Rare
Frequency of ponding: Occasional
Available water storage in profile: Low (about 5.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4w
Hydrologic Soil Group: A/D
Hydric soil rating: Yes

Sa—St. Johns fine sand

Map Unit Setting

National map unit symbol: 4mx8
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Lynn haven and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Lynn Haven

Setting

Landform: Depressions, marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear

Parent material: Loamy marine deposits

Typical profile

A - 0 to 11 inches: fine sand
Bh - 11 to 35 inches: sand
C - 35 to 60 inches: sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 5.95 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 3.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 4w
Hydrologic Soil Group: A/D
Hydric soil rating: Yes

Se—Santee loam

Map Unit Setting

National map unit symbol: 4mxb
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Brookman and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Brookman

Setting

Landform: Depressions, flood plains
Landform position (three-dimensional): Tread
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Parent material: Loamy marine deposits

Typical profile

A - 0 to 16 inches: sandy clay loam
Btg - 16 to 50 inches: sandy clay
BCg - 50 to 60 inches: sandy clay loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.57 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Available water storage in profile: Moderate (about 7.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 6w
Hydrologic Soil Group: C/D
Hydric soil rating: Yes

Sk—Seabrook loamy fine sand

Map Unit Setting

National map unit symbol: 4mxd
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition

Ridgeland and similar soils: 97 percent
Minor components: 3 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Ridgeland

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Sandy marine deposits

Typical profile

A - 0 to 9 inches: loamy fine sand
C - 9 to 60 inches: sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat poorly drained
Runoff class: Very low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 5.95 in/hr)
Depth to water table: About 18 to 30 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 3.8 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: B
Hydric soil rating: No

Minor Components

Rutlege
Percent of map unit: 3 percent
Landform: Depressions, flood plains
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

Sm—Seewee complex

Map Unit Setting
National map unit symbol: 4mxf
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition
Witherbee and similar soils: 97 percent
Minor components: 3 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Witherbee

Setting
Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Sandy marine deposits

Typical profile
A - 0 to 6 inches: loamy fine sand
E - 6 to 21 inches: loamy fine sand
Bh - 21 to 30 inches: fine sand
C - 30 to 65 inches: fine sand

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Somewhat poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: About 12 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Low (about 4.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: A/D
Hydric soil rating: No

Minor Components

Rutlege

Percent of map unit: 3 percent
Landform: Depressions, flood plains
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Hydric soil rating: Yes

St—Stono fine sandy loam

Map Unit Setting

National map unit symbol: 4mxg
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Nakina and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Nakina

Setting

Landform: Depressions, marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Concave, linear
Across-slope shape: Concave, linear
Parent material: Loamy marine deposits

Typical profile
Ap - 0 to 9 inches: fine sandy loam
E - 9 to 17 inches: fine sandy loam
Btg - 17 to 37 inches: sandy clay loam
Cg - 37 to 60 inches: loamy fine sand

Properties and qualities
Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Very poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 5.95 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: Rare
Frequency of ponding: None
Available water storage in profile: Moderate (about 7.7 inches)

Interpretive groups
Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: A/D
Hydric soil rating: Yes

W—Water

Map Unit Setting
National map unit symbol: 4mxk
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Not prime farmland

Map Unit Composition
Water: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Wa—Wadmalaw fine sandy loam

Map Unit Setting
National map unit symbol: 4mxl
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Wadmalaw and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Wadmalaw

Setting

Landform: Marine terraces, depressions
Landform position (three-dimensional): Tread
Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Parent material: Loamy marine deposits

Typical profile

A - 0 to 9 inches: fine sandy loam
Eg - 9 to 13 inches: sandy loam
Btg - 13 to 51 inches: sandy clay loam
BCg - 51 to 83 inches: sandy clay loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 5.95 in/hr)
Depth to water table: About 0 inches
Frequency of flooding: None
Frequency of ponding: Occasional
Available water storage in profile: High (about 9.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: A/D
Hydric soil rating: Yes

WgB—Wagram loamy fine sand, 0 to 6 percent slopes

Map Unit Setting

National map unit symbol: 4mxm
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Chisolm and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Chisolm

Setting

Landform: Marine terraces
Landform position (three-dimensional): Tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loamy marine deposits

Typical profile

A - 0 to 8 inches: loamy fine sand
E - 8 to 32 inches: loamy fine sand
Bt - 32 to 50 inches: sandy clay loam
BC - 50 to 60 inches: sandy clay loam

Properties and qualities

Slope: 0 to 6 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Runoff class: Very low
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 5.95 in/hr)
Depth to water table: About 36 to 60 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 7.4 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2s
Hydrologic Soil Group: A
Hydric soil rating: No

Yo—Yonges loamy fine sand

Map Unit Setting

National map unit symbol: 4mxq
Elevation: 0 to 70 feet
Mean annual precipitation: 42 to 52 inches
Mean annual air temperature: 51 to 75 degrees F
Frost-free period: 220 to 240 days
Farmland classification: Farmland of statewide importance

Map Unit Composition

Yonges and similar soils: 100 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Yonges

Setting

Landform: Marine terraces, depressions
Landform position (three-dimensional): Tread

Down-slope shape: Linear, concave
Across-slope shape: Linear, concave
Parent material: Loamy marine deposits

Typical profile

Ap - 0 to 10 inches: loamy fine sand
Eg - 10 to 14 inches: loamy fine sand
Btg - 14 to 58 inches: sandy clay loam
Cg - 58 to 84 inches: fine sandy loam

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Poorly drained
Runoff class: Very high
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.57 to 5.95 in/hr)
Depth to water table: About 0 to 6 inches
Frequency of flooding: None
Frequency of ponding: None
Available water storage in profile: Moderate (about 8.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 3w
Hydrologic Soil Group: A/D
Hydric soil rating: Yes

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Appendix B Dupont-Wappoo Watershed Master Plan SOP

FINAL

Dupont-Wappoo

Watershed Master Plan

Standard Operating Procedure (SOP)

City of Charleston

and

Charleston County

Prepared by:

AECOM

August 2017

Record of Revisions

DESCRIPTION OF REVISION	DATE	REVISED BY

Statement of Limitations

Table of Contents

List of Tables

List of Figures

Section 1 Project Overview

1.1 Introduction and Purpose of SOP

The City of Charleston (City) has initiated Watershed Master Planning as a holistic approach to evaluate existing conditions and identify and prioritize proposed solutions to stormwater problems throughout the City. Watershed Master Planning provides in-depth analysis and planning, accounts for unique considerations or points of emphasis in each watershed/drainage area, and provides a rigorous foundation of technical information which the City can use to make decisions and prepare for the future. The City's Watershed Master Planning approach consists of (5) components:

1. Infrastructure Mapping/Asset Inventory
2. Condition Assessment
3. Stream and Wetland Assessment
4. Hydraulic and Hydrologic Modeling
5. Prioritization of Proposed Projects

Use of standardized procedures, equipment of high accuracy, and consistent methods for mapping and modeling analysis is vital to avoid introduction of error and to produce quality results. For this reason, a standard operating procedure (SOP) manual has been developed. This SOP is intended to serve as a comprehensive guide for Watershed Master Plans (WMP) in the City of Charleston now and into the future.

This SOP covers the collection, storage, processing and analysis of data necessary to complete a Watershed Master Plan within the City of Charleston and has been customized specifically to the City's stormwater database. The SOP has been prepared to ensure consistent assessments and analyses regardless of who performs the work or the location in the City. Use of this SOP provides continuity between City of Charleston and adjacent municipalities with respect to stormwater modeling, prioritization of projects and maintenance efforts, as well as development of design standards for problem areas.

It is expected that the SOP will be re-issued at the beginning of each WMP project with minor updates, as needed. The specific project area is addressed in Section 1.2, Project Overview and Boundaries. Updating this section allows some customization of focus in each watershed. Section 5.6, Living Document, contains a brief list of some topics that may need to be updated in the SOP over time. Such updates might include changes in equipment or accuracy requirements, software, field procedures, public outreach plan, or specific features to be mapped, inventoried or assessed. Similarly, modeling procedures, prioritization of projects, design storm or sea level change scenarios may be modified as WMP projects proceed around the City.

1.2 Project Overview and Boundaries

The project boundaries are comprised of portions of the Dupont and Wappoo watersheds in West Ashley. The boundaries were determined using existing elevation data to loosely follow the drainage divides. The project area is made up of a mix of high density commercial development, including several shopping centers, the Citadel Mall and Ashley Town Center shopping areas in the central portion of the project area bordering the major roads, and older residential areas around the perimeter of the project area. The project area boundaries are: Savage Road in the west; Paul Cantrell Blvd in the north (including the southeastern quadrant of the I-526 interchange); Ashley River Road (US-61) in the northeast; the Nottingham neighborhood east of Wappoo Road; and the West Ashley Greenway in the south.

The primary drainage feature for this watershed is a large drainage channel conveying runoff from the Citadel Mall area to a tidal creek flowing under Ashley Town Center Drive and discharging to the Stono River. The majority of this watershed consists of curb and gutter drainage through the commercial areas, and a network of small roadside drainage ditches in the older residential areas north of the mall and east of Orleans Road. This area is extremely flat and experiences ponding and backwater influence during storm events concurrent with high tides in the Stono River. With on-going development and the potential for redevelopment in the area around the Citadel Mall, this drainage network will be evaluated to determine the potential for stormwater improvements associated with redevelopment.

1.3 Cooperating Agencies and Stakeholders

Watershed boundaries and drainage patterns do not necessarily align with municipal boundaries, and in some areas, Watershed Master Planning may involve bordering municipalities or entities. In these areas, the City will coordinate with Charleston County (for unincorporated areas of Johns Island, West Ashley and Cainhoy), the Town of James Island, the Town of Mount Pleasant, the City of North Charleston, and Daniel Island Company.

The Charleston Water System (CWS) and South Carolina Department of Transportation (SCDOT) may also be involved in Watershed Master Plans for the City of Charleston. CWS owns the drinking water and wastewater infrastructure that is often found in the same rights-of-way as the stormwater infrastructure, and is involved in planning of future projects where utility conflicts may arise. Additionally CWS shares an interest in evaluating infrastructure resiliency related to sea level rise. SCDOT owns and maintains drainage infrastructure along the SCDOT right of way. Coordination is needed for maintenance, traffic control and in planning future drainage projects which may involve SCDOT right of way.

Finally, community stakeholders will be involved in City of Charleston Watershed Master Planning efforts. Community stakeholders include residents of the neighborhoods located in the watershed, and business owners in the commercial districts of the watershed. Members of the public in the Charleston area who may be interested in or impacted by future watershed projects form the final group of stakeholders.

Watershed Master Plan Cooperating Agencies and Stakeholders are shown in Figure 1-1. Project Coordination is discussed in Section 1.4 and Public Communication, including Stakeholder outreach, is discussed in Section 1.5.

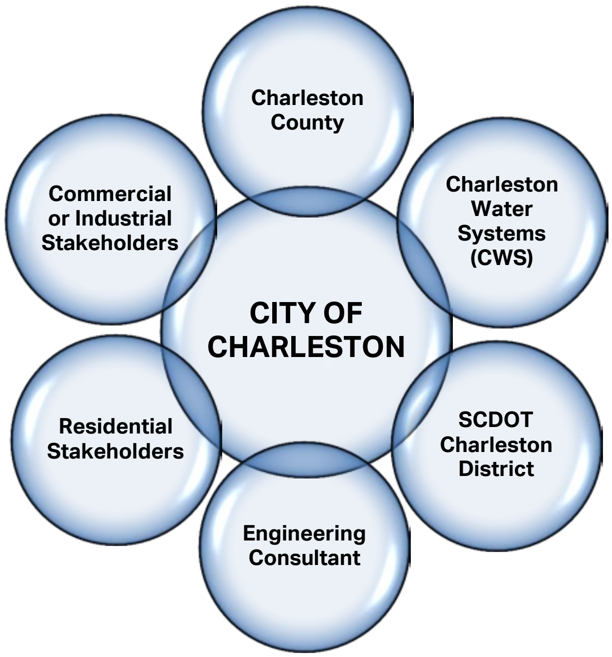


Figure 1-1 Watershed Master Plan Cooperating Agencies and Stakeholders

1.4 Project Coordination

The City of Charleston will serve as the lead for all project communication and coordination with other agencies and stakeholders. The City will also be the final authority for any decisionmaking required during the project. Maintenance of structures and access to commercial areas or private property for the purposes of data collection are two primary areas of project coordination. Another key issue is coordination of traffic control. These topics are discussed in greater detail in Section 2.

At the beginning of each Watershed Master Plan project, key points of contact (POC) should be identified for adjacent municipalities and other agencies. Roles and responsibilities should be identified for project tasks and communication channels should be established. A project coordination matrix should be completed to ensure all parties are involved in the relevant tasks. A template project coordination matrix is shown in Table 1-1. Public outreach and communication are discussed in the following section.

Table 1-1 Project Coordination Matrix Template

COORDINATION ELEMENT	KEY POINTS OF CONTACT
Public Meetings, Communication with Public	
GIS and Data Management	
Modeling Validation and Protocol	
Field Notifications	
Traffic Control	
Stream and Wetland Assessment	
Gathering Information for Recurring Problem Areas	
Maintenance and Access Issues	
Sea Level Rise	

1.5 Communication Plan

Public communication and outreach are an important part of the Watershed Master Planning process. Communication is needed both to inform the public of the efforts being undertaken in their community, as well as to obtain input from residents and businesses in the project area. Residential and commercial stakeholders will be invited to attend one or more public meetings at the beginning of each Watershed Master Plan project. These meetings will be held in order to introduce the project scope, timeframe and expected outcomes, as well as introduce key members of the project team, including the City Stormwater Program Manager, City Planner for that area, Public Information Officer, and their counterparts at Charleston County. Additionally, key members of the engineering consultant's team will be introduced. The meeting will provide information regarding the areas of work, schedule, how to identify field crew members, safety precautions and other information regarding the field data collection which will be visible to the public. Finally, input will be solicited regarding problem areas, historical high water marks and other information relevant to drainage in the watershed.

Consistent and productive communication with the public throughout the project is vital to project success. Communication with the public throughout the project will be managed by the City Planner and their counterpart at Charleston County, in coordination with the respective Public Information Officers. Public notifications will be via newspaper announcement, the City's website, neighborhood mailers or door hangers, or other method as deemed appropriate by the City for each particular watershed. A *Project Notification Letter* on City letterhead is included in *Appendix I*. The project communication flow chart is provided in Figure 1-2.

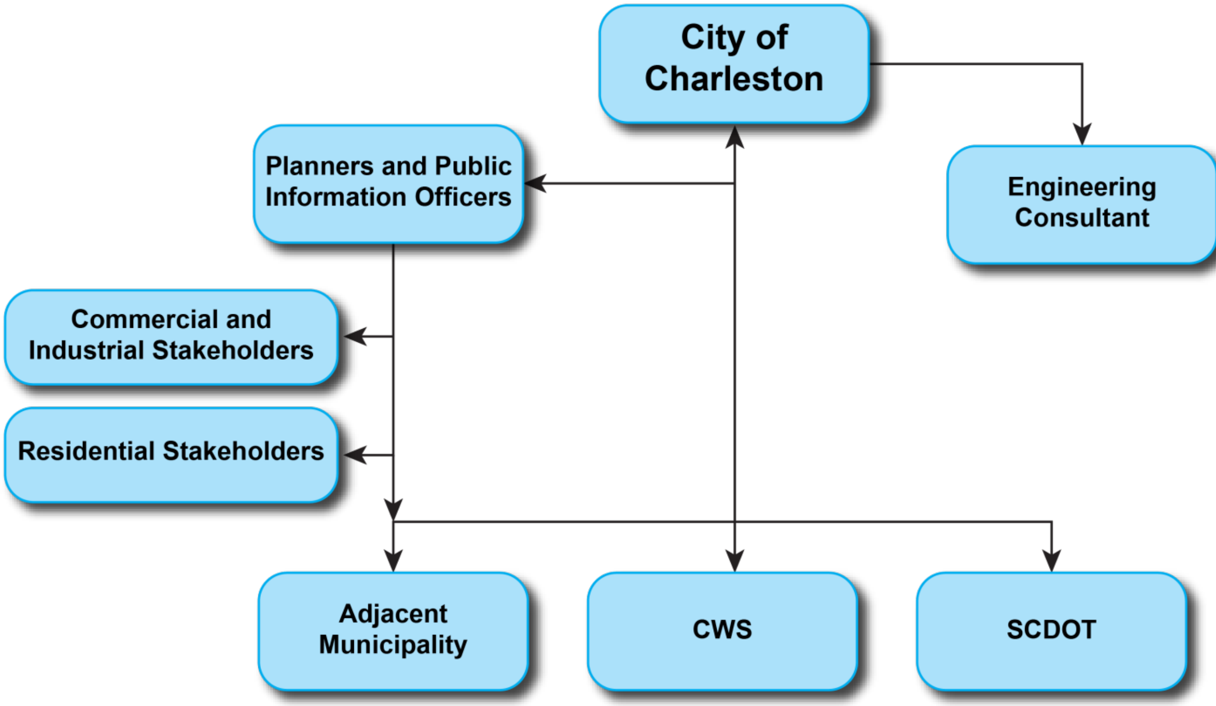


Figure 1-2 Communication Flow Chart

The engineering consultant's field personnel will drive marked company vehicles and wear safety vests with the company logo in order to be easily identified by members of the public. Field personnel will carry a copy of the City's notification letter and project fact sheet in order to answer questions if approached by members of the public. The field crew leader will visit schools 24-48 hours prior to arrival for field mapping in order to coordinate access to school grounds and ensure school administrators are aware of the survey work. Field crews will respect members of the public and their property at all times. If a citizen's questions or concerns are not sufficiently answered by the City's letter, the field crew will defer the public to the Engineering Consultant's Project Manager, or to the City's Stormwater Program Manager, as directed by the City. Field crews will take note of name, date, time, location, contact information, property location and subject matter when communicating with the general public and other stakeholders. This information will be provided to the Survey Manager and discussed with the Project Manager as needed in order to ensure continued success in field activities.

Residential, commercial and industrial stakeholders may be invited to attend one or more public meetings as each Watershed Master Plan project nears completion. These final meetings will be held in order to provide a summary of the work completed and the conclusions and recommendations that have resulted from the field work, analysis and modeling in that watershed. Public input may be solicited on the results and recommendations in order to further clarify priorities in the watershed.

Section 2 Field Data Collection

2.1 Overview of Data Collection and Terminology

As described in Section 1.1, each Watershed Master Plan in the City of Charleston will have three layers of data collected in the field. Field data will be collected using global positioning satellite (GPS) technology. Where GPS cannot achieve position data to meet the accuracy requirements established herein, a differential level and Total Station will be used. All data will be captured into the City's geographic information system (GIS) database for stormwater. The three layers of field data collection are shown below in Table 2-1. Further detail can be found using the References column in the table.

Table 2-1 Three Layers of Field Data

STORMWATER INFRASTRUCTURE MAPPING AND ASSET INVENTORY	**REFERENCES**
Inlets	Section 2.8 Section 3 Table 2-8 *Appendix A- Stormwater Inventory Data Dictionary* *Appendix B- Stormwater Inventory Illustrated Guide*
Manholes/Junctions	
Outlets	
Discharge Points	
Fittings	
Pipes	
Culverts	
Channels	
BMPs	
End Structures	
STORMWATER INFRASTRUCTURE CONDITION ASSESSMENT	**REFERENCES**
Structural Defects	Section 2.9 Table 2-9 *Appendix C- Condition Assessment Data Dictionary and Scoring* *Appendix D- Condition Assessment Illustrated Guide*
Operations and Maintenance Defects	
Supplemental Stormwater Defects	
STREAM AND WETLAND ASSESSMENT	**REFERENCES**
Stream Reaches	Section 2.10 Table 2-10 and Table 2-11 *Appendix E- Stream and Wetland Assessment Data Dictionary* *Appendix F- Stream and Wetland Assessment Illustrated Guide*
Wetland Sites	
Water Quality Problems	
Utilities Condition	
Aquatic Improvement Opportunity	

Infrastructure Mapping and Asset Inventory – This is the first layer of field data collection. Each individual, real world object composing the stormwater infrastructure, known as a **feature or asset**, will be mapped and assigned a unique identifier code known as an **AssetID** (alphanumeric code) in the database. Descriptive information, known as **attributes**, will be collected for each asset. Attributes collected in the field are primarily measurements such as dimensions, and observations such as type, shape or configuration, and material. Some attributes have a pre-determined list of possible choices known as a **domain**. Domains simplify field data collection and prevent data entry errors since the attributes are selected from a drop-down menu in GIS. Additional attributes are calculated in the office using the data collected in the field. Similar features are grouped together into a **feature class** (for example, inlets or pipes), and feature classes are grouped together into a **feature dataset**.

Condition Assessment – This is the second layer of field data collection. As each asset is mapped and inventoried, the survey crew will immediately assess the condition of each asset. The condition assessment evaluates each component of the stormwater system according to structural defects, operations and maintenance (O&M) defects, and supplemental stormwater defects. Within each of these categories, several defects are possible. Each defect will be identified and evaluated as to severity, i.e., how much that defect may be impacting the function of that stormwater component.

Stream and Wetland Assessment – This is the third layer of field data collection. This assessment will focus on stream reaches or wetland sites that may be good candidates for stream or wetland enhancement. Existing natural resources data will be collected for each stream reach or wetland site, sufficient to characterize and evaluate potential for enhancement projects at these locations. In addition, the field crew will collect data regarding water quality problems, utility conflicts and aquatic improvement opportunities.

2.2 Summary of Existing Data and Information Gaps

The City of Charleston has a significant amount of existing data available to inform the project team and assist in preparing for each Watershed Master Plan project. Existing data will be gathered at the beginning of each project and evaluated by the project team. Gathering baseline information prior to deploying for field activities will increase the efficiency of the field crews and provide higher overall quality of data and deliverables. Existing information includes the following:

- 1984 Master Drainage Plan
- SCDOT drainage maps
- As-built drawings
- LiDAR data
- USGS topographic quadrangle map(s)
- Aerial imagery
- Tidal data
- Easement records
- Maintenance records
- Storm high water records

The Master Drainage Plan, SCDOT maps and as-built drawings for recent development in the City have been digitized and are available in the City's stormwater GIS. This includes approximate locations of the stormwater infrastructure, and limited attribute data available, such as pipe diameter or material. This baseline GIS data will be prepared in a mapbook for use by the field crew. Information gaps will be identified and an attempt will be made to obtain the missing information prior to field deployment.

In addition to the geographic and numerical data listed above, it is important to gather available institutional and community knowledge. This addresses the human element and provides perspective on what is important to the community, how the municipalities and communities are impacted by the drainage system in that watershed, and what has occurred in the past related to storms and drainage problems or solutions. In order to gather this useful institutional and community knowledge, the project team will do the following:

- Interview City/County maintenance or stormwater staff
- Field tour with City/County maintenance or stormwater staff
- Review maintenance/flooding records with City/County staff
- Gather information from Public Meetings (see Section 1.5)

This information can be used to focus efforts on problem areas and ensure that proposed solutions address both community and municipal concerns.

2.3 Field Preparation Activities

In order to prepare for field deployment, the Engineering Consultant and field team will conduct the following activities:

- Review existing GIS data, maps and aerial imagery
- Locate geodetic and tidal monuments using online resources
- Select benchmark locations and create benchmark network for project area
- Conduct field reconnaissance
- Determine route/coverage strategy
- City will provide advance notice to property owners
- Check/calibrate all field equipment
- Check tide schedule
- Daily safety tailgate meetings
- Weekly planning and review of field issues

Many of these field preparation activities will be repeated as the field crew moves from one portion of the watershed to another; however, the benchmark network will remain fixed.

2.4 Field Equipment and Accuracy

Accuracy of data collection and production of quality results are dependent upon consistent use of hardware of an established standard, and up-to-date software, as well as standard procedures as described elsewhere in this SOP. Table 2-2 lists the equipment models, software, and accuracy for the GPS, topographic survey and condition assessment equipment that will be used in this project. Accuracy values published by the equipment manufacturers represent ideal conditions and may not always be achieved in field conditions.

Table 2-2 GPS and Survey Equipment and Accuracy

GPS AND SURVEY EQUIPMENT	
Mapping Grade GPS	Trimble R1 Horizontal Accuracy: ± 3 meters Vertical Accuracy : N/A
Survey Grade GPS Base Station and Rover	TopCon Hiper V Horizontal Accuracy: ± 10 mm Vertical Accuracy : ± 15 mm
GPS Tablet and Software	Dell Lat tablet 7202 Win 10 Pro, Wireless Lan, Built-in GPS ESRI CartoPac software
GPS Field Controller and Software	TopCon FC-5000 Windows 10, Wireless/Bluetooth enabled, Built-in cameras TopCon Magnet Field software ver 2.0
Survey Total Station	TopCon Robotic Total Station PS-103 Accuracy (Angle): ± 3 in Accuracy (Distance): 1.5 mm + 2 ppm TopCon Magnet Field software ver 2.0
Survey Level	Sokkia Automatic Level $C3_1$ Accuracy (Angle): 2 mm
CONDITION ASSESSMENT EQUIPMENT	
Pole Camera	Envirosight Quickview airHD
Pole Camera Tablet and Software	Samsung Galaxy S2 tablet with Envirosight software
STREAM AND WETLAND ASSESSMENT EQUIPMENT	
Mapping Grade GPS	Trimble GeoExplorer 6000 Horizontal Accuracy: ± 1 m Vertical Accuracy : ± 1 m
Tablet and Software	iOS (iPhone, iPad) ESRI Collector for ArcGIS, version 10.4.0

Accuracy values as published by manufacturer.

Table 2-3 lists the minimum standards for geodetic survey accuracy of utility systems, including stormwater. Stream and wetland assessment GPS data is expected to be less accurate due to more interference from tree canopy in natural channels and wetlands. Stream and wetland points will supplement the stormwater feature dataset and the two datasets will be linked using the unique ID assigned to each feature during system mapping.

Table 2-3 Minimum Accuracy Standard for Geodetic Survey of Utilities

TYPE	RELATIVE ACCURACY (95% CONFIDENCE)	MAX PDOP	MIN # OF SATELLITES	SITE CALIBRATION
Static	GNSS 0.078 v 1:50,000	5	4	N
Property Corner	Positions 0.078 v 1:20,000	5	4	N
RTK GNSS	0.078 v 1 PPM dist from Base	3	5	Y
VRS GNSS	0.078	3	5	N

PDOP - Point Dilution of Precision
VDOP - Vertical Dilution of Precision
HDOP - Horizontal Dilution of Precision
RTK - Real Time Kinematic
VRS - Virtual Reference Station
GNSS - Global Navigation Satellite System

Assume Mapping Grade PDOP < 2 ft for single epoch collection and PDOP < 4 ft for epoch averaging (20 epochs minimum). Assume Survey Grade HDOP < 1.0 ft and VDOP < 0.10 ft. Mapped Assets will have horizontal accuracy of ± 0.1 ft and vertical accuracy of ± 0.1 ft.

Field data collection will be supervised by a licensed professional land surveyor (PLS) to ensure that data is properly referenced to geodetic and tidal benchmarks for accurate representation of data in the City's database. Table 2-4 provides a list of the primary field equipment needed in order to collect field data, access and mark locations, and ensure safe field activities. Metal detectors may be used to located paved over or buried structures, however metal detectors may respond to ferrous iron not associated with the stormwater system. Structures will not be mapped on the basis of metal detector response alone.

Table 2-4 Field Equipment

OTHER FIELD EQUIPMENT	
Pipe Mic	Measure pipe invert
Metal Detector	Locate buried or paved over ferrous (iron) structures
Survey rod	Measure elevations where GPS cannot obtain signal
Survey wheel	Measure distance
Flash light with clamp or tether	View interior of catch basins, manholes, pipes or culverts
Vehicles	4x4 with strobe lights and rooftop flasher for traffic safety
Stylus pens	For use with GPS and pole camera tablets
Survey kit (tape, flags, stakes, etc.)	Mark features or offset locations
Paint pens	Label feature ID on each structure
Shovels	Clean out structures prior to measurement or assessment
Manhole lifter	Lift or move manhole cover or inlet grate
Bush ax	Clear heavy vegetation to gain access to feature
Survey Crew Ahead Signage	Warn oncoming traffic of surveyors adjacent to roadways
Orange cones	Safety equipment
Personal Protective Equipment (PPE)	Safety equipment, clothing and boots

2.5 Datum, Benchmarks and Base Station

Datum – The City of Charleston uses the North American Datum NAD83 (2011) for horizontal coordinate reference and the North American Vertical Datum NAVD88 for vertical coordinate reference. Data will be published in South Carolina State Plane Coordinates (SC SPC) in units of International Feet (iFoot).

Benchmarks – Benchmarks will comply with minimum standards for geodetic surveying as described below. At the beginning of the project, benchmark locations will be selected at accessible locations free of traffic and other circumstances that could damage or displace a GPS antenna. Benchmark sites will also be void of visible multipath conditions that exist above a 10 degree signal mask above the horizontal horizon. The location marker will be a MAG nail in a hard, permanent, stable material or a countersunk 5/8" diameter, 2 ft long rebar driven 1 inch below grade.

The survey crew will create a local benchmark reference network that meets or exceeds the USGS benchmark protocol standards for a second order-class I (1:50,000) for horizontal control and a first order-class I (0.5 ft or less) for vertical data. Benchmarks will have a relative accuracy of ± 0.1 ft within the project area. Benchmarks will be dispersed throughout the project area in locations conducive to both Static and RTK GPS operations.

Base Station – A base station will be set up as part of the benchmark network. The base station will be set up and removed daily in the nearby work area to ensure the highest accuracy possible. Base station setup will be verified by staking to a third known point. The tie equality and data errors will be recorded by taking a field check point and recoding the inverse in the field book. If the error is > 0.1 ft horizontally (HDOP) or vertically (VDOP), then the system will not be considered adequately set up and will need to be re-evaluated for error in the setup, multipath potential in the surroundings, satellite constellation geometry, and atmospheric conditions. If conditions outside of the setup impact the work, then a delay will be required until conditions correct. Once GPS RTK equipment is set up and operation within tolerance has been verified, the crew will proceed to complete the planned work.

Table 2-5 contains a summary of requirements regarding datum and benchmarks.

Table 2-5 Geodetic Data Collection Requirements

GEODETIC SURVEY STANDARDS	CITY OF CHARLESTON STANDARDS
Horizontal Control datum	NAD83
Vertical Control datum	NAVD88
Coordinate System (Projection)	SPCS, South Carolina zone
Units	International Feet (1 inch=2.54 cm)
Benchmarks	Geodetic and Tidal
Benchmark/Base Station Accuracy	± 0.1 ft

2.6 Overview of 2-Pass Process

Field efforts for stormwater system mapping and condition assessment will be performed in a 2-pass process. (Stream and wetland assessment will be performed separately.) The latest version of the GIS database will be downloaded onto the field data collector/tablet daily prior to going to the field and this data will be updated and/or supplemented throughout the day. At the end of each field day, the data will be uploaded to the project folder.

Pass 1 – Use existing data in GIS (from as-builts, master plans, SCDOT maps and other sources) to verify stormwater infrastructure assets and locations, map new assets, and collect/complete attribute data for all of the assets. Pass 1 will use mapping grade GPS to verify or collect the horizontal (X,Y) coordinate of the asset to within an accuracy of ± 3 m horizontally. All data will be collected using CartoPac. New assets will be assigned a temporary AssetID in the field and will be renumbered with a permanent AssetID using a processing tool in the office. Additionally, Pass 1 will include condition assessment of the asset inventory, including capturing digital photography (and zoom video as needed) of the assets and identifying any observed defects.

At some locations, the GPS signal may be blocked by existing structures or trees. In this case, the survey crew will move to a nearby open area and shoot an offset point during Pass 1, mark it with paint or a survey flag, and update the location with accurate position data during Pass 2. Condition assessment may or may not be able to be performed, depending upon the maintenance condition. See Section 2.12 for further information on encountering obstacles in the field. If the survey crew cannot gain access to the asset, or cannot collect GPS or condition assessment data due to maintenance issues, this asset location will be identified during Pass 1 and a maintenance/access request will be submitted to the City for each such location. See Sections 2.13 and 2.14 for information on maintenance and access issues.

Pass 2 – Capture the horizontal and vertical (X,Y,Z) coordinates of all assets identified during Pass 1. Pass 2 will use survey grade GPS to collect the location data to within ± 0.1 ft horizontally and ± 0.1 ft vertically, using the field data collector tablet. If the X,Y,Z coordinate cannot be captured with GPS during Pass 2, a survey level or Total Station will be used to collect the position and elevation data. Multiple control point checks will be performed throughout the day in order to verify continued accuracy of data collection. Additionally, Pass 2 will include completing condition assessment of assets that were not accessible or required maintenance during Pass 1. Pass 2 may also include collecting additional data that may have been missed or which requires verification based upon routine quality control checks. Attribute data will be collected using CartoPac. A geoprocessing tool will be used to update the database with the correct coordinates and associated condition assessments, and to maintain the connectivity of the network.

Survey crew members will be assigned specific roles and responsibilities in order to ensure consistency and reduce field errors. Pass 1 GPS, Pass 2 GPS, pole camera operation and condition assessment, will be performed by the same team members as much as possible throughout the watershed. Table 2-6 provides a detailed Work Breakdown Structure for the survey crew to ensure consistent results at each location.

Table 2-6 Work Breakdown Structure for Survey Crew

TASK #	PASS 1	OFFICE OR FIELD
01.01	Charge Equipment	Office
01.02	Start CartoPac and Tremble R1 GPS	Office
01.03	Download Database, latest version	Office
01.04	Each Day: Check Equipment Settings, Safety Tailgate	Field
01.05	Locate Asset / Verify AssetID	Field
01.06	Set up Safe Work Zone (as needed)	Field
01.07	Select or Create Feature	Field
01.08	Paint Asset ID and Downstream Arrow with White Paint	Field
01.09	Area Photo *	Field
01.10	Close-Up Photo *	Field
01.11	Internal Photo *	Field
01.12	Enter or Update Asset Characteristic Attributes	Field
01.13	Paint Point of Measurement for Invert Depth	Field
01.14	Measure Invert Depth(s) and Dimensions	Field
01.15	Conduct Condition Assessment	Field
01.16	Defects Photo(s) *	Field
01.17	Pole Camera Photos/Videos of Point Features and Pipes *	Field
01.18	Return Cover / Grate or Close Doors	Field
01.19	Move to Next Asset and Repeat from Task 1.05	Field
01.20	End of Day Upload Data to Cloud	Office
01.21	End of Day Save Zoom Photos and Videos to Project Folder	Office
02.00	**PASS 2**	**OFFICE OR FIELD**
02.01	Charge Equipment	Office
02.02	Start CartoPac and TopCon Hiper V GPS	Office
02.03	Check Satellite Almanac	Office
02.04	Load Pass 1 Coordinates and Asset IDs	Office
02.05	Each Day: Set up Base Station, Check Settings, Safety Tailgate	Field
02.06	Locate Monument, Complete Control Point Check	Field
02.07	Verify GPS Accuracy	Field
02.08	Locate Asset / Verify Asset ID	Field
02.09	Set up Safe Work Zone (as needed)	Field
02.10	Update Coordinates	Field
02.11	Collect Attribute Data (if not during Pass 1)	Field
02.12	Complete Condition Assessment and Photos (if not during Pass 1)	Field
02.13	Return Cover / Grate or Close Doors	Field
02.14	Remove Survey Flags and Stakes	
02.15	Move to Next Asset and Repeat from Task 2.08	Field
02.16	Locate Monument at Mid-Day, Complete Control Point Check	Field
02.17	Verify GPS Accuracy at Mid-Day	Field
02.18	Locate Monument at End of Day, Complete Control Point Check	Field
02.19	Verify GPS Accuracy at End of Day	Field
02.20	End of Day Retrieve Base Station	Field
02.21	Save Data to Project Folder	Office
02.22	Create Export for GIS	Office

** See Section 2.11 for additional information on photographing features.*

2.7 Field Observations and Measurements

Attributes (measurements or descriptors) will be collected for each feature out in the field. Some of the attributes are collected directly by the GPS. Others must be measured in the field. The rest are observed values which do not require measurements or calculations. This includes type, shape, material, presence/absence of a specific characteristic, yes/no observations, etc. All field data will be entered in CartoPac as it is collected. Table 2-7 provides a list of the attributes which will be collected directly in GIS or measured, and applicable feature classes are shown for each attribute. Inlets, outlets, pipes and culverts have various configurations which affect measurement of dimensions and where a GPS elevation should be collected. Procedures for collecting these field measurements are described below. Definitions for bold terms are found after the table.

See Section 2.8 for information regarding field data collection for each feature class. See Section 3.4 for information on how invert elevation and other attributes are calculated using field measurements. See *Appendix A* for measuring dimensions and elevations.

Procedures for Elevations and Depths

The most important elevation is the **invert elevation**, for use in calculations, design and modeling. If possible, it is desirable to collect the invert elevation directly with GPS. This includes open features such as pipes and culverts with open entrances, open channels and BMPs. If the invert is not accessible due to the configuration of the feature, sediment/debris obstructing the invert, or the GPS signal is blocked, a surface elevation should be collected from a central, marked point and the depth (also called a measure-down) should be recorded.

For closed structures, such as inlets, manholes/junctions, outlets, and pipes intersecting these structures, the invert elevation may not be accessible and a **rim elevation** and a **depth to invert** measurement will be required. For riser outlets with multiple openings, it may be necessary to collect measure-downs for secondary or tertiary entrances (weir notches or orifices). If the rim elevation is not accessible, such as for some inlet or outlet structures with a slab or ceiling above the entrance, a **top elevation** should be collected and the **depth to rim** recorded. Then the depth to invert is measured down from the rim. Examples include a curb inlet, box top inlet or box-top riser outlet. Where pipes are recessed in a closed structure, a Pipe Mic will be used to measure the depth to invert. The Pipe Mic will be attached to a fiberglass precision survey level rod with a calibrated scale in 0.01 ft increments and a bullseye level. The combined error of the setup will be ± 0.03 ft. If the cover, lid or grate is removed, this thickness should be included in the depth measurement.

Where pipes or culverts intersect channels or BMPs, the invert may be inaccessible due to sediment/debris or presence of a tide valve, or the invert may be accessible but the signal may be blocked due to canopy cover. In these situations, **a top of pipe elevation** should be collected if there is no headwall, and a depth to invert be measured from the top of pipe. If there is a headwall, the **headwall elevation** should be collected at the top-center of the headwall and the depth to top of pipe should be measured, followed by the depth to invert.

Table 2-7 Attribute Measurements

FIELD GPS	**DIRECTLY COLLECTED IN GPS**	**APPLICABLE FEATURE CLASSES**
Latitude, Longitude (X,Y Coordinate)	Location determined by GPS	*- All feature classes*
Elevation	**Invert Elevation (Z Coordinate)**	*- Pipes or culverts intersecting open channels or BMPs - Channels - BMPs*
	Rim Elevation	*- Manholes/ junction boxes - Some inlet and outlet structures - Pipes intersecting these structures*
	Top Elevation top of structure or top of pipe	*- Some inlet and outlet structures with slabs above the entrance - Pipes and culverts with no headwall - Pipes with tide valves*
	Headwall Elevation	*- Pipes and culverts with headwalls - Pipes with tide valves*
	Top of Bank Elevation **Bottom of Bank Elevation**	*- Channels - BMPs (dry ponds)*
	Normal Water Surface Elevation	*- BMPs (wet ponds)*
Length	Autogenerated for linear features	*- Pipes, Culverts, Channels*
Perimeter	Autogenerated for polygon features	*- BMPs*
Area	Autogenerated for polygon features	*- BMPs*
FIELD MEASUREMENTS	**HOW MEASUREMENT IS COLLECTED**	**APPLICABLE FEATURE CLASSES**
Depth to Invert	Pipe Mic	*- Interior of inlet, manhole/ junction box or outlet structure and intersecting pipes*
	Survey Rod	*- Pipes or culverts intersecting open channels or BMPs - Channels - BMPs*
Depth to Rim	Tape Measure	*- Some inlet and outlet structures*
Depth to Top of Pipe	Tape Measure	*- Pipes and culverts with headwalls*
Diameter	Tape Measure	*- Circular structures or openings (outlets structures, inlet or manhole covers, orifices, pipes, culverts)*
Dimensions * **Length** **Width** **Height**	Tape Measure or Survey Tape	*- Square or rectangular structures or openings (inlet entrance, junction box dimensions, riser, orifice, weir notch, overflow spillway, gate, non-circular pipes, box culverts, width of channels, or BMP dimensions)*

* *Certain dimensions, such as for channels, BMPs, and wide emergency spillway outlets, may not be easily collected in the field. Instead, these will be calculated using the survey grade GPS data.*

DEFINITIONS

Invert Elevation – This elevation is the low point of the feature, for example: the bottom of a catch basin, manhole, or outlet structure; the lowest point of a channel cross-section or BMP (pond); or the elevation of the bottom of the curve of a pipe entrance or exit.

Rim Elevation – This terminology is typically used in wastewater to describe the elevation of the manhole cover. The term has been expanded to include stormwater manholes, as well as the elevation of the entrance of water to a typical grate inlet. For this SOP, rim elevation will also be used to describe the primary entrance where the largest volume of water enters the inlet or outlet structure. For outlet structures with multiple entrances, the rim elevation is the largest opening. The rim elevation and depth to invert are used to calculate the invert elevation for the bottom of the structure, as well as any connecting pipes.

Top Elevation – This elevation may be the top of an inlet or outlet structure which has a slab or ceiling above the entrance which prevents directly collecting an invert elevation or a rim elevation. Top elevation may also be the top of a pipe or culvert without a headwall, or the top of a pipe which has a tide valve preventing direct collection of the invert elevation.

Headwall Elevation – The top-center elevation of a headwall at the end of a pipe or culvert.

Top of Bank Elevation – The elevation at top of the embankment alongside an open channel or around the perimeter of a BMP (pond).

Toe of Bank – The elevation at the bottom, or toe, of the embankment, inside an open channel or BMP. The invert of a channel is typically, although not always, lower than the toe of the embankment. The toe of bank may not be accessible in wet ponds or constructed wetlands.

Normal Water Surface Elevation – The normal elevation of the water impounded in a wet pond. This elevation should be measured at least three days after a rain event in order to ensure that the pond has drained back to the normal elevation.

Depth to Invert – The method of measuring invert depth will vary for certain features types. For closed structures, depth to invert is the vertical distance from the rim or entrance down to the bottom of the structure. For pipes or culverts intersecting channels or BMPs, the depth to invert is the vertical distance from the top of pipe down to the invert of the pipe or culvert.

Depth to Rim – Vertical distance from a top slab or ceiling of an inlet or outlet structure to the rim of that structure.

Depth to Top of Pipe – Vertical distance from a headwall down to the top of a pipe or culvert.

Diameter – The diameter attribute records the inner diameter. If the pipe or culvert is damaged or deflected, the original size should be recorded and the deflection should be noted in the condition assessment. This attribute should only be used for circular features.

Dimensions – Length, width and height attributes record dimension measurements for square or rectangular features, or square or rectangular openings through which water flows. The fields to be used will vary for certain features. For example, *a curb inlet* will use height and length, while a *grate-top inlet* will use length and width, and a *combination inlet* will use all three. Channels and BMPs may not have uniform dimensions (for example, channel width varies at different sections, and BMP ponds are rarely perfectly round). Dimension measurements should be taken to record the representative value rather than the extreme value. If dimensions for large features cannot be efficiently measured, they will be calculated.

2.8 Stormwater System Mapping and Asset Inventory

As described in Sections 1.1 and 2.1, the first layer of field data collection is stormwater system mapping and asset inventory. The City's stormwater GIS database contains numerous feature classes. This SOP focuses on 10 of the feature classes within the stormwater feature dataset which require field data collection. The features which will be mapped make up the City's stormwater conveyance system and are primarily located in the right of way or drainage easements. Certain BMPs (ponds) which discharge into the City's system will also be mapped and assessed.

Table 2-8 shows a summary of the data that will be collected under this SOP. A series of data tables showing the full structure of the feature classes, attributes and domains which will be collected under this SOP is found in *Appendix A, Stormwater Inventory Data Dictionary*. Some of the attributes which cannot be determined using field data, are not needed for a Watershed Master Plan, or are more appropriate for entry by City staff, will not be collected under this SOP. Certain material domain choices, and certain inlet type and BMP type domain choices will not be collected under this SOP. These are highlighted in gray in *Appendix A*.

Table 2-8 Stormwater System Mapping

FEATURES (ASSETS)	FEATURE CLASS CATEGORY
Inlets **Manholes/Junctions** **Outlets**	Point Features
Discharge Points **Fittings**	
Elevations	
Pipes **Culverts** **Channels**	Linear Features
BMPs	Polygon Features
COMPONENTS	**FEATURE CLASS CATEGORY**
End Structures	Associated with Point and Linear Features

The following paragraphs provide map and inventory guidelines, special considerations for each feature class, and identify which feature classes do not require field data collection or have limited collection of certain attributes or domain choices. Photographs of each feature type, including various configurations and materials, are included in *Appendix B, Stormwater Inventory Illustrated Guide*.

MAP AND INVENTORY GUIDELINES

Primary Function – If a certain feature appears to be serving two purposes, that feature will be mapped according to its primary function. For example, if an inlet is also serving as a junction box, it will be mapped as an inlet. If a pipe or culvert is also part of the outlet for a BMP, it will be mapped as a pipe or culvert.

Upstream Structures on Private Property – Attribute data collection for stormwater infrastructure which is directly connected to the City's collection system will be limited to that which is needed for model input. This will include: invert elevation, diameter or other dimensions, and material. Linear upstream features on private property may not be fully mapped (i.e., will not be carried to the upstream node) and may not contain complete attribute data. Upstream structural BMPs (wet ponds, dry ponds, wetlands) will be fully mapped and inventoried, however the upstream infrastructure which drains into the BMP will not.

Attribute Selection – When describing a feature, the focus will be on collecting information that will be most useful for design and maintenance of the system. For situations where more than one domain choice is applicable, choose the domain value which has more impact on the performance or condition of the system. For example, a pipe which is *Projected from Fill* and which also has a *tide valve*, has two possible choices from the End Structures domain. *Tide valve* should be selected, as it is more important to the function of the pipe.

FEATURE CLASSES REQUIRING FIELD DATA COLLECTION

Inlets – There are several types or configurations of inlets which may be identified. Inlet types which are unlikely to be found in the right of way and/or project area will not be collected under this SOP. Inlet types which will be collected are: *curb inlets*, *grate top inlets*, *drop inlets*, *combination inlets*, *box top inlets* and *curb cuts*.

Manholes/Junctions – Manholes and junction boxes perform the same function, a node structure connecting upstream and downstream pipes and providing access for maintenance or repairs. The primary difference is the shape – round for manholes, square or rectangular for junctions. Often, the type and/or shape of the cover are also different.

Outlets – There are several types or configurations of outlets which may be identified. Some riser outlet structures have multiple entrances for water. These are not mapped with separate GPS points. Only the high flow entrance is mapped. Independent weir or orifice plate outlet structures are mapped with a separate GPS point. Older BMPs may only have a primitive emergency spillway as the outlet structure. Some BMPs may only have an outflow pipe; in this case, it will be mapped in the Pipes feature class rather than with the Outlets.

Pipes – Pipes may intersect with upstream/downstream structures (inlets, manholes/junctions, outlets) or they may intersect with an open channel or BMP at one or both ends. For a pipe intersecting a structure (inlet, manhole/junction, outlet): identify *Flared End* or *Projected from Fill*. For a pipe intersecting a channel or BMP: identify the end structure (*headwall*, *wingwalls*, *rip-rap*, *tide valve*, etc.). If not identifiable in the field, pipe material may be identified using the condition assessment zoom video.

Culverts – Culverts differ from pipes in that they are open at both ends and convey water underneath a road, railroad tracks, trails or other embankments. Culverts may intersect with an open channel or BMP at one or both ends. Identify the end structure (*headwall*, *wingwalls*, *rip-rap*, etc.). If not identifiable in the field, culvert material may be identified using the condition assessment zoom video.

Channels – Channels must be a minimum of 1 ft deep and 6 ft long in order to qualify as a channel for mapping purposes. (Trench drains are often less than 1 ft deep but still qualify for mapping if located in the public drainage system.) A new reach or segment of the channel will begin when: the bed material changes; the slope changes sharply; dimensions change significantly; the angle changes more than 30°; or at the intersection with another channel. Channels will be mapped with at least one upstream and one downstream cross-section. Channel cross-sections will be located during Pass 1 (see Elevations below) and mapped during Pass 2. Pass 2 crews will survey channels according to the channel shape (U, V, trapezoid, etc.) identified during Pass 1. Top of bank, toe of bank and invert elevation will be captured along the channel. Top and toe elevations will be used to calculate side slope.

BMPs – Collection of BMP data under this SOP is limited to those structural BMPs that are located within the right of way, on public land, or which directly discharge to the stormwater collection system and are needed for modeling purposes. A number of types of BMPs are likely only to be found on private and/or newly developed land and will not be collected. Field data collection will be limited to the following: *wet ponds*, *dry ponds* and *constructed wetlands*. Constructed wetlands may be former natural wetlands or ponds which have been converted into a BMP. BMPs will be mapped with top of bank elevation and at normal pool elevation for wet ponds and constructed wetlands. For dry ponds, the toe of bank elevation will be captured around the interior of the BMP. Pairs of top and toe elevations will be used to calculate side slope. Dry pond depth will be measured at the lowest point, if possible. Outlet structure(s) and conveyance from the BMP to the public stormwater system will be mapped; inflows to the BMP will not be mapped, however inflows and outflows will be counted.

Elevations – All surface topographic point data collected for channels and BMPs will be housed in the Elevations feature class. This includes channel cross-sections and embankments of BMPs. Pass 1 crews will identify locations for channel cross-sections using the "Cross-Section Location" subtype. The Elevations feature class will contain XYZ coordinate data only; no other attributes or calculations will be stored here. These points will be used to calculate the bottom slope, side slope and depth reported in the channels and BMPs feature class tables. These elevations will also be available for later use with LiDAR data or for modeling or design purposes.

End Structures – Several feature classes have an attribute to identify end structures, also known as Structure Type. End structures are identified as a component of the relevant feature, thus allowing condition assessment of the structure; however the component is not mapped with a separate GPS point. These components are often found at the end of linear features (pipes, culverts and channels), but may also be found in BMPs or on outlet structures. End structures include: *headwalls/wingwalls*, *scour slabs*, *rip-rap*, *gate structures*, *tide valves* and *bars/racks*. If there is more than one end structure (for example, both *wingwalls* and a *scour slab*), choose the most significant for purposes of condition assessment, and note other end structures in the comments field.

FEATURE CLASSES REQUIRING PRIMARILY OFFICE PROCESSING

Several of the feature classes included under this SOP (**Discharge Points**, **Fittings**, **Basins**) will use field data but efforts will primarily consist of office processing. Additionally, several feature classes are used to build the geometric network and do not directly require field data collection (**Stormwater Network Junctions** and **Virtual Drain Line**).

Discharge Points – Discharge points will not be independently mapped or assessed. Field data will be used to identify the last feature at the end of the drainage pathway, immediately prior to discharge to surface waters. This will limit the number of points which are identified as NPDES outfalls. The GPS point and a few relevant attributes will be copied from the appropriate asset to the discharge points feature class. Minimal attributes will be populated in order to avoid duplication of data from the feature class where the asset is housed.

Fittings – Tee junctions have been identified from SCDOT as-built drawings and are shown in the digitized GIS data. Survey crews will investigate these locations in order to determine whether an access structure (inlet, manhole or junction) has been constructed during the years since the as-built was prepared. If nothing is visible on the surface, the fittings data will remain in the database, with the source identified as *As-built* data, and a GPS point will not be collected. During office processing, these fittings will be assigned a value of *Inactive* in the ActiveFlag attribute. If a new structure is present, it will be mapped to replace the fitting.

Basins – Large drainage basins were identified in the 1984 Master Drainage Plan and assigned BasinIDs. The BasinID names were primarily based on major streets rather than on hydrologic drainage boundaries. As each watershed is mapped, BasinIDs will be revised according to the name of the watershed drainage area. Any points mapped in the project area which drain outside of the watershed will retain the original BasinID.

FEATURE CLASSES NOT INCLUDED IN THIS SOP

Several feature classes house data which is rarely found (for example, stormwater force mains), is not likely to be found within the City's collection system or is only likely to be found on private land and/or in newly developed areas with modern stormwater BMPs. As such, the following feature classes will not be mapped, inventoried, assessed or modeled under this SOP: **Manufactured Treatment Devices**, **Permeable Pavement**, **Cisterns**, **Storm System Valves**, **Stormwater Force Mains** and **Storm Network Structures**.

2.9 Condition Assessment

All of the stormwater system assets which are inventoried and mapped under this SOP will have a condition assessment performed at the same time. A consistent approach to condition assessment is necessary in order to accurately characterize existing deficiencies in the stormwater infrastructure and develop an effective way to prioritize improvements. A methodology for conducting condition assessment on stormwater infrastructure has been developed specifically for the City of Charleston and is tied into the City's stormwater GIS.

DEVELOPMENT OF STORMWATER CONDITION ASSESSMENT METHODOLOGY

This methodology for condition assessment of stormwater infrastructure has been partially adapted from the National Association of Sewer Service Companies (NASSCO) standards for condition assessment of sanitary sewer systems. Due to the similarities between sanitary sewer and stormwater infrastructure, NASSCO Pipeline Assessment Certification Program (PACP) and Manhole Assessment Certification Program (MACP) standards are applicable to stormwater pipes, culverts, manholes and junctions. The PACP and MACP (hereafter "NASSCO") standards have been simplified and modified to better represent the City's goals and uses of the stormwater condition assessment data and to represent conditions typically found in stormwater systems. Defects that are specific to sanitary sewer systems were eliminated. For stormwater features outside of the scope of NASSCO, such as inlets, outlets, end structures, open channels and BMPs, components and terminology of NASSCO were utilized where appropriate and were supplemented with defect categories and descriptions aligned to the particular stormwater system feature.

There are several key differences between condition assessment of a sanitary sewer system and a stormwater system which drove the development of this modified methodology. Stormwater pipes are typically shallower than sanitary sewers, particularly in the Lowcountry. Stormwater systems contain both enclosed and open features, and a much larger variety of structures and end structures. Some stormwater features are built into the landscape (e.g., channels and BMPs) while others are similar to the pipe and manhole sequence typical in wastewater systems. Assessing structures as watertight is much less important for stormwater compared to wastewater, due to public health concerns over leaking sanitary sewer systems. Hydrogen sulfide and other chemical impacts play a significant role in wastewater systems but are not as significant in stormwater systems. Finally, wastewater flows are more predictable than storm flows (excepting for the influence of excessive infiltration/inflows on wastewater systems), so stormwater systems more often have defects resulting from occasional large storms.

The methods used in condition assessment are dependent upon the types of defects likely to be encountered, as well as the types of repairs likely to be needed. A myriad of pipe lining and repair techniques are available for various types of wastewater pipe materials and the NASSCO method assesses these situations in detail. Stormwater systems have less variety of pipe materials and sections requiring repair are often just replaced for convenience. Sanitary sewer condition assessment is largely dependent on the use of closed circuit television (CCTV) equipment to obtain detailed observations and measurements, counts of defects and precise locations within the manhole or sewer pipe to quantify defect severity. The City's stormwater condition assessment identifies defects and determines severity using zoom camera and visual inspections for the interior or pipes, culverts and structures. Use of a zoom camera rather than CCTV is more expeditious and provides a level of detail more appropriate for a stormwater system condition assessment. CCTV is not effective for surface features such as channels or BMPs, therefore the condition assessment method needed to be stretched to account for these features.

The majority of defects have a Descriptor and/or Modifier. Descriptors provide further description of the problem such as different types of erosion, obstructions, or surface damage. Modifiers indicate the severity of the defect. Descriptors and modifiers are choices that the survey crew must make from a drop-down menu on the tablet, and the domains are linked to the condition tables in the GIS database. The NASSCO method has been streamlined by eliminating and/or reducing the number of options for describing a defect or the severity of the defect. The NASSCO descriptors and modifiers were reduced for the City's stormwater condition assessment. For example, length of a defect, continuity, clock position within a pipe, or percentage defect to the nearest 5%, existence of multiple similar defects, defect direction, or defect location, all of which are included in the NASSCO method, were not directly included in the stormwater condition assessment. The severity ratings were reduced from 5 categories to 3 categories. The list of modifier choices for some defects was decreased, as described in the following paragraphs.

Appendix C contains the complete *Condition Assessment Data Dictionary and Scoring*, including the list of descriptor and modifier domains. *Appendix D* contains the *Condition Assessment Illustrated Guide.* This appendix contains definitions of each type of defect, as well as photographic examples of how those defects vary for different types of stormwater features and different materials.

Defects are broken into three (3) main categories: Structural, Operations and Maintenance (O&M), and Supplemental Stormwater. The structural and O&M categories are based on the NASSCO categories of the same name. The supplemental stormwater category ("supplemental") was developed specifically for the City of Charleston. Table 2-9 summarizes the stormwater features, defect categories and specific defects which will be evaluated under this SOP.

Table 2-9 Stormwater Condition Assessment Defects

FEATURE CLASS (ASSET)	DEFECT CATEGORIES	DEFECTS
Inlets **Manholes/Junctions** **Outlets** **Pipes** **Culverts** **Channels** **BMPs**	Structural Defects	Crack Fracture Broken Hole Deformed (≤40%) Collapse (>40%) Joint Surface Damage Brick/Block/Rock Decayed Sag
	O&M Defects	Deposits (≤25%) Obstruction (>25%) Roots Infiltration
	Supplemental Stormwater Defects	Erosion Vegetation Submergence

Condition assessment will not be performed for Discharge Points or Fittings.
Condition assessment will be performed for End Structures (headwalls, tide valves, etc.).

Structural Defects – Structural defects include: Crack, Fracture, Broken, Hole, Deformed, Collapsed, Joint, Sag, Surface Damage, Brick/Block/Rock and Decayed. Brickwork was expanded to Brick/Block/Rock to include the materials likely to be found in a stormwater system. An additional defect, Decayed, has been added to account for structural materials such as wood and rubber that are not generally found in sanitary sewers but could be found in sluice gates, flashboard risers or tide valves in a stormwater system. Buckling of flexible pipes was included under the Deformed category. Weld Failure, Point Repair and Lining Features were eliminated. The Surface Damage defect category was condensed to remove defects more often found in sewer systems (e.g., defects produced by hydrogen sulfide) and to reflect defects most common to stormwater structures. Based on NASSCO, a threshold was established to differentiate Deformed from Collapse (40% cross-sectional area affected).

Operations and Maintenance (O&M) Defects – O&M defects are: Deposits, Roots, Obstructions, and Infiltration. Vermin and Testing, and Grouting were eliminated. The Deposits and Obstacles/Obstructions defect categories were revised and aligned to reflect commonly occurring conditions in stormwater pipes and channels. The sub-groups for Attached and Ingressed deposits were eliminated, and the list of Settled deposits was expanded. For example, Grease and Ragging were removed, and Sediment, Gravel, Woody Debris and Garbage were added. Condition Assessment for Deposits and Obstruction was further simplified by establishing a threshold (25% cross-sectional area affected) for differentiation of Deposits versus Obstruction. The Roots defect category was retained, except for location details (such as inside or outside of the sewer pipe). Under the Infiltration defect category, the descriptors were reduced and combined.

Supplemental Stormwater Defects – This category was created in order to assess features or conditions typically found in stormwater systems that are not otherwise assessed within the NASSCO method. Supplemental defects are: Erosion, Vegetation and Submergence.

Erosion descriptors describe soil erosion and scour in channels and around structures in the stormwater system. Erosion is the general lowering of the ground surface over a wide area. Scour is a localized loss of soil, often around a structure. Erosion and scour can cause sediment transport and water quality issues, and undermine and collapse structures and channels. Descriptors are: *Bottom Erosion/Sour, Bank Erosion/Scour, Geotextile Visible, Tree Roots Exposed, Scour Around/Beneath Structure*. An erosion assessment is further characterized as *Minor*, *Moderate* or *Severe*.

Vegetation descriptors describe live vegetation (or lack thereof) in open channels, at the ends of culverts, and located at inlets, outlets or BMPs. Descriptors are: *Bare Earth, Aggressive Maintenance, Overgrown Grasses/Weeds, Trees/Brush, Growth on Structure, Wetland Fringe Distressed*. Bare Earth channels are susceptible to erosion, as are channels subjected to Aggressive Maintenance. Overgrown Grasses/Weeds, Trees/Brush, or Growths on the structure (e.g., barnacles on a tide valve) would hinder the stormwater drainage system. Fringe wetlands, which occur along or near the edge of a body of water, are an indicator of the health of the water body. Loss of the wetland fringe can lead to erosion of embankments. A modifier *of Limited, Patchy* or *Extensive* is used to describe the general spatial distribution of the vegetation. Vegetation conditions may vary according to season.

Submergence descriptors describe the hydraulic condition at the ends of pipes, culverts, inlets and outlets. These descriptors are *Standing Water* and *Flowing Water*, with modifier identifying the percent submergence. Submergence conditions may be affected by recent rainfall, high groundwater table and/or tidal influence. Re-evaluation may be necessary if submergence appears to be due to recent rainfall. Apparent groundwater or tidal influence should be noted in the comments field.

CONDITION ASSESSMENT GUIDELINES

Condition assessment will be completed during Pass 1 for all sites, unless prevented by a maintenance, access or traffic issue. For those cases, condition assessment will be completed during Pass 2. Condition assessment data will be collected on the tablet and linked to the primary stormwater dataset using the AssetID. There is a one-to-many relationship between the asset and the condition tables allowing for more than one condition assessment to be logged for each asset. For each asset, multiple defects may be identified and recorded. The condition assessment is limited to observations of defects that are visible to the survey crew and can be seen on the pole camera screen or video. The range of the pole camera is approximately 50 ft of zoom inside a pipe, depending upon light conditions.

Multiple Defects – To account for multiple similar defects (e.g. multiple cracks), a higher severity rating of Moderate or Severe will be assigned to the feature. For a single defect or few defects visible, a severity rating of Minor will be assigned.

Multiple Descriptors – A defect can only be assigned a single descriptor, and a single corresponding modifier (severity). If there are multiple applicable descriptors, choose the descriptor which is most significantly impacting the function or condition of the asset.

Components – Condition assessment will be performed on all features identified in Table 2-9. In addition to these features, the NASSCO method can be applied to significant components, or parts, of those features. This applies primarily to structural components of inlets and manholes/junctions, with components such as *cover, frame, ladder* or *wall*. Condition assessment will also be performed on end structures, which are also treated as components. These end structures may be present on outlets, pipes, culverts, channels and BMPs.

Upstream/Downstream – Upstream and downstream fields are included in CartoPac in order to identify defects on each End Structure (headwalls, etc.). This field may also be used to provide a generalized location of defects found in linear features (pipes, culverts, channels).

Connections – Defects often occur at the point of connection between linear features (pipes, culverts) and point features (inlets, manholes/junctions, outlets). Defects also often occur at the interface of channels and pipes or culverts. These connection points should be scrutinized and photographed during the condition assessment.

Visual Observations – The condition assessment is limited to visible observations by field crew and zoom camera. The field crew will conduct assessments of conditions that can be determined in the field. Review of zoom videos will be conducted in-office as necessary for completion of the condition assessment, such as for identification of pipe material or discernment of other fine detail better viewed in the office setting.

Assessing Significance – When identifying defects and determining severity of those defects, the focus should be on collecting information that will be the most useful in determining necessary maintenance, repair or upgrade of the system.

Other Observations – Condition assessment is focused on identifying defects which affect function of the drainage system. Occasionally the field crew may come across information the City may wish to know but which does not qualify as a defect. This information should be noted in Comments field. For example: a stormwater manhole with a sanitary sewer manhole cover should be identified in the Comments field so that the City can address it.

2.10 Stream and Wetland Assessment

Stream and Wetland Assessments will be conducted for 10 stream reaches or wetland sites within the project area in order to identify potential stream and wetland enhancement project opportunities. A desktop site search will first be performed using existing GIS data in order to identify 10 candidate sites. Desktop analysis will include review of parcel data, existing buildings and roads, the National Wetland Inventory, soils data, hydrology data, tree canopy cover, impervious surface cover, land uses, aerial photographs, historical records, etc. Candidate sites will be prioritized based on factors such as ownership type (public/private), number of parcels/landowners per site, resource size, land cover, value added components, and position within the watershed.

A rapid field assessment protocol will be used to collect baseline data that will support characterization and further prioritization of sites. This protocol requires the field crew to move quickly and record general observations that best represent the site. Assessment data will be collected in the field using ArcGIS Collector software on a mobile device. ArcGIS Collector is a mobile data collection application that publishes field collected data directly to a cloud server (ArcGIS Online hosted by ESRI) in real-time. If a fatal flaw is identified at any point during the site assessment, the flaw will be documented and the assessment will end at that point for that site. A fatal flaw is a site characteristic which would disqualify the site from consideration for enhancement activities. If a site is eliminated from the candidates list, the desktop analysis procedure will be used to identify a replacement site.

GPS data will be collected at each of the 10 candidate sites. Stream and wetland assessments will be conducted after the survey crew has completed mapping the system (Pass 1, 2) so that the stream and wetland assessment field crew can link the stream and wetland assessment dataset to the primary stormwater dataset using the AssetID. Stream sites will be linked to the appropriate asset in the channels feature class; wetland sites may be linked to either the channels or BMP feature class depending on which asset is in closer proximity or is deemed more appropriate in relating to the assessed wetland feature. Individual point locations with observed water quality problems, utilities conflicts, or opportunities for aquatic improvement will be linked to the corresponding stream reach or wetland site using the StreamReachID or SiteID respectively.

Photos will be taken at each of the candidate sites during the stream and wetland assessment, with sufficient coverage and detail to document existing conditions, to assist in selection of three priority sites, and for use in conceptual level design. Photographs of noteworthy features, including pollution sources, utilities present, problems, or opportunity areas, will be taken to support metrics evaluations. For stream reaches, photos should be taken from an upstream vantage point looking downstream, and vice versa, according to the procedures in Section 2.11. For wetland sites, photos should be taken to provide area coverage of the entire site and close up views of identified issues or opportunities. The field crew will use the convention of left and right banks identified looking downstream. Field photos for each feature will be captured using the mobile device running ArcGIS Collector and will be directly stored in the geodatabase as attachments related to that feature. Multiple photos can be linked to a single feature in the database.

Field assessment forms in ArcGIS Collector will consist of a series of parameters to characterize streams and wetlands, as well as a series of parameters to identify problems and potential solutions at each site. Each parameter will be evaluated according to metrics such as good/fair/poor, presence/absence, or similar criteria. In addition to other field observations, the field crew will evaluate wetland soils, vegetation and hydrology according to US Army Corps of Engineers (USACE) guidance and observations will be recorded on the USACE Atlantic and Gulf Coastal Plain Region (Version 2.0) Wetland Determination Form for each assessed wetland. Scanned copies of the form will be stored as an attachment to the wetland feature class. The individual metrics are then used to determine the overall objective evaluation (rating) of the reach or site, and a corresponding numeric score is assigned.

In the stream and wetland assessment dataset, parameters are attributes and metrics (ratings and scores) are domains. Parameters for stream reach and wetland site features are shown in Table 2-10. Water Quality Problems, Utility Conflicts, and Aquatic Improvement Opportunity parameters are shown in Table 2-11. *Appendix E* contains a copy of the *Stream and Wetland Assessment Data Dictionary*. *Appendix F* contains a copy of the *Stream and Wetland Assessment Illustrated Guide.* This Illustrated Guidance depicts examples of the various stream and wetland parameters (attributes) to be collected, and includes modifiers (ratings) such as *Excellent, Good, Fair* and *Poor*, similar to the Condition Assessment. In the Water Quality Problems, Utility Conflicts, and Aquatic Improvement Opportunities portions of the dataset, all attributes are observations of presence/absence, therefore they are not shown in the Illustrated Guidance.

Upon completion of the initial assessment, the 10 candidate sites will be ranked. The 3 highest priority sites will be selected by the City for potential stream or wetland enhancement projects. Additional field investigation may be necessary in order to fully characterize the 3 priority sites sufficient to develop a conceptual plan for each site. The conceptual plan will depict proposed improvements for each priority site. A map, narrative of field assessment, and ranking matrix will be prepared for the 10 candidate sites. Summary report, concept plan and preliminary cost estimate for full design and construction will be prepared for the 3 priority sites.

Table 2-10 Stream and Wetland Assessment Features

FEATURE CLASS	CATEGORY	PARAMETERS (ATTRIBUTES)
Stream Reach	Channel Stability	Bank stability Stream bend stability Root exposure Bank material Cross-section shape
	Channel Sediment	Bed deposition Bed scour Point bars
	Physical Instream Habitat	Wetted perimeter Bed form diversity Channel alteration
	Water Quality	Film or Algae fouling Water clarity Odor
	Riparian Habitat	Buffer width Canopy coverage
Wetland Site	Hydrology	Existing hydrology
	Vegetation	Upland buffer width Vegetative alterations
	Water Quality	Algae presence

Table 2-11 Stream and Wetland Defects, Conflicts and Opportunities

RELATED TABLES	PARAMETERS (ATTRIBUTES)
Water Quality Problems	Presence or absence of water quality problem(s) Visual evidence of discharge Dumping in aquatic resource Leaking infrastructure Suspect odor Suspect water appearance Erosion and sediment control violation
Utility Conflicts	Presence or absence of utility conflict Type of utility present Other problems identified
Aquatic Improvement Opportunity	Presence or absence of aquatic improvement opportunity Potential stormwater control measure (SCM) type Potential aquatic resource enhancement type Potential aquatic resource preservation type

2.11 Photographing Features

Photographs are necessary in order to document each asset in the City's stormwater inventory. These photos will be used to verify field data during office processing quality control checks, in defect analysis for the condition assessment, in maintenance/access requests, and in evaluating potential stream and wetland enhancement sites. Zoom videos will also be used in order to identify defects inside stormwater structures and along channels and BMPs. Still photos can be captured from the zoom videos while in the field and/or during office processing. Acceptable file types for photos and videos should be verified with the City. The AssetID label on each structure or a labeled survey flag must be included in each photo/video and file name for easy identification and proper linking in the database.

The following process should be followed to photograph features:

- ☐ Identify feature and paint AssetID on the structure, if possible.
- ☐ If AssetID cannot be painted on structure, place labeled survey flag instead.
- ☐ Place arrow card showing downstream flow direction.
- ☐ Use the GPS data collector to take photograph(s) (Close-ups, Area, Internal, Issues and Defects). Take photos in the order given in Table 2-12.
- ☐ Use the pole camera Zoom to take video of the interior of inlets, manholes/junctions, outlets, pipes and culverts, as well as open channels and BMPs. Extract zoom photographs from video as needed.
- ☐ Pole Camera videos may be omitted for interior point features (inlets, manholes/junctions, outlets) less than 4 ft deep, if the condition assessment can be performed with visual observations and documented with photos in CartoPac.
- ☐ Use the naming convention to name each photo. An automated geoprocessing tool can be used for batch naming/numbering of photos in the office.
- ☐ Link photos to Asset ID in GIS database.

Table 2-12 provides a minimum list of photos/videos required for feature identification of each feature type. More photos can be taken if necessary. Table 2-13 contains a brief explanation of each type of photo/video, including condition assessment photos. The photo and video naming convention is described in the following text, and examples are given in Table 2-14.

Table 2-12 Feature Identification and Assessment Photos

FEATURES (ASSETS)	PHOTO / VIDEO
Inlets **Manholes/Junctions** **Outlets**	Close-up Area Internal Zoom / video
Pipes **Culverts**	Close-up Area Zoom / video
Channels includes stream assessment	Close-up Area Zoom / video
BMPs includes wetland assessment	Close-up Area Zoom / video
Discharge Points * **End Structures**	Close-up Area Zoom / video

* *Discharge Points and End Structures will not be separately photographed, however these points will be captured in the Close-up and Area photos of the feature to which they are attached.*

Table 2-13 Description of Photos

PHOTO / VIDEO	DESCRIPTION
Close-Up Photo (C) Point features Linear features Polygon features	Top/exterior of structure is the primary subject of photo for point features (Inlets, Junctions/Manholes, Outlets). Entrance or exit of structure is the primary subject of the photo for linear features (Pipes or Culverts). Close-up photos will also be used to document defects in non-structural features (Channels, BMPs) during the condition assessment. Close-up photos will be used to identify specific water quality problems, utilities condition, and/or aquatic improvement opportunity photos from the stream and wetland assessment.
Area Photo (A) Point features Linear features Polygon features	Purpose is to identify characteristics near structure, and help maintenance crews to locate structure/area. Asset in the foreground, with local area in the background for point features (Inlets, Junctions/Manholes, Outlets). Asset in the foreground with photographs oriented upstream and downstream for linear features (Pipes, Culverts, Channels, including stream assessment sites). Series of photographs taken from single vantage point around perimeter of asset for polygon features (BMPs, including wetland assessment sites).
Internal Photo (I) Point features	Interior of structure is the primary subject of photo. Photograph taken standing above structure looking down into point features (Inlets, Junctions/Manholes, Outlets). Purpose is to show configuration and condition of asset, materials and sizes.
Issue Photo (S) Point features Linear features Polygon features	Photo(s) taken for the purpose of documenting a maintenance or access issue. These photos should show a close-up, area and internal view of the problem, as appropriate, but should be labeled as an Issue photo. Issue photos will be used on maintenance and access request forms.
Zoom Video (V) **Zoom Photo (Z)** Point features Linear features Polygon features	Video taken from the upstream and downstream vantage point of linear features (Pipes, Culverts, Channels) and around perimeter of polygon features (BMPs). Each channel reach should be photographed. Defect photos may be extracted from zoom video. Use video as needed for stream and wetland assessment sites.
Defect Photo (D) Point features Linear features Polygon features	A picture of a Structural defect, Operations and Maintenance defect or Supplemental defect (erosion/vegetation/submergence) that impedes flow or has a negative impact on the function of the asset. Defect photos may look identical to Close-up, Area or Internal photos, however they are separate photographs, are linked to the condition assessment portion of the database and labeled separately.

PHOTO AND VIDEO NAMING CONVENTION

Photos of all stormwater, stream and wetland assessment features will adhere to the naming convention shown below and examples listed in Table 2-14. Basic photo naming will follow the format below. Flow direction and clock position are included in the naming as needed.

Asset Inventory Photo Names

AssetID + Photo Code + Photo# + Date
(For point features and polygons)

AssetID + Flow Direction + Photo Code + Photo# + Date
(Linear Features)

- AssetID will be assigned automatically for photos taken with the GPS collector.
- The appropriate photo code label will be selected for each photo as it is taken. Photo codes are: C, A, I, S.
- Photos are automatically numbered sequentially starting with 01.
- Date will be presented in Year-Month-Day (YYMMDD) format (i.e., 20170510) for ease in file sorting and tracking.
- Flow direction will be included for linear features (pipes, culverts, channels). Flow direction (UP, DN) is the direction of the photo taken from the vantage point of a linear feature (i.e., UP is looking upstream, and DN is looking downstream).
- Flow direction may be difficult to discern in the field, particularly if the features are dry. Flow direction should be determined using the available basemap data, pipe diameter increasing in the downstream direction, and visual field indicators such as flow lines and sediment or leaf pack deposition.

Condition Assessment Zoom Photo/Video Names

AssetID + Zoom Code + Photo/Video# + Date
(For point features and polygons)

AssetID + Clock Position + Zoom Code + Photo/Video# + Date
(For pipes accessed via a point feature)

AssetID + Flow Direction + Zoom Code + Photo/Video# + Date
(For culverts and channels)

- AssetID will be entered manually for photos/videos taken with the pole camera.
- AssetID for inlets, manholes/junctions, outlets, culverts, channels and BMPs will remain as assigned for zoom photos/videos.
- AssetID for pipes will be assigned according to the AssetID of the point feature (inlet, junction/manhole or outlet) into which the pole camera is inserted. Pipe

photos and videos will be renamed using the correct pipe AssetID (rather than the intersecting point feature) during post-processing.

- The appropriate zoom code label will be used for each zoom photo and video. Zoom codes are: Z, V.
- Clock position will be used to identify the location of a pipe intersecting a point feature (inlet, manhole/junction/outlet). From the surface, looking down into the point feature, pipes are labeled 1 through 12, with 6 o'clock as the outflow, downstream direction.
- Flow direction (UP/DN) will be included for linear features (culverts and channels). UP/DN will be added for pipe features during post-processing re-naming.
- If there appear to be multiple outflow pipes, choose the largest diameter pipe or the middle of a multi-barrel configuration as the downstream, 6 o'clock position.
- AssetID and the time and date stamp will be included on all zoom photos and videos. This marking is permanent and may not match the file name if the AssetID is re-assigned after the image is taken.

Condition Assessment Defect Photos

AssetID + DefectCode + Photo# + Date
(For point features and polygons)

AssetID + Flow Direction + DefectCode + Photo# + Date
(For linear features)

- DefectCode will initially be assigned as D. Standard NASSCO defect codes will be added to the defect photo name during post-processing.
- Defect photos may be very similar to the Close-up, Area, and Internal photos taken during the asset inventory.

Stream and Wetland Photos

StreamReachID +AssetID + Flow Direction + Photo Code + Photo/Video# + Date

SiteID + AssetID + Photo Code + Photo/Video# + Date

- The StreamReachID or Wetland SiteID will be appended to the appropriate channel or BMP AssetID from the asset inventory.
- The appropriate photo code label will be selected for each photo as it is taken. Photo codes are: C, A. If videos are taken, the codes are: V, Z.

Table 2-14 Naming Convention for Photo and Video Files

PHOTO / VIDEO	CODE	NAMING CONVENTION	EXAMPLE
Close-Up Photo	C	*AssetID + C + Photo# + Date*	INLT00001_C01_YYMMDD CLVT00005_C03_YYMMDD SBMP00012_C02_YYMMDD
Area Photo	A	*AssetID + A + Photo# + Date* *AssetID + Flow Direction + A + Photo# + Date*	MH00002_A01_YYMMDD CLVT00002_DN_A01_YYMMDD PIPE 00018_UP_A02_YYMMDD SBMP00012_A05_YYMMDD
Internal Photo	I	*AssetID + I + Photo# + Date*	INLT00005_I01_YYMMDD JX00031_I01_YMMDD OUTL00108_I01_YYMMDD
Issue Photo	S	*AssetID + S + Photo# + Date* *AssetID + Flow Direction + S + Photo# + Date*	MH00002_S01_YYMMDD CLVT00002_DN_S01_YYMMDD SBMP00012_S05_YYMMDD
Zoom Video	V	*AssetID + V + Video# + Date* *AssetID + Clock Position + V + Video# + Date* *AssetID + Flow Direction + V + Video# + Date*	INLT00005_V01_YYMMDD INLT00005_6_V01_YYMMDD → PIPE00038_DN_V01_YYMMDD INLT00005_12_V01_YYMMDD → PIPE00041_UP_V01_YYMMDD CHNL00001_DN_V01_YYMMDD SBMP00019_V02_YYMMDD
Zoom Photo	Z	*AssetID + Z + Photo# + Date* *AssetID + Clock Position + Z + Photo# + Date* *AssetID + Flow Direction + Z + Photo# + Date*	MH00017_Z01_YYMMDD OUTL00018_6_Z01 → PIPE00094_DN_Z01_YYMMDD OUTL00018_9_Z01 → PIPE00088_UP_Z01_YYMMDD CHNL00001_DN_Z01_YYMMDD SBMP00019_Z02_YYMMDD
Defect Photo	D	*AssetID + D + Photo# + Date* *AssetID + Flow Direction + D + Photo# + Date*	INLT00011_D01_YYMMDD CLVT00111_UP_OBB01_YYMMDD SBMP00019_D01_YYMMDD
Stream and Wetland Assessment Photos	C A V Z	<u>*StreamReachID or SiteID +*</u> *+ AssetID + C + Photo# + Date* *+ AssetID + A + Photo# + Date* *+ AssetID + V + Video# + Date* *+ AssetID + Z + Photo# + Date* ** include Flow Direction for Stream Reaches.*	STR01_ CHNL00009_C01_YYMMDD STR04_CHNL00319_DN_A02_YYMMDD STR07_CHNL01485_UP_V01_YYMMDD WET01_SBMP00012_C01_YYMMDD WET03_SBMP00089_A07_YYMMDD WET05_SMBP00103_Z02_YYMMDD

IMAGE FILE PROCESSING

Post-processing in the office may be used to re-label or re-number the photos and videos as needed. Pipe photos and videos will be renamed using the correct pipe AssetID (rather than the intersecting point feature) during post-processing. Flow direction will also be added. Discharge Point photos will be copied from the relevant feature class and linked to the Discharge Point feature class. Certain photos from the asset inventory may be copied for use as defect photos in the condition assessment portion of the database. Defect codes will be added to photo names during post-processing. Photos taken with a different device or at a different time will be manually labeled and linked in the correct table of the database. Photos may be extracted from zoom videos during field work or during post-processing.

2.12 Encountering Obstacles in the Field

A number of obstacles may arise during field activities which complicate field data collection. Potential obstacles include:

1. Location blocks GPS signal.
2. Offset is required for XY coordinate.
3. Debris blocks structure; cannot collect invert elevation or depth/diameter measurement; cannot do condition assessment.
4. Cannot physically access the location.
5. Features to be mapped are located in street and require traffic control.
6. High tide prevents accurate data collection in tidally influenced areas of system.
7. Structure encountered which is not in the Data Dictionary or Illustrated Guidance.

Where conditions exist which complicate data collection, survey personnel will make notes and photograph conditions. This will be reported to the Survey Manager for review and resolution. The following is a list of potential alternatives for obstacles encountered during field data collection. All alternatives will achieve an equivalent level of data accuracy.

1. If the location blocks the GPS signal during Pass 1, the survey crew will move to a nearby open area and shoot an offset point during Pass 1, mark it with paint or a survey flag, and note in the Comments field that the point was an offset. Update the location with accurate position data during Pass 2.

2. If the GPS data cannot meet a residual HDOP of < 0.1 ft or a VDOP of < 0.1 ft, the crew will note the condition and set a benchmark point nearby. If mapping grade horizontal data can be procured through epoch averaging, only one vertical control point is needed (Pass 1). If both horizontal and vertical accuracies cannot be obtained then two control points will need to be set (Pass 2). The control points should be on either side of the asset if possible or at least 200 ft apart and within

500 ft of the asset. A total station can then be used to locate the asset. Closed loops with closure or doubled angles and distances that are Class A (1:10,000) or less are required to meet the transverse loop protocol.

3. If data collection cannot be completed due to maintenance issues, the survey crew will mark the Asset ID, note the location Needs Maintenance field of the handheld data collector and return to complete data collection after maintenance has been performed. When revisiting the asset, the survey crew will update the X,Y position of the offset point with the GIS mobile tools (CartoPac) and complete the condition assessment. See Section 2.13 for further detail.

4. If data collection cannot be completed due to access issues, the survey crew will note the location in the Accessible field of the handheld data collector and return to complete data collection after access has been facilitated. When revisiting the asset, the survey crew will update the X,Y position of the offset point with the GIS mobile tools (CartoPac) and complete the condition assessment. See Section 2.14 for further detail.

5. If data collection cannot be completed due to traffic safety concerns, the location will be noted in the Comments field. Arrangements will be made for traffic control along each corridor, as needed, and the field crew will return to the location and collect all of the missing data from that corridor as scheduled by the City in coordination with SCDOT. See Section 2.15 for further detail.

6. Route planning will take into account tide schedules in tidally influenced areas of the stormwater system, particularly at the outfalls. The survey crew will collect GPS coordinates if possible to do so. If condition assessment cannot be completed due to tidal conditions, the survey crew will return to that location when the tide has ebbed.

7. Unusual circumstances will be noted in the Comments field and discussed with the Project Manager. Frequent encounters of assets not able to be stored in the database may warrant changes to the data structure. This must first be discussed with the City.

2.13 Maintenance Issues

At some locations it will be difficult to complete mapping and condition assessment due to maintenance issues. Maintenance issues are temporary problems that can be resolved with equipment such as a backhoe or vacuum truck, or with manual labor. Permanent problems, such as a collapsed structure or tree growing in the structure will be captured in the Condition Assessment. Maintenance issues may include:

- Accumulated sediment or debris in structures
- Standing water or sludge in structures
- Heavy overgrowth of vegetation

In order to maximize efficiency, survey crews will attempt to resolve minor maintenance issues in the field. The GPS coordinate will be collected if the survey crew can clear the structure with less than 5 minutes of digging or clearing vegetation with a bush axe. The condition assessment will be completed if the structure is less than 50% full or can be cleared sufficiently to visualize the majority of the structure on the pole camera screen.

If the survey crew is unable to collect data due to accumulated sediment or debris, standing water or sludge, overgrown vegetation, or other maintenance issues, they will collect a GPS point as close as possible, and mark this location. The particular Maintenance issue will be identified using the "Needs Maintenance" field on the GPS tablet and photo(s) will be taken to document the issue. The Maintenance and Access request will initially be entered during Pass 1 and updated after maintenance is completed, during Pass 2.

A maintenance and access tracking spreadsheet will be exported from the GIS database for all features that have maintenance or access issues and will be provided to the City on a bi-weekly basis. The spreadsheet will have the X,Y coordinate, AssetID, Issue Types, Comments, Location and Date. In addition, a report form will be generated for each location requiring maintenance or access. The form will include the above listed information, along with Issue Photo(s) and a location map for the specific feature.

The City will provide updated status regarding completed and scheduled maintenance using the maintenance tracking spreadsheet. After maintenance has been completed, the survey crew will return to the identified locations and collect the necessary data during Pass 2. For locations where heavy equipment is required to lift a manhole cover, an inlet grate or concrete box top, the survey crew will coordinate timing with the City maintenance crew. A second record will be created during Pass 2 for any assets that were inaccessible or required maintenance. Maintenance completed dates will be updated from the tracking spreadsheet to the database. This will establish a maintenance recordkeeping system in GIS which can be used for MS4 compliance purposes.

2.14 Access Issues

The City will coordinate access to private, commercial or industrial areas with individual property owners. Where project personnel and their agents will be entering onto the developed property of others, an attempt to contact the property owner will be made on-site. Field crews will carry a copy of a letter on City letterhead describing the work, in order to present to property owners and gain access to private, commercial or industrial areas. The *Project Notification Letter* is found in *Appendix I*.

Some locations will be difficult to access for the purposes of mapping and condition assessment. Access issues may be resolved with communication between the City and the private landowner, or with the use of equipment such as a track hoe with lifting chain. Permanent problems, such as a manhole cover paved over, may also be captured in the Condition Assessment if the City is unable to resolve the issue before Pass 2. Circumstances preventing access may include:

- Fencing or locked gate
- Manhole cover or inlet grate paved over or stuck
- Concrete box-top inlets or oversized manhole or inlet covers requiring heavy equipment to lift
- Owner denies entry to private, commercial or industrial property
- Other constraints which make the site unsafe for the survey crew, including site-specific conditions or aggressive dogs

If the survey crew is unable to access a location due to physical or other constraints, they will collect a GPS point as close as possible, and mark this location. The particular Access issue will be identified using the "Accessible" field on the GPS tablet and photo(s) will be taken to document the issue. All sites marked as inaccessible will be collated into a spreadsheet and provided to the City every two weeks. Coordination regarding Access requests will follow the same procedures identified in Section 2.13 for sites requiring maintenance.

2.15 Field Safety and Traffic Safety

Project-specific Field Safety and Traffic Safety Plans will be developed and implemented for each Watershed Master Plan project to provide safe operating procedures, guidelines, and practices for field personnel. Safe Work Plans must contain the minimum health and safety requirements for field personnel to conduct work in the safest possible manner, consistent with applicable policy, procedures and work practices. The City reserves the right to review and amend these plans in accordance with City requirements. The *Safe Work Plan, Appendix G* and *Traffic Safety Plan*, *Appendix H* are the minimum standards developed for this project. A safety briefing will be conducted at the beginning of field work, after more than two weeks break from field work, after a significant change in site conditions or field activities, and whenever new field staff report to the project site. The field crew will conduct a daily safety tailgate meeting prior to beginning the work day.

At a minimum, the Safe Work Plan must include the following elements:

- Hazard Assessment – Prior to beginning work, significant hazards will be identified and measures will be undertaken to mitigate risks. Field personnel will hold Daily Tailgate Safety Meetings and complete Task Hazard Assessments.
- Fitness for Duty – Field personnel will arrive at work fit for duty and capable of performing their job responsibilities in a safe, secure, productive and effective manner.
- Training and Qualifications – Field personnel will be qualified and trained to perform their responsibilities. Field safety and traffic safety will be overseen by a competent person.
- Personal Protective Equipment (PPE) – Field personnel will wear and use minimum required PPE for each work location, weather condition or other relevant situation.
- Site Controls – The site supervisor will identify safe work zones and appropriate signs, signals and barricades as needed for each survey area.
- Emergency Response – Hospital or clinic locations nearest the project area will be identified in case of injury or illness. Communication and incident reporting procedures will be established and key points of contact will be listed in the plan.

The Safe Work Plan will evaluate working conditions (traffic, weather, wildlife or other natural hazards, lighting, time of day, isolated areas, etc.), identify hazards, and specify mitigation measures and PPE required for those working conditions. Where there is a perceived danger or risk with continuing work or dialogue in any situation, field personnel will retreat to a safe location and report the situation to the site supervisor immediately. Table 2-15 identifies the primary hazards, mitigation and PPE anticipated for Watershed Master Plan projects.

Table 2-15 Significant Hazard Identification, Mitigation and PPE

HAZARD	MITIGATION	PPE
Traffic *live and moving vehicles or equipment*	Pull vehicles as far off the road as possible. Activate four-way hazard lights. Park in a location which blocks personnel from oncoming traffic. Maintain safe distance from moving vehicles/ equipment, visual contact with drivers and operators. Stage activities away from vehicles and paths of travel. Use signs, cones and a flag-person as needed to warn oncoming traffic. Avoid turning back on traffic. Do not enter the roadway except to cross the road. Make road crossings perpendicular to traffic flow.	High visibility vests Steel toe boots Hard hats and safety glasses (as needed)
Driving and Vehicles	Maintain alertness of traffic conditions, shoulder obstacles and pedestrians when moving from one survey location to the next. Use hazard lights to warn vehicles to follow at a distance. Wear seat belts regardless of the distance of travel. Mitigate glare.	Seat belts Sunglasses
Heat or Sun Exposure	Use the Buddy system. Conduct heat stress monitoring. Implement a heat stress control plan. Take additional breaks, spend more time in the shade and drink water frequently on days with high heat index. Move indoors during thunder and lightning.	Hat Sunglasses Sunscreen Water
Natural Biological Hazards *Wildlife (such as snakes or alligators); hazardous insects or plants (such as mosquitoes, ticks, poison oak/ivy)*	Use disposable (Tyvek) coveralls, insect repellent (24% DEET or similar), light colored clothing, field/snake boots, and barrier creams. Conduct frequent tick checks. Thoroughly clean field clothing and equipment. Check for snakes and alligators in or near ponds, channels and culverts prior to entry.	Long pants and shirts Snake boots Insect deterrents
Working in or near Water *Water more than 3 ft deep, fast moving stream, or water body with soft bottom creating entrapment hazard*	Use caution when approaching stream banks and ponds. Use pole to determine water depth prior to wading. Do not wade in water above knee-depth unless approved to do so. Move in an upstream direction. Avoid fast moving water and wading after storms.	Footwear appropriate to the site, PFD
Slips, Trips and Falls	Evaluate work area and access routes for potential hazards. Eliminate hazards, erect barricades or place warning signs, cones or survey flagging or paint.	Footwear appropriate to the site
Manual Lifting *Manhole covers, inlet grates, debris*	Use a manhole lifter to aid in removing manhole covers and inlet grates. Do not attempt to lift oversized covers or grates without assistance or heavy equipment. Use leather work gloves to protect hands and wear steel toe boots to protect feet in case of dropped cover or grate.	Leather gloves Manhole lifter Steel toe boots

The Traffic Safety Plan addresses Traffic Protection and Traffic Control requirements for conducting survey operations on highways and roads. Traffic safety measures will be implemented throughout the project, and will include use of parked vehicle(s) with flashing lights, signage, and cones in order to warn drivers and protect field personnel. Traffic Control will be on an as-needed basis to be determined during the planning phase and Pass 1 data collection. During Pass 1, field personnel will document the project areas where traffic control is required. Traffic control measures will be determined and implemented for Pass 2 data collection.

At a minimum, the Traffic Safety Plan will include the following elements:

- Signage
- Vehicle parking
- Flashing lights
- PPE
- Flagger
- Buddy system
- Situational awareness
- Weather conditions
- Escape route
- Loading/unloading
- Entry to roadway

When required, formal traffic control will be coordinated through the City, SCDOT and police/sheriff as needed in order to enable field crews to access areas within the travel lanes, medians, or shoulder areas which cannot be safely surveyed without lane diversion(s) or closure(s). Traffic Control measures will be compliant with *the SCDOT Work Zone Safety Guidelines for the South Carolina Department of Transportation, Municipalities, Counties, Utilities, and Contractors* (2013 or latest version), which presents guidelines for work zone traffic control on short-term work sites on roads and streets in rural and small urban areas. A Traffic Control Zone consists of:

- Advance Warning Area – tells traffic what to expect ahead
- Transition Area – moves traffic out of its normal path
- Buffer Space – provides protection for traffic and workers
- Work Space – for workers and equipment
- Termination Area – allows traffic to resume normal driving

Field personnel will follow the life-preserving principles and watch out for their fellow workers, drivers and pedestrians to ensure that everyone returns home safe at the end of the day.

2.16 Notifications

The following notifications will be made, as needed, during the field portion of the project:

Emergency Notifications – The field crew will call 911/police dispatch immediately if they find weapons or other evidence of criminal activity. The field crew will notify the project manager (PM) immediately thereafter. The field crew will notify the PM if they observe active illicit discharges or sanitary sewer overflows. The PM will in turn notify the City and the City will notify the Charleston Water System POC. The field crew will notify the PM if they observe a serious maintenance issue or defect that is likely to produce flooding or dangerous conditions in the immediate future. The PM will in turn notify the City.

Routine Notifications – The field crew will notify the survey crew chief and the PM of any unusual interactions with the public, issues encountered in the field, or difficulties in collecting data.

MS4 Compliance Notifications – The field crew will notify the PM if they observe apparent but not active illicit connections/illicit discharges, or active construction site discharges. The PM will notify the City.

2.17 Field Quality Control Measures

Quality assurance (QA) and quality control (QC) measures will be implemented as part of daily activities throughout the project. Daily office QA measures will include equipment checks, vehicle checks, and battery charging prior to field work. Daily field QC will be focused on GPS equipment accuracy. This will include checking setup of the Base Station in the morning, checking setup of field data collectors in the morning, and control point checks 3 times per day with a nearby benchmark and the Base Station during Pass 2. Daily field QC measures will also include daily checks to ensure all required fields have been completed in the GIS. These tasks are included in the Work Breakdown Structure in Table 2-6.

The field crew will maintain a list of any features, if uncertain of feature classification or condition assessment, appropriate narrative comments, or other questions which may need to be evaluated by the PM or survey crew chief. This list will be maintained separate from the database. Field GPS and survey data collected will be reviewed by the survey manager for quality and compliance with project accuracy (HDOP, VDOP) standards. Deficiencies will be corrected. Stream and wetland assessment data will be checked at the halfway point (five sites) and again after completion of the field work (10 sites). When all field data collection is complete, the PM will review the data set and ensure that field data is complete and accurate and all required QA/QC procedures were implemented. Additional GIS data quality checks are described in Sections 3.10 and 3.11. Field data quality will be verified prior to the beginning of the modeling, analysis and prioritization portion of the project.

2.18 Limitations

This SOP covers the collection of GIS data in the form of infrastructure mapping, condition assessment and stream and wetland assessment, of the City's stormwater system within the project boundaries. Mapping and assessment is limited primarily to the drainage features within the approximate City of Charleston, Charleston County and SCDOT rights-of-way. Mapping and assessment of drainage infrastructure or BMPs (specifically wet ponds or dry ponds) on private property will be conducted with owner permission only and will be limited to the structures which discharge directly into the municipal stormwater system and which are necessary for model development. Upstream structures on private property may contain incomplete attribute tables since only the data necessary for modeling will be collected, where the conveyance or structure ties in to the City's system. Access to private property will be coordinated by the City. Limiting the modeling primarily to the City's infrastructure, and not including all of the BMPs which may be found on commercial, industrial or residential property will produce conservative modeling results. This will allow a built-in safety factor when the City makes decisions using modeling predictions in the future.

Mapping and assessment will be limited to specific feature classes, attributes and domain values, as directed by the City. These will be determined at the beginning of the project and indicated in *Appendix A, Stormwater Inventory Data Dictionary*. The condition assessment is limited to observations of defects that are visible to the survey crew and that can be seen on the pole camera screen or video. The range of the pole camera is approximately 50 ft of zoom inside a pipe or culvert, from each end. The stream and wetland assessment is limited to evaluation of 10 candidate sites.

This SOP does not include the following activities:

- Subsurface utility locating services;
- Smoke or dye testing of pipe connections;
- CCTV inspection of pipes;
- Confined space entry;
- Use of boats or submerged wading to access wet pond risers, etc.;
- Use of heavy equipment to open/access stormwater structures;
- Inaccessible areas due to fences, walls, safety concerns, etc.;
- Extensive maintenance required;
- Mapping and assessment of residential downspouts, yard drains or swales;
- Residential driveway culverts less than 15 inches in diameter, unless necessary for modeling. Will be determined on a case by case basis for each drainage area.

Maintenance, access and traffic control issues will be handled as described in Sections 2.13, 2.14 and 2.15. Any other issues or unique circumstances will be handled according to the project team coordination and communication procedures in Sections 1.4 and 1.5.

Section 3 Data Management

3.1 City of Charleston GIS Requirements

The City of Charleston maintains a variety of GIS datasets, including stormwater data. This data is housed in the City's GIS database, and is accessible to the public via an online GIS portal. The City uses this data for many purposes including asset inventory, maintenance, project planning and review, public outreach, management and decisionmaking. The data can be downloaded and used by, among others, planning and engineering firms working on projects within the City. Data produced using this SOP will be uploaded to the online portal after quality control reviews have been completed. The portal address is:

http://gis.charleston-sc.gov/dataportal

The following items prescribe the basic requirements in order to meet the City's GIS standard. Additional detail regarding the database structure and components, naming convention, data management and other GIS topics are covered in the remainder of Section 3.

Database - At the beginning of each Watershed Master Plan project, the City will provide a copy of the City's official ESRI ArcGIS geodatabase to be used as the basis for all deliverables. The delivered geodatabase must contain the same network, feature classes, fields, tables, etc. as the original geodatabase provided by the City, and must be cumulative (containing data from all previous deliverables). The ArcGIS software used in the deliverables should be the same version as provided by the City. Older versions may be acceptable; newer versions are not acceptable. There should be no changes to the structures of any of the contents of the geodatabase (feature classes, tables, etc.) unless approved by the City.

Fields – The feature classes in the geodatabase delivered must contain only those fields present in the original geodatabase provided by the City. There should be no changes unless approved by the City. Fields must retain their original definitions (type, length).

Domains – Some attributes have predefined domain values which standardize the appropriate codes for those fields. These may be coded value domains or range domains, and are defined in the geodatabase provided by the City. Attributes must match the defined domain values. Notify the City if attribute values are found during field work that do not appear in the domain list.

Stormwater Network – The stormwater network provided by the City is an ESRI geometric network consisting of pipe and related features in a stormwater system dataset. All network datasets, rules and configurations present in the original geometric network must be preserved in deliverables.

3.2 GIS Data Structure

Data Model – The City's Stormwater feature dataset is based upon the Local Government Information Model (LGIM). The stormwater feature dataset has been modified to suit the City's stormwater data requirements. As Watershed Master Plans are developed for various areas of the City, a variety of infrastructure will be discovered during the mapping process. Additionally, continued growth and development in the City will result in construction of more modern BMPs and stormwater facilities. As such, the geodatabase has been modified in order to ensure that the data structure will be sufficient to allow the City to adequately describe and store stormwater data in the future.

Feature Naming Convention - A standardized naming convention has been established so as to ensure consistent nomenclature is used for naming each feature/asset. All assets have a system generated **Globally Unique Identifier (GUID)**. A unique identifier called the **AssetID** is assigned for each infrastructure feature and allows identification by feature class, with the GUID underlying. The AssetID consists of a 4-letter prefix to identify the feature class, followed by a 5-digit number to identify the exact asset. AssetID prefixes are shown in Table 3-1. Numbering begins with 00001 and continues sequentially and automatically (00002, 00003, etc.) as assets are mapped throughout the City. A **LegacyID** field is also available in order to track assets which were re-named from the City's previous stormwater database.

The AssetID will be used as the primary linkage field in GIS. All assets existing in the database from as-built data have an AssetID assigned. For newly discovered assets, a temporary label will be assigned in the field (*AssetID + X + number starting at 90,000*). New Assets will be re-labeled with the next available sequential number in the watershed using a batch geoprocessing tool. AssetIDs for structures which have been demolished will be retired.

Each stream and wetland assessment site will be assigned an AssetID during the initial system mapping. Once the 10 stream and wetland sites have been identified, each will be assigned a unique **StreamReachID** or wetland **SiteID**. These IDs will be used to link the stream and assessment feature classes. The AssetID will be used to link the stream and wetland dataset to the primary stormwater infrastructure dataset.

Stormwater Data Structure - The City's stormwater GIS database will consist of two datasets and several additional data tables, linked together by relationship tables. All of the feature and attribute information and associated photo documentation will be captured in the City's stormwater GIS, organized by feature class. All of the condition assessment data, including maintenance requests, and associated photo documentation will be captured in the City's primary stormwater dataset. All of the Stream and Wetland Assessment data and associated photo documentation will be captured in the stream and wetland dataset.

The City's Stormwater geodatabase structure is presented in Figure 3-1.

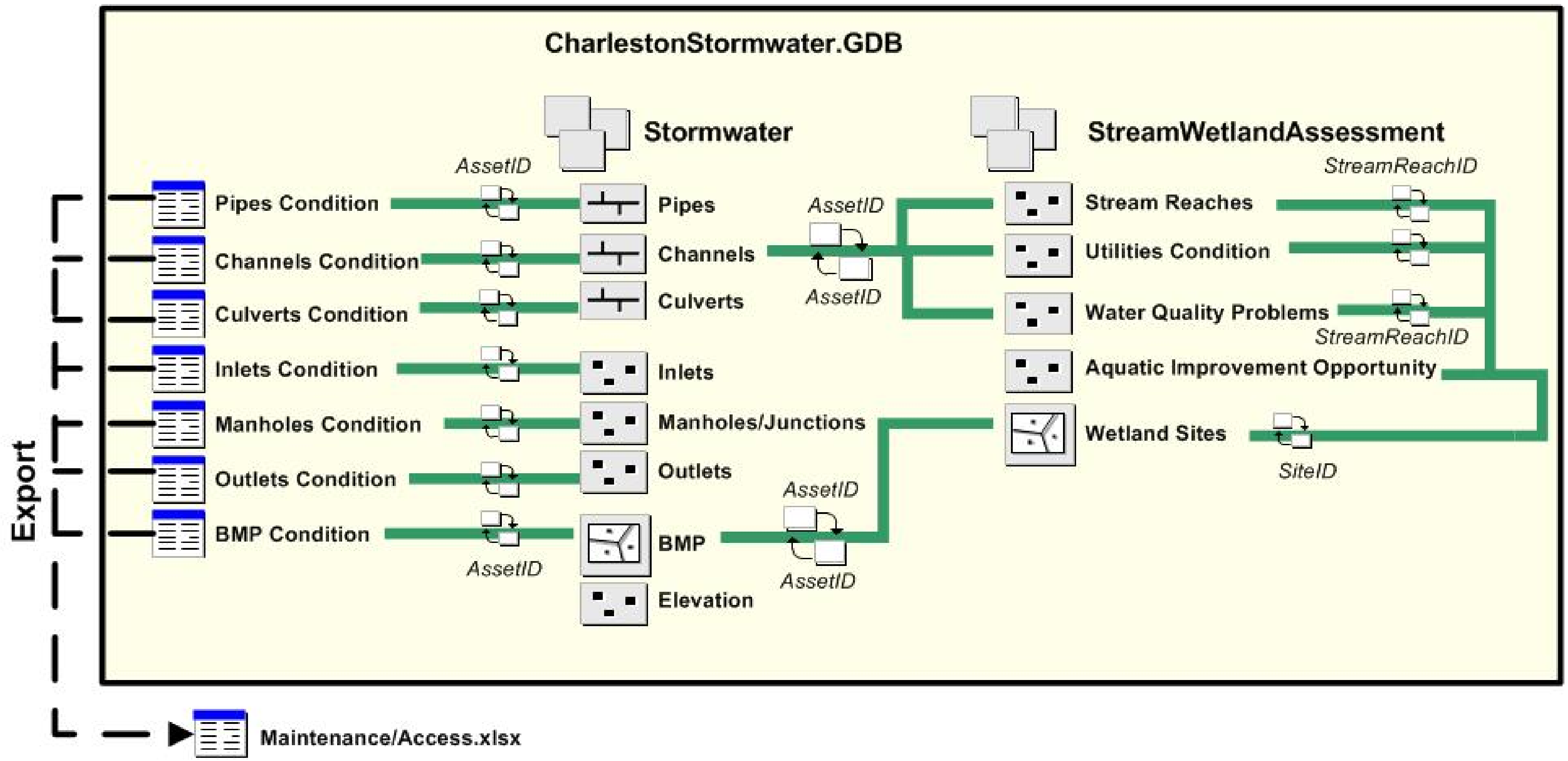


Figure 3-1 City of Charleston Stormwater Data Structure in GIS

3.3 Features, Attributes and Domains

The feature classes which will be mapped under this SOP are listed in Table 3-1. This table also shows attributes with referenced domains, as well as the AssetID prefix, for each feature inventoried. The entire list of feature classes, attributes and domains in the stormwater dataset is provided in the *Stormwater Inventory Data Dictionary, Appendix A*.

Table 3-1 Stormwater Feature Classes and Naming Convention

<table>
<tr><th>FEATURE CLASS</th><th colspan="4">ATTRIBUTES ASSOCIATED WITH DOMAINS</th><th>ASSET ID PREFIX</th></tr>
<tr><td>INLETS
swInlet</td><td>Inlet Type
Combo Inlet
Curb Inlet
Grate Inlet
Box Top Inlet
Drop Inlet
Curb Cut</td><td>Cover Mark
Stamped City Logo
Stamped Manuf Logo
Stamped No Dumping
Stamped Storm Drain
Graphical Design only
Generic no mark
Also applies to MH/JX</td><td colspan="2">Inlet Cover Type
Door
Circular Grate
Rectangular Grate
Manhole Cover
No Access</td><td>swINLT</td></tr>
<tr><td>MANHOLES/ JUNCTIONS
swManhole</td><td colspan="2">Manhole or Junction Type
Standard Manhole
Diversion Manhole
Sedimentation Manhole
Standard Junction Box
Junction Box w/ Diversion
Sedimentation Junction Box
Cleanout</td><td colspan="2">Manhole or Junction
Standard Manhole Cover
Standard w/ Lock
Standard w/ Ears
Rectangular Cover
Hinged Doors
Cleanout Cover w/ Lock
Cleanout Cover w/o Lock</td><td>swMNHL</td></tr>
<tr><td rowspan="2">OUTLETS
swOutletStructure</td><td colspan="2">Outlet Type
Weir
Gate
Riser
Orifice
Spillway</td><td>Gate Type
Sluice Gate
Radial Gate</td><td>Riser Type
Round
Square
Bell-mouth
Perforated
Combination</td><td rowspan="2">swOUTL</td></tr>
<tr><td colspan="2">Weir Shape, Spillway Type
Adjustable Weir
Circular
Irregular
Rectangular
Trapezoid
V-Notched
Combination
Labyrinth</td><td colspan="2">Weir Type
Broad-crested
Sharp-crested</td></tr>
<tr><td>DISCHARGE POINTS
swDischargePoint</td><td colspan="4">Discharge Point Type
Overflow Spillway
Channel
Pipe
Bridge
Culvert</td><td>swDGPT</td></tr>
</table>

<table>
<tr><th>FEATURE CLASS</th><th colspan="3">ATTRIBUTES ASSOCIATED WITH DOMAINS</th><th>ASSET ID PREFIX</th></tr>
<tr><td>FITTINGS
swFitting</td><td colspan="3">Fitting Type
Tees</td><td>swFITG</td></tr>
<tr><td>ELEVATIONS
swElevation</td><td colspan="3">Elevation Type
Bench Mark
Top of Bank
Bottom of Bank
Top of Curb
Bottom of Curb
Normal Water Surface Elevation
Bottom / Low Point of Channel
Other (see Comment)</td><td>swELEV</td></tr>
<tr><td>PIPES
swGravityMain</td><td>Pipe Type
Gravity Main
Secondary Line
Underdrain</td><td>Pipe Shape
Circular
Rectangular
Trapezoidal
Triangular
Elliptical
Arched</td><td rowspan="3">End Structure Type
Flared End Section
Projected from fill
Straight Headwall
Angled Wingwalls
Square Wingwalls
Mitered Headwall
Slab
Rip Rap
Gate Structure
Tide Valve
Bars/Rack
End Structure Type may also be used for Outlets</td><td>swPIPE</td></tr>
<tr><td>CULVERTS
swCulvert</td><td colspan="2">Culvert Shape
Circular
Rectangular
Trapezoidal
Triangular
Elliptical
Arched</td><td>swCLVT</td></tr>
<tr><td>CHANNELS
swChannel</td><td>Channel Type
Channel
Ditch
Swale
Bioswale
Trench Drain</td><td>Channel Shape
Trapezoidal
Rectangular
Parabolic/U-shaped
Triangle/V-shaped</td><td>swCHNL</td></tr>
<tr><td>BMPS
swStructureBMP</td><td colspan="2">BMP Type
Wet Pond
Dry Pond
Wetlands</td><td>BMP or Channel Material
Aluminum
Asphalt
Blocks/pavers
Brick
Concrete
Earthen
Fiberglass
Geotextile
Grass
Plastic
Rip rap
Steel
Stone
Vegetation
Wood</td><td>swSBMP</td></tr>
</table>

3.4 GIS Calculations and Batch Processing

A number of attributes will be populated in the office with calculations using the field measured values, or through the use of geoprocessing tools and scripts. Table 3-2 below provides a list of the attributes which will be calculated in GIS or populated via batch processing. Applicable feature classes are shown for each calculation.

Table 3-2 Attribute Calculations and Batch Processing

ATTRIBUTE	HOW ATTRIBUTE IS CALCULATED	APPLICABLE FEATURE CLASSES
Latitude (X-Coordinate)	Geoprocessing tool updates Pass 1 coordinate with Pass 2 coordinate	*All feature classes*
Longitude (Y-Coordinate)	Geoprocessing tool updates Pass 1 coordinate with Pass 2 coordinate	*All feature classes*
Invert Elevation (Z-Coordinate)	Geoprocessing tool calculates: *Rim Elevation - Depth to Invert* *Top Elevation - Depth to Rim - Depth to Invert* *Top of Pipe - Depth to Invert* *Headwall Elevation - Depth to Top of Pipe - Depth to Invert* *Top of Bank Elevation - Depth to Invert* Elevation uses Pass 2 vertical coordinate	*Closed structures and connecting pipes* *Pipes w/ Tide Valves* *Pipes and Culverts w/ or w/o Headwalls* *Channels, BMPs*
Cover Depth	Geoprocessing tool calculates: *Rim Elevation – Depth to Invert + Diameter* Average of upstream and downstream values	*Pipes which intersect an inlet or manhole/ junction box*
Bottom Slope	Geoprocessing tool calculates: *(Upstream Invert Elev - Downstream Invert Elev) / Length*	*Pipes, Culverts, Channels*
Side Slope	Geoprocessing tool calculates: *(Top of Bank Elev –Toe of Bank Elev) / Vertical Distance from Top to Toe* Average value	*Channels, BMPs*
AssetID	Geoprocessing tool for AssetID corrections	*All feature classes*
Photo Names	Geoprocessing tool for batch Photo Naming	*All photos*
BasinID	Batch naming using 1984 Master Drainage Plan	*All features in project area*

Coordinates – The digitized data has an X,Y coordinate and sometimes has an invert elevation (attribute) populated; however, the invert elevation is not associated with the underlying coordinate. Once the location has been mapped, the survey grade data will replace the mapping grade X,Y coordinate with an XYZ coordinate, and the Z-coordinate will overwrite the invert elevation attribute field.

Invert Elevation (Z Coordinate) – Calculated for every feature where the GPS elevation cannot be collected directly in the field. Invert elevation is calculated in batch processing by subtracting the depth from the surface elevation, as shown in the table. For pipes which intersect a structure (inlets, manholes/junctions, outlets), the rim elevation will be used from the upstream/downstream structure in order to calculate invert elevation. The top elevation, depth to rim and rim elevation will be stored in the appropriate feature class for that structure. The measured depth to invert and calculated invert elevation will be reported in the pipes feature class. For inlet or outlet structures with a top slab or ceiling above the entrance, and for pipes and culverts with headwalls, an additional depth measurement must be made in order to use a common elevation (rim, or top of pipe, respectively) from which to subtract during batch calculations.

Cover Depth – Calculated for pipes which intersect an inlet, manhole or junction box at both ends. Rim elevation will be used to calculate the cover depth, by subtracting the depth to invert and then adding the pipe diameter. Average cover depth will be calculated by averaging the upstream and downstream values. Pipes and culverts which intersect open channels do not have upstream or downstream structures and therefore do not have rim elevations from which to calculate cover depth.

Bottom Slope – Calculated for linear features (pipes, culverts, channels) using the difference of the upstream and downstream invert elevations (low point of the channel), divided by the length of the linear feature. The length is autogenerated in GIS using the upstream and downstream coordinates.

Side Slope – Calculated for channels and BMPs. For channels and dry BMPs (ponds), side slope will be calculated using the difference in top of bank and toe of bank elevations divided by the vertical distance between top of bank and toe of bank. For wet BMPs (ponds), side slope will be calculated using the difference in top of bank elevation and normal water surface elevation. For channels, both a left slope and a right slope are calculated, each as the average of an upstream and downstream side slope. For BMPs, the side slope should be the average or representative value of the side slope around the edge of the BMP.

3.5 Units of Measure

Units of Measure (UOM) are assigned for each attribute field in the GIS database. These units of measure are standardized for the survey coordinate system as well as for each attribute measured in the field or calculated in the office. This ensures that data is presented in a consistent manner and helps to prevent errors resulting from combining data with different units, for purposes of modeling or analysis. Table 3-3 provides UOMs for attributes to be measured in this project.

Table 3-3 Units of Measure for Each Type of Attribute

ATTRIBUTE	UNIT OF MEASURE
Invert Depth	Feet rounded to the nearest 10^{th}
Elevations	Feet rounded to the nearest 10^{th}
Diameter	Inches
Width	Feet rounded to the nearest 10^{th}
Height	Feet rounded to the nearest 10^{th}
Slope	Unitless decimel
Side Slope	Unitless decimel
Length	Feet rounded to the nearest 10^{th}
Perimeter	Feet rounded to the nearest 10^{th}
Area	Square Feet rounded to the nearest 10^{th}

Feet in English Units

3.6 Comments Field

The Comments field supports mapping and data analysis, and provides additional information about the feature beyond what is described in the other attributes. This field may be used to describe:

- A unique design characteristic;
- An unusual circumstance encountered during data collection;
- Analysis or calculation performed in order to arrive at an attribute value;
- Situations where the feature was only partially mapped or partial attribute information completed;
- Provide details when “other” or “combination” is selected for an attribute; or
- To hold temporary status information as the project progresses.

Any temporary status information, such as maintenance issues, will be removed prior to final deliverable or stored solely in the Maintenance data tables. The Comments field is not a catch-all and should not be used in lieu of accurately completing the required attribute fields. Comments should be separated with the pound sign (#).

The Comments field will use narratives with standard language for items which are expected to be repeated at multiple locations within a feature class. Comments or notations should be consistent such that the same comment should be used to reference similar notes or observations and allow for sorting or querying by comment. For example, since the project boundary does not strictly follow the watershed boundary, it may be necessary to note that a certain point represents the extent of field effort, particularly if further infrastructure may be present upstream. A Comment such as "Edge of project boundary" can be noted in such cases.

3.7 Metadata

Existing City of Charleston stormwater data does not have metadata. Metadata will be created for each feature class and provided as part of the database deliverable. Metadata will be created according to the ISO 19115 (2014). These standards describe the content, structure and eXtensible Markup Language (XML) format of the metadata. Figure 3-2 shows an outline of the information which will be included in the created metadata. In addition to the created metadata, attribute fields have been added to each feature class to record the source, date collected and accuracy of data. This allows delineation between field surveyed data, and data derived from as-builts, aerial imagery or other sources.

ISO STANDARD OUTLINE FOR METADATA

- **Resource Maintenance Scope** (include scope description of project)
- **Credit** (include name of contractor, date awarded, start date and project end date)
- **Quality Report** (should include updates to the Level Description tabs and Extent tabs)
- **Report Type under the Quality Report tab (Gridded Data Positional Accuracy) Dimension to include Horizontal and Vertical**

  Measure Date
  Measure Name (include contractor name and award date)
  Description (average accuracy of over lifetime of project)
- **Spatial Reference System** (if spatial reference system used for field collection differs from the source data then a new Reference System must be added with completed Authority Citation)

Figure 3-2 Metadata Content and Structure

3.8 Management of GIS Data

All project files will be stored in a working directory on a secure remote server (cloud) hosted by the engineering consultant. The GIS data will be stored in an enterprise multi-editing SQL/SDE ESRI geodatabase utilizing the City's GIS schema. Use of the cloud allows multiple team members to access and update the project files simultaneously. Figure 3-3 illustrates how GIS data is managed using cloud services. The geodatabase is built to work in a connected environment (online access via mobile data or wifi) with live production enterprise database or in a disconnected mode where data is cached on the local device. The majority of field data collection will be completed in disconnected mode, and the data will be uploaded nightly to the cloud. The cumulative database, include any data processing which occurred after the daily download, will be downloaded in the morning prior to starting field work.

All in-house edits must be saved before leaving the workstation and all editors must stop the editing mode before leaving the workstation for more than 30 minutes. An automated process will run nightly that will kill all in-house connections to the database. At this time, automated quality control checks, assignment of AssetIDs and other functions will be performed on the newly downloaded data. Post processing of data, including quality control checks, will be performed on a daily and weekly basis.

A new folder will be created for each day's work in the working directory. The folder for each day's work will be named according to the following simple file naming convention: **Z_YYMMDD** *where Z = PHOTOS* or other file category, and *YYMMDD = date of data collection.* Digital photographs and videos taken utilizing the zoom camera will be uploaded nightly to the project working directory. Asset photos and videos will be stored in the feature dataset; defect photos will be stored in the condition assessment dataset. During the project, photos will also be stored in a separate folder on the cloud, so that the field crew can access photos of previously mapped assets using a device with wifi or hotspot internet access. This will allow the field crew to quickly access the photos for reference without having to maintain the full database and photo directory on the tablet. Stream and Wetland Assessment GIS data will be stored in the geodatabase and photographs will be linked in the same manner as feature and condition assessment photographs.

The engineering consultant will utilize the City's ArcGIS Online data and the Check Out/Check In process. Stormwater data will be checked out at the beginning of the project and field data will be collected and populated into the City's schema according to the processes outlined in this SOP. The City's existing data in the Watershed Master Plan project area will either be verified and supplemented, or deleted if determined to be incorrect or if the infrastructure is no longer present. Edits will be made to the checked out data only. This workflow for data delivery will allow for simultaneous edits so that the City can make updates to the Stormwater data outside of the project area while the consultant is updating their checkout and managing their quality control process. Upon completion of the project, a second check out will be made, and the data within the project area only will be updated with the newly collected and QC reviewed data. This data will be checked back in to the City's ArcGIS Online data portal as a final, accepted deliverable. The consultant's edits will not be visible to the City, or to citizens accessing the portal, until the final data has been accepted by the City and checked back in.

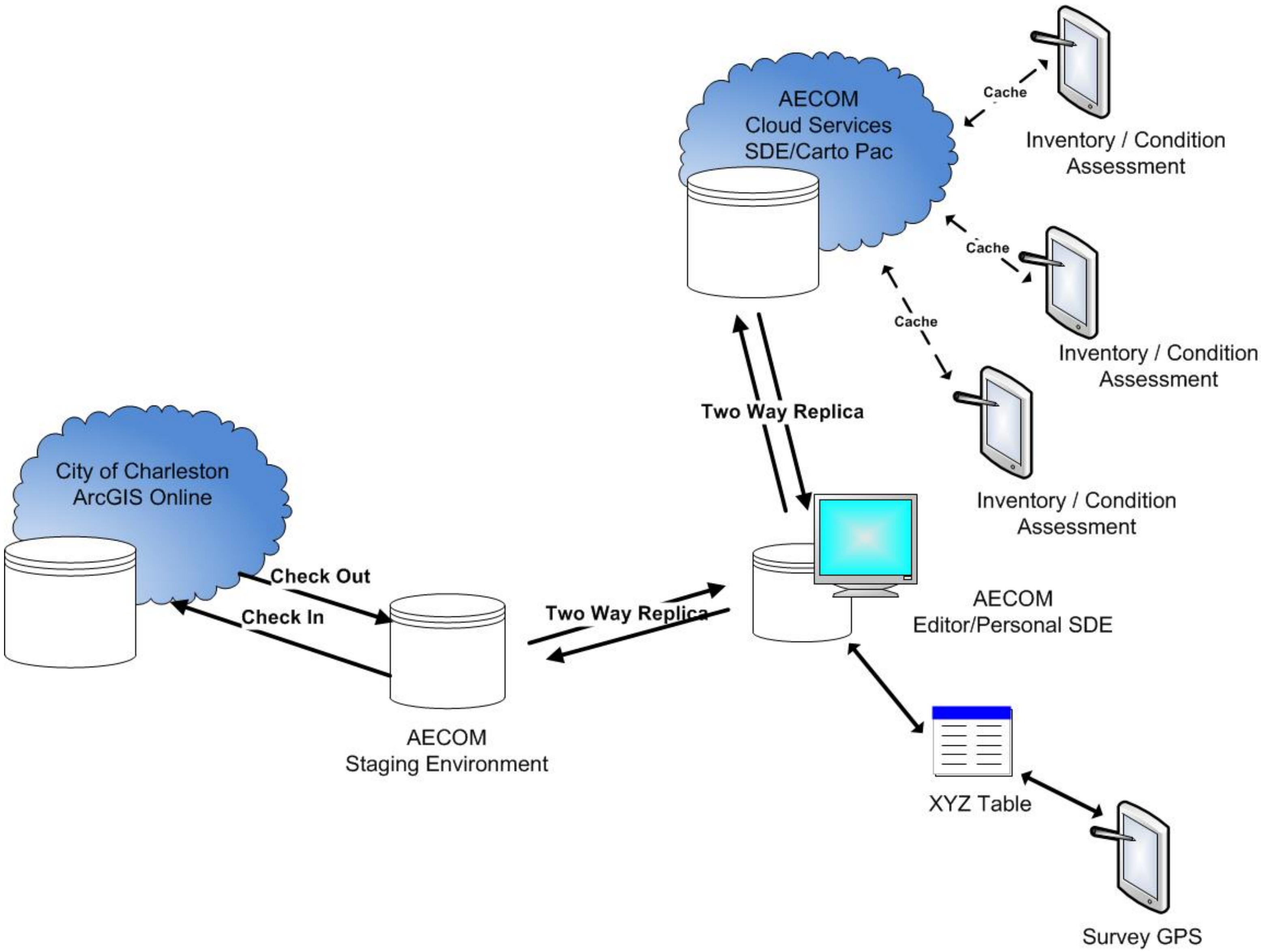


Figure 3-3 Data Management Graphic

3.9 Management of non-GIS data

The majority of data in this project will be captured in the field and either directly stored in the GIS database or linked to it (such as photographs taken with the GIS tablet). The rest of the data will be managed outside of the database, as follows:

Maintenance/Access Spreadsheet – A tracking spreadsheet will be exported from GIS database for all features that have maintenance or access issues on a bi-weekly basis. The spreadsheet will have the X,Y coordinate, AssetID, Issue Types, Comments, Location, Date, and associated picture reference. Each spreadsheet (dated by submittal) and associated maintenance forms (with photos and map) will be stored in the working directory. Maintenance and Access tables will be linked to the stormwater dataset.

Photos and Videos – The majority of photos and videos will be taken using the GPS tablet/handheld data collector or pole camera, and these will be uploaded nightly to the proper directory. In the event that additional photos or videos are taken with other devices (such as a smartphone or digital camera), these can be manually named with the appropriate AssetID, stored in the same directory with the other photos and videos, and manually linked to the geodatabase as needed. Photos/videos taken with other devices should include a GPS tag to aid in linking the photo to the proper AssetID.

Field Notes – Survey crews will maintain hard copy survey log books throughout the project. Stream and wetland crews will maintain hard copy field forms. Relevant records will be scanned and stored electronically in the same directory with the rest of the project files, for reference as needed.

3.10 Stormwater Topology Rules

Topology is the spatial relationship between feature classes in a feature dataset. Topology rules define the relationship between two features within the same feature class, or between two feature classes. Topology rules may also be used to define subtypes within and between feature classes. The following relationships may be used to establish the stormwater network, to ensure valid relationships are created in the GIS and to accurately represent co-located or linked features in the database and on the maps.

Dead End Junctions – There should be no dead end junctions (inlets, manholes/junction boxes or outlets). Each of these structures should have at least one pipe, culvert or open channel connected downstream.

Orphans – There should be no orphan stormwater features. (Exception: points derived from as-builts which cannot be field verified and have been notated as ActiveFlag - inactive.)

Direction of Flow - Pipes must be digitized in the direction of flow to build the geometric network and support modeling activities. Invert elevations should decrease while diameters should increase in the downstream direction.

Upstream vs. Downstream Invert Elevations – Invert elevations should decrease as flows move downstream. Therefore, the downstream invert elevation of upstream pipe, culvert or open channel must be greater than upstream invert elevation of the downstream pipe, culvert or open channel. (This rule may sometimes be violated, especially in flat areas.)

Snapping – All features must be snapped to the appropriate corresponding feature (for example, inlets must be snapped to their corresponding pipes). The most accurate feature should be used as the snapping target. For example, if feature locations are updated with GPS coordinates, the locations of any connected features must be adjusted to snap to the more accurate feature.

Connections to Appropriate Feature Type – Features must connect to appropriate features.

- The downstream end of a stormwater pipe may connect to an open channel, intersect a basin, or connect to an inlet, outlet or manhole/junction.
- An inlet must connect to a stormwater pipe. (Exception: curb cuts)
- Manholes and junction boxes must connect to a stormwater pipe.
- Outlets must connect to a stormwater pipe, unless the outlet is solely an emergency spillway, in which case the spillway may connect to an open channel.
- Culverts must connect to an open channel or intersect a BMP.
- Channels may intersect with other channels, culverts, or with a BMP.
- Discharge Point Type must match the upstream connected feature type.

Intersections - Stormwater pipes do not self-intersect. Culverts do not self intersect. Channels do not self intersect.

Overlaps – Stormwater pipes do not overlap each other or self-overlap. Culverts do not overlap each other or self overlap. Channels do not overlap each other or self overlap. BMPs do not overlap each other. BMPs do not overlap an open channel.

Dangles – BMPs must not have dangles (i.e., dangling end of a line extending past the node). Tee fittings must not have dangles. Intersecting channels must not have dangles. Pipes must not have dangles.

Polygon Contains Point – BMPs must contain at least one outlet structure.

Buildings – Stormwater features may not intersect (be located underneath) a building.

3.11 GIS Data Management Quality Control Measures

Topology rules and other quality control checks will be used to ensure the GIS database is complete and correct. A QA/QC Checklist is provided in Table 3-4. It includes overall checks for completeness, quality, accuracy and data structure, as well as specific queries and QC items for each part of the database. The QA/QC goals are:

- To verify the data collected is valid, accurate and consistent
- To verify the data has been properly processed and presented
- To verify the database and map deliverables meet the City's technical requirements for GIS deliverables
- To ensure proper review of all deliverables

Table 3-4 GIS QA/QC Checklist

√	ELEMENT TO CHECK	DESCRIPTION
STORMWATER DATABASE OVERALL		
	Required Fields	All required fields are populated.
	Completeness	All assets in the stormwater network are present in the GIS network database. There are no duplicate AssetIDs.
	Datum	All GPS points are properly referenced to the correct datum.
	Comments Field	Comments field is used to describe unique configurations or issues associated with data collection that cannot be stored in another attribute. Comments are standardized, comma delimited, ordered, and necessary.
	Units of Measure	Measured values use correct units.
	Photos	All required photos are properly stored and linked to the database.
	Videos	All videos are properly stored, not linked to the database.
	Photo and Video Naming	All photos and videos are named correctly according to the naming convention.
	File Naming	All files are named correctly according to the file naming convention.
	Feature Naming	All features (assets) are named correctly according to the feature class naming convention.
	Metadata	Metadata have been created for each feature class, are complete, and follow the ISO standard and format.
	Aerial Imagery	Features have been checked against recent aerial photography, buildings feature classes, and other ancillary GIS data to ensure that features do not cross buildings or surface waters.
STORMWATER FEATURE DATASET		
	Spatial Accuracy	If GPS coordinates were obtained for a feature, the GIS feature has been updated with these coordinates. The XY coordinate fields in the attribute table for these features have also been updated. Coordinates are in units of international feet.
	As-built Points	All points populated from as-built data have been: (1) updated with new XYZ coordinate and Source identified by date of field mapping; (2) deleted and AssetID retired if structure confirmed no longer present; or (3) kept, with Source of data identified as as-built data, ActiveFlag status as “Inactive” and Comment “not able to be located” or “field checked but (tees) may still be present”.
	Flow and Connectivity of Network	Flow and connectivity issues within the dataset as well as any data gaps or missing/inconsistent data values have been identified and corrected in order to ensure a functioning geometric network.
	New Structures	Any new structures added to the network have been properly integrated into the geometric network following the topology rules described in this document. The new structures have been assigned proper AssetIDs.
	Duplicate Features	There are no duplicate features. Any duplicate features have been identified and deleted. This refers to features that have the same geometry (spatially coincident), as well as features that may not have exactly the same geometry but represent the same feature.
	Invalid Geometry	There are no features containing invalid geometry (null geometries, zero-length pipes, etc.). Any Pipe or Culvert Lengths less than 3.5 ft have been verified.

√	Element to Check	Description
	Slopes	Pipes with negative slopes, zero slopes, and Slopes greater than 3% have been identified, checked and flagged in the Comment field for the related feature.
	Multipart Lines	There are no multipart features (cases in which multiple lines are represented as a single line).
	Basin IDs	BasinIDs from the 1984 Master Drainage Plan have been revised for the specific project/watershed area. BasinIDs for features which drain outside of the project watershed retain the 1984 Master Drainage Plan ("Basins" feature class) BasinIDs.
	Middle Pipe Attributes	Comparison of attributes of Pipes upstream and downstream of the pipe being checked (the "middle" pipe). If the material, diameter and pipe shape attributes of the upstream and downstream pipes are the same, then the attribute values of the "middle" pipe should also match.
	Pipe Shape and Materials	Some combinations of Pipe shape and pipe material are not valid. For each pipe, the combination of material and shape attribute values must be checked to ensure that it is a valid combination. Valid material and shape combinations are as follows: - Clay, PVC, HDPE and ductile iron pipes must be circular in shape - Concrete, brick and steel pipes may have different cross-sectional shapes.
	Culvert Shape and Materials	Some combinations of Culvert shape and material are not valid. For each culvert, the combination of material and shape attribute values must be checked to ensure that it is a valid combination. Valid combinations are as follows: - Box culvert must be concrete, brick or stone - Arch culvert may be concrete, brick, stone or corrugated metal - Round and elliptical culverts may be concrete, corrugated metal or some type of plastic material
	Non-Circular Pipes or Culverts	A non-circular Pipe or Culvert has unique values for its Width and Height. The Diameter field is not populated.
	Invert Elevations	The upstream Invert Elevation of a single feature is greater than downstream Invert Elevation of that feature.
	Top or Rim Elevations	The Top Elevation is greater than or equal to the Rim Elevation. The Rim Elevation is greater than or equal to the Invert Elevation. The Top Elevation is greater than (never equal to) the Invert Elevation.
	Structure Depth	Structure Depth is greater than or equal to the distance from structure Rim Elevation to Invert.
	Headwall	Pipe or Culvert Diameter is less than the InvertDepth if there is a headwall End Structure.
	End Structures	For Pipes/Culverts intersecting a structure (Inlet, Outlet, Manhole, Junction, Headwall): identify *Flared End* or *Projected from Fill* as End Structure. For Pipes/Culverts intersecting a Channel: identify *headwalls/wingwalls, riprap, scour slab, tide valve*, etc. For Outlets, identify *bars/racks*. Also identify End Structures for Channels and BMP inlet/outlet protection. If there is more than one End Structure, note in Comments.

√	ELEMENT TO CHECK	DESCRIPTION
	Inlet Dimensions	All Inlets have Length populated. *Curb inlets, box top inlets* and *curb cuts* have Height populated. *Grate top* and *drop inlets* have Width populated.
	Inlet Access Type	Inlet Access Types which are square or rectangular have AccessLength and AccessWidth dimension fields populated. AccessDiameter fields are not populated.
	Manhole/Junction Cover Type	Manhole/Junction Cover Types which are rectangular or square should have CVWidth and CVLength dimension fields populated. CVDiameter are not populated.
	Pipe Type	*Gravity Main* is assigned to the primary drain line and *Secondary Line* is assigned to all tributaries.
	Outlet Structures	Circular Outlet structures use RiserSize or Diameter fields; square or rectangular Outlet structures use the dimension fields Length, Width and Height. RiserSize and Diameter are not populated.
	Discharge Points	Discharge Points are only located at the end of the flow path adjacent to surface waters.
	Markings	Inlets, Outlets, and Manholes/Junctions may have temporary or permanent markings. Temporary markings (paint, sticker, sign or plate) are identified in the Stencil attribute; permanent markings (engraved or stamped into metal cover, lid or grate) are identified with the AccessMark or CVMark attributes.
CONDITION ASSESSMENT TABLES		
	Condition Assessment	Condition Assessment dataset identifies the location of each defect, including inspection records. Each condition assessment performed is logged in the inspection tables.
	Inspection Tables	The features in each of the inspection tables correspond to mapped features. Therefore, all features present in the inspection tables also exist as a feature in the primary Stormwater dataset, and contain matching AssetID values.
	Inspection Status	For cases in which structures could not be found in the field, were not accessible, or could otherwise not be inspected, documentation is provided in the corresponding feature inspections table.
	Offset Points	Condition Assessment offset points from Pass 1 are assigned to the correct point in Pass 2. Offset points have been checked using a geoprocessing tool and a visual check.
STREAM AND WETLAND ASSESSMENT DATASET		
	Stream Reaches and Wetland Sites	A point for the downstream end of each stream reach will be created and the Stream Reach data will be recorded for that point. Features in the Stream Reaches and Wetland Sites tables must also exist as a feature in the primary stormwater dataset, and contain matching AssetID values.
	Point data for water quality issues, utilities, and aquatic improvement opportunities	Cross-reference review to nearest adjacent stream or wetland site to ensure locations and related Site IDs are recorded accurately

Section 4 Modeling and Analysis

4.1 Modeling Overview

The Interconnected Pond Routing (ICPR) model, Version 3 will be applied to complete Hydrologic and Hydraulic analysis (H&H) for the watershed project area. This analysis will determine stormwater runoff rates for various storm events and the corresponding response of the stormwater infrastructure in the project area. Local relative Sea Level Change (SLC) will be estimated for the project area using to the methodology presented in the US Army Corps of Engineers Engineering Regulation (ER) No. 1100-2-8162, “Incorporating Sea Level Change in Civil Works Programs”. These SLC conditions will establish tailwater conditions for the ICPR model, which will be used to model the response of the City’s infrastructure for the various storm events under these potential SLC scenarios. The modeling will evaluate the performance of the drainage system under existing conditions and potential SLC conditions, and will be used to make recommendations for addressing identified problems in the system.

ICPR is a comprehensive H&H modeling system that can be used for a wide range of stormwater networks, from individual ponds to complex stormwater systems with thousands of structures. ICPR offers several benefits, which include the following:

- The model is approved for floodplain analysis by the Federal Emergency Management Agency (FEMA). Therefore, the model developed can also be used to support changes in existing FEMA floodplain mapping.
- ICPR Version 3 includes a graphical user interface that is useful for developing stormwater system network schematics, entering and verifying model input, and viewing and presenting model results.
- ICPR can account for tidal influence, backwater effects, detention/retention pond routing, branched or looped networks, free surface flow, pressure flow or surcharged conditions, reversed flow, flow transfer, storage at online or offline stormwater facilities, and a number of other features that are necessary for modeling a variety of conditions throughout the City.

ICPR consists of three principal components: basins, nodes, and links. The hydrology component of ICPR generates stormwater runoff hydrographs for each basin based on the NRCS Curve Number Method (TR-20) with hydrologic inputs such as regional rainfall data, soil characteristics, and land use. Stormwater runoff hydrographs for basins are directed to nodes within the stormwater system. Nodes can represent stormwater inlets, outlets, manholes, junctions, ponds, and specific locations along pipes, culverts, or channels. Links connect nodes and can represent pipes, channels, or weirs. The hydraulic component of ICPR uses basin stormwater runoff hydrographs to calculate water elevations or stages at each node. Flow rates within links are calculated based on stages at nodes. The model output is used to determine hydraulic effects of the various storm events on the modeled infrastructure.

The USACE has developed a methodology and guidance for incorporating local relative SLC into civil works projects, which can be applied to stormwater and drainage projects. The methodology prescribed is a scenario-based approach. This approach provides a range of possible water level changes for various time horizons without assigning a specific value. The range accounts for the uncertainty associated with projecting future sea level conditions and allows community planners and designers to determine the appropriate amount of sea level change based on the acceptable level of risk for a given project.

4.2 Model Development, Analysis and Results

ICPR model input will consist of field GPS-collected survey data of the City's stormwater infrastructure. Field survey data will be collected in GIS format and necessary fields will be extracted to spreadsheets for use in modeling. ICPR model input requirements have been verified and aligned to the City's stormwater GIS database features, subtypes and attributes to ensure all data necessary for the modeling effort will be collected; however the terminology for stormwater structures used in ICPR is not identical to the terminology used for stormwater features in GIS. The modeling team will use recent LiDAR data to create drainage basins for the model.

ICPR will be used to perform an H&H analysis of the overall watershed and storm drainage system for the 2-, 5-, 10-, 25-, 50- and 100-year frequency and 24-hour duration storm events, with SCS Type III rainfall distribution. Existing conditions will be modeled in order to determine existing flows, flood elevations, capacity and conveyance problems in the system. Recommendations regarding general categories such as increasing capacity or installing new structures will be made on the basis of the existing condition modeling results.

ICPR has the capability to model the system with obstructions, such as sediment deposits or intruding roots. ICPR also has the ability to account for backwater or standing water in the system. While information regarding deposits, obstructions, and submerged infrastructure will be collected as part of the condition assessment, the system will be modeled in a "clean" state. All obstructions or backwater/standing water conditions will be assumed to be zero. Modeling outcomes will therefore present the full design capacity of the system.

4.3 Model Validation and Calibration

Validation compares simulation output with real system observation using data which was not used to build the model. During the validation process, ICPR output will be compared with actual historical drainage system observations. Validation of the ICPR model will be performed for predicted stage, flow, and velocity output. For proper validation, data must be available in the form of rainfall, stage, flow, and/or high water marks for specific storm events, land use, and hydraulic conditions. Rainfall data provided by NOAA and USGS, and empirical evidence from City staff and residents will be used for calibration and validation of the model. In cases where there are few rainfall gage stations, and no long-term stations measuring upland stream flows, the results developed by the model (e.g., road overtopping and/or structural flooding for particular design storms) will be compared to known high water marks or historical flooding to validate the results generated by the model. Submergence observations from the condition assessment may be used to validate submerged infrastructure shown in modeling results. Problem areas will be reviewed by City staff to evaluate whether the results calculated by the models are reasonable. Based on this comparison of the model to the real drainage system, adjustment of various model parameters (i.e., calibration) will be needed so that model outputs more closely approximate reality. This calibration process is typically iterative, occurs as part of model validation, and each subsequent adjustment is based on previous iteration results.

4.4 Sea Level Rise Modeling

Local relative SLC incorporates the global rate of Sea Level Rise (SLR) as well as factors that influence local relative water levels, which for the coastal Carolinas, is primarily vertical land movement (subsidence) but can also include local hydrodynamic changes. The USACE methodology detailed in USACE ER 1100-2-8162 will be used to find a range of local relative SLC values represented by "low", "intermediate", and "high" curves. The local SLC "low" curve is extrapolated from the historic rate of SLC using local tide gage data from the National Oceanic and Atmospheric Administration (NOAA). The "intermediate" and "high" curves are calculated by applying exponential rates of change to a selected timeframe (i.e., between a base year and a future year). The base year is the midpoint of the current tidal epoch, and the future year is selected as the end of the desired planning horizon. The "high" curve reflects the upper bound of the suggested range of possible water level increases. Computed SLC estimates will be compared to publically available projections for the Southeastern US.

Figure 4-1 below shows an example of projected Low, Intermediate, and High SLC curves using data from Charleston Harbor for a hypothetical time period.

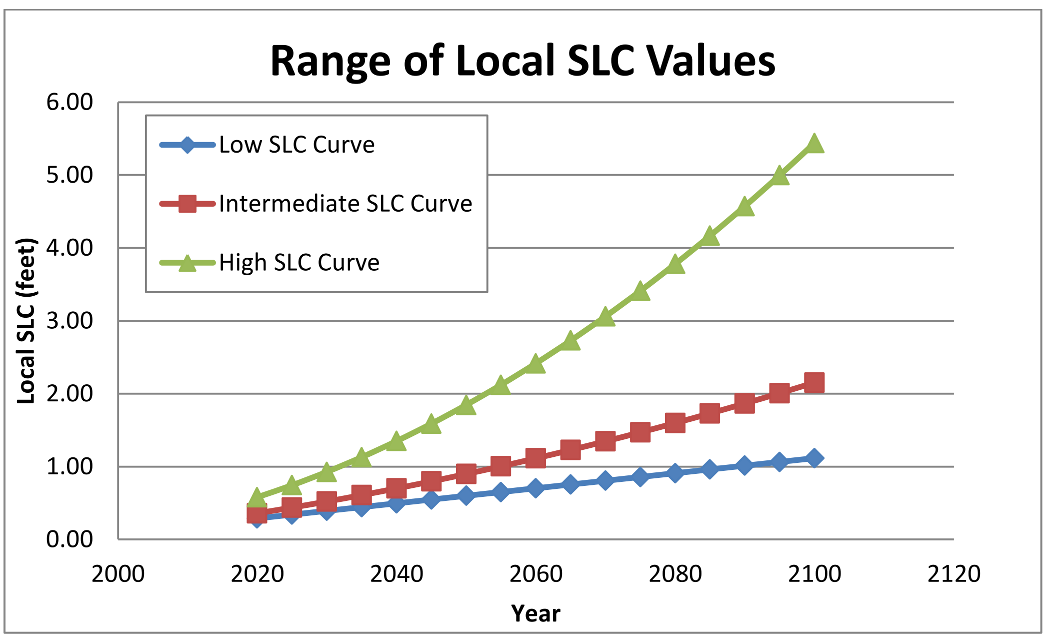


Figure 4-1 Projected Low, Intermediate, and High SLC curves in Charleston Harbor

The NOAA tide gage for Charleston Harbor is located at the southeast corner of the Union Pier Terminal and has a period of record of 117 years. The current tidal epoch consists of water level measurements collected at the gage from 1983 to 2001. The base year (midpoint) is 1992. All existing local tidal datum (i.e., MLLW, MLW, MSL, MHW, MHHW), as well as the conversion to the NAVD88 are based on average water elevations recorded from the current tidal epoch. In order to be valid for SLC projections the period of record should span at least two tidal epochs, or 40 years. The Charleston Harbor gage has a suitable period of record needed to apply the USACE methodology, and will be used to determine the range of SLC values for the project area. This gage has a published SLC rate of 0.00315 m/yr (i.e., 3.15 mm/yr). This value should be used in lieu of the global rate (i.e., 0.0017 m/year or 1.7 mm/year) for local relative SLC estimates.

Global SLR and/or local SLC rates should be revised as appropriate based on updated SLR science, periodic International Panel on Climate Change (IPPC) reports, revisions to the National Climate Assessment produced by a Federal Advisory Committee for the US Government, revisions to the USACE sea level change methodology, or other credible sources of data and information. Rainfall data is available from NOAA and design storms may be revised as more weather data is accumulated. Vertical land movement is available from various sources including NOAA Technical Report No. 65. The data derived from the Charleston Harbor gage, including datum and estimated SLC rates, should be updated once the new tidal epoch is available, which is expected 2022.

4.5 Modeling Summary

The modeling effort will consist of two parts – existing conditions modeling for a range of storm sizes, and sea level rise conditions for a series of future time horizons. Modeling runs are shown in Table 4-1. The ICPR model will be validated and calibrated using data specific to the project watershed.

Table 4-1 Modeling Summary

MODELING RUNS	TOOL	DESIGN CONDITIONS	NOTES
System Capacity - Existing Conditions	ICPR Model	2-, 5-, 10-, 25-, 50- and 100-yr frequency, 24-hr duration storms	Assume zero obstructions, zero submergence, zero backwater
Validation and Calibration	Rainfall Data Tidal Data High Water Marks City staff records	2-, 5-, 10-, 25-, 50- and 100-yr frequency, 24-hr duration storms	Compare model output to historic values
Sea Level Rise Elevation Projections	USACE ER 1100-2-8162 (latest version)	Years 2050, 2075, and 2100	Future increases in sea level should be considered for MHHW, king tides, and the design storm surge water level.

4.6 Analysis of Condition Assessment Data

During the field condition assessment, each feature will be assessed and defects will be identified in GIS. Each defect will be assigned a **Condition Grade**. Each feature will be assigned one or more **Feature Grades**. The numerical scores for each defect and feature will then be used to determine (3) ratings: **Quick Rating**, **Overall Rating**, and **Rating Index**. These grading and rating methods are based on NASSCO's PACP Condition Grading System. The ratings help to summarize the condition assessment information for planning and prioritizing maintenance, repair and capital improvement projects. Condition Assessment grading and rating can be found in *Appendix C*, *Condition Assessment Data Dictionary and Scoring*. This appendix provides a legend for how defects are graded by severity, and includes examples of grading and rating for various defects.

Condition Grade (CG) – Condition Grade considers the immediate visible defect and the potential for deterioration and failure. Defects will be evaluated as to severity, as appropriate. Severity values are selected from three options which describe the extent of the defect, such as: minor / moderate / severe; limited / patchy / extensive; or a percentage of area or cross-sectional area, 25% / 50% / 75%, etc. Each of these severity values has a corresponding numerical score, which ranges from 1 for minor to 5 for most significant, and this number is assigned in the GIS database for each defect. If there are multiple instances of a defect on a particular asset, the defect is only identified once; however, the severity is increased due to the frequency. More instances of the defect increase the likelihood of failure, therefore that feature will have a higher condition grade. Condition grades are shown in Table 4-2.

Table 4-2 Condition Assessment Grading

CONDITION GRADE (CG)	NASSCO DESCRIPTION	FAILURE POTENTIAL
5	Most Significant Defect	Failure is imminent - requires immediate attention
4	Significant Defect	Severe defects - risk of future failure
3	Moderate Defect	Moderate defects - deterioration may continue
2	Minor to Moderate Defect	Minor defects - low risk of failure
1	Minor Defect	Minor defects - failure unlikely in the foreseeable future

Feature Grade (FG) – Often a feature has multiple defects. The feature grade is calculated by multiplying the condition grade by the number of occurrences at each grade level (N), as shown in the equation below. Feature grades are calculated separately for each of the three defect categories (structural, O&M and supplemental). Therefore, a given feature may have a feature grade score at each condition grade level 1 through 5, in each of the three defect categories, for up to 15 individual feature grades. For example, a feature with 3 structural defects of grade 4 will have a structural FG_4 score of 12. A feature with no defects for grade 2 will have a feature grade score of zero for that condition grade. Feature grading is based on NASSCO's Segment Grade Scores.

$$FG_N = (Condition\ Grade\ N) \times (Number\ of\ Defects\ at\ Condition\ Grade\ N)$$

The three rating systems provide three perspectives on evaluating the significance of the defects. Each rating is calculated separately for structural, O&M and supplemental categories, therefore each feature will have up to three Quick Ratings, three Overall Ratings, and three Rating Indices. Table 4-3 shows how the ratings are determined using the condition grades and feature grades.

Table 4-3 Condition Assessment Rating Systems

Condition Grade (CG)	Number of Defects			Feature Grade (FG_N)			
	Structural	O&M	SW	Structural	O&M	SW	
5				FG_5	FG_5	FG_5	
4				FG_4	FG_4	FG_4	
3				FG_3	FG_3	FG_3	
2				FG_2	FG_2	FG_2	
1				FG_1	FG_1	FG_1	
Total # Defects							
Overall Feature Rating (OR)							*(Sum)*
Feature Rating Index (RI)							*(Average)*

Quick Rating (QR) – The QR is a shorthand way of expressing the number of occurrences for the two highest severity condition grades of each single feature. For example, a QR of 4532 indicates 5 occurrences of grade 4 and 2 occurrences of grade 3. The QR Rating provides a quick snapshot to help prioritize repairs and maintenance. Sorting a list of QR values allows quick identification of the highest severity and frequency of defects for each feature, however maintenance and repair priorities must be applied to determine whether a high condition grade, high defect frequency, category of defect, or other criteria is used to select projects. QR is based on the NASSCO PACP Quick Rating.

Overall Rating (OR) – The five individual Feature Grades are summed for an Overall Rating in each of the structural, O&M and supplemental stormwater categories. For example, a feature with structural FG_4 = 12 and FG_1 = 5 and no other defects would have a structural OR value of 17. A high overall rating could result from a high number of low severity defects, or a low number of high severity defects, or a mixture of low and high. OR is based on NASSCO's Overall Pipe Rating.

Rating Index (RI) – The RI is an average of the Feature Grades and indicates the overall defect severity for the feature. It is calculated by dividing the Overall Rating by the total number of defects. For example, a feature with structural OR = 17, and a total of 8 structural defects, would have a structural RI value of 2.1. Since the RI is an average value, it does not indicate whether there are many or few defects, with high or low condition grades. RI is based on NASSCO's Pipe Rating Index.

The ratings alone are inadequate for determining if a particular asset should be repaired or replaced. Many other factors should be considered. The fact that a certain asset has significant defects does not necessarily mean the asset requires immediate action. Similarly, feature ratings do not indicate whether a series of infrastructure in a roadway or a neighborhood has defects, since the ratings assess individual features and groups of features. Engineering judgment should be used to identify when certain defects, combinations of defects, or combinations of features, defects and locations, require immediate attention.

4.7 Criteria for Prioritization of Maintenance and Repair Projects

Condition assessment data will be used to make recommendations for maintenance and repair projects. Locations requiring minor maintenance in order to facilitate data collection will be identified during the project. Stormwater facilities requiring more substantial maintenance will be identified during the project prioritization. Maintenance and repair are generally defined below:

Maintenance Projects – Work required in order to continue the function of a stormwater facility or to prevent decline or failure of that facility.

Repair Projects – Intervention required to restore the function, up to and including replacement, but not including increase of capacity or function beyond the original design.

The following factors will be used in order to prioritize maintenance and repair projects:

- Location – proximity to major roadways and population density (residential and commercial land uses)
- Capacity – loss due to obstructions
- Severity of defect
- Frequency of defect
- Category of defect (structural, O&M or supplemental)
- Potential impact in event of failure

4.8 Criteria for Prioritization of Capital Improvement Projects

ICPR modeling will produce asset-level analysis of capacity problems and surcharging of inlets and manholes. Results regarding capacity will be used to score and rank assets as follows:

- Sufficient capacity
- Surcharge but not overflowing
- Surcharge and overflowing

Modeling results and rankings will be used to generate potential projects to address capacity and flooding issues. Types of projects which will be evaluated:

- Structures to add/eliminate
- Capacity/flood control improvement projects
- BMP/water quality improvement projects

Proposed projects will be ranked according to the below criteria:

- Constructability/feasibility
- Traffic
- Critical infrastructure
- Impact to property owners
- Benefits by number of people served

Additional criteria may be used to address Sea Level Change:

- Risk tolerance
- Desired project design life

Proposed projects should evaluate the range of potential water level increases in conjunction with risks to project assets, their sensitivity to inundation, and their ability to be adapted for higher water levels. The low curve in Figure 4-1 may be appropriate for projects that are not sensitive to flooding (i.e., a baseball field), whereas the high curve in Figure 4-1 may be appropriate where there is a high cost to inundation (i.e., a sewage lift station or a hospital).

The appropriate time horizon for which the SLC curves should be applied is project specific. For major civil works projects, a reasonable minimum time horizon may be a design life of 30 years, or the anticipated useful life of the project. A shorter time horizon could be used, if the project design includes adaptive risk management to account for increased inundation levels in the event that future sea levels are greater than initially planned for. Projects with a longer time horizon should assume greater changes will occur in SLC and in local building codes and projects should be sited and designed accordingly.

4.9 Criteria for Stream and Wetland Enhancement Projects

Ten stream reaches or wetland sites will be assessed for potential enhancement projects in the watershed. This list of ten sites will be narrowed down to three priority sites using the ranking criteria proposed as follows:

- Project feasibility
- Project constraints
- Potential for improvement
- Project cost
- Value to community (mitigation, public access, etc.)
- Project located on government-owned land

Projects will be scored and a conceptual (planning level) design will be prepared for the three priority sites. This information will be included in the Watershed Master Plan.

4.10 Considerations in Making Recommendations

The stormwater system inventory and results of the modeling analysis, condition assessment and stream and wetland assessment will be used to form a complete picture of the project watershed area.

Maintenance, Repair or Capital Improvement – Projects will be proposed to improve drainage throughout the watershed. Criteria may need to be adjusted, or matrix rankings may need to be weighted, according to the City's priorities in each watershed area. For example, in watersheds where redevelopment is a priority, the focus may be on improvements to high density commercial areas. In other watersheds, neighborhood-level flooding or water quality may be the primary concerns. The scoring matrix is intended to be flexible to allow for adaptation throughout the City. Project recommendations should consider ease of system maintenance in the future.

Stream and Wetlands Enhancements – Recommendations may include: altering the physical characteristics of a resource (i.e., stream and riparian zone stabilization measures); removing site-specific stressors (i.e., invasive species, abandoned infrastructure, etc.); alterations to improve overall hydrologic regime; re-establishment of a native vegetative community and/or improvements to the upland buffer areas; recordation of site protection instruments (i.e., conservation easement, covenant or acquisition of property); specific activities designed to address the source of degradation, provide improved water quality and ecological benefits and/or improve the physical, chemical or biological function of the system.

Design Standards – Recommendations may be included in the Watershed Master Plan to address future development or redevelopment in the watershed. Any such recommendations would be specific to the project watershed, and would be a supplement to the City's Stormwater Design Standards Manual, latest revision. The City may adopt these recommendations by establishing the project watershed as a Special Stormwater Management Area and amending the Design Standards Manual accordingly. Design standards recommendations should consider ease of system maintenance, and accessibility, in the future.

Section 5 Presentation of Data

5.1 List of Deliverables and Format

Table 5-1 provides a checklist of deliverables, including the format and other details necessary in order to ensure consistent products are provided to the City. All electronic deliverables will be provided on a hard drive, organized into directories for ease of access. Report and associated appendices will also be provided on a disc.

Table 5-1 Checklist of Deliverables, Format and Details

	DELIVERABLES	FORMAT AND DETAILS
	ESRI ArcGIS Geodatabase - Project .mxd - Stormwater feature dataset - Condition Assessment tables - Maintenance and Access tables - Stream and Wetland dataset - Symbology Layer files - Created Metadata - Photos - Zoom Videos - Dynamic Map pages - Daily Control Point Checks (.csv file)	Database format provided/approved by the City Culmination of all updated feature classes, feature attachments, condition tables, condition attachments, maintenance and access tables and forms, stream and wetland dataset and attachments Photos linked to GIS database via attachment tables Videos stored separately Database and all associated deliverables will be delivered on a hard drive
	Mapbook - Index Grid with Legend	(3) hard copies, bound PDF
	Maintenance/Access Requests - Tracking status - Request Forms with photos and map	Excel Spreadsheet and/or summary tables in Watershed Master Plan (report). Include dates identified, submitted and completed. Copies of all forms submitted (PDF)
	Condition Assessment - Matrix - Report Forms	Matrix spreadsheet Forms for high priority assets

	DELIVERABLES	FORMAT AND DETAILS
	Watershed Master Plan (report) - Storm modeling results - Sea Level Change modeling results - Maintenance recommendations (repair/replace) with prioritized ranking and cost evaluation (based on condition assessment) - System analysis with prioritized recommendations for capacity and infrastructure improvement (based on modeling results) - Proposed schedule for upgrading system - Stream and Wetland Assessment with prioritized ranking - (3) priority projects with preliminary design and cost evaluation - Recommendations for watershed-specific design standards - Summary of stormwater inventory	(10) bound hard copies of Watershed Master Plan (report) PDF Disc Model 2, 5, 10, 25, 50 and 100-yr, 24-hr storms (Type III rainfall distribution) Model range of sea level elevations for time horizon(s) TBD by the City Prioritization tables - Maintenance - System improvements - Stream and Wetland Sites Preliminary cost evaluation for proposed projects Timeline schedule Design standards recommendations list Map of project boundaries Map of proposed project sites Summary tables of inventory mapped and assessed in the project area
	ICPR Model (watershed-specific)	Delivered on hard drive along with all other electronic deliverables

5.2 File Naming Convention

A standardized file naming convention has been established so as to ensure consistent nomenclature is used in every deliverable. The filename of the delivered geodatabase will use the following naming convention:

SW1234_ABC_XYZ_YYYYMMDD.GDB

Where SW1234 = example Project Number
ABC = Project/Basin ID revised from 1984 Master Drainage Plan
XYZ = Prime Contractor ID
YYYYMMDD = 8 digit date

5.3 Map Grid and Legend

A map grid, scale and symbology/legend for mapbook deliverables will be established prior to beginning field data collection activities. Approval will be obtained from the City. Existing as-built and master drainage plan data may be used to establish an appropriate grid and scale. An index Map of grids may be used to track progress of field work and maintenance. The map grid will be overlain on the most recent aerial imagery and will show the project boundary.

5.4 QA/QC Measures for Deliverables

All draft and final deliverables will undergo thorough review prior to submittal to the City of Charleston. The map, document, spreadsheet, model output and any other deliverable format will be provided to one or more persons of appropriate technical expertise on the project team for review. The Project Manager will verify all reviews have been made and updates have been incorporated prior to releasing deliverables to the City.

5.5 Long-term Maintenance and Management of Data and Model

Primary ownership of data will reside with the City. The stormwater feature inventory, condition assessment, maintenance, and stream and wetland assessment data will be housed in GIS. This data will be updated by the City GIS department as as-builts are submitted for new construction projects, and/or as the City conducts maintenance or completes repair or capital improvement projects identified in the Watershed Master Plan. Primary ownership of the ICPR model will also reside with the City.

Successful upkeep of the GIS data and ICPR model will require routine sharing of data between the City and adjacent municipalities. A Memorandum of Agreement could be developed to establish a procedure for ensuring the latest updates are distributed to relevant points of contact in adjacent municipalities. These municipalities would update the model as projects or drainage improvements occur within the model boundaries, and distribute the updated model out to the points of contact for each municipality.

5.6 Living Document

This SOP is a living document. It was created to provide consistent data collection, storage, processing and analysis procedures, to ensure standardized use of stormwater terminology for the purpose of feature identification and condition assessment, and to produce accurate and consistent results regardless of the entity performing the work. As work proceeds around the City, it may be necessary to modify this SOP.

Examples of possible modifications include changes to the following:

- GPS, survey or condition assessment equipment or accuracy
- ESRI GIS software
- Procedures to improve field efficiency
- Address issues within a specific watershed
- Adapt for cooperating municipal agencies
- Public communication plan
- Specific feature classes, attributes or domains used in GIS
- Criteria for prioritizing maintenance and projects
- Rainfall amounts or design storms
- Modeling software and procedures
- Local sea level change rates or nationally recognized methodology
- Presentation of deliverables

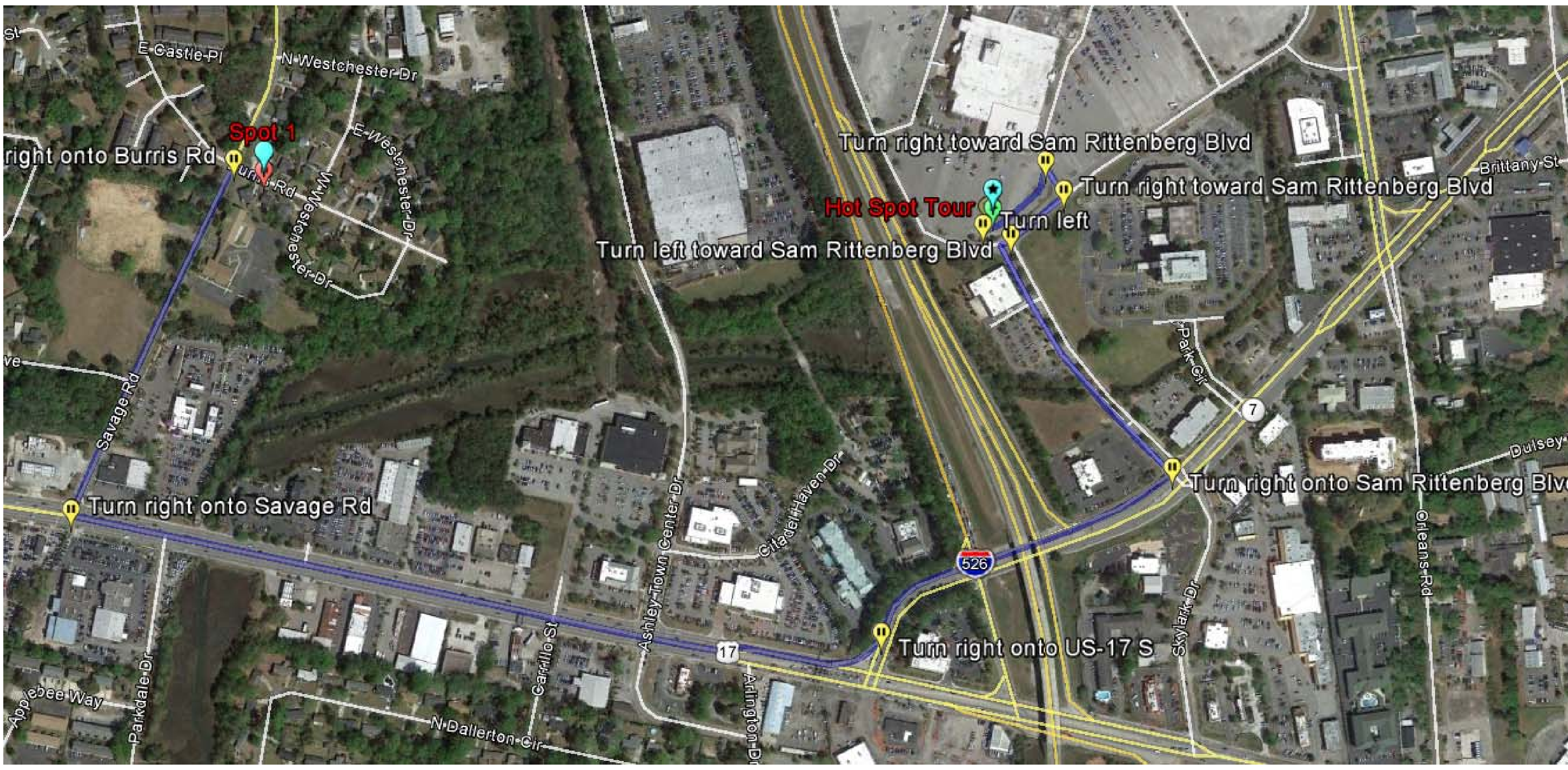
All modifications must be approved by the City of Charleston. Changes to the SOP should be logged in the Record of Revisions at the beginning of this document.

Appendix C Flooding Hot Spots

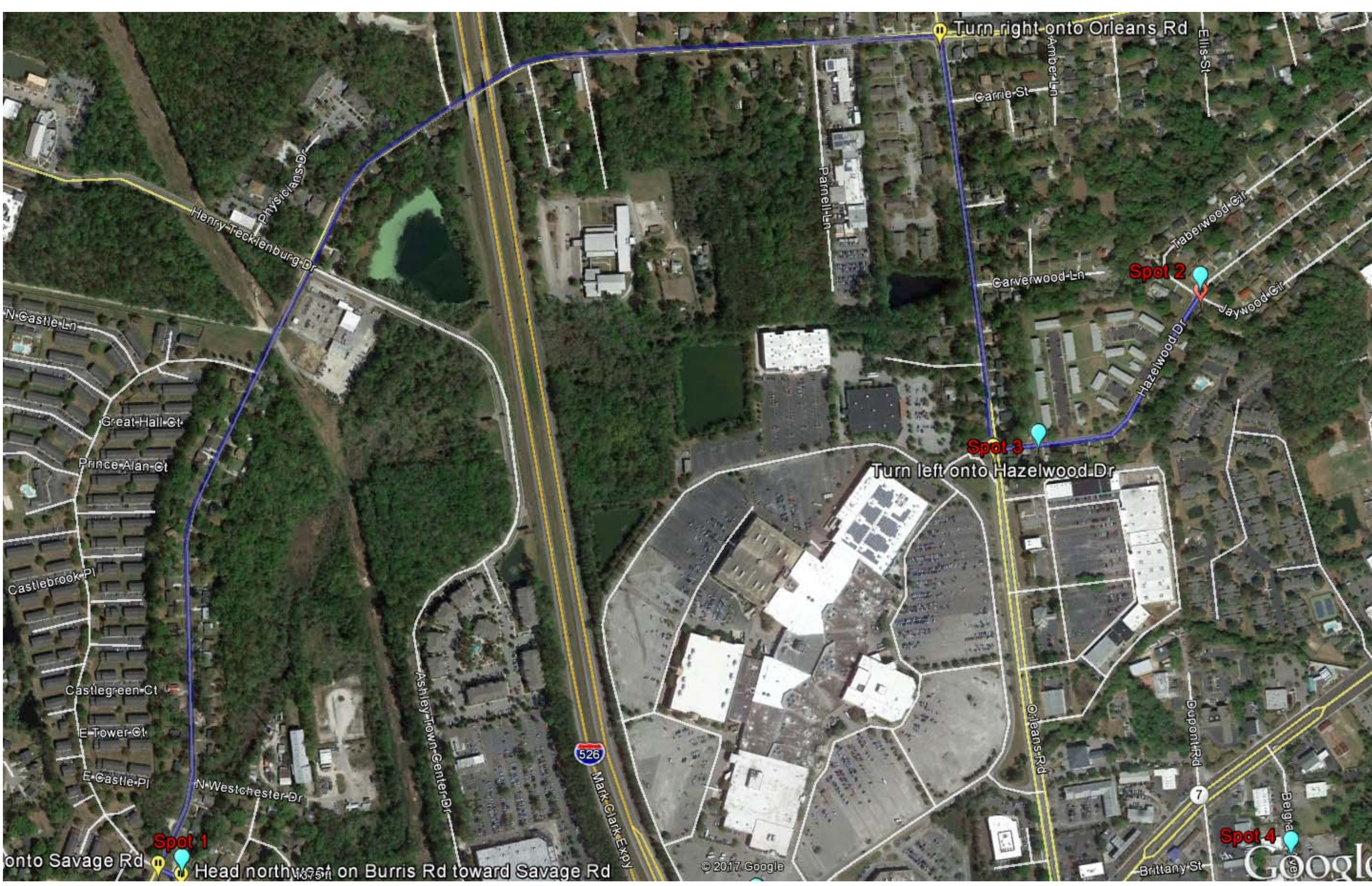
August 18, 2017 DuWap Wiindhsield Tour

Meeting Location - Sears/Citadel Mall

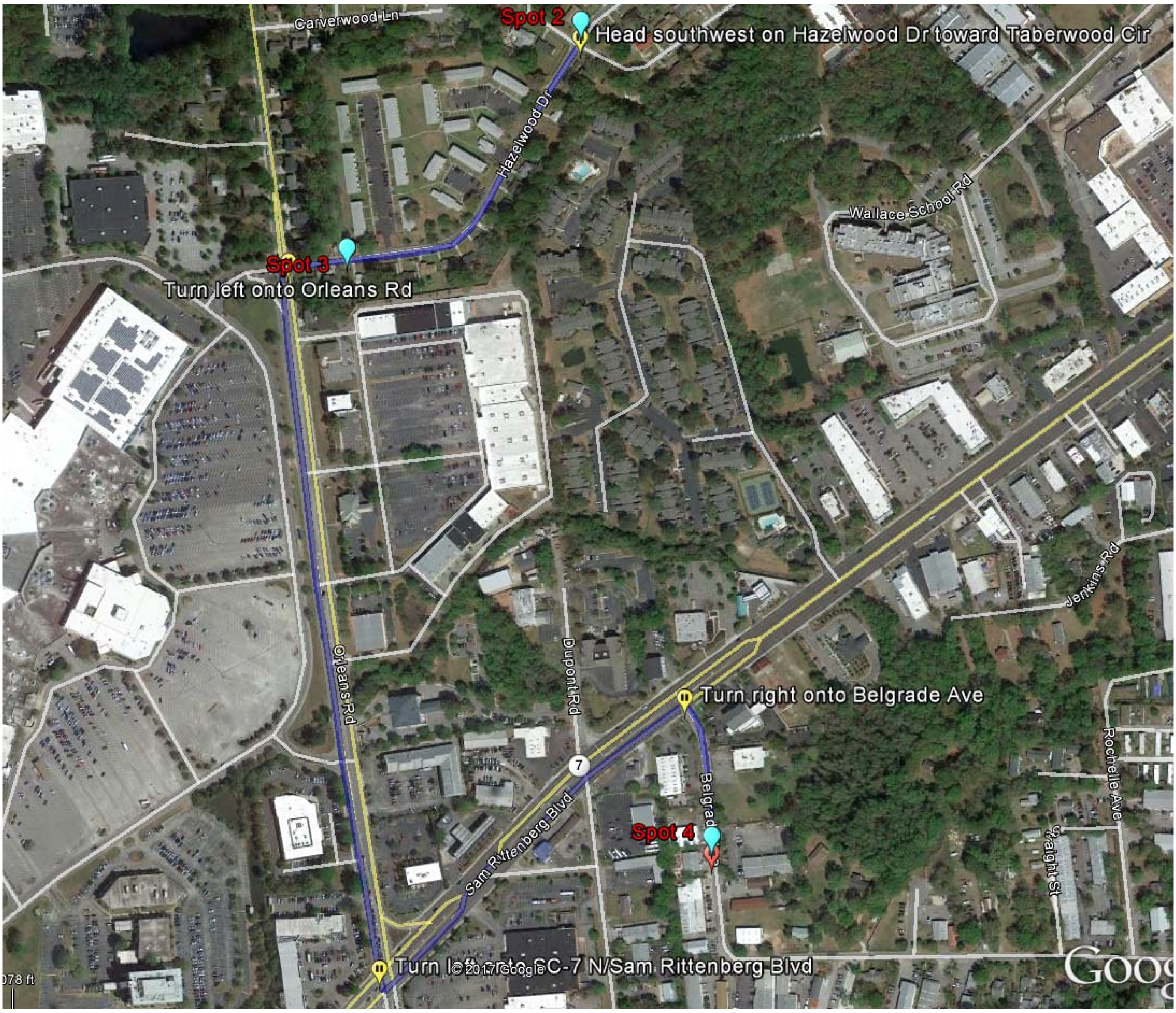
Directions from **Sears/Citadel Mall** to **Hot Spot 1** (Burris & Savage Rd area – localized flooding into wetland area/complex).



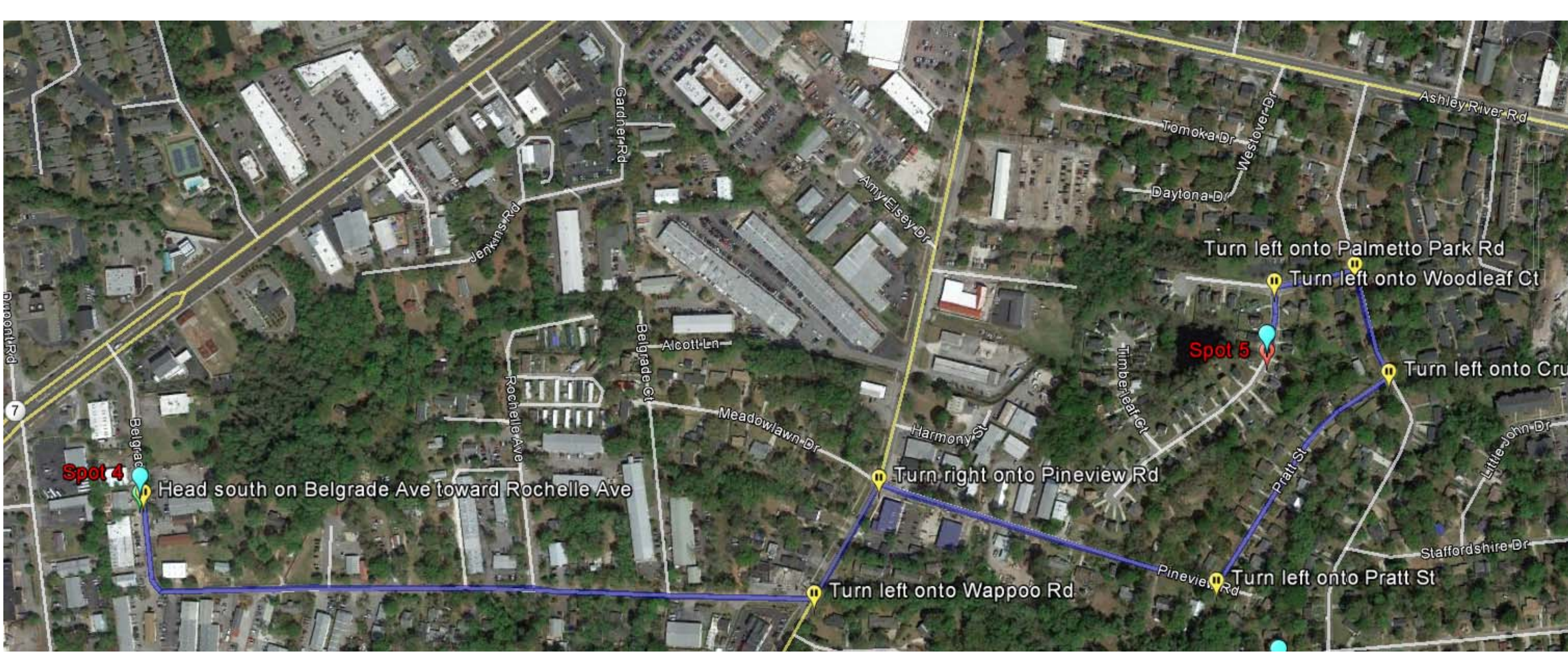
Directions from **Hot Spot 1** to **Hot Spot 2** (Taberwood, Hazelwood, Jaywood Drive localized flooding area) and **Hot Spot 3** (Orleans Gardens Apartments localized flooding. Open system gets blocked/backed up trying to drain into closed system).



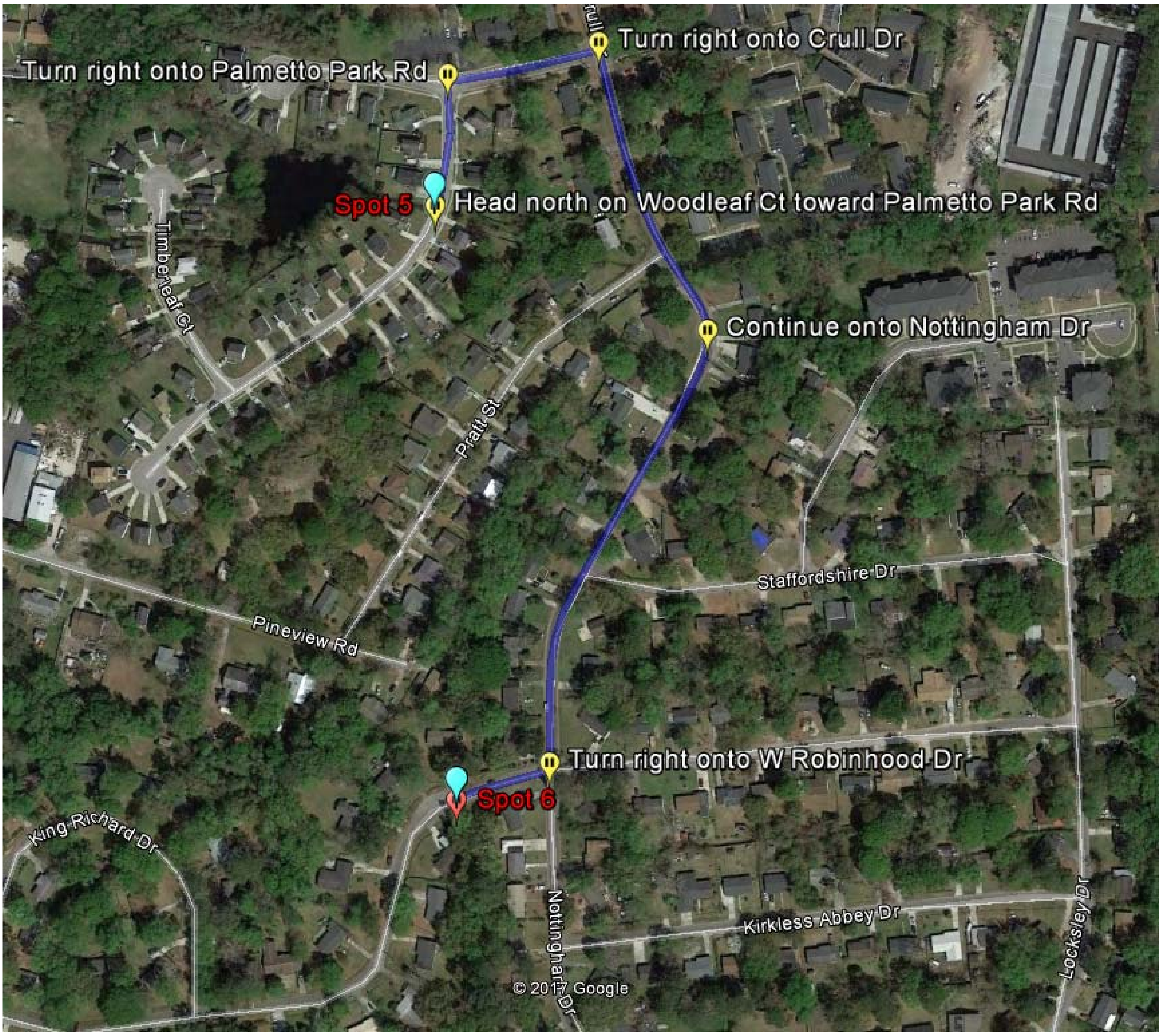
Directions from **Hot Spots 2/3** to **Hot Spot 4** (Belgrade Ave area – localized flooding).



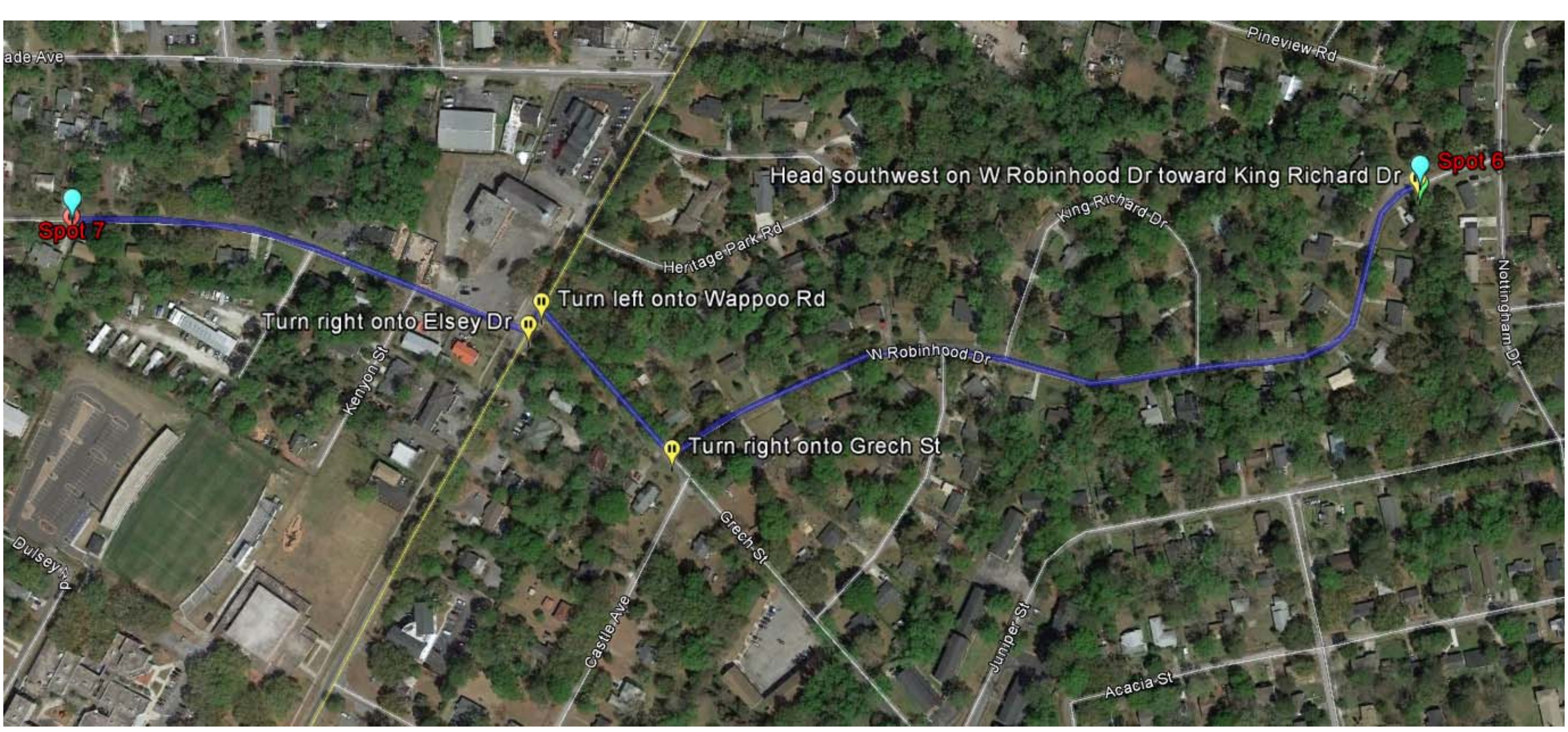
Directions from **Hot Spot 4** to **Hot Spot 5** (Woodleaf Court – localized flooding and pond of unknown functionality).



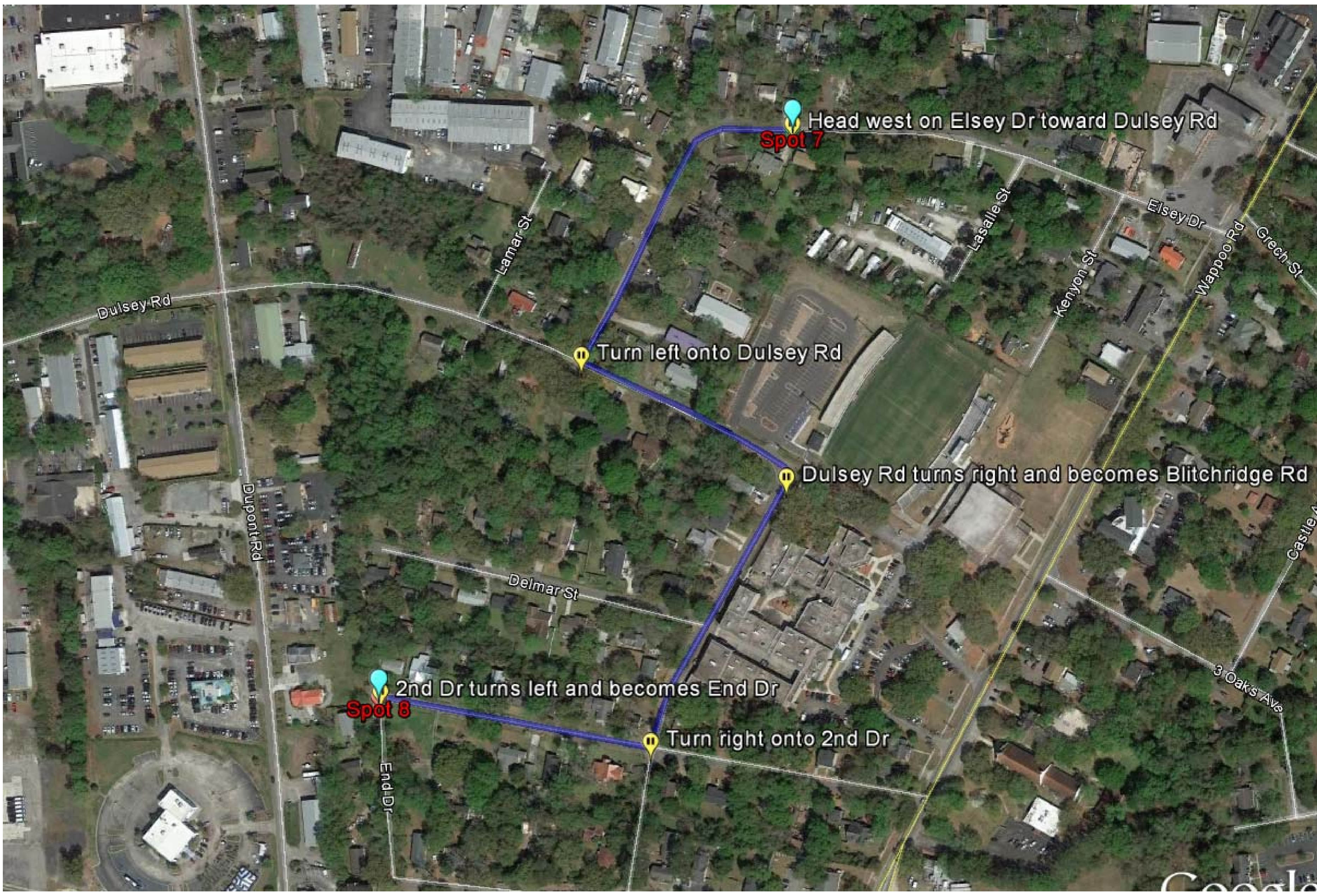
Directions from **Hot Spot 5** to **Hot Spot 6** (W. Robinhood Drive – localized flooding).



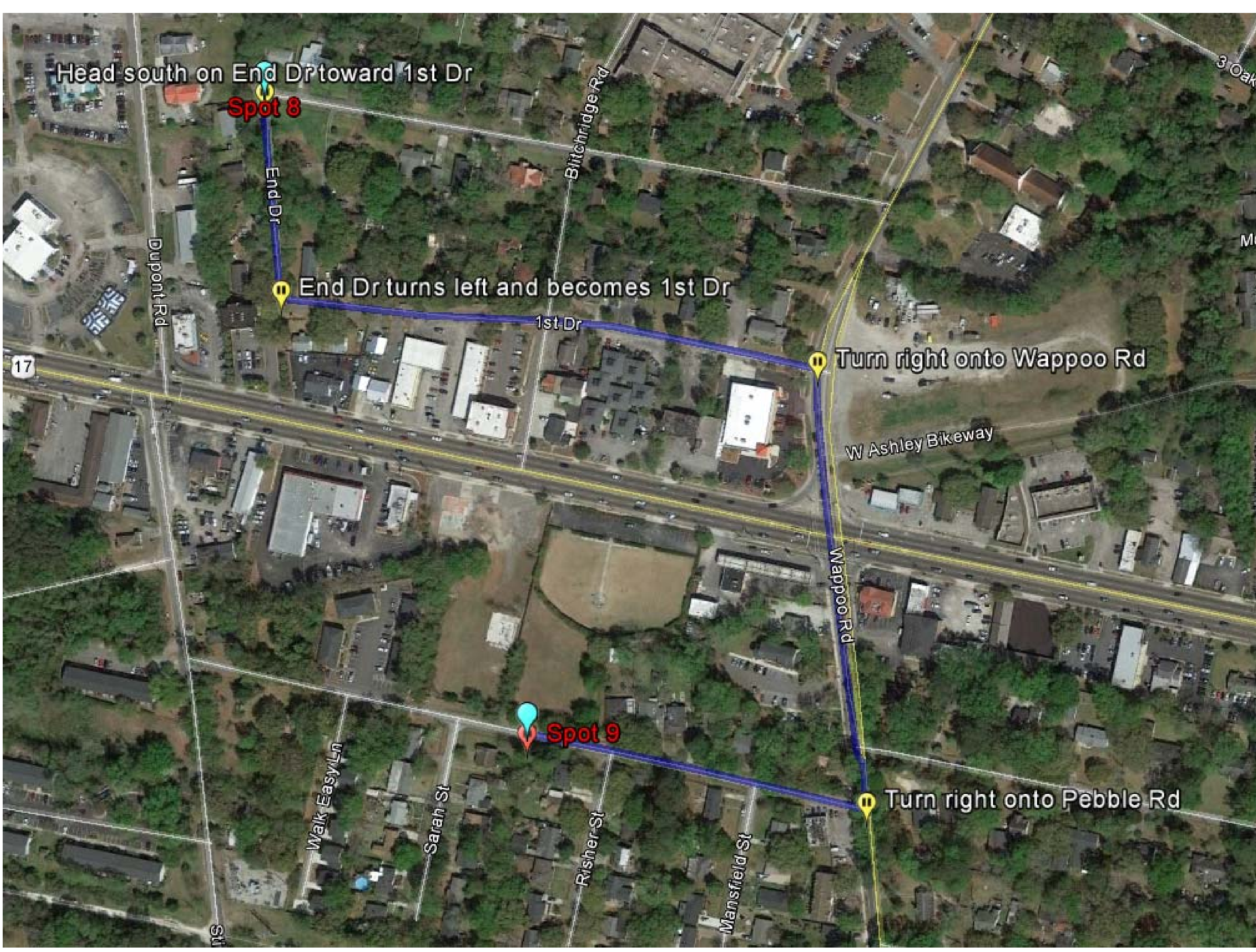
Directions from **Hot Spot 6** to **Hot Spot 7** (Elsey Drive area – localized flooding).



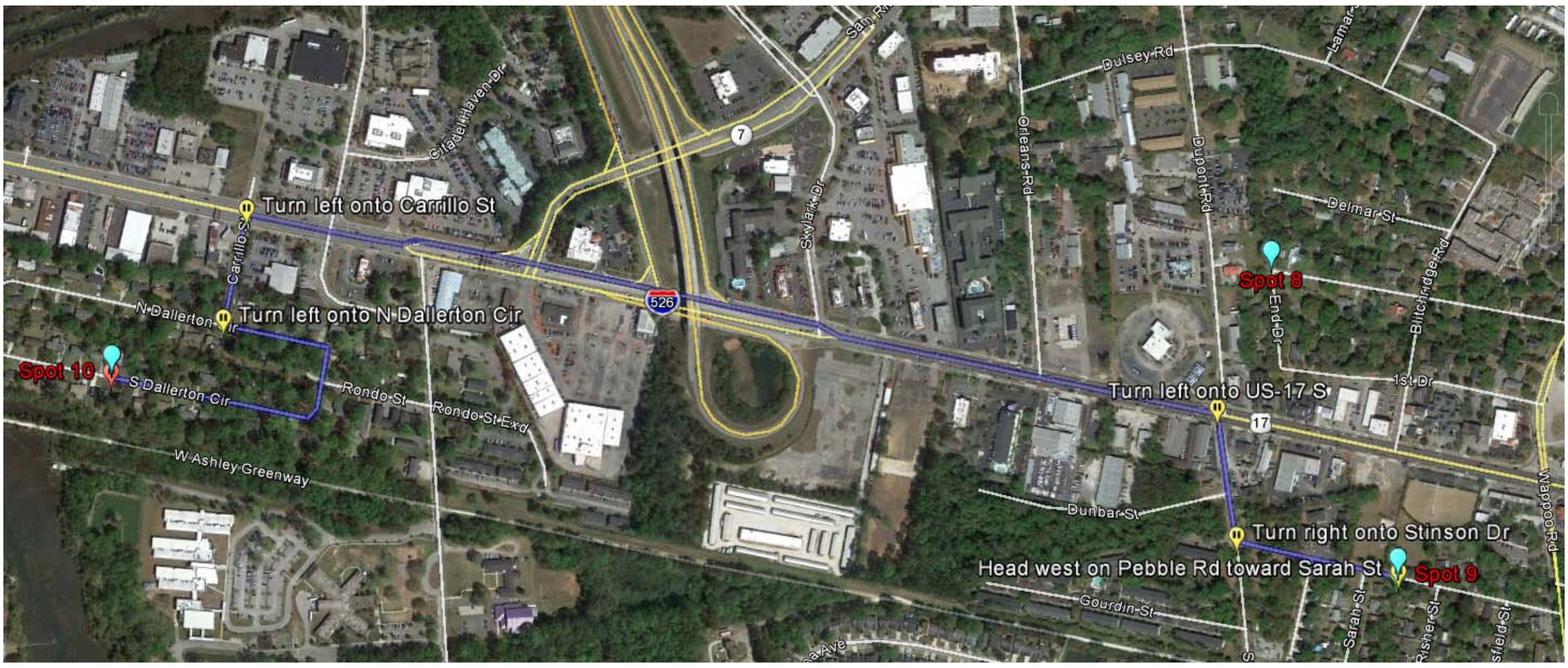
Directions from **Hot Spot 7** to **Hot Spot 8** (2nd & End Drive – localized flooding).



Directions from **Hot Spot 8** to **Hot Spot 9** (Pebble road area – street flooding – may or may not be in watershed).



Directions from **Hot Spot 9** to **Hot Spot 10** (S. Dallerton Circle – localized flooding).



Return to **Sears/Citadel Mall**.

Appendix D Runoff CN Tables 2-2a to 2-2d

Table 2-2a Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and I_a = 0.2S.

2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2b Runoff curve numbers for cultivated agricultural lands [1]

Cover description			Curve numbers for hydrologic soil group			
Cover type	Treatment [2]	Hydrologic condition [3]	A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition, and I_a=0.2S
2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes, (d) percent of residue cover on the land surface (good ≥ 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table 2-2c Runoff curve numbers for other agricultural lands [1]

Cover description: Cover type	Hydrologic condition	Curve numbers for hydrologic soil group: A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. [2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm). [5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and $I_a = 0.2S$.
2 ***Poor:*** <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 ***Poor:*** <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 ***Poor:*** Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 2-2d Runoff curve numbers for arid and semiarid rangelands [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition [2]	A [3]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1 Average runoff condition, and I_a, = 0.2S. For range in humid regions, use table 2-2c.
2 Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: > 70% ground cover.
3 Curve numbers for group A have been developed only for desert shrub.

Appendix E Sheet Flow Publication

References on time of concentration with respect to sheet flow

William Merkel, Hydraulic Engineer
USDA, NRCS, National Water and Climate Center
Beltsville, MD

December 17, 2001

Introduction

Certain references found in the technical literature were reviewed with their statements concerning sheet flow characteristics. Concern was expressed that the maximum sheet flow length in TR-55 was reduced from 300 feet to 100 feet in the recently developed Windows TR-55 software system. Technical information to justify the revision was requested. Though only one of the studies focused on the length of sheet flow (McCuen and Spiess), several give useful insights on the appropriate length, roughness, and depth related to sheet flow. For the following references, some direct quotes from the papers are included along with narrative comments. After a review of the papers, a brief summary of this investigation and some general conclusions are offered for consideration.

Woodward and Welle, NRCS, Northeast NTC, Hydrology Technical Note N4, 1986.

Quote:

The Manning-kinematic solution is sound, defensible, and easy to use. Therefore, it is recommended that this equation be used to compute Tt for the overland flow segment. The maximum flow length of 300' with a most likely length of 100' should be used in overland flow computations for unpaved areas. Paved areas may have longer lengths of sheet flow until flow becomes channelized in gutters or low areas of parking lots. The range of mean depth is 0.002' for paved areas to 0.02' for vegetated areas.

Narrative:

One approach to estimating the length of sheet flow may be to define a maximum depth for which sheet flow applies. With respect to depth, the Manning equation may be used to estimate depth based on discharge, Manning n and slope (assuming a one foot width). There are several ways to estimate the discharge at the end of a selected length of sheet flow. A set of 12 references is included with this paper, which presumes that the statement was based on those references (though the authors did not state which specific reference).

W. O. Ree, A Progress Report on Overland Flow Studies, USDA, Agricultural Research Service, Southern Plains Branch, 1963.

Quote:

Overland flow occurs in every watershed to some degree. Whether it is extensive enough or the flow length great enough to influence the hydrograph needs to be determined. One method for estimating the average length of overland flow was developed by Robert E. Horton. In his classic work on geomorphology, he shows that the average length of overland flow, lo, can be estimated by the relation:

$$lo = 1 / (2\ Dd) \qquad (1)$$

Where Dd is the drainage density defined as:

$$Dd = \text{sum of stream lengths for the watershed} / \text{area of the watershed} \qquad (2)$$

Thus, if the length of all channels that are fed directly by overland flow can be measured, it is possible to estimate the average overland flow length. An attempt was made to do this for the 206-acre grassed watershed operated by the Stillwater Hydraulic Laboratory. Every waterway visible on an aerial photograph of the watershed was carefully measured. It was found that the sum of the lengths of all drainageways was about 48,900 feet. This value and the value for the area were substituted into equations 1 and 2 and the average length of overland flow was calculated to be 92 feet.

The determination of what constituted a drainageway was quite a subjective one. By searching for still smaller channels it would be possible to produce a different estimate of lo. Nevertheless, it is thought that the estimate made does indicate the order of magnitude of overland flow and that it is large enough to have an important role in the determination of the hydrograph of outflow.

Narrative:

The calculation of overland flow (sheet flow) length by equation 1 requires the sum of stream lengths and area of the watershed to be in consistent units. For example, if Dd is 48,900 feet, the area of the watershed also should be in square feet or 206 acres times 43,560 square feet per acre. These values result in the average overland (sheet) flow length of 92 feet.

Even though this relationship was developed using geomorphic data, it also has a physical interpretation. If all flow concentrations are identified on a map of the watershed, lo represents the average maximum distance from locations in the watershed to the nearest flow concentration. This applies to distances from points along the watershed boundary to the nearest flow concentration as well as points within the watershed which are between flow concentrations. This average value of sheet flow length may vary according to the definition of flow concentration and how it is measured. It also represents a watershed average value and not the sheet flow length which falls on the path used to calculate time of concentration. This procedure is most applicable in small undeveloped watersheds with a relatively homogeneous drainage network. Using this procedure in developed or partially developed areas has limitations in that the density of identified flow concentrations may vary significantly within the watershed (for example, dense in developed and wide-spread in undeveloped areas). The "average" value may not have practical meaning because of this variability. Dividing the watershed into subwatersheds could be considered in such cases. The practical use of this procedure is related to getting a general estimate of sheet flow length in a watershed. As an alternative, after the flow concentrations are identified, sheet flow distances may be measured at several locations in a watershed to get a similar general idea or estimate. Another use of the procedure would be to develop estimates of average sheet flow length for various geomorphic regions or urban development characteristics.

Quote:

Supply rate Inch/hr	Depth at outflow Inches
1	0.26
2	0.39
3	0.50
4	0.59

Narrative:

The table above was developed using an overland flow equation developed by Horton which estimates the depth of overland flow based on Manning n, slope, supply rate (rainfall intensity), and overland flow length. This gives an order of magnitude of the depth of overland flow of 0.59 inch (0.05 feet) for a 4 inch per hour rainfall intensity.

Quote:

Channel research at Stillwater, Oklahoma, has included a study of low flows. These were conducted in flat-bottomed channels 3 feet wide and 96 feet long, with a bed slope of 5 percent. The sides of the channels were low concrete curbs about 0.2 foot high. While these tests were made primarily in connection with the studies of the hydraulics of vegetation-lined waterways, the low flow data may be useful in the investigation of overland flow problems.

Narrative:

The report includes results of these tests for different kinds of grass cover and cover density. Results of one test were plotted which show relationship of discharge to depth at the end of the 96 foot slope. A discharge of 0.01 cfs / foot of width had a depth of 0.05 feet.

Engman, E. T., Roughness Coefficients for Routing Surface Runoff, ASCE Hydraulics Division Conference, Frontiers in Hydraulic Engineering, August, 1983.

Quotes:

Data used in this study were collected on plots to evaluate erosion rates and volumes for different soils and management practices by the Agricultural Research Service-USDA stations in West Lafayette, Indiana, Oxford, Mississippi, and Tucson, Arizona. The plots were typical of those used in erosion research and varied in length from about 10 to 20 m and in width from about 1.7 to 4 m. Simulated rainfall was applied to the plots at a constant intensity that varied from plot to plot and location but were generally was between 5 to 10 cm / hr. Runoff was measured with a flume and continuous stage recorder that provided accurate timing and the shape of the hydrograph.

In using these roughness values one should be aware of two potential limitations: (1) These values are valid for so-called sheet flow or overland flow before significant channelization occurs. Thus these data will be valid for relatively short slopes. Exactly what length of slope these values will be valid for is unknown at this time. However, as slopes approach 50 to 100 meters in length one would expect channelization to begin or else very large and unreasonable depths of overland flow would be calculated; (2) These values include the effect of rain drop impact which tends to increase the effective roughness.

Narrative:

The author includes a table of Manning n values for sheet flow surfaces. Some values from that table are included in Table 3-1 of TR-55 (1986 printing). The author states these values of Manning n apply to relatively short slopes. They were developed on plots of 10 to 20 meters in length and so have that limited applicability. With respect to depth, high Manning n for dense grass and woods would definitely produce an unreasonable depth if the sheet flow length were extended to 300 feet. This reference reinforces the case for considering both length and depth of sheet flow simultaneously.

Engman, E. T., Roughness Coefficients for Routing Surface Runoff, ASCE Journal of Irrigation and Drainage, Vol. 112, No. 1, pages 39-49, February 1986.

Quote:

Information for choosing roughness coefficients is fairly common for streams, channels and canals. Typically, Manning's n values can be estimated with guidance from descriptive information and photographs. However, very little information is available for shallow depth of overland flow over natural surfaces.

Narrative:

This paper is related to the reference by Engman above. It contains a summary of a literature review concerning overland flow and additional analyses of plot data. The published table of Manning n values is somewhat different from the 1983 paper. It contains some different cover, tillage practices, and surface residue categories as well as some changes in recommended Manning n for some surfaces.

The author reports the mean, standard deviation, and range of Manning n determined for each cover type and the number of experiments with each cover type. The range of values indicate Manning n can vary by a factor of about 1.5 to 3 or greater for most surface types. The sheet flow travel time will thus have a possible wide range based on the estimate of Manning n for the surface. The estimated depth of flow could also have a wide range of values based on the Manning n selected. TR-55 uses a single value of Manning n for each cover type. It masks the variability of the underlying data. Using the mean of the various cover and tillage conditions, the travel time value which is calculated could have an error of plus or minus 25 to 50 percent (assuming the cover type and condition are selected properly).

Quote:

The depth of calculated flow should not become too large. On long flow planes, the routing models may calculate depths that may be unrealistically large. The users must be aware of this and limit flow plane lengths. It appears that excessive depths would not be encountered if slope lengths are on the order of 150-300 feet (50-100 m).

Narrative:

This quote is similar to that of the other paper by Engman above. However, the depth should be estimated and length adjusted accordingly. Appropriate depths of overland or sheet flow are addressed in other reviewed papers.

Parsons, D. A., Depths of Overland Flow, USDA-SCS, SCS-TP-82, July 1949.

Quotes:

Runoff was measured from an area 6 feet wide by 47.5 feet long with sheet metal boundaries. The soil was Decatur clay loam from north Alabama. It was bare and had been considerably compacted.

One of the 50-foot tilting plots was also used in determination of overland flow depths on an excellent stand and growth of Korean lespedeza. The vegetation was green and nearly mature.

Narrative:

Several more types of cover and shorter plot lengths (and a few longer plots) were investigated. Results of this study are again primarily limited to short slopes and extending these results to long slopes is questionable.

Quote:

The formation of rills and gullies, in effect, shortens the distance, L, of overland flow. Instead of beginning at the upper boundary and increasing progressively until it reaches the lower boundary, the flow originates at the upper boundary, or divides between rills, and ends, in part, in concentrated flow uphill from the lower boundary. The concentrated flows in these channels may be much greater in depth than the average, but the relative area of the land that is covered by these flows is sufficiently small for this factor to be outweighed by the effect of shortening the distance of overland flow. The mere presence of rills or flow concentrations rather than their depth seems to be the more important influence.

Narrative:

The authors found some flow concentrations before the end of the 50 foot long plots. Data were analyzed as if all flow were overland (sheet) flow. Special analytical treatment of flow concentrations was not reported.

Quote:

When $\rho = 1$, the time of concentration, tc, is

$$tc = \frac{4}{3} * \frac{43200\ D}{rf}$$

Narrative:

Based on their field experiments, the authors developed an equation for time of concentration (tc), which in the current context is travel time for sheet flow, based on slope parameters. These include average depth of flow (D) in feet and runoff rate (rf) in inches per hour. The units for tc in the above equation are seconds. Interpretations of how D and rf are estimated are contained in the report. The average depth of overland flow is dependent on the slope, length, and roughness as well as the discharge or runoff rate. The meaning of the symbol $\rho = 1$ is that the runoff rate has reached its maximum after a period of constant rainfall intensity. The authors used hydraulic theory to develop various relationships for laminar and turbulent flow and used Reynolds number and kinematic viscosity of water in their derivations.

Ree, Wimberley, and Crow, Manning n and The Overland Flow Equation, Transactions of the ASAE, Volume 20, Number 1, pages 89-95, 1977.

Quote:

The average length of overland flow was determined by dividing the watershed area by twice the total length of all waterways.

The delineation of drainageways on a contour map is highly subjective and is the product of the mapmaker's ideas and practices. Yet, the calculated length of overland flow depends completely on the value of the total drainageway length. Thus describing as exactly as possible how drainageways were determined becomes essential if results are to be meaningful.

Smooth contours were drawn, which fit the survey points chosen, to obtain a good representation of the topography using a 5-ft contour interval. The drainage pattern was drawn on the finished map extending the drainageways through the last contour, which indicated a draw or valley.

Watershed	Average Slope (percent)	Length of overland flow (meters)
W-1	4.43	69.5
W-3	5.13	61.9
W-4	6.66	60.0

Narrative:

The same equation was used to estimate overland (sheet) flow length as used in the above Status Report by Ree. The sheet flow lengths ranged from 200 to 230 feet. Like the authors state, defining the stream locations is subjective. In the Status Report by Ree, streams were located using aerial photos, and in this study, they were defined on a hand produced topographic map. It would be interesting to see what sheet flow lengths would result from an aerial photo determination on the three watersheds. Examining the contour map of the 92 acre watershed W-3 reproduced in the paper, there are large areas within the watershed where no stream has been identified. It is entirely possible that some streams were missed which would cause the overland flow length to be shorter.

Quote:

The Manning n value data for this study were obtained from tests on grass-lined unit channels at the laboratory. These are flat-bottomed channels (0.91 m wide and 29.26 m long) with a 5 percent bottom slope.

Narrative:

Again, the study is based on a flow length of about 100 feet. Results are applicable for that length.

Quote:

Fig. 1 (Photograph) An example for a good cover condition in watershed W-3. The average overland flow equation for this condition is q = 1.48 D ^ 1.22. The equivalent Manning n for a flow depth of 1 cm is 0.31.

Narrative:

The authors make limited reference to the depth of overland flow such as in this caption to the photograph labeled Figure 1. 1 cm depth is approximately 0.03 foot. In Figure 6, a plot of discharge versus depth shows depths of 1 cm and less.

Emmett, W., The Hydraulics of Overland Flow on Hillslopes, USGS Professional Paper 662-A, US Government Printing Office, 1970.

Quotes:

Seven field sites in west central Wyoming were selected for verification of laboratory data. The field sites were 7 feet wide, about 45 feet long, and approximately represented four slope angles.
The flume used in this investigation was constructed with a plywood bed… The width was 4 feet and the length was 16 feet. Flume slope was adjustable by hydraulic jacks at the lower end….

Narrative:

Length of overland flow experiments is again limited to under 50 feet. The slopes of the seven field sites ranged from 2.9 to 33 percent.

Quote:

On nearly flat slopes, microrelief features on the order of only 0.1 foot appeared to dictate the paths of the flow concentrations. However, on steeper slopes, small microrelief features did not appreciably alter the down-slope gradient and their influence on concentrations of flow was masked.

As explained earlier, the flow rarely occurred as a uniform sheet of water and the majority of water travelled downslope in several lateral concentrations of flow; however, these concentrations were not considered rill flow.

Report content:

Figures 11 through 15 show plots with average flow depth of 0.05 foot or less for the field tests. Table D includes average flow depths of 0.04 foot or less (with most under 0.02 foot) for laboratory experiments. Manning n values ranged from less than 0.01 up to 0.10 for the laboratory tests and from 0.10 to greater than 2.0 with most falling between 0.20 and 1.0 for the natural ground.

Narrative:

Depth of flow was not uniform across the slope because the natural ground surface and laboratory soil surface was not smooth. The slope of the plots was also not uniform in the longitudinal direction. This caused differences in depth as flow proceeded downslope. This is typical of natural surfaces in many areas. Table C shows results of depth measurements at one of the field sites measured at one foot intervals across the slope and 2 foot intervals downslope. The range of flow depth was 0.0 to 0.09 feet (with most depths between 0.01 and 0.06 feet) indicating magnitude of microrelief. The surface in the natural ground tests was fine to moderate grain size (D50 values were from 0.09 to 0.48 mm) and vegetation cover ranged from 8 to 35 percent. Equations were applied with respect to the average depth of flow across the slope. The depths were shallow enough that what flow concentrations were present, they were not deep enough to classify them as rills.

McCuen and Spiess, Assessment of Kinematic Wave Time of Concentration, unpublished manuscript, November, 1993.

Quote:

Current practices use the flow length, L, as the limiting criterion when using a kinematic wave equation to calculate travel time. According to the 1986 TR-55 documentation, the flow length in Eq. 3 must be less than 300 feet. Some localities believe 300 feet is too long and limit L to 100 feet. However, there does not appear to be documented evidence that shows these limits are justified.

The use of flow length alone as a limiting factor for the kinematic wave equation can lead to circumstances where the kinematic wave assumptions are no longer valid. Overprediction will generally occur for lengths with high Manning's n values and/or flat slopes. For instance, lengths of grassed surfaces of much less than 100 feet may have significant depression storage, as may flat areas. In such a case, the kinematic wave equation will overpredict the sheet-flow travel time.

Narrative:

This is the prime study focusing on the limits (including sheet flow length) in the use of the Manning-kinematic equation for computing sheet flow travel time. Background is given concerning research on the length of sheet flow and development of the Manning-kinematic travel time equation. Eq. 3 mentioned in the above quote is the sheet flow travel time equation which is contained in TR-55 (1986 printing). The approach in this study is to consider the theory and assumptions of kinematic flow and actual field measurements to develop practical limits on the use of the Manning-kinematic travel time equation similar (but not the same) as in the NRCS TR-55 computer program.

According to the authors, length alone is not an appropriate as a criterion. The authors mention Manning n and slope as additional factors to be considered.

Quote:

Times of concentration and watershed characteristics from 59 field and laboratory experiments were analyzed to determine a suitable limit for the kinematic equation. The data used in this analysis represented a wide range of watershed sizes, slopes, and ground conditions.

Narrative:

The authors considered data for paved and unpaved surfaces. Range in length was from 12 to 3033 feet. Range in Manning n was 0.0073 to 0.4. Slopes ranged from 0.001 to 0.162 ft/ft.

Quotes:

The composite parameter nL/ √S, where the variables are as described in Eq. 1, will be developed and assessed in this paper as an accurate and useful criterion when estimating travel times using the kinematic wave equation. This criterion is a conceptually more rational limit than both the flow length and the product iL (where i is the rainfall intensity) because it incorporates main properties of sheet flow. Also, the criterion nL/ √S can differentiate a 100-feet flow length with a steep slope and low Manning's n and the same length with a flat slope and high Manning's n, each of which have the same flow length, but quite different flow conditions.

In summary, the nL/ √S criterion provided better goodness of fit statistics than the length. While the statistics for iL as a criterion were comparable to those of nL/ √S, the latter is preferred because it is composed of variables that are related to the physical processes that underlie kinematic flow. Thus nL/ √S is a more rational criterion than iL for limiting the use of Eq. 2 in estimating sheet-flow travel times. The analysis for an upper limit for nL/ √S of 100 provided the best overall results and suggested an upper limit of about 100.

Narrative:

Equations 1and 2 mentioned in the above quote are general kinematic time of concentration equations developed from theory. The term "time of concentration" is used with reference to the uniform slope length. If this slope length were the sheet flow length for a watershed which also had shallow concentrated and channel flows the term would be interpreted as "sheet flow travel time".

Tc = C1 (nL/ √S) ^ C3 / i ^ C2 (1)

Tc = 0.93 (nL/ √S) ^ 0.6 / i ^ 0.4 (2)

Tc is the time of concentration in minutes, i is the rainfall intensity (in/hr), L is the length of sheet flow (ft), n is Manning's roughness coefficient, S is the slope (ft/ft), and C1, C2, C3 are coefficients.

The authors investigated whether a limit based on sheet flow length (L), the value iL (product of intensity in inches per hour and sheet flow length), or nL/ √S fit the data the best. They decided on the term nL/ √S. If this limit were set at 100, an example of the application follows. For a surface of dense grass, n = 0.24, and slope of 0.02 ft/ft, the maximum length of sheet flow would be 59 ft (corresponding to a value of nL/√S of 100). Inserting these values into the TR-55 sheet flow travel time equation and assuming the 2-year 24 hour rainfall is 3 inches, the travel time would be 0.16 hour.

Quote:

The SCS Kinematic Wave Equation. Equation 3 has the same structure as the generalized model of Equation 1. However, it has different coefficients and uses the 2-year 24-hour rainfall depth rather than the intensity for the time of concentration (Welle and Woodward, 1986). The use of a depth that is not dependent on the time of concentration is desirable because it simplifies the solution procedure by eliminating the need to iterate. However, the exponents of 0.8 amd 0.5 in Eq. 3, rather than 0.6 and 0.4 in Eq. 2, produce an equation that must be dimensionally balanced through the coefficients. The SCS equation could not be tested with our data because the 2-year 24-hour depth was not obtainable for many of the data samples, obviously for the laboratory data. Thus the limit for nL/ √S of 100 cannot be applied to the SCS equation, and use of this limit may result in inaccurate estimates of Tc with Equation 3. The larger exponent of 0.8 for the nL/ √S term suggests that the limiting value for Eq. 3 would be less than the limit of 100 for Eq. 2. Equating the two nL/ √S terms of Eqs. 2 and 3 with their respective exponents of 0.6 and 0.8

yields a limit of 31.6 for the SCS kinematic wave equation. However this was not tested and it ignores the differences in the two rainfall terms. Further study of this is needed.

Narrative:

The authors have some reservations on application of a limit of 100 on the value of $nL/\sqrt{S}$ for use in the SCS (NRCS) kinematic wave travel time equation. Equations 2 and 3 give reasonably close results for travel time especially in the NRCS Type 2 rainfall distribution region. If Manning n is 0.24, slope is 0.02 ft/ft, L = 59 feet, and 2-year 24 hour rainfall is 3 inches, the travel time using Eq. 3 (NRCS equation) is 0.16 hour. Since Eq. 2 uses intensity instead of 2-year 24-hour rainfall, intensity needs to be estimated for a duration equal to the travel time. At the location of Cincinnati, Ohio, where the 2-year 24-hour rainfall is 3 inches (TP-40 atlas), the 2-year 5-minute rainfall is 0.44 inches (intensity of 5.3 inches per hour) and the 2-year 15-minute rainfall is 0.85 inches (intensity of 3.4 inches per hour). The short duration rainfalls were read from maps in the NOAA NWS Hydro – 35 publication. Since 0.16 hour is approximately 10 minutes, interpolating the intensity gives approximately 4.35 inches per hour. Substituting this intensity of 4.35 inches per hour along with n = 0.24, S = 0.02, and L = 59 feet into Eq. 2 produces a travel time of 0.14 hour. Further study of the author's reservations could be made but this example indicates the limit is applicable to the NRCS kinematic wave travel time equation.

Summary of Investigations

Although this investigation did not include an exhaustive search of the literature, enough references were studied in order to get a general overview of status of knowledge and practice concerning sheet flow characteristics. A number of additional references were studied but not included in this review because they did not add significant technical information or insights. Most of the studies considered the major aspects of sheet flow; length, slope, roughness, and a number of related factors; soil, vegetation, rainfall intensity, geomorphology, etc. Most also considered theory of hydraulics and kinematic or flow routing. That no definitive results are stated, does not reflect on the quality of the research but on the complexity of the problem. The studies focusing on depth of sheet flow give general guidelines on what is realistic in the field. Defining the point where small flow concentrations become what may be called shallow concentrated flow is a key to analyzing this problem. Complications in defining this point include variations in soil type, vegetation (or lack of it), slope, and rainfall intensity.

Defining conditions used in the various experiments is important because, especially when gathering data and developing various models, one needs to be careful not to extrapolate the results beyond the conditions where they were measured and developed.

The experiments on unpaved areas clearly focused on relatively short sheet flow lengths. Experiments on paved areas focused on a wider range of lengths. Whether these support a limit on sheet flow length of 100 feet is not definitive but, especially for unpaved areas, it appears reasonable until further research can be completed. One commonality of the studies was the shallow depth being considered, generally less than 0.1 foot. Studies of Manning n indicated roughness values were significantly greater for sheet flow than for channel flow.

The concept of linking hydraulic and hydrologic theory to measured data will lead to the best formulation of models to analyze sheet flow and also the best guidelines for using them in engineering practice.

Further investigation of sheet flow characteristics is needed. A method to consider length, slope, depth, and roughness is practical and feasible. With all the variability across the country with respect to soil, land use, climate, geomorphology, etc, there is no substitute for investigating sheet flow characteristics of the watershed in the field.

Appendix F Time of Concentrations Standard Template

Time of Concentration

Basin	Node	Type	TOC (Min)	Area_ac
DuWapB_1	DuWapN_1	Basin	12.00	12.68
DuWapB_201	DuWapN_201	Basin	12.00	10.02
DuWapB_10	DuWapN_10	Basin	10.00	13.06
DuWapB_210	DuWapN_210	Basin	10.00	10.18
DuWapB_101	DuWapN_101	Pond	10.00	1.84
DuWapB_102	DuWapN_102	Pond	10.00	1.03
DuWapB_103	DuWapN_103	Pond	10.00	0.04
DuWapB_105	DuWapN_105	Pond	10.00	0.12
DuWapB_106	DuWapN_106	Pond	10.00	0.16
DuWapB_107	DuWapN_107	Pond	10.00	0.26
DuWapB_211a	DuWapN_211a	Basin	10.00	11.89
DuWapB_11a	DuWapN_11a	Basin	10.00	9.49
DuWapB_211b	DuWapN_211b	Basin	10.00	8.91
DuWapB_11b	DuWapN_11b	Basin	10.00	3.41
DuWapB_312	DuWapN_312	Basin	18.74	12.84
DuWapB_212	DuWapN_212	Basin	18.74	4.46
DuWapB_12	DuWapN_12	Basin	18.74	6.96
DuWapB_13	DuWapN_13	Basin	10.00	31.07
DuWapB_14	DuWapN_14	Basin	10.00	14.95
DuWapB_15	DuWapN_15	Basin	10.03	31.79
DuWapB_216	DuWapN_216	Basin	10.00	27.37
DuWapB_16	DuWapN_16	Basin	10.00	20.43
DuWapB_17	DuWapN_17	Basin	10.00	39.83
DuWapB_18	DuWapN_18	Basin	35.00	2.83
DuWapB_219a	DuWapN_219a	Basin	16.69	8.57
DuWapB_19a	DuWapN_19a	Basin	16.69	6.66
DuWapB_19b	DuWapN_19b	Basin	16.69	9.55
DuWapB_219b	DuWapN_219b	Basin	16.69	8.09
DuWapB_2	DuWapN_2	Basin	13.80	24.72
DuWapB_20	DuWapN_20	Basin	10.00	15.66
DuWapB_21	DuWapN_21	Basin	31.34	11.4
DuWapB_22	DuWapN_22	Basin	15.16	7.68
DuWapB_222	DuWapN_222	Basin	10.00	7.46
DuWapB_23	DuWapN_23	Basin	11.25	22.07
DuWapB_324	DuWapN_324	Basin	10.00	8.11
DuWapB_224	DuWapN_224	Basin	10.00	4.18
DuWapB_24	DuWapN_24	Basin	10.00	3.15
DuWapB_25	DuWapN_25	Basin	10.00	26.04
DuWapB_225	DuWapN_225	Basin	10.00	15.7
DuWapB_26	DuWapN_26	Basin	10.00	33.02
DuWapB_27	DuWapN_27	Basin	23.53	4.79
DuWapB_28	DuWapN_28	Basin	31.52	43.01
DuWapB_229	DuWapN_229	Basin	38.76	33.89

Time of Concentration

Basin	Node	Type	TOC (Min)	Area_ac
DuWapB_29	DuWapN_29	Basin	38.76	15.54
DuWapB_3	DuWapN_3	Basin	14.55	73.86
DuWapB_30	DuWapN_30	Basin	28.64	26.50
DuWapB_230	DuWapN_230	Basin	28.64	13.33
DuWapB_31	DuWapN_31	Basin	50.28	14.07
DuWapB_32	DuWapN_32	Basin	10.00	11.68
DuWapB_33	DuWapN_33	Basin	29.43	4.37
DuWapB_34	DuWapN_34	Basin	10.00	16.62
DuWapB_234	DuWapN_234	Basin	10.00	13.98
DuWapB_334	DuWapN_334	Basin	10.00	8.38
DuWapB_35a	DuWapN_35a	Basin	10.00	8.62
DuWapB_35b	DuWapN_35b	Basin	10.00	5.71
DuWapB_35c	DuWapN_35c	Basin	10.00	2.34
DuWapB_36	DuWapN_36	Basin	10.00	37.17
DuWapB_37	DuWapN_37	Basin	10.00	46.22
DuWapB_238	DuWapN_238	Basin	31.25	35.84
DuWapB_38	DuWapN_38	Basin	31.25	32.32
DuWapB_338	DuWapN_338	Basin	31.25	30.69
DuWapB_4	DuWapN_4	Basin	10.00	2.27
DuWapB_40	DuWapN_40	Basin	10.00	11.79
DuWapB_240	DuWapN_240	Basin	10.00	4.74
DuWapB_41	DuWapN_41	Basin	18.46	25.02
DuWapB_241	DuWapN_241	Basin	18.46	19.57
DuWapB_42	DuWapN_42	Basin	48.22	10.22
DuWapB_43	DuWapN_43	Basin	34.27	7.03
DuWapB_44	DuWapN_44	Basin	17.16	3.32
DuWapB_45	DuWapN_45	Basin	18.71	12.43
DuWapB_46	DuWapN_46	Basin	23.38	5.39
DuWapB_47	DuWapN_47	Basin	22.64	3.11
DuWapB_48	DuWapN_48	Basin	10.00	23.27
DuWapB_49	DuWapN_49	Basin	10.00	8.28
DuWapB_5	DuWapN_5	Basin	10.00	11.41
DuWapB_50	DuWapN_50	Basin	11.81	22.18
DuWapB_250	DuWapN_250	Basin	11.81	11.97
DuWapB_51	DuWapN_51	Basin	10.00	12.91
DuWapB_52	DuWapN_52	Basin	24.99	9.42
DuWapB_53	DuWapN_53	Basin	15.52	2.38
DuWapB_54	DuWapN_54	Basin	21.14	6.73
DuWapB_55	DuWapN_55	Basin	10.00	11.06
DuWapB_56	DuWapN_56	Basin	10.00	26.84
DuWapB_57	DuWapN_57	Basin	10.00	3.74
DuWapB_257	DuWapN_257	Basin	10.00	3.66
DuWapB_58	DuWapN_58	Basin	10.00	25.88

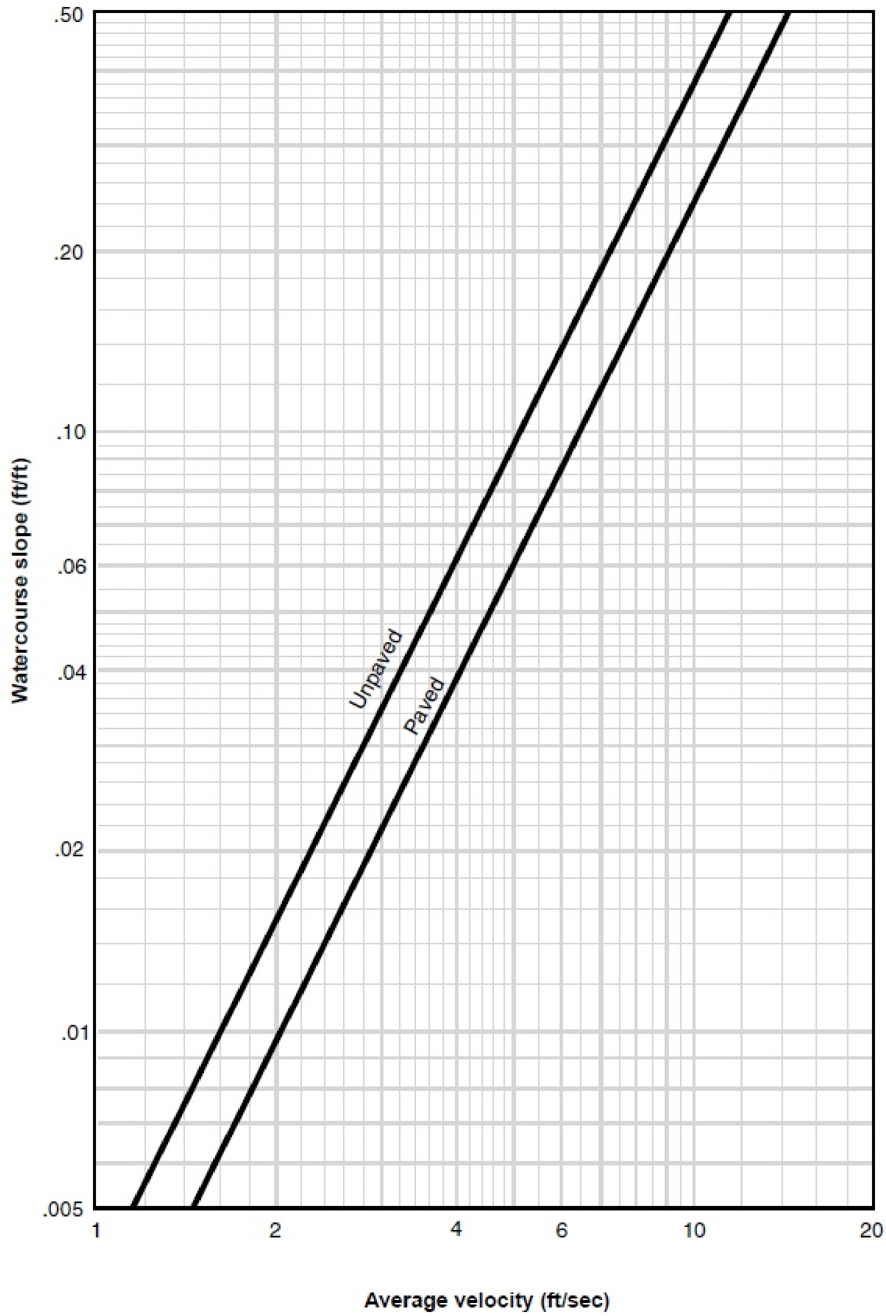
Time of Concentration

Basin	Node	Type	TOC (Min)	Area_ac
DuWapB_59	DuWapN_59	Basin	10.00	16.47
DuWapB_6	DuWapN_6	Basin	10.00	7.94
DuWapB_61	DuWapN_61	Basin	10.00	22.87
DuWapB_62	DuWapN_62	Basin	13.03	5.24
DuWapB_63	DuWapN_63	Basin	10.00	3.57
DuWapB_263	DuWapN_263	Basin	10.00	3.50
DuWapB_64	DuWapN_64	Basin	10.00	8.73
DuWapB_65	DuWapN_65	Basin	10.60	3.33
DuWapB_66	DuWapN_66	Basin	16.98	6.78
DuWapB_267	DuWapN_267	Basin	10.00	11.55
DuWapB_67	DuWapN_67	Basin	10.00	7.63
DuWapB_70	DuWapN_70	Basin	10.00	9.28
DuWapB_270	DuWapN_270	Basin	10.00	5.3
DuWapB_71	DuWapN_71	Basin	10.00	19.24
DuWapB_72	DuWapN_72	Basin	10.00	23.82
DuWapB_73	DuWapN_73	Basin	10.00	8.70
DuWapB_273	DuWapN_273	Basin	10.00	6.74
DuWapB_74	DuWapN_74	Basin	15.73	15.16
DuWapB_274	DuWapN_274	Basin	15.73	7.91
DuWapB_76	DuWapN_76	Pond	10.00	0.17
DuWapB_77	DuWapN_77	Pond	10.00	2.93
DuWapB_78	DuWapN_78	Pond	10.00	1.11
DuWapB_79	DuWapN_79	Pond	10.00	1.08
DuWapB_7a	DuWapN_7a	Basin	10.00	5.72
DuWapB_207b	DuWapN_207b	Basin	10.00	8.77
DuWapB_7b	DuWapN_7b	Basin	10.00	8.77
DuWapB_80	DuWapN_80	Pond	10.00	0.4
DuWapB_82	DuWapN_82	Pond	10.00	0.74
DuWapB_84	DuWapN_84	Pond	10.00	0.11
DuWapB_9	DuWapN_9	Basin	60.33	7.79
DuWapB_90	DuWapN_90	Pond	10.00	0.97
DuWapB_91	DuWapN_91	Pond	10.00	0.57
DuWapB_93	DuWapN_93	Pond	10.00	0.26
DuWapB_94	DuWapN_94	Pond	10.00	0.20
DuWapB_95	DuWapN_95	Pond	10.00	0.08
DuWapB_97	DuWapN_97	Pond	10.00	0.21
DuWapB_98	DuWapN_98	Pond	10.00	0.4
DuWapB_9b	DuWapN_9b	Basin	10.00	5.87
DuWapB_209b	DuWapN_209b	Basin	10.00	3.25

Table 3-1: Roughness Coefficients (n) for Sheet Flow			
Item	Surface Description		n
1.0	Smooth surface (pavement, gravel or bare soil)		0.01
2.0	Fallow (no residue)		0.05
3.1	Cultivated soils, residue cover < 20%		0.06
3.2	Cultivated soils, residue cover > 20%		0.17
4.1	Short grass prairie		0.15
4.2	Dense grasses		0.24
4.3	Bermudagrass		0.41
5.0	Range (nature)		0.13
6.1	Light underbrush woods		0.40
6.2	Dense underbrush woods		0.80

Table 3-2: Manning's Coefficient (n) for channels and pipes				
Item	Conduit material	n		Average n
1	Asbestos-cement pipe	0.011	0.015	0.013
2	Brick	0.013	0.017	0.015
3	Cement lined and seal coated Cast Iron Pipe	0.011	0.015	0.013
4	Concrete (monolithic)	0.012	0.014	0.013
5	Concrete pipe	0.011	0.015	0.013
6	Plain Corrugated Metal Pipe	0.022	0.026	0.024
7	Paved invert corrugated metal pipe	0.018	0.022	0.02
8	Spun asphalt lines corrugated metal pipe	0.011	0.015	0.013
9	Plastic pipe (smooth)	0.011	0.015	0.013
10	Vitrified clay pipes	0.011	0.015	0.013
11	Vitrified clay liner plates	0.013	0.017	0.015
12	Line channel with Asphalt	0.013	0.017	0.015
13	Line channel with Concrete	0.012	0.018	0.015
14	Lined channel with Rubble or riprap	0.011	0.02	0.0155
15	Lined channel with Vegetal	0.02	0.035	0.0275
16	Earth, straight and uniform open channel	0.02	0.03	0.025
17	Earth, winding, fairly uniform open channel	0.025	0.04	0.0325
18	Excavated or dredged - Rock	0.03	0.045	0.0375
19	Excavated or dredged - Unmaintained	0.05	0.14	0.095
20	Fairly regular section Natural channel	0.03	0.07	0.05
21	Irregular section Natural channel with pools	0.04	0.1	0.07

Figure 3-1 Average velocities for estimating travel time for shallow concentrated flow



Time of Concentration Calculations using TR-55 Methodology:

OUTFALL: ______________________

Subbasin ID **DuWapB_46**

Sheet Flow

1. Surface description (Table 3-1, TR-55)	**Short grass prairie**		U/S Elev =	**17.85**
2. Manning's roughness coeff., n (Table 3-1, TR-55)	0.15		D/S Elev =	**17.59**
3. Flow length, L (total L <= 300 ft)	**100.00**	ft		
4. Two-year 24-hour rainfall, P	4.20	in		
5. Slope, s	0.0026	ft/ft		
6. Tt = [(0.007*(nL)^0.8)/(P^0.5)*(s^0.4)]	**0.32**	hr		

Shallow concentrated flow

7. Flow length, L	**287.37**	ft	U/S Elev =	**17.59**
8. Watercourse slope, s	0.8030	ft/ft	D/S Elev =	**15.28**
9. Surface description (Table 3-3, HEC-22)	**Unpaved**			
10. Average velocity, V (Figure 3-1)	18.876	ft/s		
11. Tt = (L / (3600*V))	**0.00**	hr		

Channel/Pipe flow

12. Diameter of pipe, D	**1.13**	ft	U/S Elev =	**15.28**
13. Cross sectional flow area, a	0.99	ft^2	D/S Elev =	**11.49**
14. Hydraulic radius, R = 0.25*D	0.28	ft		
15. Flow length, L	**760.00**	ft		
16. Slope, s	0.005	ft/ft		
17. Surface description (Table 3-2, TR-55/HEC-22)	**Concrete pipe**			
18. Manning's roughness coeff., n	0.013			
19. V = (1.49/n)*(R^(2/3))*(S^0.5)	3.48	ft/s		
20. Tt = (L / (3600*V))	**0.06**	hr		

22. Watershed Tc (add Tt in steps 6, 11 and 20)	***0.39***	**hr**

Appendix G NOAA Unit Hydrograph Technical Manual

Unit Hydrograph (UHG) Technical Manual

National Weather Service - Office of Hydrology
Hydrologic Research Laboratory
&
National Operational Hydrologic Remote Sensing Center

Introduction

The software IHABBS or Integrated Hydrologic Automated Basin Boundary System was developed at the National Weather Service (NWS) - National Operational Hydrologic Remote Sensing Center (NOHRSC) and installed at the RFC's. IHABBS is the basis for the Unit Hydrograph or UHG software. The UHG software and corresponding data sets were developed at the NOHRSC primarily due to the request of several RFCs following the successful deployment of IHABBS. UHG provides the capability to generate, compare, and edit a variety of synthetic unit hydrographs for basins within the RFC area of responsibility.

The ability to produce these unit hydrographs will aid RFCs in their calibration and forecasting activities, as quality stream flow data is not always readily available for use in deriving unit hydrographs. These synthetic unit hydrographs may be generated and then modified as part of the calibration or forecast routine. In addition, qualitative stream flow predictions may also be made at ungauged sites. Finally, the Weather Forecast Office Hydrologic Forecast System (WHFS) will contain a hydrologic modeling system that will require a unit hydrograph, possibly for basins that are not part of an RFC forecasting segment. In these cases, RFCs will be able to generate unit hydrographs and pass them to the Weather Forecast Offices (WFOs) for use in the WHFS.

Methodologies

While a number of methods for constructing unit hydrographs were considered, the initial version of UHG employs two methods, although a number of options allow for considerable flexibility. The two methods are the SCS Dimensionless Unit Hydrograph and several time-area based approaches. Most of the parameters such as distances and areas are calculated based on a series of GIS layers that are provided with the UHG software or with the original IHABBS installation. The GIS data layers methods employed are described herein.

GIS Data

Perhaps the most unique aspect of this tool is the quality of the GIS data layers that accompany the installation of UHG. The data layers have undergone considerable preprocessing to ensure hydrologic compatibility, referred to as "hydrologically clean". This is meant to imply that processes such as the filling of depressions and the assigning of flow directions has been properly completed. Each grid cell has been assigned a flow direction and it has been assured that all grid cells flow off of the data sets. Thus there are no "mirrored" cells that flow into each other. In addition, the EPA river reach files (RF1) have been slightly altered to ensure that streams are located in the valleys of the digital elevation model (DEM).

- **SCS Dimensionless Unit Hydrograph**

  The Soil Conservation Service (SCS) dimensionless unit hydrograph procedure is one of the most well known methods for deriving synthetic unit hydrographs in use today. References for this method can be found in most hydrology textbooks or handbooks. The primary reference for this method may be considered as the Soil Conservation Service - *National Engineering*

Handbook, *Section 4*, *Hydrology* (SCS 1972). There are a number of versions of this reference occurring both before and after the given date.

The dimensionless unit hydrograph used by the SCS was developed by Victor Mockus and was derived based on a large number of unit hydrographs from basins that varied in characteristics such as size and geographic location. The unit hydrographs were averaged and the final product was made dimensionless by considering the ratios of q/q_p (flow/peak flow) on the ordinate axis and t/t_p (time/time to peak) on the abscissa, where the units of q and q_p are flow/inch of runoff/unit area. This final, dimensionless unit hydrograph, which is the result of averaging a large number of individual dimensionless unit hydrographs, has a time-to-peak located at approximately 20% of its time base and an inflection point at 1.7 times the time-to-peak. The dimensionless unit hydrograph is illustrated in Figure 1. Figure 1 also illustrates the cumulative mass curve for the dimensionless unit hydrograph. Table 1 provides the ratios for the dimensionless unit hydrograph and the corresponding mass curve.

The curvilinear unit hydrograph may also be represented by an equivalent triangular unit hydrograph. Figure 2 illustrates the equivalent triangular unit hydrograph. Recall that the unit hydrograph is the result of 1-inch of excess rainfall (of duration D) spread uniformly over the basin. This 1-inch of excess rainfall is also indicated in Figure 2 to aid in the definition of the timing parameters, which will be discussed momentarily. Using the geometry of the triangle, one can see that the unit hydrograph has 37.5% (or 3/8) of its volume on the rising side and the remaining 62.5% (or 5/8) of the volume on the recession side. Using the dimensionless timing values on the x-axis, one can solve for the time base in terms of the time-to-peak.

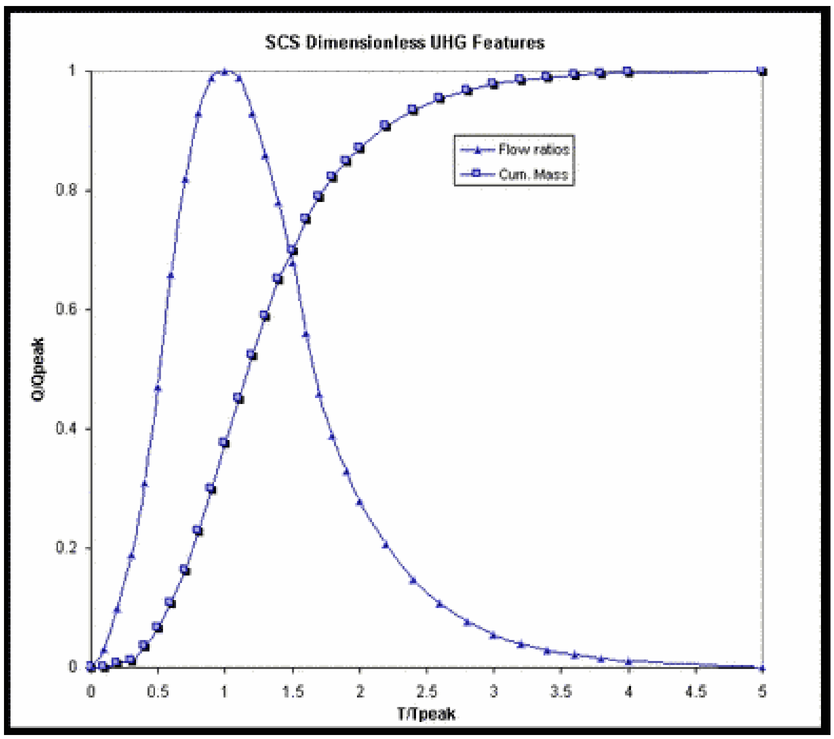


Figure 1 - SCS Dimensionless unit hydrograph and mass curve

The following relationships are made and will be useful in further developing the peak rate relationships. Note that the time base, T_b, of the triangular unit hydrograph extends form 0 to 2.67 and that the time to peak, T_p, is at 1.0, thus the time base is 2.67 times the time to peak or:

$$T_b = 2.67 \times T_p$$ **Equation 1**

and that the recession limb time, T_r, is then 1.67 times the time to peak.

$$T_r = T_b - T_p = 1.67 \times T_p$$ **Equation 2**

Using the geometric relationships of the triangular unit hydrograph of Figure 2, the total volume under the hydrograph is found by (area under 2 triangles):

$$Q=\frac{q_p T_p}{2}+\frac{q_p T_r}{2}=\frac{q_p}{2}(T_p+T_r)$$ **Equation 3**

Table 1 - Ratios for dimensionless unit hydrograph and mass curve.

Time Ratios (t/t_p)	Discharge Ratios (q/q_p)	Mass Curve Ratios (Q_a/Q)	Time Ratios (t/t_p)	Discharge Ratios (q/q_p)	Mass Curve Ratios (Q_a/Q)
0.0	0.000	0.000	1.6	0.560	0.751
0.1	0.030	0.001	1.7	0.460	0.790
0.2	0.100	0.006	1.8	0.390	0.822
0.3	0.190	0.012	1.9	0.330	0.849
0.4	0.310	0.035	2.0	0.280	0.871
0.5	0.470	0.065	2.2	0.207	0.908
0.6	0.660	0.107	2.4	0.147	0.934
0.7	0.820	0.163	2.6	0.107	0.953
0.8	0.930	0.228	2.8	0.077	0.967
0.9	0.990	0.300	3.0	0.055	0.977
1.0	1.000	0.375	3.2	0.040	0.984
1.1	0.990	0.450	3.4	0.029	0.989
1.2	0.930	0.522	3.6	0.021	0.993
1.3	0.860	0.589	3.8	0.015	0.995
1.4	0.780	0.650	4.0	0.011	0.997
1.5	0.680	0.700	4.5	0.005	0.999
			5.0	0.000	1.000

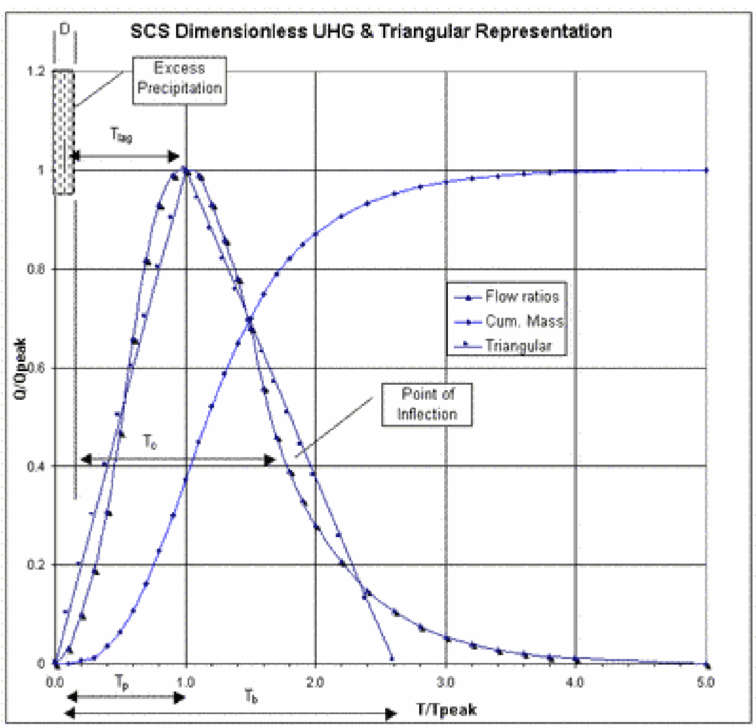


Figure 2 - Illustration of dimensionless curvilinear unit hydrograph and equivalent triangular hydrograph.

The volume, Q, is in inches (1 inch for a unit hydrograph) and the time is in hours. The peak rate, q_p, in inches per hour, is found to be :

$$q_p = \frac{2Q}{T_p + T_r}$$ **Equation 4**

It is desirable to have the peak flow of the unit hydrograph in terms of cfs per inch per square mile of drainage area. To accomplish this, the term, q_p, in the above equation is converted to cubic feet per second and the drainage area, A (mi^2), is brought into the equation, which results in an equation of expressing the runoff per inch per square mile:

$$q_p = \frac{654.33 x 2 x A x Q}{T_p + T_r}$$ **Equation 5**

The 645.33 is the conversion used for delivering 1-inch of runoff (the area under the unit hydrograph) from 1-square mile in 1-hour (3600 seconds). Noting again that the recession limb time, T_r, is 1.67 times the time to peak, T_p. Substituting in these relationships from Equation 1 above, Equation 5 is rewritten:

$$q_p = \frac{484 AQ}{T_p}$$ **Equation 6**

Because the above relationships were developed based on the volumetric constraints of the triangular unit hydrograph, the equations and conversions are also valid for the curvilinear unit hydrograph, which, proportionally, has the same volumes as the triangular representation. The conversion constant (herein called the peaking factor) 484 is the result of the large number of unit hydrographs from a wide range of basin characteristics and actually reflects the ability of the watershed to retain and delay the flow. Note that the value 484 is the result of assuming that the recession limb is 1.67 time the rising limb (time to peak). This may not be applicable to all watershed types.

Steep terrain and urban areas may tend to produce higher early peaks and thus values of the peaking factor may tend towards 600. Likewise, flat swampy regions tend to retain and store the water, causing a delayed, lower peak. In these circumstances values may tend towards 300 or lower (SCS 1972; Wanielista, et al. 1997). It would be very important to document any reasons for changing the constant from 484, effectively changing the shape of the unit hydrograph. When changing the shape of the unit hydrograph, one must keep in mind the ratios of the volumes under the rising and recession sides of the original dimensionless unit hydrograph and the resulting volume under the unit graph must remain at 1 inch. More information concerning the peak factor estimation is provided in "SCS Parameter Estimation", below.

The peak rate may also be expressed in terms of other timing parameters besides the time-to-peak. From Figure 2:

$$T_p = \frac{D}{2} + L$$ **Equation 7**

where D = the duration of the unit excess rainfall and L = the basin lag time, which is defined as the time between the center of mass of excess rainfall and the time to peak of the unit hydrograph. The peak flow is now written as:

$$q_p = \frac{484AQ}{\frac{D}{2} + L}$$ **Equation 8**

The SCS (1972) relates the lag time, L, to the time of concentration, T_c by :

$$L = 0.6 * T_c$$ **Equation 9**

Combining this with other relationships, as illustrated in the triangular unit hydrograph, the following relationships develop:

$$T_c + D = 1.7 T_p$$ **Equation 10**

and

$$\frac{D}{2}+0.6T_c=T_p$$ **Equation 11**

From this, the duration D may be expressed as:

$$D = 0.133\ T_c$$ **Equation 12**

Equations 1 through 10 provide the basis for the SCS Dimensionless Unit Hydrograph method in UHG. Equation 12 provides a desirable relationship between duration and time of concentration, which should provide enough points to accurately represent the unit hydrograph, particularly the rising limb.

SCS Parameter Estimation

It is necessary to estimate the area and a timing parameter for construction of the SCS unit hydrograph. In addition, the peaking factor, which defaults to 484 may be altered by the user. BUGHTool calculates a triangular unit hydrograph. This was done for several reasons, the main being that while the original SCS method provides dimensionless values for a curvilinear unit hydrograph, there are no dimensionless values for unit hydrographs that peak earlier or later. In other words, if a peaking factor other than 484 is used (see Equation 6), then the resulting unit hydrograph would require new dimensionless flow and timing ratios.

Area

Suffice it to say that the drainage area, A, should be obtained with as much accuracy and precision as is possible. Within the context of the planned implementation at RFC's, the area already have been estimated as part of IHABBS. For the basins typically to be encountered by the RFCs and WFOs, the 15-arc second data should provide areas within a few percent. Rost (1998) found that the 15-arc second data used in both IHABBS and UHG is capable of accurately delineating basins that are well below 50 square kilometers (20 square miles).

Peaking Factor

The "peaking factor" essentially controls the volume of water on the rising and recession limbs. The default value is 484 as illustrated in the original derivation and Equation 6. This is; however, a user option in UHG when using the SCS method. Table 2 provides some guidance for the selection of this parameter.

Table 2 - Hydrograph peaking factors and recession limb ratios (Wanielista, et al. 1997)

General Description	Peaking Factor	Limb Ratio (Recession to Rising)
Urban areas; steep slopes	575	1.25
Typical SCS	484	1.67
Misxed urban/rural	400	2.25
Rural, rolling hills	300	3.33
Rural, slight slopes	200	5.5
Rural, very flat	100	12.0

Timing

The timing parameter is somewhat difficult to estimate and rather subjective, however; this parameter has considerable influence on the values of the unit hydrograph. Underestimating the unit hydrographs "timing" will cause the peak to occur earlier and higher, while over estimating will cause a delayed and lower peak. There are several methods for estimating the timing parameter in UHG. These methods are discussed in detail below.

1. **SCS Lag Equation**

   The SCS lag equation is an empirical approach developed by the SCS, which estimates lag time directly. The SCS (1972) also recommends that the lag equation be used on basins that may be considered somewhat homogeneous in nature and less than 2000 acres in size. Due to these restrictive recommendations, the method may be rather limited in application to most of the basins which are typically encountered in the daily forecasting operations of the NWS; however, due to the relative ease of estimation and the potential for having smaller basins, this method will be included. Restrictions on the use of the lag equation should be stated, although some leeway beyond the 2000 acres size limit may be justifiable. The SCS lag equation is given as:

   $$T_{lag} = \frac{L^{0.8}(S+1)^{0.7}}{1900(\%Slope)^{0.5}}$$ **Equation 13**

   where : T_{lag} = lag time in hours

   L = Length of the longest drainage path in feet

   S = (1000/CN) - 10

   CN =curve number

   %Slope = The average watershed slope in %

   It will also be necessary to derive the average SCS curve number (CN). At the present time, the curve number is a user input; however, the average curve number for the basin will be computed using a raster curve number data layer.

   The remaining parameters are the Length, L, and the % Slope. The length, L is the length of the longest drainage path from the watershed outlet to the watershed divide, which is generally obvious for most watersheds. The length is calculated using the 15-arc second flow direction grid, which was included in the IHABBS installation. Each cell's flow path is traced to basin outlet and the longest flow (by distance) is noted and recorded.

   The somewhat more difficult parameter is the slope. The slope is calculated from a 15-arc second slope data set. The difficulty in using an average slope is the possibility of non-contributing areas being used in the average slope calculation. For example, areas very near the stream may be somewhat steep and be the main source of contributing area to a runoff hydrograph, while the land farther away from the stream may be a mild sloping plateau that does not readily contribute to the basin response. The effect would be to include the mild sloping cells in the average slope calculation, producing a mild average slope and a lower peaking, longer lag time unit hydrograph.

2. **Segmental Approaches**

   In the segmental velocity or segmental approach, the parameter being estimated is essentially the time of concentration or longest travel time within the basin. In general, the longest travel time corresponds to the longest drainage path; however, there may be situations and basin configurations that allow for some shorter travel distances to have longer travel times, due to land use and/or flow type. As in the case of the SCS lag equation, each grid cell's flow is traced to the basin outlet and the travel time across each downstream grid cell en route to the outlet is calculated. The sum of all of the travel times represents the time of concentration. Equation 7 is then used to estimate the lag time for use in calculating the SCS dimensionless unit hydrograph. Under the segmental approach, there are several options for estimating the travel time across each cell, which are described in the following sections.

   - *Constant velocity*

     The constant velocity method is a very simplistic approach that allows the user to assign a constant velocity to all grid cells. Again, the flow path of cell is traced to the basin outlet and travel times across each grid cell are summed to estimate the longest travel time. The user must supply the constant velocity.

   - *Land Use Based*

This option will not be available in the first release, however; a description of the planned implementation is provided. Travel times are calculated for each grid cell using an equation of the following form to calculate velocities:

$$V = kS^{\frac{1}{2}}$$ **Equation 14**

Where *k* is a coefficient based on the particular land use. The travel length across the cell divided by the velocity (time = distance/velocity) provides an estimate of the travel time. McCuen (1989) and SCS (1972) provide values of *k* for several land uses. Table 3 provides values of *k* for various land uses. *A* land use grid layer will be eventually be deployed, which will provide similar land use types and corresponding *k* values as illustrated in Table 3.

Table 3 - Coefficients of velocity (fps) versus slope (%) relationship for estimating travel velocities (McCuen 1989; SCS 1972).

K	**Land Use / Flow Regime**
0.25	Forest with heavy ground litter, hay meadow (overland flow)
0.5	Trash fallow or minimum tillage cultivation; contour or strip cropped; woodland (overland flow)
0.7	Short grass pasture (overland flow)
0.9	Cultivated straight row (overland flow)
1.0	Nearly bare and untilled (overland flow); alluvial fans in western mountain regions
1.5	Grassed waterway
2.0	Paved area (sheet flow); small upland gullies

- *Flow Type Based*

This method is very similar to the "Land Use Based" method, however; instead of land use categories, the velocity is based on an assumed flow type. The three flow types are overland flow, swale flow, and channel flow. Travel times are calculated for each grid cell using an equation of the form:

$$V = kS^{\frac{1}{2}}$$ **Equation 15**

Where *k* is a coefficient based on the flow type. The Michigan Department of Natural Resources - Land and Water Management Division ((Sorrell and Hamilton 1991) provide relationships, as illustrated in Table 4.

Table 4 - Coefficients of velocity (fps) versus slope (%) relationship for estimating travel velocities (Sorrell and Hamilton 1991).

Flow Type	***K***
Small Tributary - Permanent or intermittent streams which appear as solid or dashed blue lines on USGS topographic maps.	2.1
Waterway - Any overland flow route which is a well defined swale by elevation contours, but is not a stream section as defined above.	1.2
	0.48

Sheet Flow - Any other overland flow path which does not conform to the definition of a waterway.	

Flow type is determined within UHG in the following manner. Overland flow is considered to exist for a "short distance" on all cells that have no upstream cells (i.e. the ridge top cells). The "short distance", which defaults to 50 meters (~164 feet), is also a user option ranging between 0 and 100 meters (0 to 328 feet). Swale flow is then considered to exist until a channel cell is reached. Channel cells are defined in one of two ways in UHG.

First, the user may opt to use the EPA river reach files (RF1) which are included in the installation of IHABBS. Any cell that coincides with a river cell is considered to be a channel cell and the appropriate coefficient, k is applied. The alternative method is to use the flow accumulation data layer to define the channel cells. In this option, the user selects a threshold accumulation value, which essentially states that any cell having a flow accumulation greater than the threshold value is considered to be a channel cell. The threshold runoff value is easily described by attempting to estimate how much drainage area is required before a stream channel is formed.

The best method of assigning this threshold parameter is to first look at USGS topographic maps and other sources of "local" data and determine the extent of the first order streams in an area. The location of the "tips" of these first order streams should then be located on one of the UHG raster data images. The user may "query" raster layers and determine the flow accumulation value at the 'heads" of several first order streams. This flow accumulation value can then be used in UHG to establish channel flow cells.

- *Flow Accumulation Based*

  Maidment et al. (1994) provide the basis for this method, where velocity is calculated:

  $$V = V_{mean} \frac{S^b A^c}{\left[S^b A^c\right]_{mean}}$$ **Equation 16**

  Where V = the velocity of the cell, V_{mean} = the mean velocity in the basin, S = slope, A = upstream drainage area, and a and b are coefficients. Equation 13 can be rearranged into:

  $$V = \frac{V_{mean}}{\left[S^b A^c\right]_{mean}} S^b$$ **Equation 17**

  and allowing :

  $$k = \frac{V_{mean}}{\left[S^b A^c\right]_{mean}}$$ **Equation 18**

  then Equation 18 essentially becomes the same as Equations 14 and 15. In the UHG application, the denominator of Equation 18 is easily calculated using the flow direction grid, the flow accumulation grid, and the slope grid data layers. The more difficult of the parameters is the "mean velocity" or V_{mean}. In this version of UHG, the mean velocity will be a user input parameter.

3. **Triangular Shape**

   UHG calculates a triangular shaped unit hydrograph and there is some concern about the ability of this shape to be used in an operational setting. In general, it can be said that the triangular version will not cause or introduce noticeable differences in the simulation of a storm event, particularly when one is concerned with the peak flow. For long term simulations, the triangular unit hydrograph may have potential impacts; however, due to the uncertainties in the "exact" dimensionless ratios, which would be needed for a curvilinear unit hydrograph, it has been decided to use the triangular function.

In order to account for concerns arising over the shape of the triangular version, the option to fit a gamma distribution has been added. Aron and White (1982) fitted a gamma probability distribution using peak flow and time to peak data. The gamma distribution is:

$$f(t;a,b) = \frac{t^a e^{-t/b}}{b^{a+1}\Gamma(a+1)}$$ **Equation 19**

McCuen (1989) provides a procedure for implementation of this method:

Step #1 - Compute:

$$f_a = \frac{q_p t_p}{A}$$ **Equation 20**

where :

q_p = peak flow in cfs

t_p = time to peak in hours

A = drainage area in acres

Step #2 - Find the value of "a" from the following :

$$a = 0.045 + 0.5 f_a + 5.6 f_a^2 + 0.3 f_a^3$$ **Equation 21**

Step #3 - The ordinates of the unit hydrograph are calculated from:

$$q(f) = q_p f^a e^{a(1-f)}$$ **Equation 22**

Figure 3 illustrates the fitting of the gamma distribution to a triangular unit hydrograph.

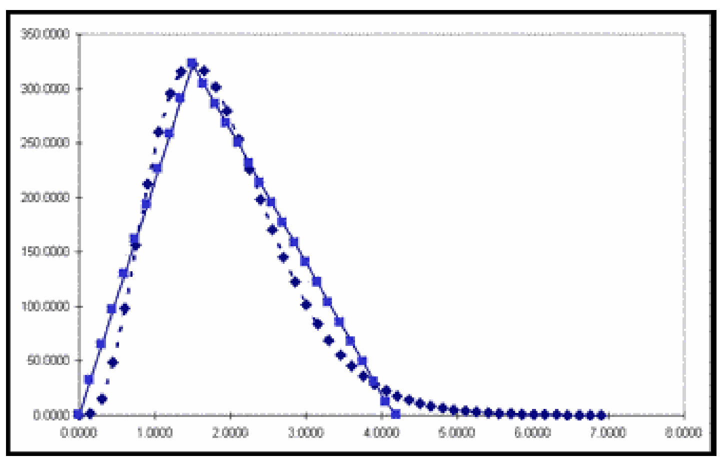


Figure 3 - Gamma fitted distribution of a triangular unit hydrograph.

Time-Area Methods

Time-area unit hydrograph theory establishes a relationship between the travel time and a portion of a basin that may contribute runoff during that travel time. Clark (1945) is one of early examples of this method. The U. S. Army Corps of Engineers at the Hydrologic Engineering Center (HEC 1996) provide a description of a modified time-area approach, known as the ModClark method, which is part of the recently released HEC-HMS computer model (HEC 199x).

In a time-area approach, the watershed is traditionally broken into areas of approximately travel time. These lines of equal travel time are known as *isochrones*. Figure 4 illustrates the breaking of a watershed into areas by isochrones. The mean travel time of each sub-area is calculated and the resulting *time-area* curve is produced. Most of the "time-area" methods utilize a common, basic approach in determining the final unit hydrograph. Summing the incremental areas and corresponding travel times (6 in Figure 4) enables the formation of a cumulative time-area curve. Thus, the total time can be thought of as the time of concentration of the watershed with 100% of the basin area being accounted for at the time of concentration.

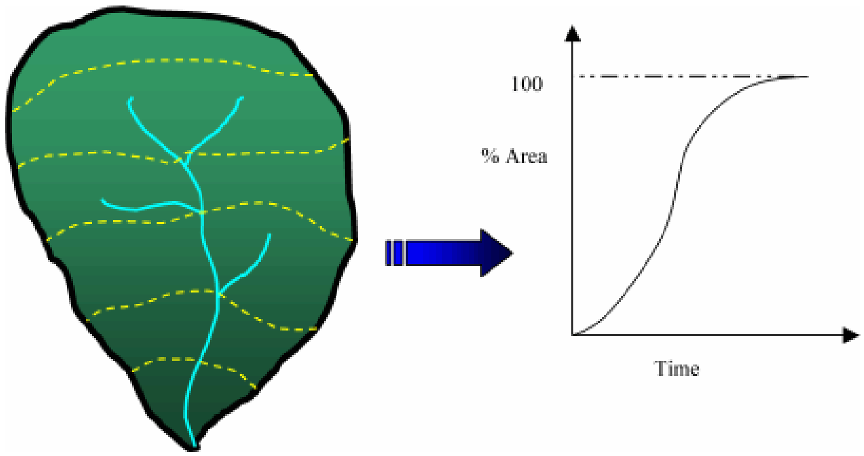


Figure 4 - Hypothetical watershed divided into 6 areas of approximately equal travel time to the outlet. Corresponding accumulative *time-area* curve is also illustrated.

Each of the partial areas (between isochrones) responds in the time associated with that area. Therefore, the cumulative time-area curve is a summation of the individual areas. The contributions of the individual areas can be illustrated with a histogram. One can visualize a uniform depth of water (1" for a unit hydrograph) on each of the zones within the isochrones. The volume of water of each area reaches the outlet at the travel time associated with that area. This is effectively a volume over a time period, which is a flow. Figure 5 illustrates a *time-discharge histogram* associated with the hypothetical basin of Figure 4.

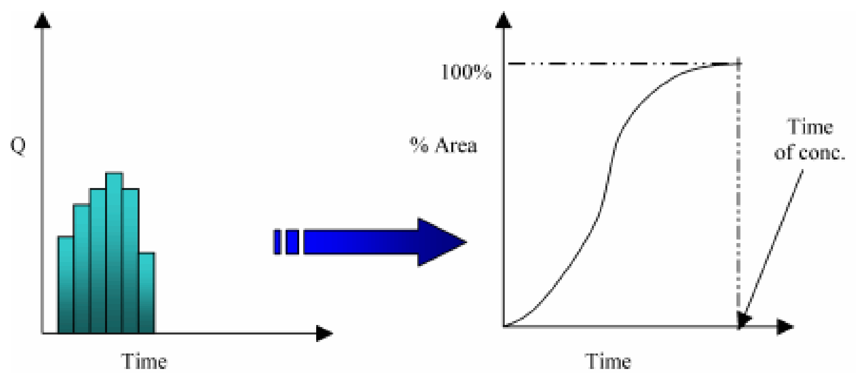


Figure 5 - Time-area histogram and associated cumulative time-area diagram.

The time-area histogram is really a *translation* hydrograph because the volume of water on each area within the basin is simply "translated" to the outlet using the associated travel time for the translation time. A this point, a unit hydrograph (in discrete form) exists. This "instantaneous" unit hydrograph is the result of 1-inch of instantaneous excess precipitation being placed on the individual areas and then translated to the outlet of the basin, arriving at the time associated with the travel time of area.

Watersheds also have the ability to store and delay the flow that passes through. This storage effect is seen in reservoirs as they attenuate a hydrograph. In order to model this effect, the translation unit hydrograph is routed through a linear reservoir. The concept of routing the translation unit hydrograph is illustrated in Figure 6.

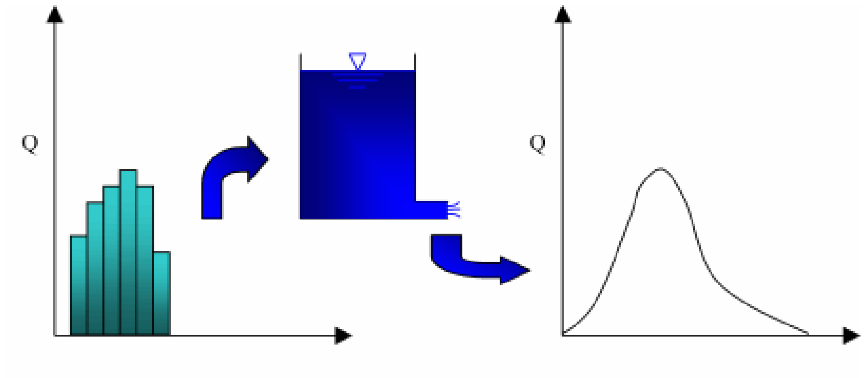


Figure 6 - Illustration of translation unit hydrograph being routed through linear reservoir.

The instantaneous unit hydrograph (IUH) is then calculated by routing the translation unit hydrograph the linear reservoir, having a routing coefficient, R. This is accomplished by the following equation :

$$IUH_i = cI_i + (1-c)IUH_{(i-1)}$$ **Equation 23**

where :

IUH_i = ordinate of the instantaneous unit hydrograph

I_i = Value at time *I* of the translation unit hydrograph

and

$$c = \frac{2\Delta t}{2R + \Delta t}$$ **Equation 24**

Where Dt = the time step used in the calculation of the translation unit hydrograph. The routed unit hydrograph is still considered to be an instantaneous unit hydrograph. A final unit hydrograph of a given duration can be found by lagging the instantaneous unit hydrograph by the desired duration and averaging the ordinates. The desired duration must be a multiple of the original time step employed in the computations above.

Within the time-area based approach, there are 3 different choices for "moving and delaying" the water en route to the basin outlet. Each of the methods uses the distributed nature of the raster data sets to varying degrees.

1. **Standard Approach**

   The first method is very similar to the ModClark method (HEC 1996). Each grid cell in the basin is assumed to have 1-inch of excess precipitation dropped on it instantaneously. This volume of water is then translated to the outlet and will arrive based on the cells known travel time to the outlet. The travel time to the outlet may be calculated in several ways itself, as in the SCS method described above. Once the water is translated to the outlet, it is grouped into an appropriate bin, which depends on the time interval of the computation. In other words, if the time interval is 1 hour and a cell arrives in 1.283 hours then that water is placed in the bin that spans hours 1 to 2. Likewise, a cell that arrives in 6.98 hours would have its volume of water placed in the bin spanning the hour 6 to 7, and so on.

   This is basically the same as creating a cumulative time-area curve and desegregating into bins of the desired computation interval. Next the volume of water in each of the bins is then routed though a linear reservoir using Equation 20. The reservoir routing coefficient is the same for all bins (and grid cells) regardless of their location in the basin or time of arrival at the outlet. The method of estimating or determining the reservoir routing coefficient, R, is described below.

2. **Distributed Linear Reservoir**

This time-area method is basically identical to the first, with the exception that each grid cell arrives at the outlet at its specified arrival time, however; the reservoir routing coefficient is dependant upon time it takes the cell to travel to the basin outlet.

3. **Fully Distributed Approach**

The final method is somewhat more complicated. This method is thought of as a distributed unit hydrograph method, although that may sound like a contradiction in terms. The distributed method moves and delays the water across each cell as it travels to the basin outlet. Again, each cell is assumed to receive 1-inch of excess precipitation. This precipitation is routed off the cell on which it falls using a time-area method and breaking the cell into an equal number of isochrones of travel time. This is done for all cells. The water that leaves the cells is in the form a unit hydrograph for only one cell. The unit hydrograph for that cell is then lagged or translated across each downstream cell and routed through a linear reservoir on each cell. The lagging across each cell is dependent on the travel time across the cell and the reservoir routing is dependent on a reservoir routing coefficient, which is calculate for each cell. The lagging and routing continues downstream until the final hydrograph is tabulated at the outlet. This is a unit hydrograph that has resulted from lagging and routing 1-inch of excess precipitation throughout the watershed to the outlet in a distributed fashion.

This distributed method is not perceived by the authors to be necessary on all watersheds, as it will be most applicable on watersheds that have very complex topology and drainage patterns. Experience thus far indicates that the time to peak and the magnitude of the are not drastically different from other time-area methods; however, the distributed method has been able to capture subsequent peaks much better.

Time-Area Parameter Estimations

The basic parameters that are necessary to estimate are travel times, basin area, and a method of estimating the linear reservoir routing coefficient, R.

Area

Suffice it to say that the drainage area, A, should be obtained with as much accuracy and precision as is possible. Within the context of the planned implementation at RFC's, the area already have been estimated as part of For the basins typically to be encountered by the RFCs and WFOs, the 15-arc second data should provide areas within a few percent. Rost (1998) found that the 15-arc second data used in both IHABBS and UHG is capable of accurately delineating basins that are well below 50 square kilometers (20 square miles).

Linear Reservoir Coefficient Estimation

The linear reservoir coefficient is very difficult to estimate. The most appropriate and desirable method of estimation is to utilize stream flow data and estimate the parameter as previously discussed. Clark (1945) provided a means of estimating R by considering a measured hydrograph and calculating R by :

$$R = -\frac{Q}{dQ/dt}$$ **Equation 25**

where : Q, dq, and dt are measured at the inflection point on the recession limb of a hydrograph at the gauge site. The routing coefficient, R, may also be estimated by dividing the volume under the recession limb by the flow at the inflection point on the recession limb (HEC 1982). In ungauged basins, it is possible to estimate the reservoir routing coefficient from a nearby basin (or a nested basin) and apply it to the ungauged basin.

A second desirable method is to estimate the coefficient from a number of nearby basins and perform a linear regression analysis including such parameters as area, slope, channel information, etc.. With this in mind, it is obviously preferred that the user performs some type of analysis to estimate the linear storage parameter in some a priori manner for the basin or a nearby basin. In the absence of all other inputs, the longest travel time from the any cell to the basin outlet may be used to estimate the routing coefficient (Wanielista, Kerten, & Eaglin 1997). From experience and personal contact with other researchers and engineers, a value of 0.7 times the longest travel time may be used for the value of the linear routing coefficient. The user is able to change this multiplier.

Timing Estimates

All of the options in the segmental approach described above are again available for use with the time area approach. These methods are described in above and are provided here for completeness.

1. **Segmental Approaches**

   In the segmental velocity or segmental approach, the parameter being estimated is essentially the time of concentration or longest travel time within the basin. In general, the longest travel time corresponds to the longest drainage path; however, there may be situations and basin configurations that allow for some shorter travel distances to have longer travel times, due to land use and/or flow type. As in the case of the SCS lag equation, each grid cell's flow is traced to the basin outlet and the travel time across each downstream grid cell en route to the outlet is calculate. The sum of all of the travel times represents the time of concentration. Equation 7 is then used to estimate the lag time for use in calculating the SCS dimensionless unit hydrograph.

   - *Constant velocity*

     The constant velocity method is a very simplistic approach that is included in UHG . This method allows the user to assign a constant velocity to all grid cells. Again, the flow path is of cell is traced to the basin outlet and travel times across each grid cell is summed to estimate the longest travel time. The user must supply the constant velocity.

   - *Land Use Based*

     This option will not be available in the first release, however; a description of the planned implementation is provided. Travel times are calculated for each grid cell using an equation of the form:

     $$V = kS^{\frac{1}{2}}$$ **Equation 14**

     Where *k* is a coefficient based on the particular land use. McCuen (1989) and SCS (1972) provide values of *k* for several land uses. Table 5 provides values of *k* for various land uses. *A* land use grid layer will eventually be included in the UHG installation.

Table 5 - Coefficients of velocity (fps) versus slope (%) relationship for estimating travel velocities (McCuen 1989; SCS 1972).

K	**Land Use / Flow Regime**
0.25	Forest with heavy ground litter, hay meadow (overland flow)
0.5	Trash fallow or minimum tillage cultivation; contour or strip cropped; woodland (overland flow)
0.7	Short grass pasture (overland flow)
0.9	Cultivated straight row (overland flow)
1.0	Nearly bare and untilled (overland flow); alluvial fans in western mountain regions
1.5	Grassed waterway
2.0	Paved area (sheet flow); small upland gullies

   - *Flow Type Based*

     This method is very similar to the "Land Use Based" method, however; instead of land use categories, the velocity is based on an assumed flow type. The three flow types are overland flow, swale flow, and channel flow. Travel times are calculated for each grid cell using an equation of the form :

$$V = kS^{\frac{1}{2}}$$ **Equation 15**

Where *k* is a coefficient based on the flow type. The Michigan Department of Natural Resources - Land and Water Management Division ((Sorrell and Hamilton 1991) provide relationships, as illustrated in Table 6. The user has control of these values, although the default values are those listed in Table 6.

Table 6 - Coefficients of velocity (fps) versus slope (%) relationship for estimating travel velocities (Sorrell and Hamilton 1991).

Flow Type	*K*
Small Tributary - Permanent or intermittent streams which appear as solid or dashed blue lines on USGS topographic maps.	2.1
Waterway - Any overland flow route which is a well defined swale by elevation contours, but is not a stream section as defined above.	1.2
Sheet Flow - Any other overland flow path which does not conform to the definition of a waterway.	0.48

Flow type is determined within UHG in the following manner. Overland flow is considered to exist for a "short distance" on all cells that have no upstream cells (i.e. the ridge top cells). The "short distance", which defaults to 50 meters (~164 feet), is also a user option ranging between 0 and 100 meters (0 to 328 feet). Swale flow is then considered to exist until a channel cell is reached. Channel cells are defined in one of two ways in UHG.

First, the user may opt to use the EPA river reach files (RF1) which are included in the installation of IHABBS. Any cell that coincides with a river cell is considered to be a channel cell and the appropriate coefficient, k is applied. The alternative method is to use the flow accumulation data layer to define the channel cells. In this option, the user selects a threshold accumulation value, which essentially states that any cell having a flow accumulation greater than the threshold value is considered to be a channel cell. The threshold runoff value is easily described by attempting to estimate how much drainage area is required before a stream channel is formed.

The best method of assigning this threshold parameter is to first look at USGS topographic maps and other sources of "local" data and determine the extent of the first order streams in an area. The location of the "tips" of these first order streams should then be located on one of the UHG raster data images. The user may "query" raster layers and determine the flow accumulation value at the 'heads" of several first order streams. This flow accumulation value can then be used in UHG to establish channel flow cells.

- *Flow Accumulation Based*

  Maidment et al. (1994) provide the basis for this method, which is based on the following equation:

  $$V = V_{mean} \frac{S^b A^c}{\left[S^b A^c \right]_{mean}}$$ **Equation 16**

  Where V = the velocity of the cell, V_{mean} = the mean velocity in the basin, S = slope, A = upstream drainage area, and a and b are coefficients. Equation 16 can be rearranged into:

$$V = \frac{V_{mean}}{\left[S^b A^c\right]_{mean}} S^b$$ **Equation 17**

and allowing :

$$k = \frac{V_{mean}}{\left[S^b A^c\right]_{mean}}$$ **Equation 18**

then Equation 18 essentially becomes the same as Equations 14 and 15. In the UHG application, the denominator of Equation 18 is easily calculated using the flow direction grid, the flow accumulation grid, and the slope grid data layers. The more difficult of the parameters is the "mean velocity" or V_{mean}. In this version of UHG, the mean velocity will be a user input parameter.

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Appendix H Model Network

APPENDIX-H MODEL NETWORK

Appendix I Model Calibration Log

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.69	0.68
2	9	DuWapMH_351	9.14	9.12	-0.02
3	4	DuWapMH_366	8.01	8.68	0.67
4	5	DuWapMH_389	11.44	12.41	0.97
5	7	DuWapMH_421	7.57	8.22	0.65
6	6	DuWapMH_449	11.35	10.79	-0.56
7	9	DuWapMH_92	9.14	8.60	-0.54
8	2	DuWapN_27	10.14	11.75	1.61
9	3	DuWapN_51	10.91	12.08	1.17
10	8	DuWapN_71	8.51	8.34	-0.17

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.69	0.68
2	9	DuWapMH_351	9.14	9.12	-0.02
3	4	DuWapMH_366	8.01	8.68	0.67
4	5	DuWapMH_389	11.44	12.41	0.97
5	7	DuWapMH_421	7.57	8.22	0.65
6	6	DuWapMH_449	11.35	10.79	-0.56
7	9	DuWapMH_92	9.14	8.60	-0.54
8	2	DuWapN_27	10.14	11.75	1.61
9	3	DuWapN_51	10.91	11.78	0.87
10	8	DuWapN_71	8.51	8.34	-0.17

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.69	0.68
2	9	DuWapMH_351	9.14	9.12	-0.02
3	4	DuWapMH_366	8.01	8.68	0.67
4	5	DuWapMH_389	11.44	12.41	0.97
5	7	DuWapMH_421	7.57	8.22	0.65
6	6	DuWapMH_449	11.35	10.79	-0.56
7	9	DuWapMH_92	9.14	8.60	-0.54
8	2	DuWapN_27	10.14	11.74	1.60
9	3	DuWapN_51	10.91	11.78	0.87
10	8	DuWapN_71	8.51	8.34	-0.17

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.70	0.69
2	9	DuWapMH_351	9.14	9.13	0.00
3	4	DuWapMH_366	8.01	8.70	0.69

4	5	DuWapMH_389	11.44	12.41	0.97
5	7	DuWapMH_421	7.57	8.22	0.65
6	6	DuWapMH_449	11.35	10.79	-0.56
7	9	DuWapMH_92	9.14	8.61	-0.53
8	2	DuWapN_27	10.14	11.49	1.35
9	3	DuWapN_51	10.91	11.78	0.87
10	8	DuWapN_71	8.51	8.35	-0.16

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.70	0.69
2	9	DuWapMH_351	9.14	9.13	0.00
3	4	DuWapMH_366	8.01	8.70	0.69
4	5	DuWapMH_199	11.44	12.40	0.96
5	7	DuWapMH_421	7.57	8.22	0.65
6	6	DuWapMH_449	11.35	10.79	-0.56
7	9	DuWapMH_92	9.14	8.61	-0.53
8	2	DuWapN_27	10.14	11.49	1.35
9	3	DuWapN_51	10.91	11.78	0.87
10	8	DuWapN_71	8.51	8.35	-0.16

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.56	0.55
2	9	DuWapMH_351	9.14	9.19	0.05
4	5	DuWapMH_199	11.44	12.40	0.96
5	7	DuWapMH_421	7.57	8.23	0.66
6	6	DuWapN_82	11.35	10.82	-0.53
7	9	DuWapMH_92	9.14	8.69	-0.45
8	2	DuWapN_27	10.14	11.21	1.07
9	3	DuWapN_51	10.91	11.78	0.87
10	8	DuWapN_71	8.51	8.30	-0.21

APPENDIX-I Model Calibration Log

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.50	0.49
2	9	DuWapMH_351	9.14	9.17	0.04
4	5	DuWapMH_199	11.44	11.45	0.01
5	7	DuWapMH_421	7.57	8.22	0.65
6	6	DuWapN_82	11.35	11.01	-0.34
7	9	DuWapMH_92	9.14	8.67	-0.47
8	2	DuWapN_27	10.14	10.52	0.38
9	3	DuWapN_51	10.91	11.73	0.82
10	8	DuWapN_71	8.51	8.25	-0.26

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.50	0.49
2	9	DuWapMH_351	9.14	9.17	0.04
4	5	DuWapMH_199	11.44	11.45	0.01
5	7	DuWapMH_421	7.57	8.22	0.65
6	6	DuWapN_82	11.35	11.01	-0.34
7	9	DuWapMH_92	9.14	8.67	-0.47
8	2	DuWapN_27	10.14	10.52	0.38
9	3	DuWapN_51	10.91	11.46	0.55
10	8	DuWapN_71	8.51	8.25	-0.26

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.47	0.46
4	5	DuWapMH_199	11.44	11.45	0.01
5	7	DuWapMH_421	7.57	8.17	0.60
6	6	DuWapN_82	11.35	11.01	-0.34
7	9	DuWapMH_92	9.14	9.57	0.44
8	2	DuWapN_27	10.14	10.52	0.38
9	3	DuWapN_51	10.91	11.36	0.45
10	8	DuWapN_71	8.51	8.15	-0.36

S_No	Check	Node	Field Elevation	Model Elevation	Delta
1	4	DuWapMH_299	8.01	8.47	0.46
4	5	DuWapMH_199	11.44	11.45	0.01
5	7	DuWapMH_421	7.57	8.10	0.53
6	6	DuWapN_82	11.35	11.01	-0.34
7	9	DuWapMH_92	9.14	9.57	0.44
8	2	DuWapN_27	10.14	10.52	0.38
9	3	DuWapN_51	10.91	11.36	0.45
10	8	DuWapN_71	8.51	8.15	-0.36

Node	Before		After	
DuWapN_51	Stage	Area	Stage	Area
	11.13	2.19	9.132	0.048
	12.13	2.7	10.13	0.60
	13.13	3.47	11.13	2.40
	14.13	4.6	12.13	2.70
			13.13	3.47
			14.13	4.60

P_105	
Depth Before	2
Depth After	2
Bottom Clip Before	1
Bottom Clip After	0.50
Entrance Loss Before	0.5
Entrance Loss After	0.25

L_0320P	
Depth Before	1.5
Depth After	2
Bottom Clip Before	0
Bottom Clip After	0.00
Entrance Loss Before	0.5
Entrance Loss After	0.25

Deleted
Deleted DuWapB_85
DuWapN_85

Deleted
P_132
P_122
P_123
Channel_74
DuWapMH_389
DuWapMH_179

Deleted
DuWapMH_449

L-0360P	
DS Invert Before	
DS Invert After	7.15
L-0380P	Invert DS = 7.15
DS Invert Before	
DS Invert After	7.15

P_81 - Connected to DuWapN_82 instead of DuWapMH_449

P_9	
Mannings n Before	0.013
Mannings n After	0.02

P_12	
Mannings n Before	0.013
Mannings n After	0.02

Channels	
Mannings n Before	0.035
Mannings n After	0.028
Channel_203	
Channel_73	
Channel_12	
Channel_42	
Channel_119	
Channel_210	
Channel_209	
Channel_15	
Channel_205	
Channel_7	
Channel_16	
Channel_121	
Channel_14	
Channel_44	
Channel_46	
Channel_48	
Channel_47	
Channel_204	
Channel_49	
Channel_131	
Channel_116	
Channel_100	
Channel_110	
Channel_61	
Channel_62	
Channel_55	
Channel_28	
Channel_3	

Node	
DuWapN_27	
8.22	0.75
9.72	1.25
Storage added between 8.22 and 10.72	

Node	
DuWapN_51	
8.63	0.25
Storage added between 8.63 and 9.132	

Node	
DuWapN_26	
7.34	0.5
8.23	1
9.23	2
10.23	3
Storage added between 7.34 and 11.23	

Node	
DuWapN_250	
6.56	0.1
7.05	0.2
8.05	0.5
9.05	1
10.05	2
Storage added between 6.56 and 11.05	

Node	
DuWapN_62	
10.36	0.5
Storage added between 10.36 and 11.86	

Node	
DuWapN_61	
9.28	2
10.04	5
11.04	8
Storage added between 7.34 and 11.23	

P_9	DuWapMH_92		
Mannings n Before	0.013	Bottom Clip Before	0
Mannings n After	0.02	Bottom Clip After	1

P_12	DuWapMH_92		
Mannings n Before	0.013	Bottom Clip Before	0
Mannings n After	0.02	Bottom Clip After	1

P_105	DuWapN_51
Bottom Clip Before	0.5
Bottom Clip After	0.1

L-0280P	DuWapN_51
Diameter Before	1.25
Diameter After	5

Node	
DuWapMH_421	
Added storage	
Stage	Area
1.9	0.5
2.9	0.75
3.9	1

P_151	DuWapMH_421
Diameter Before	2.5
Diameter After	3

Appendix J Node Maximum Stage Result Summary

APPENDIX-J Node Maximum Stage Result Summary

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_1	17.22	19.37
25 Year 24 Hour_SS_SLR	DuWapMH_10	12.11	12.69
25 Year 24 Hour_SS_SLR	DuWapMH_101	13.18	13.53
25 Year 24 Hour_SS_SLR	DuWapMH_103	7	8.63
25 Year 24 Hour_SS_SLR	DuWapMH_104	7.99	10.16
25 Year 24 Hour_SS_SLR	DuWapMH_105	8.5	9.99
25 Year 24 Hour_SS_SLR	DuWapMH_106	9.97	8.68
25 Year 24 Hour_SS_SLR	DuWapMH_107	7.8	10.06
25 Year 24 Hour_SS_SLR	DuWapMH_108	17.18	18.41
25 Year 24 Hour_SS_SLR	DuWapMH_109	12.31	12.38
25 Year 24 Hour_SS_SLR	DuWapMH_11	8.33	8.64
25 Year 24 Hour_SS_SLR	DuWapMH_111	13.09	8.8
25 Year 24 Hour_SS_SLR	DuWapMH_112	8.68	8.92
25 Year 24 Hour_SS_SLR	DuWapMH_113	13.2	15.48
25 Year 24 Hour_SS_SLR	DuWapMH_114	10.14	11.45
25 Year 24 Hour_SS_SLR	DuWapMH_115	8.62	9.14
25 Year 24 Hour_SS_SLR	DuWapMH_116	6.91	8.59
25 Year 24 Hour_SS_SLR	DuWapMH_117	9.24	9.23
25 Year 24 Hour_SS_SLR	DuWapMH_118	18.7	15.62
25 Year 24 Hour_SS_SLR	DuWapMH_119	8.92	10.17
25 Year 24 Hour_SS_SLR	DuWapMH_12	8.58	8.66
25 Year 24 Hour_SS_SLR	DuWapMH_121	5.24	9.25
25 Year 24 Hour_SS_SLR	DuWapMH_123	7.64	9.17
25 Year 24 Hour_SS_SLR	DuWapMH_124	17.44	18.41
25 Year 24 Hour_SS_SLR	DuWapMH_128	8.06	8.88
25 Year 24 Hour_SS_SLR	DuWapMH_129	9.21	9.19
25 Year 24 Hour_SS_SLR	DuWapMH_13	5.89	8.8
25 Year 24 Hour_SS_SLR	DuWapMH_130	4.76	8.48
25 Year 24 Hour_SS_SLR	DuWapMH_131	6.67	9.43
25 Year 24 Hour_SS_SLR	DuWapMH_132	9.28	9.41
25 Year 24 Hour_SS_SLR	DuWapMH_133	9.17	9.46
25 Year 24 Hour_SS_SLR	DuWapMH_134	3.15	8.27
25 Year 24 Hour_SS_SLR	DuWapMH_135	7.04	8.6
25 Year 24 Hour_SS_SLR	DuWapMH_136	13.25	13.57
25 Year 24 Hour_SS_SLR	DuWapMH_137	9.28	8.68
25 Year 24 Hour_SS_SLR	DuWapMH_14	7.59	8.72
25 Year 24 Hour_SS_SLR	DuWapMH_140	4.78	8.6
25 Year 24 Hour_SS_SLR	DuWapMH_141	12.23	13.52
25 Year 24 Hour_SS_SLR	DuWapMH_143	9.25	9.83
25 Year 24 Hour_SS_SLR	DuWapMH_144	16.45	13.4
25 Year 24 Hour_SS_SLR	DuWapMH_146	21.1	18.37
25 Year 24 Hour_SS_SLR	DuWapMH_147	19.8	16.87
25 Year 24 Hour_SS_SLR	DuWapMH_15	8.03	8.97
25 Year 24 Hour_SS_SLR	DuWapMH_151	9.28	9.94
25 Year 24 Hour_SS_SLR	DuWapMH_152	9.4	9.25
25 Year 24 Hour_SS_SLR	DuWapMH_153	12.28	12.73

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_154	8	9.18
25 Year 24 Hour_SS_SLR	DuWapMH_155	14.96	10.43
25 Year 24 Hour_SS_SLR	DuWapMH_156	9.64	9.12
25 Year 24 Hour_SS_SLR	DuWapMH_157	13.51	13.54
25 Year 24 Hour_SS_SLR	DuWapMH_158	12.76	13.69
25 Year 24 Hour_SS_SLR	DuWapMH_159	16.4	17.85
25 Year 24 Hour_SS_SLR	DuWapMH_162	11.5	9.43
25 Year 24 Hour_SS_SLR	DuWapMH_17	7.67	8.72
25 Year 24 Hour_SS_SLR	DuWapMH_171	8.1	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_172	4.53	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_173	7.74	10.39
25 Year 24 Hour_SS_SLR	DuWapMH_174	10.09	10.28
25 Year 24 Hour_SS_SLR	DuWapMH_175	10.01	11.92
25 Year 24 Hour_SS_SLR	DuWapMH_177	8.05	9.77
25 Year 24 Hour_SS_SLR	DuWapMH_180	9.5	9.61
25 Year 24 Hour_SS_SLR	DuWapMH_181	10.7	9.61
25 Year 24 Hour_SS_SLR	DuWapMH_182	5.25	8.16
25 Year 24 Hour_SS_SLR	DuWapMH_184	4.5	8.88
25 Year 24 Hour_SS_SLR	DuWapMH_186	5.2	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_188	13.14	13.57
25 Year 24 Hour_SS_SLR	DuWapMH_189	10.85	9.24
25 Year 24 Hour_SS_SLR	DuWapMH_19	7.65	8.68
25 Year 24 Hour_SS_SLR	DuWapMH_190	10.09	11.84
25 Year 24 Hour_SS_SLR	DuWapMH_191	5.22	9.59
25 Year 24 Hour_SS_SLR	DuWapMH_192	7.76	9.31
25 Year 24 Hour_SS_SLR	DuWapMH_193	16.87	17.28
25 Year 24 Hour_SS_SLR	DuWapMH_194	16.75	14.33
25 Year 24 Hour_SS_SLR	DuWapMH_195	12.88	15.41
25 Year 24 Hour_SS_SLR	DuWapMH_196	9.2	9.23
25 Year 24 Hour_SS_SLR	DuWapMH_197	12	10.01
25 Year 24 Hour_SS_SLR	DuWapMH_199	11.25	12.46
25 Year 24 Hour_SS_SLR	DuWapMH_20	9.13	8.99
25 Year 24 Hour_SS_SLR	DuWapMH_206	7.25	10.16
25 Year 24 Hour_SS_SLR	DuWapMH_207	14.22	11.56
25 Year 24 Hour_SS_SLR	DuWapMH_21	15.51	11.93
25 Year 24 Hour_SS_SLR	DuWapMH_212	10.9	9.68
25 Year 24 Hour_SS_SLR	DuWapMH_213	6.1	9.01
25 Year 24 Hour_SS_SLR	DuWapMH_214	8	8.91
25 Year 24 Hour_SS_SLR	DuWapMH_218	5.12	9.46
25 Year 24 Hour_SS_SLR	DuWapMH_219	8.26	8.96
25 Year 24 Hour_SS_SLR	DuWapMH_22	14.58	11.75
25 Year 24 Hour_SS_SLR	DuWapMH_220	15.74	12.15
25 Year 24 Hour_SS_SLR	DuWapMH_221	8.21	9.79
25 Year 24 Hour_SS_SLR	DuWapMH_222	4.08	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_223	9.42	10.43
25 Year 24 Hour_SS_SLR	DuWapMH_224	16.4	13.17

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_225	11.69	12.57
25 Year 24 Hour_SS_SLR	DuWapMH_227	7.4	8.7
25 Year 24 Hour_SS_SLR	DuWapMH_228	3.88	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_229	5.63	8.23
25 Year 24 Hour_SS_SLR	DuWapMH_23	12.66	15.4
25 Year 24 Hour_SS_SLR	DuWapMH_230	6.69	8.31
25 Year 24 Hour_SS_SLR	DuWapMH_231	6.25	8.35
25 Year 24 Hour_SS_SLR	DuWapMH_232	7.15	8.99
25 Year 24 Hour_SS_SLR	DuWapMH_233	6.65	9.45
25 Year 24 Hour_SS_SLR	DuWapMH_235	8.53	10.08
25 Year 24 Hour_SS_SLR	DuWapMH_236	4.39	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_238	4.89	9.6
25 Year 24 Hour_SS_SLR	DuWapMH_24	11.15	13.26
25 Year 24 Hour_SS_SLR	DuWapMH_240	6.58	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_241	6.58	9.45
25 Year 24 Hour_SS_SLR	DuWapMH_243	3.57	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_244	3.57	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_245	4.2	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_246	4.21	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_248	5.23	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_249	7	8.97
25 Year 24 Hour_SS_SLR	DuWapMH_250	8.5	11.14
25 Year 24 Hour_SS_SLR	DuWapMH_251	8.48	10.77
25 Year 24 Hour_SS_SLR	DuWapMH_252	8.46	10.43
25 Year 24 Hour_SS_SLR	DuWapMH_253	8.8	11.54
25 Year 24 Hour_SS_SLR	DuWapMH_254	8.75	12.23
25 Year 24 Hour_SS_SLR	DuWapMH_255	9.26	11.91
25 Year 24 Hour_SS_SLR	DuWapMH_256	8.26	12.57
25 Year 24 Hour_SS_SLR	DuWapMH_257	8.5	12.73
25 Year 24 Hour_SS_SLR	DuWapMH_258	7.67	9.51
25 Year 24 Hour_SS_SLR	DuWapMH_259	10.6	12.92
25 Year 24 Hour_SS_SLR	DuWapMH_260	11.26	12.98
25 Year 24 Hour_SS_SLR	DuWapMH_261	11.4	13.02
25 Year 24 Hour_SS_SLR	DuWapMH_262	11.8	13.07
25 Year 24 Hour_SS_SLR	DuWapMH_264	12.3	13.16
25 Year 24 Hour_SS_SLR	DuWapMH_267	9.2	9.03
25 Year 24 Hour_SS_SLR	DuWapMH_268	17.48	14.85
25 Year 24 Hour_SS_SLR	DuWapMH_269	17.89	16.44
25 Year 24 Hour_SS_SLR	DuWapMH_27	17.1	18.37
25 Year 24 Hour_SS_SLR	DuWapMH_270	19.23	18.28
25 Year 24 Hour_SS_SLR	DuWapMH_271	7.86	6.86
25 Year 24 Hour_SS_SLR	DuWapMH_272	8.03	7.03
25 Year 24 Hour_SS_SLR	DuWapMH_273	8.14	7.14
25 Year 24 Hour_SS_SLR	DuWapMH_274	9.6	11.83
25 Year 24 Hour_SS_SLR	DuWapMH_275	7	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_276	8.33	8.84

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_277	9	8.92
25 Year 24 Hour_SS_SLR	DuWapMH_278	7	8.83
25 Year 24 Hour_SS_SLR	DuWapMH_279	8	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_28	16.44	17.47
25 Year 24 Hour_SS_SLR	DuWapMH_280	8.51	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_281	7.9	8.96
25 Year 24 Hour_SS_SLR	DuWapMH_282	8.3	9.03
25 Year 24 Hour_SS_SLR	DuWapMH_287	3.1	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_288	14.5	12.25
25 Year 24 Hour_SS_SLR	DuWapMH_289	8.54	8.88
25 Year 24 Hour_SS_SLR	DuWapMH_290	14.2	13.51
25 Year 24 Hour_SS_SLR	DuWapMH_291	11.25	13.3
25 Year 24 Hour_SS_SLR	DuWapMH_292	13.43	13.07
25 Year 24 Hour_SS_SLR	DuWapMH_293	11.5	10.03
25 Year 24 Hour_SS_SLR	DuWapMH_294	13.59	13.77
25 Year 24 Hour_SS_SLR	DuWapMH_295	15.25	14.81
25 Year 24 Hour_SS_SLR	DuWapMH_296	14.6	14.33
25 Year 24 Hour_SS_SLR	DuWapMH_297	15.6	15.15
25 Year 24 Hour_SS_SLR	DuWapMH_298	10.26	9.46
25 Year 24 Hour_SS_SLR	DuWapMH_299	8.87	9.2
25 Year 24 Hour_SS_SLR	DuWapMH_3	10.05	12.88
25 Year 24 Hour_SS_SLR	DuWapMH_30	8.58	8.79
25 Year 24 Hour_SS_SLR	DuWapMH_301	10	9.74
25 Year 24 Hour_SS_SLR	DuWapMH_302	7.5	9.17
25 Year 24 Hour_SS_SLR	DuWapMH_304	9.98	9.47
25 Year 24 Hour_SS_SLR	DuWapMH_305	9.93	10.43
25 Year 24 Hour_SS_SLR	DuWapMH_306	9.28	9.54
25 Year 24 Hour_SS_SLR	DuWapMH_307	10.43	9.38
25 Year 24 Hour_SS_SLR	DuWapMH_308	9.28	9.53
25 Year 24 Hour_SS_SLR	DuWapMH_309	12.55	13.55
25 Year 24 Hour_SS_SLR	DuWapMH_31	7.46	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_310	12.5	13.52
25 Year 24 Hour_SS_SLR	DuWapMH_311	11.8	13.35
25 Year 24 Hour_SS_SLR	DuWapMH_312	11.5	13.33
25 Year 24 Hour_SS_SLR	DuWapMH_313	5.12	9.61
25 Year 24 Hour_SS_SLR	DuWapMH_315	21.53	23.34
25 Year 24 Hour_SS_SLR	DuWapMH_317	22.08	23.34
25 Year 24 Hour_SS_SLR	DuWapMH_318	13	11.26
25 Year 24 Hour_SS_SLR	DuWapMH_32	11	9.68
25 Year 24 Hour_SS_SLR	DuWapMH_322	10.96	9.65
25 Year 24 Hour_SS_SLR	DuWapMH_329	20.4	17.27
25 Year 24 Hour_SS_SLR	DuWapMH_33	7.04	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_330	8.8	9.22
25 Year 24 Hour_SS_SLR	DuWapMH_331	11.1	12.98
25 Year 24 Hour_SS_SLR	DuWapMH_332	9	12.92
25 Year 24 Hour_SS_SLR	DuWapMH_333	10.1	12.88

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_334	8.4	8.96
25 Year 24 Hour_SS_SLR	DuWapMH_335	5.5	8.88
25 Year 24 Hour_SS_SLR	DuWapMH_336	14.1	12.73
25 Year 24 Hour_SS_SLR	DuWapMH_337	10.7	12.72
25 Year 24 Hour_SS_SLR	DuWapMH_338	10.1	11.92
25 Year 24 Hour_SS_SLR	DuWapMH_339	9.5	9.65
25 Year 24 Hour_SS_SLR	DuWapMH_34	7.24	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_341	9.07	10.07
25 Year 24 Hour_SS_SLR	DuWapMH_342	8.23	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_343	11.25	13.02
25 Year 24 Hour_SS_SLR	DuWapMH_344	11.75	13.07
25 Year 24 Hour_SS_SLR	DuWapMH_346	12.47	13.16
25 Year 24 Hour_SS_SLR	DuWapMH_351	7.5	9.68
25 Year 24 Hour_SS_SLR	DuWapMH_352	8.96	11.14
25 Year 24 Hour_SS_SLR	DuWapMH_353	8.81	10.77
25 Year 24 Hour_SS_SLR	DuWapMH_354	8.44	10.42
25 Year 24 Hour_SS_SLR	DuWapMH_355	9.32	11.53
25 Year 24 Hour_SS_SLR	DuWapMH_356	9.23	11.91
25 Year 24 Hour_SS_SLR	DuWapMH_357	9.13	12.23
25 Year 24 Hour_SS_SLR	DuWapMH_358	8.98	12.57
25 Year 24 Hour_SS_SLR	DuWapMH_359	9.31	12.73
25 Year 24 Hour_SS_SLR	DuWapMH_36	9.78	10.25
25 Year 24 Hour_SS_SLR	DuWapMH_360	12.25	11.42
25 Year 24 Hour_SS_SLR	DuWapMH_361	16.9	14.85
25 Year 24 Hour_SS_SLR	DuWapMH_362	17.5	16.44
25 Year 24 Hour_SS_SLR	DuWapMH_363	7.7	10.28
25 Year 24 Hour_SS_SLR	DuWapMH_364	10.38	9.38
25 Year 24 Hour_SS_SLR	DuWapMH_366	8.87	9.2
25 Year 24 Hour_SS_SLR	DuWapMH_367	11.5	9.43
25 Year 24 Hour_SS_SLR	DuWapMH_368	12	9.98
25 Year 24 Hour_SS_SLR	DuWapMH_369	12	9.74
25 Year 24 Hour_SS_SLR	DuWapMH_370	11.25	11.32
25 Year 24 Hour_SS_SLR	DuWapMH_371	12.1	13.5
25 Year 24 Hour_SS_SLR	DuWapMH_372	11.4	12.73
25 Year 24 Hour_SS_SLR	DuWapMH_373	6.6	8.88
25 Year 24 Hour_SS_SLR	DuWapMH_374	4	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_375	8.8	9.23
25 Year 24 Hour_SS_SLR	DuWapMH_377	8.14	9.18
25 Year 24 Hour_SS_SLR	DuWapMH_379	10.2	11.84
25 Year 24 Hour_SS_SLR	DuWapMH_380	7.4	11.83
25 Year 24 Hour_SS_SLR	DuWapMH_381	8.25	9.68
25 Year 24 Hour_SS_SLR	DuWapMH_382	6.1	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_383	6.1	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_384	8.3	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_385	7.9	10.28
25 Year 24 Hour_SS_SLR	DuWapMH_386	19.1	18.28

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_387	11.69	12.7
25 Year 24 Hour_SS_SLR	DuWapMH_388	12	12.46
25 Year 24 Hour_SS_SLR	DuWapMH_390	14.6	14.33
25 Year 24 Hour_SS_SLR	DuWapMH_391	14.7	14.81
25 Year 24 Hour_SS_SLR	DuWapMH_392	15.3	15.15
25 Year 24 Hour_SS_SLR	DuWapMH_393	14.8	13.77
25 Year 24 Hour_SS_SLR	DuWapMH_394	12.61	13.07
25 Year 24 Hour_SS_SLR	DuWapMH_396	3	9.6
25 Year 24 Hour_SS_SLR	DuWapMH_397	7.81	6.81
25 Year 24 Hour_SS_SLR	DuWapMH_398	8.26	7.26
25 Year 24 Hour_SS_SLR	DuWapMH_399	8.03	7.03
25 Year 24 Hour_SS_SLR	DuWapMH_40	11.93	10.07
25 Year 24 Hour_SS_SLR	DuWapMH_400	7.97	6.97
25 Year 24 Hour_SS_SLR	DuWapMH_402	13.6	11.23
25 Year 24 Hour_SS_SLR	DuWapMH_403	8.54	7.54
25 Year 24 Hour_SS_SLR	DuWapMH_404	12	12.87
25 Year 24 Hour_SS_SLR	DuWapMH_405	18.6	19.37
25 Year 24 Hour_SS_SLR	DuWapMH_406	18.64	19.37
25 Year 24 Hour_SS_SLR	DuWapMH_407	18.67	19.37
25 Year 24 Hour_SS_SLR	DuWapMH_408	4.6	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_409	11.7	13.35
25 Year 24 Hour_SS_SLR	DuWapMH_41	8.44	7.44
25 Year 24 Hour_SS_SLR	DuWapMH_410	12.8	13.54
25 Year 24 Hour_SS_SLR	DuWapMH_411	12.4	13.57
25 Year 24 Hour_SS_SLR	DuWapMH_412	14.01	8.68
25 Year 24 Hour_SS_SLR	DuWapMH_413	6	9.6
25 Year 24 Hour_SS_SLR	DuWapMH_414	1.5	9.61
25 Year 24 Hour_SS_SLR	DuWapMH_415	6.35	9.31
25 Year 24 Hour_SS_SLR	DuWapMH_416	16	14.26
25 Year 24 Hour_SS_SLR	DuWapMH_417	9.7	10.43
25 Year 24 Hour_SS_SLR	DuWapMH_418	11.4	13.33
25 Year 24 Hour_SS_SLR	DuWapMH_419	11.41	10.16
25 Year 24 Hour_SS_SLR	DuWapMH_42	16.56	18.83
25 Year 24 Hour_SS_SLR	DuWapMH_420	7.51	9.98
25 Year 24 Hour_SS_SLR	DuWapMH_421	5.58	8.68
25 Year 24 Hour_SS_SLR	DuWapMH_424	6.9	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_425	4.5	9.61
25 Year 24 Hour_SS_SLR	DuWapMH_426	10.8	12.46
25 Year 24 Hour_SS_SLR	DuWapMH_429	4.06	8.85
25 Year 24 Hour_SS_SLR	DuWapMH_431	6.2	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_432	8.5	8.97
25 Year 24 Hour_SS_SLR	DuWapMH_433	7.5	9.51
25 Year 24 Hour_SS_SLR	DuWapMH_434	7.7	9.79
25 Year 24 Hour_SS_SLR	DuWapMH_436	4.7	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_437	11	12.24
25 Year 24 Hour_SS_SLR	DuWapMH_438	7.81	9.31

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_440	6	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_441	6.2	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_444	7.5	8.85
25 Year 24 Hour_SS_SLR	DuWapMH_445	6.5	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_446	11.8	9.71
25 Year 24 Hour_SS_SLR	DuWapMH_448	8.16	9.98
25 Year 24 Hour_SS_SLR	DuWapMH_45	11.96	12.27
25 Year 24 Hour_SS_SLR	DuWapMH_454	13.63	8.68
25 Year 24 Hour_SS_SLR	DuWapMH_46	11.34	13.3
25 Year 24 Hour_SS_SLR	DuWapMH_462	8.8	5.82
25 Year 24 Hour_SS_SLR	DuWapMH_47	15.76	15.05
25 Year 24 Hour_SS_SLR	DuWapMH_48	17.11	17.59
25 Year 24 Hour_SS_SLR	DuWapMH_500	10.8	9.21
25 Year 24 Hour_SS_SLR	DuWapMH_51	14.04	15.11
25 Year 24 Hour_SS_SLR	DuWapMH_52	17.38	17.17
25 Year 24 Hour_SS_SLR	DuWapMH_53	10.3	11.38
25 Year 24 Hour_SS_SLR	DuWapMH_55	8.5	8.63
25 Year 24 Hour_SS_SLR	DuWapMH_56	5.23	8.51
25 Year 24 Hour_SS_SLR	DuWapMH_57	8.61	8.7
25 Year 24 Hour_SS_SLR	DuWapMH_59	8.1	8.74
25 Year 24 Hour_SS_SLR	DuWapMH_60	6.48	8.63
25 Year 24 Hour_SS_SLR	DuWapMH_61	14.18	14.62
25 Year 24 Hour_SS_SLR	DuWapMH_62	8.05	8.76
25 Year 24 Hour_SS_SLR	DuWapMH_63	7.03	8.65
25 Year 24 Hour_SS_SLR	DuWapMH_64	7.06	8.65
25 Year 24 Hour_SS_SLR	DuWapMH_65	7.2	8.68
25 Year 24 Hour_SS_SLR	DuWapMH_66	7.39	8.77
25 Year 24 Hour_SS_SLR	DuWapMH_69	6.21	9.55
25 Year 24 Hour_SS_SLR	DuWapMH_70	19.9	16.09
25 Year 24 Hour_SS_SLR	DuWapMH_71	6.53	8.75
25 Year 24 Hour_SS_SLR	DuWapMH_73	8.28	8.81
25 Year 24 Hour_SS_SLR	DuWapMH_74	8.02	8.74
25 Year 24 Hour_SS_SLR	DuWapMH_75	14.77	10.49
25 Year 24 Hour_SS_SLR	DuWapMH_76	16.89	13.55
25 Year 24 Hour_SS_SLR	DuWapMH_77	14.34	19.15
25 Year 24 Hour_SS_SLR	DuWapMH_79	15.74	15.44
25 Year 24 Hour_SS_SLR	DuWapMH_8	19.09	16.25
25 Year 24 Hour_SS_SLR	DuWapMH_80	16.36	15.75
25 Year 24 Hour_SS_SLR	DuWapMH_81	8.61	8.9
25 Year 24 Hour_SS_SLR	DuWapMH_82	8.63	8.82
25 Year 24 Hour_SS_SLR	DuWapMH_84	8.1	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_85	7.43	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_86	6.38	9.63
25 Year 24 Hour_SS_SLR	DuWapMH_87	11.7	12.62
25 Year 24 Hour_SS_SLR	DuWapMH_88	8.27	9.04
25 Year 24 Hour_SS_SLR	DuWapMH_900	9.06	10.05

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_92	9.15	9.22
25 Year 24 Hour_SS_SLR	DuWapMH_93	8.99	8.85
25 Year 24 Hour_SS_SLR	DuWapMH_95	11.72	11.18
25 Year 24 Hour_SS_SLR	DuWapMH_96	17.49	17.47
25 Year 24 Hour_SS_SLR	DuWapMH_97	17.13	17.37
25 Year 24 Hour_SS_SLR	DuWapMH_98	17.15	16.45
25 Year 24 Hour_SS_SLR	DuWapMH_99	10.37	12.01
25 Year 24 Hour_SS_SLR	DuWapN_1	19.32	20.12
25 Year 24 Hour_SS_SLR	DuWapN_10	7.53	8.71
25 Year 24 Hour_SS_SLR	DuWapN_101	8.5	8.29
25 Year 24 Hour_SS_SLR	DuWapN_102	11.02	10.58
25 Year 24 Hour_SS_SLR	DuWapN_103	17.5	18.43
25 Year 24 Hour_SS_SLR	DuWapN_105	12.94	13.75
25 Year 24 Hour_SS_SLR	DuWapN_106	11.39	10.29
25 Year 24 Hour_SS_SLR	DuWapN_107	5.73	8.33
25 Year 24 Hour_SS_SLR	DuWapN_11a	13.6	12.79
25 Year 24 Hour_SS_SLR	DuWapN_11b	16.17	16.17
25 Year 24 Hour_SS_SLR	DuWapN_12	17.02	17.93
25 Year 24 Hour_SS_SLR	DuWapN_13	5.32	8.88
25 Year 24 Hour_SS_SLR	DuWapN_14	6.72	8.37
25 Year 24 Hour_SS_SLR	DuWapN_15	8.48	8.87
25 Year 24 Hour_SS_SLR	DuWapN_16	13.24	10.06
25 Year 24 Hour_SS_SLR	DuWapN_17	8.81	9.68
25 Year 24 Hour_SS_SLR	DuWapN_18	13.41	13.96
25 Year 24 Hour_SS_SLR	DuWapN_19a	8.87	9.1
25 Year 24 Hour_SS_SLR	DuWapN_19b	8.36	8.92
25 Year 24 Hour_SS_SLR	DuWapN_2	7.62	8.75
25 Year 24 Hour_SS_SLR	DuWapN_20	8.5	9.52
25 Year 24 Hour_SS_SLR	DuWapN_201	11.82	11.46
25 Year 24 Hour_SS_SLR	DuWapN_207b	7.94	8.66
25 Year 24 Hour_SS_SLR	DuWapN_209b	6.82	8.87
25 Year 24 Hour_SS_SLR	DuWapN_21	6.82	8.86
25 Year 24 Hour_SS_SLR	DuWapN_210	8.5	8.95
25 Year 24 Hour_SS_SLR	DuWapN_211a	16.36	17.54
25 Year 24 Hour_SS_SLR	DuWapN_211b	14.11	14.59
25 Year 24 Hour_SS_SLR	DuWapN_212	16.72	17.65
25 Year 24 Hour_SS_SLR	DuWapN_216	9.51	10
25 Year 24 Hour_SS_SLR	DuWapN_219a	7.58	8.92
25 Year 24 Hour_SS_SLR	DuWapN_219b	7.68	8.92
25 Year 24 Hour_SS_SLR	DuWapN_22	9.33	9.95
25 Year 24 Hour_SS_SLR	DuWapN_222	8.83	9.17
25 Year 24 Hour_SS_SLR	DuWapN_224	8.56	9.42
25 Year 24 Hour_SS_SLR	DuWapN_225	5.66	8.16
25 Year 24 Hour_SS_SLR	DuWapN_229	16.94	17.2
25 Year 24 Hour_SS_SLR	DuWapN_23	7.7	8.6
25 Year 24 Hour_SS_SLR	DuWapN_230	9.69	10.87

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapN_234	10.36	10.43
25 Year 24 Hour_SS_SLR	DuWapN_238	7.34	7.57
25 Year 24 Hour_SS_SLR	DuWapN_24	8.68	9.06
25 Year 24 Hour_SS_SLR	DuWapN_240	6.57	8.98
25 Year 24 Hour_SS_SLR	DuWapN_241	6.7	9.04
25 Year 24 Hour_SS_SLR	DuWapN_25	7.05	9.01
25 Year 24 Hour_SS_SLR	DuWapN_250	11.05	11.32
25 Year 24 Hour_SS_SLR	DuWapN_257	8.09	9.24
25 Year 24 Hour_SS_SLR	DuWapN_26	11.23	12.24
25 Year 24 Hour_SS_SLR	DuWapN_263	9.5	9.62
25 Year 24 Hour_SS_SLR	DuWapN_267	13.91	14.13
25 Year 24 Hour_SS_SLR	DuWapN_27	12.72	12.46
25 Year 24 Hour_SS_SLR	DuWapN_270	8.09	8.74
25 Year 24 Hour_SS_SLR	DuWapN_273	12.96	13.53
25 Year 24 Hour_SS_SLR	DuWapN_274	11.94	12.49
25 Year 24 Hour_SS_SLR	DuWapN_28	4.64	9.61
25 Year 24 Hour_SS_SLR	DuWapN_29	17.53	17.73
25 Year 24 Hour_SS_SLR	DuWapN_3	17.18	17.33
25 Year 24 Hour_SS_SLR	DuWapN_30	11.8	12.14
25 Year 24 Hour_SS_SLR	DuWapN_31	7.21	8.02
25 Year 24 Hour_SS_SLR	DuWapN_312	17.9	18.51
25 Year 24 Hour_SS_SLR	DuWapN_32	8.53	8.91
25 Year 24 Hour_SS_SLR	DuWapN_324	9.26	8.87
25 Year 24 Hour_SS_SLR	DuWapN_33	5.11	7.82
25 Year 24 Hour_SS_SLR	DuWapN_334	13.27	15.43
25 Year 24 Hour_SS_SLR	DuWapN_338	15.5	15.98
25 Year 24 Hour_SS_SLR	DuWapN_34	18.3	19.29
25 Year 24 Hour_SS_SLR	DuWapN_35a	8.23	9.18
25 Year 24 Hour_SS_SLR	DuWapN_35b	10.35	10.52
25 Year 24 Hour_SS_SLR	DuWapN_35c	10.67	10.81
25 Year 24 Hour_SS_SLR	DuWapN_36	23.18	23.72
25 Year 24 Hour_SS_SLR	DuWapN_37	23.26	23.69
25 Year 24 Hour_SS_SLR	DuWapN_38	20.24	19.38
25 Year 24 Hour_SS_SLR	DuWapN_4	18.24	18.44
25 Year 24 Hour_SS_SLR	DuWapN_40	10.1	10.26
25 Year 24 Hour_SS_SLR	DuWapN_41	9.34	10.08
25 Year 24 Hour_SS_SLR	DuWapN_42	16.92	16.97
25 Year 24 Hour_SS_SLR	DuWapN_43	9.63	9.91
25 Year 24 Hour_SS_SLR	DuWapN_44	9.76	9.79
25 Year 24 Hour_SS_SLR	DuWapN_45	10.73	10.9
25 Year 24 Hour_SS_SLR	DuWapN_46	17.75	17.11
25 Year 24 Hour_SS_SLR	DuWapN_47	16.9	16.92
25 Year 24 Hour_SS_SLR	DuWapN_48	12.98	13.26
25 Year 24 Hour_SS_SLR	DuWapN_49	15.7	16.31
25 Year 24 Hour_SS_SLR	DuWapN_5	11.96	12.14
25 Year 24 Hour_SS_SLR	DuWapN_50	13.02	13.37

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapN_51	11.13	12.44
25 Year 24 Hour_SS_SLR	DuWapN_52	10.45	11.58
25 Year 24 Hour_SS_SLR	DuWapN_53	24.41	24.53
25 Year 24 Hour_SS_SLR	DuWapN_54	10.4	10.57
25 Year 24 Hour_SS_SLR	DuWapN_55	8.51	8.88
25 Year 24 Hour_SS_SLR	DuWapN_56	6.64	9.61
25 Year 24 Hour_SS_SLR	DuWapN_57	9.17	9.41
25 Year 24 Hour_SS_SLR	DuWapN_58	40.43	20.58
25 Year 24 Hour_SS_SLR	DuWapN_59	11.39	12.73
25 Year 24 Hour_SS_SLR	DuWapN_6	13.41	13.52
25 Year 24 Hour_SS_SLR	DuWapN_61	12.04	12.46
25 Year 24 Hour_SS_SLR	DuWapN_62	11.86	12.53
25 Year 24 Hour_SS_SLR	DuWapN_63	9.3	9.66
25 Year 24 Hour_SS_SLR	DuWapN_64	7.71	8.74
25 Year 24 Hour_SS_SLR	DuWapN_65	10.77	10.97
25 Year 24 Hour_SS_SLR	DuWapN_66	8.22	9.05
25 Year 24 Hour_SS_SLR	DuWapN_67	14.52	15.16
25 Year 24 Hour_SS_SLR	DuWapN_70	8.24	8.79
25 Year 24 Hour_SS_SLR	DuWapN_71	7.17	9.02
25 Year 24 Hour_SS_SLR	DuWapN_72	10.57	11.02
25 Year 24 Hour_SS_SLR	DuWapN_73	15.46	15.57
25 Year 24 Hour_SS_SLR	DuWapN_74	22.47	23.64
25 Year 24 Hour_SS_SLR	DuWapN_76	3.99	7.9
25 Year 24 Hour_SS_SLR	DuWapN_77	5.08	8.74
25 Year 24 Hour_SS_SLR	DuWapN_78	6.33	8.7
25 Year 24 Hour_SS_SLR	DuWapN_79	12.34	11.21
25 Year 24 Hour_SS_SLR	DuWapN_7a	7.78	9.14
25 Year 24 Hour_SS_SLR	DuWapN_7b	8.56	8.68
25 Year 24 Hour_SS_SLR	DuWapN_80	15.4	14.33
25 Year 24 Hour_SS_SLR	DuWapN_82	10.37	11.15
25 Year 24 Hour_SS_SLR	DuWapN_84	2.72	8.87
25 Year 24 Hour_SS_SLR	DuWapN_9	9.94	10.25
25 Year 24 Hour_SS_SLR	DuWapN_90	8.67	11.19
25 Year 24 Hour_SS_SLR	DuWapN_91	6.12	8.99
25 Year 24 Hour_SS_SLR	DuWapN_93	10.21	9.39
25 Year 24 Hour_SS_SLR	DuWapN_94	9.98	9.49
25 Year 24 Hour_SS_SLR	DuWapN_95	10.8	12.95
25 Year 24 Hour_SS_SLR	DuWapN_97	9.26	9.97
25 Year 24 Hour_SS_SLR	DuWapN_98	13.38	10.16
25 Year 24 Hour_SS_SLR	DuWapN_9b	7.48	8.38

Appendix K Link Maximum Flow Result Summary

APPENDIX-K Existing Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
Channel_1	25 Year 24 Hour_SS_SLR	DuWapMH_146	DuWapMH_329	12.34
Channel_100	25 Year 24 Hour_SS_SLR	DuWapMH_454	DuWapMH_412	38.99
Channel_101	25 Year 24 Hour_SS_SLR	DuWapN_28	DuWapMH_413	620.48
Channel_102	25 Year 24 Hour_SS_SLR	DuWapN_56	DuWapMH_414	233.1
Channel_103	25 Year 24 Hour_SS_SLR	DuWapMH_192	DuWapMH_415	17.96
Channel_104	25 Year 24 Hour_SS_SLR	DuWapMH_194	DuWapMH_416	27.15
Channel_105	25 Year 24 Hour_SS_SLR	DuWapMH_223	DuWapMH_417	17.77
Channel_106	25 Year 24 Hour_SS_SLR	DuWapMH_312	DuWapMH_418	16.44
Channel_107	25 Year 24 Hour_SS_SLR	DuWapMH_288	DuWapMH_119	12.45
Channel_108	25 Year 24 Hour_SS_SLR	DuWapMH_419	DuWapMH_206	51
Channel_109	25 Year 24 Hour_SS_SLR	DuWapMH_420	DuWapMH_448	23.51
Channel_11	25 Year 24 Hour_SS_SLR	DuWapMH_153	DuWapMH_337	23.14
Channel_110	25 Year 24 Hour_SS_SLR	DuWapMH_412	DuWapMH_421	15.06
Channel_111	25 Year 24 Hour_SS_SLR	DuWapN_209b	DuWapN_84	18.24
Channel_112	25 Year 24 Hour_SS_SLR	DuWapMH_233	DuWapMH_241	9.86
Channel_114	25 Year 24 Hour_SS_SLR	DuWapMH_240	DuWapMH_424	29.65
Channel_115	25 Year 24 Hour_SS_SLR	DuWapMH_313	DuWapMH_425	27.18
Channel_116	25 Year 24 Hour_SS_SLR	DuWapN_27	DuWapMH_426	677.14
Channel_118	25 Year 24 Hour_SS_SLR	DuWapMH_267	DuWapN_71	45.07
Channel_119	25 Year 24 Hour_SS_SLR	DuWapMH_186	DuWapMH_445	230.96
Channel_12	25 Year 24 Hour_SS_SLR	DuWapMH_175	DuWapMH_338	27.66
Channel_120	25 Year 24 Hour_SS_SLR	DuWapMH_222	DuWapMH_429	291.38
Channel_121	25 Year 24 Hour_SS_SLR	DuWapMH_156	DuWapN_241	176.52
Channel_122	25 Year 24 Hour_SS_SLR	DuWapN_23	DuWapMH_140	52.23
Channel_123	25 Year 24 Hour_SS_SLR	DuWapMH_445	DuWapMH_431	255.84
Channel_124	25 Year 24 Hour_SS_SLR	DuWapMH_444	DuWapN_21	290.6
Channel_125	25 Year 24 Hour_SS_SLR	DuWapMH_249	DuWapMH_432	72.52
Channel_126	25 Year 24 Hour_SS_SLR	DuWapMH_258	DuWapMH_433	37.27
Channel_127	25 Year 24 Hour_SS_SLR	DuWapMH_221	DuWapMH_434	8.43
Channel_128	25 Year 24 Hour_SS_SLR	DuWapMH_305	DuWapN_234	15.55
Channel_129	25 Year 24 Hour_SS_SLR	DuWapMH_244	DuWapMH_243	151.2
Channel_13	25 Year 24 Hour_SS_SLR	DuWapMH_322	DuWapMH_339	32.28
Channel_130	25 Year 24 Hour_SS_SLR	DuWapMH_243	DuWapMH_436	372.05
Channel_131	25 Year 24 Hour_SS_SLR	DuWapN_26	DuWapMH_437	62.53
Channel_132	25 Year 24 Hour_SS_SLR	DuWapMH_180	DuWapMH_413	47.2
Channel_133	25 Year 24 Hour_SS_SLR	DuWapMH_415	DuWapMH_438	16.15
Channel_134	25 Year 24 Hour_SS_SLR	DuWapMH_335	DuWapN_13	389.97
Channel_135	25 Year 24 Hour_SS_SLR	DuWapMH_191	DuWapMH_396	576.8
Channel_136	25 Year 24 Hour_SS_SLR	DuWapMH_396	DuWapMH_413	659.38
Channel_137	25 Year 24 Hour_SS_SLR	DuWapMH_413	DuWapMH_414	1275.02
Channel_138	25 Year 24 Hour_SS_SLR	DuWapMH_414	DuWapMH_425	1417.87
Channel_139	25 Year 24 Hour_SS_SLR	DuWapMH_425	DuWapMH_424	1476.98
Channel_14	25 Year 24 Hour_SS_SLR	DuWapMH_366	DuWapMH_154	91.29
Channel_147	25 Year 24 Hour_SS_SLR	DuWapMH_228	DuWapMH_445	15.29
Channel_148	25 Year 24 Hour_SS_SLR	DuWapMH_431	DuWapMH_441	252.92
Channel_15	25 Year 24 Hour_SS_SLR	DuWapMH_277	DuWapN_32	196.15
Channel_16	25 Year 24 Hour_SS_SLR	DuWapN_241	DuWapMH_282	208.42
Channel_17	25 Year 24 Hour_SS_SLR	DuWapMH_235	DuWapN_41	22.35

APPENDIX-K Existing Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
Channel_18	25 Year 24 Hour_SS_SLR	DuWapN_41	DuWapMH_341	20.81
Channel_19	25 Year 24 Hour_SS_SLR	DuWapMH_383	DuWapMH_342	154.63
Channel_2	25 Year 24 Hour_SS_SLR	DuWapMH_317	DuWapMH_315	89.27
Channel_20	25 Year 24 Hour_SS_SLR	DuWapMH_261	DuWapMH_343	15.99
Channel_201	25 Year 24 Hour_SS_SLR	DuWapN_21	DuWapMH_383	344.56
Channel_202	25 Year 24 Hour_SS_SLR	DuWapMH_408	DuWapMH_374	382.11
Channel_203	25 Year 24 Hour_SS_SLR	DuWapN_61	DuWapMH_199	58.11
Channel_204	25 Year 24 Hour_SS_SLR	DuWapMH_293	DuWapMH_197	44.63
Channel_205	25 Year 24 Hour_SS_SLR	DuWapMH_281	DuWapMH_334	15.37
Channel_207	25 Year 24 Hour_SS_SLR	DuWapMH_236	DuWapMH_222	438.39
Channel_208	25 Year 24 Hour_SS_SLR	DuWapMH_441	DuWapMH_236	332.29
Channel_209	25 Year 24 Hour_SS_SLR	DuWapMH_278	DuWapMH_287	215.87
Channel_21	25 Year 24 Hour_SS_SLR	DuWapMH_262	DuWapMH_344	16.98
Channel_210	25 Year 24 Hour_SS_SLR	DuWapMH_287	DuWapMH_186	223.59
Channel_211	25 Year 24 Hour_SS_SLR	DuWapMH_119	DuWapMH_419	7.73
Channel_212	25 Year 24 Hour_SS_SLR	DuWapMH_424	DuWapMH_440	1536.2
Channel_213	25 Year 24 Hour_SS_SLR	DuWapMH_184	DuWapMH_335	2056.69
Channel_214	25 Year 24 Hour_SS_SLR	DuWapMH_289	DuWapN_13	100.21
Channel_22	25 Year 24 Hour_SS_SLR	DuWapMH_264	DuWapMH_346	17.72
Channel_26	25 Year 24 Hour_SS_SLR	DuWapMH_157	DuWapN_273	15.77
Channel_28	25 Year 24 Hour_SS_SLR	DuWapMH_212	DuWapMH_351	32.24
Channel_29	25 Year 24 Hour_SS_SLR	DuWapMH_250	DuWapMH_352	23.62
Channel_3	25 Year 24 Hour_SS_SLR	DuWapMH_196	DuWapMH_330	11.04
Channel_30	25 Year 24 Hour_SS_SLR	DuWapMH_251	DuWapMH_353	10.62
Channel_31	25 Year 24 Hour_SS_SLR	DuWapMH_252	DuWapMH_354	43.1
Channel_32	25 Year 24 Hour_SS_SLR	DuWapMH_253	DuWapMH_355	18.6
Channel_33	25 Year 24 Hour_SS_SLR	DuWapMH_255	DuWapMH_356	13.45
Channel_34	25 Year 24 Hour_SS_SLR	DuWapMH_254	DuWapMH_357	13.79
Channel_35	25 Year 24 Hour_SS_SLR	DuWapMH_256	DuWapMH_358	11.42
Channel_36	25 Year 24 Hour_SS_SLR	DuWapMH_257	DuWapMH_359	33.09
Channel_37	25 Year 24 Hour_SS_SLR	DuWapMH_144	DuWapMH_360	20.55
Channel_38	25 Year 24 Hour_SS_SLR	DuWapMH_268	DuWapMH_361	9.4
Channel_39	25 Year 24 Hour_SS_SLR	DuWapMH_269	DuWapMH_362	12.16
Channel_4	25 Year 24 Hour_SS_SLR	DuWapMH_260	DuWapMH_331	14.1
Channel_40	25 Year 24 Hour_SS_SLR	DuWapMH_219	DuWapMH_334	73.34
Channel_41	25 Year 24 Hour_SS_SLR	DuWapMH_174	DuWapMH_363	10.58
Channel_42	25 Year 24 Hour_SS_SLR	DuWapMH_177	DuWapMH_446	20.38
Channel_43	25 Year 24 Hour_SS_SLR	DuWapMH_307	DuWapMH_364	45.44
Channel_44	25 Year 24 Hour_SS_SLR	DuWapMH_500	DuWapMH_299	68.77
Channel_45	25 Year 24 Hour_SS_SLR	DuWapMH_299	DuWapMH_366	170.94
Channel_46	25 Year 24 Hour_SS_SLR	DuWapMH_162	DuWapMH_367	50.44
Channel_47	25 Year 24 Hour_SS_SLR	DuWapMH_197	DuWapMH_368	50.6
Channel_48	25 Year 24 Hour_SS_SLR	DuWapMH_301	DuWapMH_369	64.53
Channel_49	25 Year 24 Hour_SS_SLR	DuWapN_250	DuWapMH_370	49.52
Channel_5	25 Year 24 Hour_SS_SLR	DuWapMH_259	DuWapMH_332	9.02
Channel_51	25 Year 24 Hour_SS_SLR	DuWapMH_290	DuWapMH_371	7.87
Channel_52	25 Year 24 Hour_SS_SLR	DuWapN_59	DuWapMH_372	44.33
Channel_53	25 Year 24 Hour_SS_SLR	DuWapN_13	DuWapMH_373	544.86

APPENDIX-K Existing Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
Channel_54	25 Year 24 Hour_SS_SLR	DuWapMH_246	DuWapMH_408	373.03
Channel_55	25 Year 24 Hour_SS_SLR	DuWapMH_189	DuWapMH_375	4.59
Channel_57	25 Year 24 Hour_SS_SLR	DuWapMH_302	DuWapMH_123	0.93
Channel_58	25 Year 24 Hour_SS_SLR	DuWapN_35a	DuWapMH_377	6.05
Channel_59	25 Year 24 Hour_SS_SLR	DuWapMH_123	DuWapN_222	3.94
Channel_6	25 Year 24 Hour_SS_SLR	DuWapMH_3	DuWapMH_333	11.44
Channel_61	25 Year 24 Hour_SS_SLR	DuWapMH_190	DuWapMH_379	58.63
Channel_62	25 Year 24 Hour_SS_SLR	DuWapMH_274	DuWapMH_380	162.37
Channel_63	25 Year 24 Hour_SS_SLR	DuWapN_17	DuWapMH_381	27.76
Channel_64	25 Year 24 Hour_SS_SLR	DuWapMH_384	DuWapMH_382	34.23
Channel_65	25 Year 24 Hour_SS_SLR	DuWapMH_382	DuWapMH_383	57.95
Channel_66	25 Year 24 Hour_SS_SLR	DuWapMH_171	DuWapMH_384	36.36
Channel_67	25 Year 24 Hour_SS_SLR	DuWapMH_172	DuWapMH_383	15.75
Channel_68	25 Year 24 Hour_SS_SLR	DuWapMH_173	DuWapMH_363	532.6
Channel_69	25 Year 24 Hour_SS_SLR	DuWapMH_363	DuWapMH_385	40.14
Channel_7	25 Year 24 Hour_SS_SLR	DuWapMH_282	DuWapMH_334	152.89
Channel_70	25 Year 24 Hour_SS_SLR	DuWapMH_270	DuWapMH_386	10.84
Channel_71	25 Year 24 Hour_SS_SLR	DuWapMH_224	DuWapMH_387	7.26
Channel_72	25 Year 24 Hour_SS_SLR	DuWapMH_336	DuWapMH_153	13.36
Channel_73	25 Year 24 Hour_SS_SLR	DuWapMH_199	DuWapMH_388	22.86
Channel_74	25 Year 24 Hour_SS_SLR	DuWapMH_179	DuWapMH_389	125.21
Channel_75	25 Year 24 Hour_SS_SLR	DuWapMH_296	DuWapMH_390	7.1
Channel_76	25 Year 24 Hour_SS_SLR	DuWapMH_295	DuWapMH_391	8.74
Channel_77	25 Year 24 Hour_SS_SLR	DuWapMH_297	DuWapMH_392	7.9
Channel_78	25 Year 24 Hour_SS_SLR	DuWapMH_294	DuWapMH_393	7.89
Channel_79	25 Year 24 Hour_SS_SLR	DuWapMH_292	DuWapMH_394	9.19
Channel_8	25 Year 24 Hour_SS_SLR	DuWapMH_245	DuWapMH_184	460.12
Channel_80	25 Year 24 Hour_SS_SLR	DuWapMH_181	DuWapMH_414	26.03
Channel_81	25 Year 24 Hour_SS_SLR	DuWapMH_238	DuWapMH_396	58.54
Channel_82	25 Year 24 Hour_SS_SLR	DuWapMH_397	DuWapMH_462	0
Channel_83	25 Year 24 Hour_SS_SLR	DuWapMH_398	DuWapMH_273	0
Channel_84	25 Year 24 Hour_SS_SLR	DuWapMH_272	DuWapMH_399	0
Channel_85	25 Year 24 Hour_SS_SLR	DuWapMH_400	DuWapMH_271	0
Channel_86	25 Year 24 Hour_SS_SLR	DuWapMH_182	DuWapN_225	28.15
Channel_87	25 Year 24 Hour_SS_SLR	DuWapMH_318	DuWapMH_402	20.12
Channel_88	25 Year 24 Hour_SS_SLR	DuWapMH_207	DuWapMH_318	11.95
Channel_89	25 Year 24 Hour_SS_SLR	DuWapN_238	DuWapMH_403	0
Channel_9	25 Year 24 Hour_SS_SLR	DuWapMH_128	DuWapMH_289	28.86
Channel_91	25 Year 24 Hour_SS_SLR	DuWapMH_405	DuWapMH_1	44.56
Channel_92	25 Year 24 Hour_SS_SLR	DuWapMH_406	DuWapMH_405	88.13
Channel_93	25 Year 24 Hour_SS_SLR	DuWapMH_407	DuWapMH_406	93.44
Channel_94	25 Year 24 Hour_SS_SLR	DuWapN_38	DuWapMH_407	118.61
Channel_95	25 Year 24 Hour_SS_SLR	DuWapMH_248	DuWapMH_408	11.79
Channel_96	25 Year 24 Hour_SS_SLR	DuWapMH_311	DuWapMH_409	13.11
Channel_97	25 Year 24 Hour_SS_SLR	DuWapMH_310	DuWapMH_141	21.54
Channel_98	25 Year 24 Hour_SS_SLR	DuWapMH_309	DuWapMH_410	26.4
Channel_99	25 Year 24 Hour_SS_SLR	DuWapMH_188	DuWapMH_411	8.48
DS_101	25 Year 24 Hour_SS_SLR	~~D~DS_101~N	DuWapMH_137	3.75

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
DS_102	25 Year 24 Hour_SS_SLR	~~D~DS_102~N	DuWapMH_107	11.69
DS_103	25 Year 24 Hour_SS_SLR	~~D~DS_103~N	DuWapMH_108	2.06
DS_105	25 Year 24 Hour_SS_SLR	~~D~DS_105~N	DuWapMH_136	2.11
DS_106	25 Year 24 Hour_SS_SLR	~~D~DS_106~N	DuWapMH_900	2.66
DS_107	25 Year 24 Hour_SS_SLR	~~D~DS_107~N	DuWapMH_130	7.19
DS_76	25 Year 24 Hour_SS_SLR	~~D~DS_76~N	DuWapMH_134	6.92
DS_77	25 Year 24 Hour_SS_SLR	~~D~DS_77~N	DuWapN_78	25.15
DS_78	25 Year 24 Hour_SS_SLR	~~D~DS_78~N	DuWapMH_135	20.09
DS_79	25 Year 24 Hour_SS_SLR	~~D~DS_79~N	DuWapMH_95	9.93
DS_80	25 Year 24 Hour_SS_SLR	~~D~DS_80~N	DuWapMH_235	22.71
DS_82	25 Year 24 Hour_SS_SLR	~~D~DS_82~N	DuWapMH_449	20.36
DS_84	25 Year 24 Hour_SS_SLR	~~D~DS_84~N	DuWapMH_128	19.28
DS_90	25 Year 24 Hour_SS_SLR	~~D~DS_90~N	DuWapMH_129	9.93
DS_91	25 Year 24 Hour_SS_SLR	~~D~DS_91~N	DuWapMH_121	8.61
DS_93a	25 Year 24 Hour_SS_SLR	~~D~DS_93a~N	DuWapMH_132	8.31
DS_93b	25 Year 24 Hour_SS_SLR	~~D~DS_93b~N	DuWapMH_131	4.55
DS_94	25 Year 24 Hour_SS_SLR	~~D~DS_94~N	DuWapMH_133	6.28
DS_95	25 Year 24 Hour_SS_SLR	~~D~DS_95~N	DuWapMH_53	10.82
DS_97	25 Year 24 Hour_SS_SLR	~~D~DS_97~N	DuWapMH_143	6.11
DS_98	25 Year 24 Hour_SS_SLR	~~D~DS_98~N	DuWapMH_119	1.27
L-0100P	25 Year 24 Hour_SS_SLR	DuWapN_4	DuWapN_103	3.76
L-0120P	25 Year 24 Hour_SS_SLR	DuWapMH_101	DuWapMH_310	2.6
L-0130P	25 Year 24 Hour_SS_SLR	DuWapN_18	DuWapN_105	2.41
L-0150P	25 Year 24 Hour_SS_SLR	DuWapN_42	DuWapN_80	21.29
L-0160P	25 Year 24 Hour_SS_SLR	DuWapN_44	DuWapN_101	14.29
L-0180P	25 Year 24 Hour_SS_SLR	DuWapN_55	DuWapN_91	5.49
L-0200P	25 Year 24 Hour_SS_SLR	DuWapN_64	DuWapN_91	1.38
L-0270P	25 Year 24 Hour_SS_SLR	DuWapN_35c	DuWapN_106	4.19
L-0280P	25 Year 24 Hour_SS_SLR	DuWapMH_380	DuWapN_102	5.88
L-0290P	25 Year 24 Hour_SS_SLR	DuWapN_45	DuWapN_102	24.16
L-0340P	25 Year 24 Hour_SS_SLR	DuWapN_50	DuWapN_95	13.46
L-0360P	25 Year 24 Hour_SS_SLR	DuWapN_274	DuWapN_82	19.9
L-0380P	25 Year 24 Hour_SS_SLR	DuWapN_52	DuWapN_82	15.23
L-0390P	25 Year 24 Hour_SS_SLR	DuWapN_58	DuWapMH_51	37.72
L-0400P	25 Year 24 Hour_SS_SLR	DuWapN_58	DuWapMH_52	30.91
L-0420P	25 Year 24 Hour_SS_SLR	DuWapMH_225	DuWapN_79	9.38
L-0430P	25 Year 24 Hour_SS_SLR	DuWapN_46	DuWapMH_144	18.46
L-0440P	25 Year 24 Hour_SS_SLR	DuWapMH_448	DuWapN_97	6.61
L-0450P	25 Year 24 Hour_SS_SLR	DuWapN_54	DuWapN_97	9.72
L-0490P	25 Year 24 Hour_SS_SLR	DuWapMH_158	DuWapN_273	11.46
L-0500P	25 Year 24 Hour_SS_SLR	DuWapN_5	DuWapN_90	16.86
L-0570P	25 Year 24 Hour_SS_SLR	DuWapN_33	DuWapN_76	6.72
L-0580P	25 Year 24 Hour_SS_SLR	DuWapMH_134	DuWapMH_287	6.92
L-0590P	25 Year 24 Hour_SS_SLR	DuWapMH_66	DuWapMH_13	33.37
L-0600P	25 Year 24 Hour_SS_SLR	DuWapMH_13	DuWapN_21	33.45
L-0680P	25 Year 24 Hour_SS_SLR	DuWapMH_900	DuWapMH_123	2.66
L-0690P	25 Year 24 Hour_SS_SLR	DuWapN_35b	DuWapMH_123	6.29
L-0830P	25 Year 24 Hour_SS_SLR	DuWapMH_227	DuWapN_78	15.59

APPENDIX-K Existing Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
L-1130P	25 Year 24 Hour_SS_SLR	DuWapN_263	DuWapN_94	9.21
L-1140P	25 Year 24 Hour_SS_SLR	DuWapN_338	DuWapMH_404	3.93
L-142	25 Year 24 Hour_SS_SLR	DuWapMH_429	DuWapMH_444	1286.11
P_1	25 Year 24 Hour_SS_SLR	DuWapMH_147	DuWapMH_8	12.34
P_10	25 Year 24 Hour_SS_SLR	DuWapMH_88	DuWapMH_267	20.84
P_100	25 Year 24 Hour_SS_SLR	DuWapMH_381	DuWapN_216	2.99
P_101	25 Year 24 Hour_SS_SLR	DuWapMH_418	DuWapMH_46	9.06
P_102	25 Year 24 Hour_SS_SLR	DuWapMH_23	DuWapMH_188	5.85
P_103	25 Year 24 Hour_SS_SLR	DuWapN_72	DuWapMH_189	3.41
P_104	25 Year 24 Hour_SS_SLR	DuWapMH_47	DuWapN_267	4.86
P_105	25 Year 24 Hour_SS_SLR	DuWapN_51	DuWapMH_190	6.47
P_106	25 Year 24 Hour_SS_SLR	DuWapMH_232	DuWapMH_191	5.82
P_107	25 Year 24 Hour_SS_SLR	DuWapN_47	DuWapMH_80	11.93
P_108	25 Year 24 Hour_SS_SLR	DuWapMH_107	DuWapMH_192	11.69
P_109	25 Year 24 Hour_SS_SLR	DuWapMH_438	DuWapMH_103	12.75
P_11	25 Year 24 Hour_SS_SLR	DuWapMH_88	DuWapMH_267	20.84
P_110	25 Year 24 Hour_SS_SLR	DuWapN_29	DuWapMH_48	10.7
P_111	25 Year 24 Hour_SS_SLR	DuWapMH_48	DuWapMH_96	10.67
P_112	25 Year 24 Hour_SS_SLR	DuWapMH_96	DuWapMH_97	10.67
P_113	25 Year 24 Hour_SS_SLR	DuWapMH_97	DuWapMH_193	11.37
P_114	25 Year 24 Hour_SS_SLR	DuWapMH_193	DuWapN_229	14.04
P_115	25 Year 24 Hour_SS_SLR	DuWapN_229	DuWapMH_98	27.16
P_116	25 Year 24 Hour_SS_SLR	DuWapMH_98	DuWapMH_194	27.16
P_117	25 Year 24 Hour_SS_SLR	DuWapMH_195	DuWapMH_23	5.88
P_118	25 Year 24 Hour_SS_SLR	DuWapN_334	DuWapMH_195	5.87
P_119	25 Year 24 Hour_SS_SLR	DuWapMH_117	DuWapMH_196	8.01
P_12	25 Year 24 Hour_SS_SLR	DuWapMH_92	DuWapMH_88	20.82
P_120	25 Year 24 Hour_SS_SLR	DuWapMH_375	DuWapMH_117	7.99
P_121	25 Year 24 Hour_SS_SLR	DuWapMH_53	DuWapMH_197	10.8
P_122	25 Year 24 Hour_SS_SLR	DuWapN_62	DuWapMH_198	1.92
P_123	25 Year 24 Hour_SS_SLR	DuWapMH_389	DuWapMH_199	3.76
P_125	25 Year 24 Hour_SS_SLR	DuWapMH_388	DuWapMH_99	9
P_126	25 Year 24 Hour_SS_SLR	DuWapMH_52	DuWapMH_336	29.72
P_127	25 Year 24 Hour_SS_SLR	DuWapN_48	DuWapN_59	16.25
P_128	25 Year 24 Hour_SS_SLR	DuWapN_48	DuWapN_59	16.25
P_13	25 Year 24 Hour_SS_SLR	DuWapMH_341	DuWapMH_151	11.41
P_131	25 Year 24 Hour_SS_SLR	DuWapMH_136	DuWapMH_101	2.11
P_132	25 Year 24 Hour_SS_SLR	DuWapN_62	DuWapMH_198	1.92
P_133	25 Year 24 Hour_SS_SLR	DuWapMH_11	DuWapMH_55	6.1
P_134	25 Year 24 Hour_SS_SLR	DuWapMH_446	DuWapMH_32	10.79
P_135	25 Year 24 Hour_SS_SLR	DuWapMH_446	DuWapMH_322	20.71
P_136	25 Year 24 Hour_SS_SLR	DuWapMH_32	DuWapMH_322	10.79
P_138	25 Year 24 Hour_SS_SLR	DuWapMH_206	DuWapMH_104	9.1
P_139	25 Year 24 Hour_SS_SLR	DuWapMH_104	DuWapMH_105	6.13
P_14	25 Year 24 Hour_SS_SLR	DuWapMH_151	DuWapMH_152	11.41
P_140	25 Year 24 Hour_SS_SLR	DuWapMH_105	DuWapMH_420	6.49
P_141	25 Year 24 Hour_SS_SLR	DuWapMH_57	DuWapMH_143	0
P_142	25 Year 24 Hour_SS_SLR	DuWapMH_57	DuWapMH_106	6.11

APPENDIX-K Existing Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_143	25 Year 24 Hour_SS_SLR	DuWapMH_124	DuWapMH_108	0.05
P_144	25 Year 24 Hour_SS_SLR	DuWapN_11a	DuWapMH_109	11.96
P_145	25 Year 24 Hour_SS_SLR	DuWapMH_109	DuWapMH_207	11.96
P_146	25 Year 24 Hour_SS_SLR	DuWapN_2	DuWapN_77	14.79
P_148	25 Year 24 Hour_SS_SLR	DuWapN_270	DuWapMH_59	39.45
P_149	25 Year 24 Hour_SS_SLR	DuWapMH_59	DuWapN_77	39.4
P_15	25 Year 24 Hour_SS_SLR	DuWapMH_51	DuWapMH_153	29.57
P_150	25 Year 24 Hour_SS_SLR	DuWapMH_135	DuWapMH_60	20.1
P_151	25 Year 24 Hour_SS_SLR	DuWapMH_421	DuWapMH_60	15.85
P_152	25 Year 24 Hour_SS_SLR	DuWapMH_60	DuWapMH_63	33.27
P_153	25 Year 24 Hour_SS_SLR	DuWapN_10	DuWapMH_17	25.32
P_154	25 Year 24 Hour_SS_SLR	DuWapMH_62	DuWapN_10	11.41
P_155	25 Year 24 Hour_SS_SLR	DuWapN_216	DuWapN_241	31.35
P_156	25 Year 24 Hour_SS_SLR	DuWapMH_113	DuWapMH_114	113.11
P_157	25 Year 24 Hour_SS_SLR	DuWapN_3	DuWapMH_113	113.8
P_158	25 Year 24 Hour_SS_SLR	DuWapMH_114	DuWapMH_212	34.08
P_159	25 Year 24 Hour_SS_SLR	DuWapN_40	DuWapMH_115	14.86
P_16	25 Year 24 Hour_SS_SLR	DuWapMH_337	DuWapMH_99	11.14
P_160	25 Year 24 Hour_SS_SLR	DuWapMH_115	DuWapMH_213	14.83
P_161	25 Year 24 Hour_SS_SLR	DuWapN_210	DuWapMH_62	11.43
P_162	25 Year 24 Hour_SS_SLR	DuWapMH_63	DuWapMH_64	33.27
P_163	25 Year 24 Hour_SS_SLR	DuWapMH_64	DuWapN_207b	33.28
P_164	25 Year 24 Hour_SS_SLR	DuWapN_207b	DuWapMH_65	33.28
P_165	25 Year 24 Hour_SS_SLR	DuWapMH_19	DuWapMH_65	5.03
P_166	25 Year 24 Hour_SS_SLR	DuWapMH_14	DuWapMH_66	33.33
P_167	25 Year 24 Hour_SS_SLR	DuWapN_7a	DuWapMH_66	9.67
P_168	25 Year 24 Hour_SS_SLR	DuWapN_7b	DuWapMH_19	19.96
P_169	25 Year 24 Hour_SS_SLR	DuWapN_70	DuWapN_270	25.77
P_17	25 Year 24 Hour_SS_SLR	DuWapMH_337	DuWapMH_99	11.09
P_170	25 Year 24 Hour_SS_SLR	DuWapMH_15	DuWapMH_112	9.54
P_171	25 Year 24 Hour_SS_SLR	DuWapN_19a	DuWapMH_15	9.61
P_172	25 Year 24 Hour_SS_SLR	DuWapN_219b	DuWapMH_112	19.35
P_173	25 Year 24 Hour_SS_SLR	DuWapN_19b	DuWapN_219b	10.32
P_174	25 Year 24 Hour_SS_SLR	DuWapN_219a	DuWapMH_214	19.9
P_175	25 Year 24 Hour_SS_SLR	DuWapN_9b	DuWapN_209b	3.27
P_176	25 Year 24 Hour_SS_SLR	DuWapMH_1	DuWapMH_42	3.57
P_177	25 Year 24 Hour_SS_SLR	DuWapMH_42	DuWapN_338	3.42
P_178	25 Year 24 Hour_SS_SLR	DuWapN_57	DuWapN_257	6.03
P_179	25 Year 24 Hour_SS_SLR	DuWapN_257	DuWapN_93	11.16
P_18	25 Year 24 Hour_SS_SLR	DuWapMH_394	DuWapMH_10	5.67
P_180	25 Year 24 Hour_SS_SLR	DuWapN_63	DuWapMH_69	1.59
P_181	25 Year 24 Hour_SS_SLR	DuWapMH_69	DuWapN_93	1.59
P_182	25 Year 24 Hour_SS_SLR	DuWapMH_121	DuWapMH_218	8.64
P_184	25 Year 24 Hour_SS_SLR	DuWapMH_103	DuWapN_23	18.54
P_185	25 Year 24 Hour_SS_SLR	DuWapMH_432	DuWapMH_219	36.48
P_186	25 Year 24 Hour_SS_SLR	DuWapMH_403	DuWapMH_41	0
P_187	25 Year 24 Hour_SS_SLR	DuWapMH_372	DuWapMH_10	9.5
P_188	25 Year 24 Hour_SS_SLR	DuWapMH_12	DuWapMH_11	6.11

APPENDIX-K Existing Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_189	25 Year 24 Hour_SS_SLR	DuWapMH_76	DuWapMH_220	21.96
P_19	25 Year 24 Hour_SS_SLR	DuWapMH_106	DuWapMH_12	6.11
P_190	25 Year 24 Hour_SS_SLR	DuWapMH_118	DuWapMH_76	21.96
P_191	25 Year 24 Hour_SS_SLR	DuWapMH_433	DuWapN_71	5.71
P_192	25 Year 24 Hour_SS_SLR	DuWapMH_354	DuWapMH_221	5.26
P_194	25 Year 24 Hour_SS_SLR	DuWapMH_338	DuWapN_52	11.66
P_195	25 Year 24 Hour_SS_SLR	DuWapMH_140	DuWapMH_222	26.13
P_196	25 Year 24 Hour_SS_SLR	DuWapMH_46	DuWapMH_24	9.09
P_197	25 Year 24 Hour_SS_SLR	DuWapMH_24	DuWapMH_223	10.03
P_198	25 Year 24 Hour_SS_SLR	DuWapN_67	DuWapMH_47	4.85
P_199	25 Year 24 Hour_SS_SLR	DuWapN_74	DuWapMH_224	6.12
P_2	25 Year 24 Hour_SS_SLR	DuWapMH_8	DuWapMH_70	12.34
P_20	25 Year 24 Hour_SS_SLR	DuWapMH_55	DuWapMH_103	6.13
P_200	25 Year 24 Hour_SS_SLR	DuWapN_267	DuWapMH_225	9.91
P_201	25 Year 24 Hour_SS_SLR	DuWapMH_360	DuWapN_201	12.12
P_202	25 Year 24 Hour_SS_SLR	DuWapMH_95	DuWapN_201	9.93
P_203	25 Year 24 Hour_SS_SLR	DuWapN_201	DuWapMH_111	32.5
P_204	25 Year 24 Hour_SS_SLR	DuWapMH_111	DuWapN_77	16.91
P_205	25 Year 24 Hour_SS_SLR	DuWapMH_111	DuWapMH_454	15.7
P_206	25 Year 24 Hour_SS_SLR	DuWapMH_17	DuWapMH_227	25.29
P_207	25 Year 24 Hour_SS_SLR	DuWapMH_432	DuWapMH_219	36.46
P_208	25 Year 24 Hour_SS_SLR	DuWapMH_231	DuWapMH_116	11.66
P_209	25 Year 24 Hour_SS_SLR	DuWapMH_116	DuWapMH_228	11.66
P_21	25 Year 24 Hour_SS_SLR	DuWapMH_112	DuWapN_219a	19.37
P_210	25 Year 24 Hour_SS_SLR	DuWapMH_65	DuWapMH_14	33.31
P_211	25 Year 24 Hour_SS_SLR	DuWapN_31	DuWapMH_229	11.65
P_212	25 Year 24 Hour_SS_SLR	DuWapMH_229	DuWapMH_230	11.65
P_213	25 Year 24 Hour_SS_SLR	DuWapMH_230	DuWapMH_231	11.65
P_214	25 Year 24 Hour_SS_SLR	DuWapN_66	DuWapMH_232	5.82
P_215	25 Year 24 Hour_SS_SLR	DuWapMH_132	DuWapMH_233	8.32
P_216	25 Year 24 Hour_SS_SLR	DuWapN_211b	DuWapMH_318	9.1
P_217	25 Year 24 Hour_SS_SLR	DuWapN_11b	DuWapMH_61	15.67
P_219	25 Year 24 Hour_SS_SLR	DuWapMH_71	DuWapMH_236	26.64
P_22	25 Year 24 Hour_SS_SLR	DuWapMH_31	DuWapN_324	13
P_220	25 Year 24 Hour_SS_SLR	DuWapMH_140	DuWapMH_71	26.5
P_222	25 Year 24 Hour_SS_SLR	DuWapN_225	DuWapMH_238	39.81
P_223	25 Year 24 Hour_SS_SLR	DuWapN_30	DuWapN_230	4.62
P_224	25 Year 24 Hour_SS_SLR	DuWapMH_241	DuWapMH_240	15.51
P_225	25 Year 24 Hour_SS_SLR	DuWapMH_133	DuWapMH_241	6.31
P_226	25 Year 24 Hour_SS_SLR	DuWapMH_131	DuWapN_94	4.55
P_227	25 Year 24 Hour_SS_SLR	DuWapMH_373	DuWapMH_191	550.49
P_228	25 Year 24 Hour_SS_SLR	DuWapMH_383	DuWapMH_243	119.28
P_229	25 Year 24 Hour_SS_SLR	DuWapMH_342	DuWapMH_244	120.19
P_23	25 Year 24 Hour_SS_SLR	DuWapN_24	DuWapMH_20	9.28
P_230	25 Year 24 Hour_SS_SLR	DuWapMH_383	DuWapMH_243	119.23
P_231	25 Year 24 Hour_SS_SLR	DuWapMH_374	DuWapMH_245	380
P_232	25 Year 24 Hour_SS_SLR	DuWapMH_436	DuWapMH_246	459.28
P_233	25 Year 24 Hour_SS_SLR	DuWapN_14	DuWapN_107	6.54

APPENDIX-K Existing Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_234	25 Year 24 Hour_SS_SLR	DuWapMH_129	DuWapMH_248	9.94
P_238	25 Year 24 Hour_SS_SLR	DuWapN_71	DuWapMH_249	71.11
P_24	25 Year 24 Hour_SS_SLR	DuWapN_224	DuWapN_24	8.75
P_240	25 Year 24 Hour_SS_SLR	DuWapMH_355	DuWapMH_250	5
P_241	25 Year 24 Hour_SS_SLR	DuWapMH_352	DuWapMH_251	5.07
P_242	25 Year 24 Hour_SS_SLR	DuWapMH_353	DuWapMH_252	5.22
P_243	25 Year 24 Hour_SS_SLR	DuWapMH_356	DuWapMH_253	4.92
P_244	25 Year 24 Hour_SS_SLR	DuWapMH_358	DuWapMH_254	4.78
P_245	25 Year 24 Hour_SS_SLR	DuWapMH_357	DuWapMH_255	4.85
P_246	25 Year 24 Hour_SS_SLR	DuWapMH_359	DuWapMH_256	4.99
P_247	25 Year 24 Hour_SS_SLR	DuWapMH_333	DuWapMH_257	5.19
P_248	25 Year 24 Hour_SS_SLR	DuWapMH_434	DuWapMH_258	5.44
P_249	25 Year 24 Hour_SS_SLR	DuWapMH_331	DuWapMH_259	7.3
P_25	25 Year 24 Hour_SS_SLR	DuWapN_43	DuWapN_224	8.61
P_250	25 Year 24 Hour_SS_SLR	DuWapMH_343	DuWapMH_260	14.37
P_251	25 Year 24 Hour_SS_SLR	DuWapMH_344	DuWapMH_261	14.67
P_252	25 Year 24 Hour_SS_SLR	DuWapMH_346	DuWapMH_262	15
P_255	25 Year 24 Hour_SS_SLR	DuWapN_273	DuWapMH_264	17.55
P_26	25 Year 24 Hour_SS_SLR	DuWapN_222	DuWapMH_74	2.14
P_260	25 Year 24 Hour_SS_SLR	DuWapMH_361	DuWapMH_144	6.66
P_261	25 Year 24 Hour_SS_SLR	DuWapMH_362	DuWapMH_268	6.67
P_262	25 Year 24 Hour_SS_SLR	DuWapMH_386	DuWapMH_269	6.73
P_263	25 Year 24 Hour_SS_SLR	DuWapN_1	DuWapMH_270	10.21
P_264	25 Year 24 Hour_SS_SLR	DuWapMH_271	DuWapMH_397	0
P_265	25 Year 24 Hour_SS_SLR	DuWapMH_272	DuWapMH_400	0
P_266	25 Year 24 Hour_SS_SLR	DuWapMH_399	DuWapMH_273	0
P_267	25 Year 24 Hour_SS_SLR	DuWapMH_379	DuWapMH_274	9.17
P_268	25 Year 24 Hour_SS_SLR	DuWapMH_279	DuWapMH_275	108.33
P_269	25 Year 24 Hour_SS_SLR	DuWapMH_280	DuWapMH_276	108.21
P_27	25 Year 24 Hour_SS_SLR	DuWapN_22	DuWapMH_74	15.17
P_270	25 Year 24 Hour_SS_SLR	DuWapMH_334	DuWapMH_277	98.58
P_271	25 Year 24 Hour_SS_SLR	DuWapMH_334	DuWapMH_277	98.03
P_272	25 Year 24 Hour_SS_SLR	DuWapMH_214	DuWapN_32	19.96
P_273	25 Year 24 Hour_SS_SLR	DuWapMH_275	DuWapMH_278	107.86
P_274	25 Year 24 Hour_SS_SLR	DuWapMH_276	DuWapMH_278	107.73
P_275	25 Year 24 Hour_SS_SLR	DuWapN_32	DuWapMH_279	107.85
P_276	25 Year 24 Hour_SS_SLR	DuWapN_32	DuWapMH_280	107.72
P_277	25 Year 24 Hour_SS_SLR	DuWapN_240	DuWapMH_281	13.98
P_278	25 Year 24 Hour_SS_SLR	DuWapMH_152	DuWapMH_282	11.41
P_279	25 Year 24 Hour_SS_SLR	DuWapMH_154	DuWapMH_156	72.58
P_28	25 Year 24 Hour_SS_SLR	DuWapMH_74	DuWapMH_73	8.43
P_280	25 Year 24 Hour_SS_SLR	DuWapMH_154	DuWapMH_156	72.66
P_288	25 Year 24 Hour_SS_SLR	DuWapMH_416	DuWapMH_288	12.49
P_289	25 Year 24 Hour_SS_SLR	DuWapN_15	DuWapMH_289	69.51
P_29	25 Year 24 Hour_SS_SLR	DuWapN_16	DuWapMH_154	102.73
P_290	25 Year 24 Hour_SS_SLR	DuWapN_20	DuWapMH_243	9.91
P_291	25 Year 24 Hour_SS_SLR	DuWapMH_393	DuWapMH_290	5.86
P_292	25 Year 24 Hour_SS_SLR	DuWapMH_371	DuWapMH_291	5.69

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_293	25 Year 24 Hour_SS_SLR	DuWapMH_291	DuWapMH_292	5.68
P_294	25 Year 24 Hour_SS_SLR	DuWapMH_370	DuWapMH_293	45.93
P_295	25 Year 24 Hour_SS_SLR	DuWapMH_426	DuWapN_26	12.34
P_296	25 Year 24 Hour_SS_SLR	DuWapMH_390	DuWapMH_294	6.56
P_297	25 Year 24 Hour_SS_SLR	DuWapMH_392	DuWapMH_295	7.62
P_298	25 Year 24 Hour_SS_SLR	DuWapMH_391	DuWapMH_296	7.5
P_299	25 Year 24 Hour_SS_SLR	DuWapN_49	DuWapMH_297	8.23
P_3	25 Year 24 Hour_SS_SLR	DuWapMH_70	DuWapMH_118	12.34
P_30	25 Year 24 Hour_SS_SLR	DuWapMH_402	DuWapMH_75	20.02
P_300	25 Year 24 Hour_SS_SLR	DuWapMH_306	DuWapMH_298	18.82
P_301	25 Year 24 Hour_SS_SLR	DuWapMH_364	DuWapMH_299	44.52
P_302	25 Year 24 Hour_SS_SLR	DuWapMH_367	DuWapMH_500	48.47
P_303	25 Year 24 Hour_SS_SLR	DuWapMH_368	DuWapMH_301	74.14
P_304	25 Year 24 Hour_SS_SLR	DuWapMH_377	DuWapMH_302	5.26
P_305	25 Year 24 Hour_SS_SLR	DuWapN_234	DuWapMH_339	63.67
P_306	25 Year 24 Hour_SS_SLR	DuWapMH_308	DuWapMH_304	28.03
P_307	25 Year 24 Hour_SS_SLR	DuWapMH_417	DuWapMH_305	9.15
P_308	25 Year 24 Hour_SS_SLR	DuWapMH_339	DuWapMH_306	18.83
P_309	25 Year 24 Hour_SS_SLR	DuWapMH_298	DuWapMH_307	18.81
P_31	25 Year 24 Hour_SS_SLR	DuWapMH_21	DuWapMH_155	14.3
P_310	25 Year 24 Hour_SS_SLR	DuWapMH_304	DuWapMH_307	28.02
P_311	25 Year 24 Hour_SS_SLR	DuWapMH_339	DuWapMH_308	28.04
P_312	25 Year 24 Hour_SS_SLR	DuWapMH_411	DuWapMH_309	8.83
P_313	25 Year 24 Hour_SS_SLR	DuWapMH_410	DuWapMH_310	5.66
P_314	25 Year 24 Hour_SS_SLR	DuWapMH_141	DuWapMH_311	7.7
P_315	25 Year 24 Hour_SS_SLR	DuWapMH_409	DuWapMH_312	8.31
P_316	25 Year 24 Hour_SS_SLR	DuWapMH_218	DuWapMH_313	8.81
P_318	25 Year 24 Hour_SS_SLR	DuWapN_37	DuWapMH_315	14.37
P_32	25 Year 24 Hour_SS_SLR	DuWapMH_75	DuWapMH_155	5.44
P_320	25 Year 24 Hour_SS_SLR	DuWapN_36	DuWapMH_317	18.81
P_33	25 Year 24 Hour_SS_SLR	DuWapMH_155	DuWapMH_156	19.72
P_333	25 Year 24 Hour_SS_SLR	DuWapMH_30	DuWapMH_82	1.87
P_334	25 Year 24 Hour_SS_SLR	DuWapMH_30	DuWapMH_82	1.91
P_337	25 Year 24 Hour_SS_SLR	DuWapMH_82	DuWapMH_93	1.91
P_338	25 Year 24 Hour_SS_SLR	DuWapMH_82	DuWapMH_93	1.91
P_34	25 Year 24 Hour_SS_SLR	DuWapMH_75	DuWapMH_156	22.23
P_35	25 Year 24 Hour_SS_SLR	DuWapMH_22	DuWapMH_75	7.66
P_36	25 Year 24 Hour_SS_SLR	DuWapMH_220	DuWapMH_21	14.3
P_37	25 Year 24 Hour_SS_SLR	DuWapMH_220	DuWapMH_22	7.66
P_38	25 Year 24 Hour_SS_SLR	DuWapN_34	DuWapMH_77	20.4
P_39	25 Year 24 Hour_SS_SLR	DuWapMH_77	DuWapN_334	20.38
P_4	25 Year 24 Hour_SS_SLR	DuWapMH_315	DuWapMH_146	12.34
P_40	25 Year 24 Hour_SS_SLR	DuWapN_73	DuWapMH_157	16.37
P_41	25 Year 24 Hour_SS_SLR	DuWapMH_80	DuWapMH_79	11.6
P_42	25 Year 24 Hour_SS_SLR	DuWapMH_79	DuWapMH_158	11.48
P_43	25 Year 24 Hour_SS_SLR	DuWapMH_27	DuWapMH_159	1.83
P_44	25 Year 24 Hour_SS_SLR	DuWapMH_159	DuWapN_212	5.04
P_45	25 Year 24 Hour_SS_SLR	DuWapN_212	DuWapN_211a	6.93

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_46	25 Year 24 Hour_SS_SLR	DuWapN_12	DuWapMH_159	3.69
P_47	25 Year 24 Hour_SS_SLR	DuWapN_211a	DuWapMH_28	2.55
P_48	25 Year 24 Hour_SS_SLR	DuWapMH_28	DuWapN_312	2.55
P_49	25 Year 24 Hour_SS_SLR	DuWapMH_61	DuWapN_211b	6.84
P_5	25 Year 24 Hour_SS_SLR	DuWapMH_329	DuWapMH_147	12.34
P_50	25 Year 24 Hour_SS_SLR	DuWapMH_61	DuWapN_211b	8.8
P_51	25 Year 24 Hour_SS_SLR	DuWapN_312	DuWapMH_118	10.94
P_52	25 Year 24 Hour_SS_SLR	DuWapMH_332	DuWapMH_3	6.03
P_53	25 Year 24 Hour_SS_SLR	DuWapMH_385	DuWapMH_86	12.39
P_54	25 Year 24 Hour_SS_SLR	DuWapMH_369	DuWapMH_162	48.64
P_55	25 Year 24 Hour_SS_SLR	DuWapMH_10	DuWapMH_446	9.74
P_56	25 Year 24 Hour_SS_SLR	DuWapMH_137	DuWapMH_30	3.75
P_59	25 Year 24 Hour_SS_SLR	DuWapMH_93	DuWapMH_31	3.97
P_60	25 Year 24 Hour_SS_SLR	DuWapMH_20	DuWapMH_81	9.28
P_61	25 Year 24 Hour_SS_SLR	DuWapMH_81	DuWapMH_31	9.29
P_64	25 Year 24 Hour_SS_SLR	DuWapMH_437	DuWapN_250	22.58
P_65	25 Year 24 Hour_SS_SLR	DuWapMH_33	DuWapMH_85	18.54
P_66	25 Year 24 Hour_SS_SLR	DuWapN_324	DuWapMH_33	18.67
P_67	25 Year 24 Hour_SS_SLR	DuWapN_324	DuWapMH_34	18.48
P_68	25 Year 24 Hour_SS_SLR	DuWapMH_34	DuWapMH_33	0.17
P_69	25 Year 24 Hour_SS_SLR	DuWapMH_34	DuWapMH_84	18.55
P_7	25 Year 24 Hour_SS_SLR	DuWapMH_351	DuWapMH_92	27.13
P_70	25 Year 24 Hour_SS_SLR	DuWapMH_84	DuWapMH_171	18.52
P_71	25 Year 24 Hour_SS_SLR	DuWapMH_85	DuWapMH_171	18.5
P_72	25 Year 24 Hour_SS_SLR	DuWapMH_86	DuWapMH_172	12.39
P_73	25 Year 24 Hour_SS_SLR	DuWapN_6	DuWapMH_173	19.63
P_74	25 Year 24 Hour_SS_SLR	DuWapMH_36	DuWapMH_174	10.77
P_75	25 Year 24 Hour_SS_SLR	DuWapN_9	DuWapMH_36	10.89
P_76	25 Year 24 Hour_SS_SLR	DuWapMH_108	DuWapMH_27	1.88
P_77	25 Year 24 Hour_SS_SLR	DuWapMH_99	DuWapMH_175	5.88
P_78	25 Year 24 Hour_SS_SLR	DuWapMH_99	DuWapMH_175	5.91
P_79	25 Year 24 Hour_SS_SLR	DuWapMH_387	DuWapMH_87	7.61
P_8	25 Year 24 Hour_SS_SLR	DuWapMH_330	DuWapMH_92	14.54
P_80	25 Year 24 Hour_SS_SLR	DuWapMH_87	DuWapN_274	8.45
P_81	25 Year 24 Hour_SS_SLR	DuWapMH_449	DuWapMH_177	20.36
P_82	25 Year 24 Hour_SS_SLR	DuWapN_53	DuWapN_74	14.45
P_84	25 Year 24 Hour_SS_SLR	DuWapMH_198	DuWapMH_179	3.82
P_85	25 Year 24 Hour_SS_SLR	DuWapN_30	DuWapMH_180	20.07
P_86	25 Year 24 Hour_SS_SLR	DuWapN_230	DuWapMH_40	11.23
P_87	25 Year 24 Hour_SS_SLR	DuWapMH_40	DuWapMH_181	11.23
P_88	25 Year 24 Hour_SS_SLR	DuWapN_65	DuWapN_43	2.85
P_89	25 Year 24 Hour_SS_SLR	DuWapMH_41	DuWapMH_398	0
P_9	25 Year 24 Hour_SS_SLR	DuWapMH_92	DuWapMH_88	20.85
P_91	25 Year 24 Hour_SS_SLR	DuWapN_25	DuWapMH_56	3.76
P_92	25 Year 24 Hour_SS_SLR	DuWapMH_56	DuWapMH_182	3.79
P_93	25 Year 24 Hour_SS_SLR	DuWapMH_45	DuWapN_238	3.94
P_94	25 Year 24 Hour_SS_SLR	DuWapMH_404	DuWapMH_45	3.93
P_95	25 Year 24 Hour_SS_SLR	DuWapMH_130	DuWapMH_184	7.19

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_98	25 Year 24 Hour_SS_SLR	DuWapMH_73	DuWapMH_186	8.44
P_99	25 Year 24 Hour_SS_SLR	DuWapMH_213	DuWapN_240	10.33

Appendix L Selected List of Assets for Condition Assessment

Appendix L

Selected List of Assets for Condition Assessment

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Appendix L

Selected List of Assets for Condition Assessment

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Appendix L
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Appendix L
Selected List of Assets for Condition Assessment

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swINLT008479
swINLT008480

Appendix L
Selected List of Assets for Condition Assessment

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swMNHL001793

Appendix L

Selected List of Assets for Condition Assessment

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Appendix L
Selected List of Assets for Condition Assessment

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swPIPE013831

Appendix L
Selected List of Assets for Condition Assessment

Asset ID	Asset ID	Asset ID	Asset ID
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swPIPE013835	swPIPE990050	swPIPE990162	swPIPE990226
swPIPE013840	swPIPE990051	swPIPE990163	swPIPE990230
swPIPE013849	swPIPE990059	swPIPE990164	swPIPE990231
swPIPE013850	swPIPE990062	swPIPE990165	swPIPE990232
swPIPE013851	swPIPE990066	swPIPE990167	swPIPE990234
swPIPE013852	swPIPE990067	swPIPE990168	swPIPE990422
swPIPE013853	swPIPE990068	swPIPE990169	swPIPE990423
swPIPE013854	swPIPE990069	swPIPE990170	swPIPE990445
swPIPE013855	swPIPE990071	swPIPE990171	swPIPE990446
swPIPE013856	swPIPE990075	swPIPE990172	swPIPE990448
swPIPE013857	swPIPE990077	swPIPE990173	swPIPE990450
swPIPE013858	swPIPE990078	swPIPE990174	swPIPE990453
swPIPE013859	swPIPE990079	swPIPE990175	swPIPE990454
swPIPE013875	swPIPE990082	swPIPE990176	swPIPE990455
swPIPE013879	swPIPE990083	swPIPE990177	swPIPE990456
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swPIPE013883	swPIPE990091	swPIPE990184	swPIPE990461
swPIPE013884	swPIPE990096	swPIPE990186	swPIPE990463
swPIPE013885	swPIPE990097	swPIPE990187	swPIPE990465
swPIPE013906	swPIPE990098	swPIPE990188	swPIPE990474
swPIPE013907	swPIPE990099	swPIPE990189	swPIPE990475
swPIPE013910	swPIPE990100	swPIPE990190	swPIPE990476
swPIPE013911	swPIPE990101	swPIPE990191	swPIPE990477
swPIPE013912	swPIPE990102	swPIPE990192	swPIPE990479
swPIPE990002	swPIPE990103	swPIPE990193	swPIPE990480
swPIPE990010	swPIPE990104	swPIPE990196	swPIPE990481
swPIPE990011	swPIPE990112	swPIPE990202	swPIPE990482
swPIPE990012	swPIPE990113	swPIPE990203	swPIPE990483
swPIPE990013	swPIPE990114	swPIPE990204	swPIPE990484
swPIPE990014	swPIPE990115	swPIPE990205	swPIPE990486
swPIPE990015	swPIPE990119	swPIPE990207	swPIPE990487
swPIPE990016	swPIPE990120	swPIPE990208	swPIPE990489
swPIPE990029	swPIPE990130	swPIPE990209	swPIPE990490
swPIPE990030	swPIPE990131	swPIPE990210	swPIPE990492
swPIPE990031	swPIPE990132	swPIPE990211	swPIPE990496
swPIPE990032	swPIPE990133	swPIPE990212	swPIPE990500
swPIPE990033	swPIPE990134	swPIPE990213	swPIPE990501
swPIPE990034	swPIPE990153	swPIPE990216	swPIPE990502
swPIPE990035	swPIPE990154	swPIPE990217	swPIPE990503
swPIPE990036	swPIPE990155	swPIPE990218	swPIPE990507
swPIPE990037	swPIPE990156	swPIPE990219	swPIPE990601
swPIPE990038	swPIPE990157	swPIPE990220	swPIPE990602
swPIPE990039	swPIPE990158	swPIPE990221	swPIPE990605
swPIPE990041	swPIPE990159	swPIPE990223	swPIPE990606
swPIPE990048	swPIPE990160	swPIPE990224	swPIPE990609

Appendix L
Selected List of Assets for Condition Assessment

Asset ID
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swPIPE990619
swPIPE990620
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swPIPE990672

Asset ID
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SWPIPE990708
SWPIPE990716
SWPIPE990717
SWPIPE990718
SWPIPE990719
SWPIPE990721
SWPIPE990722
SWPIPE990725

Appendix M Detailed Condition Assessment Scoring Structures

Appendix M
Detailed Condition Assessment Scoring
Structures

Asset ID	Descriptor	Modifier	Component	Component Condition	Condition Grade
swINLT001308	DSED		NA		2
swINLT007868	DSED		NA		2
swINLT007869	DSED		NA		2
swINLT007870	DSED		NA		2
swINLT007915			NA		0
swINLT007926	SMSW	LT25	NA		1
swINLT007932	OWDD	50to75	NA		4
swINLT007933	DSED		NA		2
swINLT007934	OSED	GT75	NA		5
swINLT007936	OWDD	LT50	NA		3
swINLT007938	OSED	50to75	NA		4
swINLT007939	DWOD		NA		2
swINLT007940	OSED	GT75	NA		5
swINLT007964	DGRV		NA		2
swINLT007965			NA		0
swINLT007966	SMSW	LT25	NA		1
swINLT007967	SMSW	25to50	NA		3
swINLT007996	SMSW	LT25	NA		1
swINLT007997	DWOD		NA		2
swINLT007998	SMSW	LT25	NA		1
swINLT007999	DSED		NA		2
swINLT008000	DSED		NA		2
swINLT008001	DWOD		NA		2
swINLT008002	DWOD		NA		2
swINLT008003		Severe	Other	Broken	5
swINLT008004			NA		0
swINLT008053			NA		0
swINLT008056			NA		0
swINLT008057			NA		0
swINLT008075			NA		0
swINLT008078		Minor	Frame	Broken	3
swINLT008167	SMSW	LT25	NA		1
swINLT008283	DSED		NA		2
swINLT008284	DGAR		NA		2
swINLT008291	DSED		NA		2
swINLT008292			NA		0
swINLT008293			NA		0
swINLT008304	SMSW	GT50	NA		5
swINLT008305	SMSW	25to50	NA		3
swINLT008306	OSED	LT50	NA		3
swINLT008307	SMSW	LT25	NA		1
swINLT008308	DSED		NA		2
swINLT008309			NA		0
swINLT008312	OSED	LT50	NA		3
swINLT008316	SMSW	GT50	NA		5
swINLT008319			NA		0

Appendix M
Detailed Condition Assessment Scoring
Structures

Asset ID	Descriptor	Modifier	Component	Component Condition	Condition Grade
swINLT008354	SMSW	25to50	NA		3
swINLT008360	SMSW	LT25	NA		1
swINLT008381	SMSW	LT25	NA		1
swINLT008418			NA		0
swINLT008445			NA		0
swINLT008463	SMSW	LT25	NA		1
swINLT008464	OSED	50to75	NA		4
swINLT008478			NA		0
swINLT008479	DSED		NA		2
swINLT008480	DGRV		NA		2
swINLT008481	DSED		NA		2
swINLT008482	OSED	LT50	NA		3
swINLT008483			NA		0
swINLT008484	OSED	LT50	NA		3
swINLT008486	OSED	LT50	NA		3
swINLT008487	DSED		NA		2
swINLT008488	OSED	LT50	NA		3
swINLT008489			NA		0
swINLT008490			NA		0
swINLT008491		Minor	Cover	Broken	3
swINLT008492			NA		0
swINLT008496	DSED		NA		2
swINLT008499	DSED		NA		2
swINLT008501	DGRV		NA		2
swINLT008505	MB		Wall	Missing	4
swINLT008506			NA		0
swINLT008511	DSED		NA		2
swINLT008512	DSED		NA		2
swINLT008517	SMSW	25to50	NA		3
swINLT008552			NA		0
swINLT008553	DSED		NA		2
swINLT008591	DSED		NA		2
swINLT008601			NA		0
swINLT008602	DSED		NA		2
swINLT009034			NA		0
swINLT009035	OWDD	GT75	NA		5
swINLT009045			NA		0
swINLT009046			NA		0
swINLT009047	DWOD		NA		2
swINLT009048	DSED		NA		2
swINLT009051	DWOD		NA		2
swINLT009052			NA		0
swINLT009053			NA		0
swINLT009054	RF		Wall		2
swINLT009055			NA		0
swINLT009056	OGAR	LT50	Other		3

Appendix M
Detailed Condition Assessment Scoring
Structures

Asset ID	Descriptor	Modifier	Component	Component Condition	Condition Grade
swINLT009058		Minor	Wall	Cracked	2
swINLT009062	SMSW	25to50	NA		3
swINLT009109			NA		0
swINLT009115	DGRV		NA		2
swINLT009126	SMSW	25to50	NA		3
swINLT009127	DSED		NA		2
swINLT009128	DSED		NA		2
swINLT009129	SMSW	25to50	NA		3
swINLT009130			NA		0
swINLT009131	SMSW	25to50	NA		3
swINLT009132	SMFW	LT25	NA		1
swINLT009133	SMSW	GT50	NA		5
swINLT009134	SMSW	GT50	NA		5
swINLT009135	SMSW	25to50	NA		3
swINLT009136			NA		0
swINLT009141			NA		0
swINLT009164	DSED		NA		2
swINLT009197	SMSW	25to50	NA		3
swINLT009202	DSED		NA		2
swINLT009203			NA		0
swINLT009204	DSED		NA		2
swINLT009209	SRC	Moderate	NA		3
swINLT009210	OGAR	LT50	NA		3
swINLT009215	DSED		NA		2
swINLT009216	DSED		NA		2
swINLT009217	SMSW	LT25	NA		1
swINLT009218	SMSW	LT25	NA		1
swINLT009219	SMSW	LT25	NA		1
swINLT009239	OBN	LT50	NA		3
swINLT009242	OGAR	LT50	NA		3
swINLT009282	DSED		NA		2
swINLT009283	JO	Minor	NA		2
swINLT009284	OSED	GT75	NA		5
swINLT010719			NA		0
swINLT010726	DWOD		NA		2
swINLT010734	DGRV		NA		2
swINLT010737	DSED		NA		2
swINLT010739	DSED		NA		2
swINLT010742	DSED		NA		2
swINLT010743	DSED		NA		2
swINLT010749	DSED		NA		2
swINLT010750	DSED		NA		2
swINLT010751	DWOD		NA		2
swINLT010752			NA		0
swINLT010753	SMSW	LT25	NA		1
swINLT010754	DSED		NA		2

Appendix M
Detailed Condition Assessment Scoring
Structures

Asset ID	Descriptor	Modifier	Component	Component Condition	Condition Grade
swINLT010755	SMSW	LT25	NA		1
swINLT010756	DSED		NA		2
swINLT010757	DWOD		NA		2
swINLT010758			NA		0
swINLT010774	DSED		NA		2
swINLT010782	DSED		NA		2
swINLT010783	SMSW	LT25	NA		1
swINLT010784			Cover		0
swINLT010803	SMSW	25to50	NA		3
swINLT990002		Minor	Frame	Broken	3
swINLT990003			NA		0
swINLT990004			NA		0
swINLT990009			NA		0
swINLT990010		Moderate	NA		0
swINLT990019	DSED		NA		2
swINLT990020			NA		0
swINLT990021			NA		0
swINLT990022	DSED		NA		2
swINLT990023			NA		0
swINLT990036		Severe	NA	Missing	5
swINLT990038	DSED		NA		2
swINLT990039			NA		0
swINLT990040			NA		0
swINLT990041			NA		0
swINLT990042	DSED		NA		2
swINLT990045		Moderate	NA		0
swINLT990048			NA		0
swINLT990049	DSED		NA		2
swINLT990050	DSED		NA		2
swINLT990051			NA		0
swINLT990052	DSED		NA		2
swINLT990053	DSED		NA		2
swINLT990054	DSED		NA		2
swINLT990056	DSED		NA		2
swINLT990059			NA		0
swINLT990060	OSED	50to75	NA		4
swINLT990068			NA		0
swINLT990069	DSED		NA		2
swINLT990070	DSED		NA		2
swINLT990071	DB		Frame		4
swINLT990072	DB		Frame		4
swINLT990073	DSED		NA		2
swINLT990075	SMSW	25to50	NA		3
swINLT990076			NA		0
swINLT990077	SMSW	LT25	NA		1
swINLT990078			NA		0

Appendix M
Detailed Condition Assessment Scoring
Structures

Asset ID	Descriptor	Modifier	Component	Component Condition	Condition Grade
swINLT990081	SMSW	25to50	NA		3
swINLT990082	SMSW	LT25	NA		1
swINLT990083	DSED		NA		2
swINLT990084	SMSW	25to50	NA		3
swINLT990086			NA		0
swINLT990087	DSED		NA		2
swINLT990088	DSED		NA		2
swINLT990089			NA		0
swINLT990090			NA		0
swINLT990157			NA		0
swINLT990158			NA		0
swINLT990159			NA		0
swINLT990160	SMSW	LT25	NA		1
swINLT990164	DSED		NA		2
swINLT990165			NA		0
swINLT990167			NA		0
swINLT990169	DWOD		Other		2
swINLT990171			NA		0
swINLT990172	SMSW	25to50	NA		3
swINLT990173	SMSW	LT25	NA		1
swINLT990174					0
swINLT990175	DGRV		NA		2
swINLT990176	SMSW	GT50	NA		5
swINLT990177	SMSW	25to50	NA		3
swINLT990182	SMSW	LT25	NA		1
swINLT990183	DB		NA	Cracked	4
swINLT990184	DSED		NA		2
swINLT990185			NA		0
swINLT990186	DGAR		NA		2
swINLT990187	SMSW	GT50	NA		5
swINLT990188	SMSW	LT25	NA		1
swINLT990189			NA		0
swINLT990190			NA		0
swINLT990191	SMSW	GT50	NA		5
swINLT990192	SMSW	25to50	NA		3
swINLT990193	SMSW	25to50	NA		3
swINLT990194	SMSW	LT25	NA		1
swINLT990195	SMSW	25to50	NA		3
swINLT990196	SMSW	LT25	NA		1
swINLT990197	SMSW	GT50	NA		5
swINLT990208			NA		0
swINLT990209			NA		0
swINLT990215	SMSW	LT25	NA		1
swINLT990216	SMSW	LT25	NA		1
swINLT990217	SMSW	LT25	NA		1
swINLT990218	SMSW	LT25	NA		1

Appendix M
Detailed Condition Assessment Scoring
Structures

Asset ID	Descriptor	Modifier	Component	Component Condition	Condition Grade
swINLT990223	SMSW	GT50	NA		5
swINLT990224	SMSW	GT50	NA		5
swINLT990225	SMSW	GT50	NA		5
SWINLT990231			NA		0
SWINLT990232			NA		0
swINLT990500			NA		0
swINLT990502	SMSW	LT25	NA		1
swMNHL000378	DSED		NA		2
swMNHL000379	SMSW	LT25	NA		1
swMNHL001793			NA		0
swMNHL001797	SMSW	LT25	NA		1
swMNHL001798	DCON		NA		2
swMNHL001811	DSED		NA		2
swMNHL001812	OBI	LT50	NA		3
swMNHL001813	SMSW	LT25	NA		1
swMNHL001814	SMSW	LT25	NA		1
swMNHL001816	DGAR		NA		2
swMNHL001844	DSED		NA		2
swMNHL001845	DGAR		NA		2
swMNHL001853	DSED		NA		2
swMNHL001854	SMSW	LT25	NA		1
swMNHL001856	DSED		NA		2
swMNHL001865			NA		0
swMNHL001878			NA		0
swMNHL001880			NA		0
swMNHL001881		Moderate	Cover	Broken	4
swMNHL001887	DSED		NA		2
swMNHL001922			NA		0
swMNHL001927	DSED		NA		2
swMNHL001943	DSED		NA		2
swMNHL001953			NA		0
swMNHL001954			NA		0
swMNHL001955			NA		0
swMNHL001960			NA		0
swMNHL002065	DGRV		NA		2
swMNHL002066			NA		0
swMNHL002074			NA		0
swMNHL002075	DSED		NA		2
swMNHL002076	DSED		NA		2
swMNHL002077	DSED		NA		2
swMNHL002078	OBI	50to75	NA		4
swMNHL990001			NA		0
swMNHL990002	DSED		Wall		2
swMNHL990006	MM		Wall		4
swMNHL990007			NA		0
swMNHL990008			NA		0

Appendix M
Detailed Condition Assessment Scoring
Structures

Asset ID	Descriptor	Modifier	Component	Component Condition	Condition Grade
swMNHL990009			NA		0
swMNHL990011			NA		0
swMNHL990012			NA		0
swMNHL990013	DSED		NA		2
swMNHL990015	SMSW	25to50	NA		3
swMNHL990016	DSED		NA		2
swMNHL990025	DSED		NA		2
swMNHL990026			Cover		0
swMNHL990027	DSED		NA		2
swMNHL990028	SMSW	LT25	NA		1
swMNHL990029			NA		0
swMNHL990030	DB		NA		4
swMNHL990031	SMSW	25to50	NA		3
swMNHL990032	SMSW	LT25	NA		1
swMNHL990033	SMSW	25to50	NA		3
swMNHL990034	DGAR		NA		2
swMNHL990035			Wall	Missing	4
swMNHL990036			NA		0
swMNHL990037			NA		0
swMNHL990038	SMSW	LT25	NA		1
swMNHL990039	SMSW	25to50	NA		3
swMNHL990040	SMSW	LT25	NA		1
swMNHL990041	SMSW	LT25	NA		1
swMNHL990042	DSED		NA		2
swMNHL990043	DSED		NA		2
swMNHL990044	DSED		NA		2
swMNHL990063			Other		0
swMNHL990065	SMSW	LT25	NA		1
swMNHL990066			NA		0
swMNHL990067					0
swMNHL990070	DSED		NA		2
swMNHL990071	SMSW	LT25	NA		1
swMNHL990075	DGRV		NA		2
swMNHL990076			NA		0
swMNHL990077	DSED		NA		2
swMNHL990078	SMSW	LT25	NA		1
swMNHL990080			NA		0
swMNHL990081	OBB		Cover		5
swMNHL990082			NA		0
swMNHL990083			NA		0
swMNHL990084	SMSW	LT25	NA		1
swMNHL990500			NA		0
swMNHL990502	SMSW	LT25	NA		1
swMNHL990503	SMSW	25to50	NA		3
swOUTL990002			NA		0
swOUTL990003			NA		0

Appendix M
Detailed Condition Assessment Scoring
Structures

Asset ID	Descriptor	Modifier	Component	Component Condition	Condition Grade
swOUTL990004	SMSW	LT25	NA		1
swOUTL990005	OWDD	LT50	NA		3
swOUTL990006	SMSW	LT25	NA		1
swOUTL990012	SMSW	25to50	NA		3
swOUTL990013			NA		0
swOUTL990014			NA		0
swOUTL990015			NA		0
swOUTL990016			NA		0

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL002253	VOG	Extensive	1
swCHNL002254	DWOD		2
swCHNL002256	VOG	Extensive	1
swCHNL002257	VOG	Patchy	1
swCHNL002258	VOG	Limited	1
swCHNL002259			0
swCHNL002260	VOG	Patchy	1
swCHNL002261	DSED		2
swCHNL002262	DSED		2
swCHNL002263	DSED		2
swCHNL005535	VOG	Patchy	1
swCHNL005536	OSED	50to75	4
swCHNL005562			0
swCHNL005563	DSED		2
swCHNL005564	DSED		2
swCHNL005565	DSED		2
swCHNL005566			0
swCHNL005567			0
swCHNL005568	DSED		2
swCHNL005569	DSED		2
swCHNL005570			0
swCHNL005571	ETRE	Moderate	3
swCHNL005572	VOG	Patchy	1
swCHNL005573	ETRE	Moderate	3
swCHNL005574	OWDD	GT75	5
swCHNL005575			0
swCHNL005603			0
swCHNL005617	VOG	Extensive	1
swCHNL005643	VOG	Limited	1
swCHNL005644	DSED		2
swCHNL005645	DWOD		2
swCHNL005646	DSED		2
swCHNL005674	VOG	Patchy	1
swCHNL005675	DSED		2
swCHNL005676	DSED		2
swCHNL005682	DSED		2
swCHNL005683	VOG		1
swCHNL005685	EBKES	Minor	3
swCHNL005686	EBKES	Minor	3
swCHNL005687			0
swCHNL005688	EBKES	Minor	3
swCHNL005690			0
swCHNL005691	VTB	Limited	3
swCHNL005693			0
swCHNL005694			0
swCHNL005695	DGAR		2

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL005696	EBKES	Minor	3
swCHNL005697	DSED		2
swCHNL005698	EBKES	Moderate	4
swCHNL005699	EBKES	Moderate	4
swCHNL005701	DSED		2
swCHNL005702	VOG	Limited	1
swCHNL005707	DSED		2
swCHNL005711	VOG	Limited	1
swCHNL005721	VOG		1
swCHNL005723	DWOD		2
swCHNL005724	ETRE	Moderate	3
swCHNL005736	EBKES	Moderate	4
swCHNL005744			0
swCHNL005757			0
swCHNL005809	VOG	Extensive	1
swCHNL005810	OGAR	50to75	4
swCHNL005811	SMSW	25to50	3
swCHNL005812	SMSW	LT25	1
swCHNL005813			0
swCHNL005815			0
swCHNL005816	SMSW	LT25	1
swCHNL005817	DSED		2
swCHNL005819	DSED		2
swCHNL005820	SMSW	LT25	1
swCHNL005823	DWOD		2
swCHNL005825	DSED		2
swCHNL005826	DSED		2
swCHNL005832	DWOD		2
swCHNL005833	VTB	Extensive	5
swCHNL005873	DSED		2
swCHNL005895	VOG		1
swCHNL005896	VOG		1
swCHNL005897	DSED		2
swCHNL005898	OSED	LT50	3
swCHNL005899			0
swCHNL005900	DWOD		2
swCHNL005901			0
swCHNL005902			0
swCHNL005903	EBKES	Moderate	4
swCHNL005904			0
swCHNL005905			0
swCHNL005906	SMSW	25to50	3
swCHNL005907	VOG	Limited	1
swCHNL005908	DSED		2
swCHNL005913	VOG	Patchy	1
swCHNL005916	OWDD	GT75	5

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL005917	DWOD		2
swCHNL005950			0
swCHNL005951	DWOD		2
swCHNL005952	DWOD		2
swCHNL005953	DWOD		2
swCHNL005954	DSED		2
swCHNL005955	OSED	LT50	3
swCHNL005956	DWOD		2
swCHNL005958	DSED		2
swCHNL005959	DWOD		2
swCHNL005960	DWOD		2
swCHNL005961	DWOD		2
swCHNL005962	DWOD		2
swCHNL005964	VOG	Limited	1
swCHNL005968	VOG		1
swCHNL005969	VOG	Limited	1
swCHNL005975	VTB	Extensive	5
swCHNL005976	DSED		2
swCHNL005977	DSED		2
swCHNL006002	VOG	Limited	1
swCHNL006003	VOG	Patchy	1
swCHNL006004			0
swCHNL006009	EBKES	Moderate	4
swCHNL006010	VOG	Limited	1
swCHNL006011			0
swCHNL006012	EBKES	Severe	4
swCHNL006013	VOG	Limited	1
swCHNL006017	OBI	LT50	3
swCHNL006019	DSED		2
swCHNL006021			0
swCHNL006029			0
swCHNL006030	VOG	Limited	1
swCHNL006033	EBKES	Minor	3
swCHNL006034	EBKES	Minor	3
swCHNL006036	VOG	Limited	1
swCHNL006064	EBKES	Minor	3
swCHNL006066	EBKES	Moderate	4
swCHNL006079	SMSW	25to50	3
swCHNL006081	DWOD		2
swCHNL006086	DSED		2
swCHNL006088	VOG	Patchy	1
swCHNL006106	OGAR	GT75	5
swCHNL006109	DWOD		2
swCHNL006110	DWOD		2
swCHNL006111	VOG	Limited	1
swCHNL006112	VOG	Limited	1

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL006151	EBKES	Moderate	4
swCHNL006153			0
swCHNL006160			0
swCHNL006161	EBKES	Moderate	4
swCHNL006175			0
swCHNL006180			0
swCHNL006182			0
swCHNL006183			0
swCHNL006184			0
swCHNL006185	OSED	50to75	4
swCHNL006186			0
swCHNL006187			0
swCHNL006188			0
swCHNL006189			0
swCHNL006190			0
swCHNL006194	VOG	Limited	1
swCHNL006195	OSED	50to75	4
swCHNL006196	OSED	50to75	4
swCHNL006197			0
swCHNL006212	VOG	Limited	1
swCHNL006213	VOG	Limited	1
swCHNL006214	OSED	GT75	5
swCHNL006215	OGAR	LT50	3
swCHNL006216			0
swCHNL006219	OSED	LT50	3
swCHNL006221	DSED		2
swCHNL006222	VOG	Extensive	1
swCHNL006223	VOG	Limited	1
swCHNL006224	VOG	Limited	1
swCHNL006225	SMSW	25to50	3
swCHNL006226	OSED	GT75	5
swCHNL006227	VOG	Limited	1
swCHNL006228			0
swCHNL006231			0
swCHNL006232			0
swCHNL006234			0
swCHNL006235			0
swCHNL006236	EBKES	Moderate	4
swCHNL006237	VOG	Limited	1
swCHNL006238	EBKES	Minor	3
swCHNL006239			0
swCHNL006240	VOG	Patchy	1
swCHNL006241			0
swCHNL006242			0
swCHNL006243			0
swCHNL006244			0

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL006254	VOG		1
swCHNL006255	VTB	Extensive	5
swCHNL006256			0
swCHNL006257			0
swCHNL006258	DWOD		2
swCHNL006259	OBN	50to75	4
swCHNL006262			0
swCHNL006264			0
swCHNL006265	DSED		2
swCHNL006266			0
swCHNL006267			0
swCHNL006270	DSED		2
swCHNL006271			0
swCHNL006272	DWOD		2
swCHNL006273	DWOD		2
swCHNL006274	OWDD	50to75	4
swCHNL006275	DWOD		2
swCHNL006281	OSED	GT75	5
swCHNL006444			0
swCHNL006485			0
swCHNL006486			0
swCHNL006487			0
swCHNL006529			0
swCHNL006556			0
swCHNL006557			0
swCHNL006580			0
swCHNL006581			0
swCHNL006583			0
swCHNL006584			0
swCHNL006585			0
swCHNL006586			0
swCHNL006587			0
swCHNL006588			0
swCHNL006589			0
swCHNL006590			0
swCHNL006591	DSED		2
swCHNL006592			0
swCHNL006593	OWDD	50to75	4
swCHNL006594	DSED		2
swCHNL006595			0
swCHNL006596			0
swCHNL006597	VOG	Limited	1
swCHNL006598	DSED		2
swCHNL006599	DSED		2
swCHNL006600			0
swCHNL006601			0

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL006602			0
swCHNL006603			0
swCHNL006604			0
swCHNL006606			0
swCHNL006607			0
swCHNL006608	VOG	Limited	1
swCHNL006609			0
swCHNL006612			0
swCHNL006615	DSED		2
swCHNL006616	DWOD		2
swCHNL006617	DSED		2
swCHNL006633	DSED		2
swCHNL006634	VTB	Limited	3
swCHNL006635	VOG	Limited	1
swCHNL006636	VOG	Limited	1
swCHNL006646	EBKES	Moderate	4
swCHNL006715	OWDD	LT50	3
swCHNL006716			0
swCHNL006717	EBKES	Moderate	4
swCHNL006718	OSED	50to75	4
swCHNL006719			0
swCHNL006720	OSED	50to75	4
swCHNL006721	OSED	50to75	4
swCHNL006722	OWDD	LT50	3
swCHNL006723			0
swCHNL006724	VOG	Limited	1
swCHNL006725	DWOD		2
swCHNL006726	OSED	GT75	5
swCHNL006727	OSED	50to75	4
swCHNL006728			0
swCHNL006729			0
swCHNL006730	DSED		2
swCHNL006731	OWDD	GT75	5
swCHNL006732	DSED		2
swCHNL006733	OWDD	LT50	3
swCHNL006734	DWOD		2
swCHNL006735	OSED	GT75	5
swCHNL006736	OSED	GT75	5
swCHNL006738	VTB	Extensive	5
swCHNL006739	DSED		2
swCHNL006772	DSED		2
swCHNL006796	VTB	Extensive	5
swCHNL006805	OSED	50to75	4
swCHNL006806	OSED	50to75	4
swCHNL006807	OWDD	GT75	5
swCHNL006808	OBB		5

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL006809			0
swCHNL006810			0
swCHNL006811	OWDD	50to75	4
swCHNL006812	DWOD		2
swCHNL006813	DWOD		2
swCHNL006816	DSED		2
swCHNL006904	SMSW	LT25	1
swCHNL006906	DWOD		2
swCHNL006911	SMSW	25to50	3
swCHNL006913	DSED		2
swCHNL006961			0
swCHNL006962	DSED		2
swCHNL006963	DSED		2
swCHNL006964	VOG	Patchy	1
swCHNL006965	DWOD		2
swCHNL006966	DWOD		2
swCHNL006967	VOG	Patchy	1
swCHNL006968	VOG	Extensive	1
swCHNL006969	OSED	50to75	4
swCHNL006970	DWOD		2
swCHNL006971			0
swCHNL006972	VOG	Extensive	1
swCHNL006973	DSED		2
swCHNL006981			0
swCHNL006985	OBN	50to75	4
swCHNL007014	DSED		2
swCHNL007018	DSED		2
swCHNL007028	VOG	Limited	1
swCHNL007029	OWDD	LT50	3
swCHNL007030	SMSW	25to50	3
swCHNL007031	OGAR	50to75	4
swCHNL007032	OBN	50to75	4
swCHNL007034	DSED		2
swCHNL007035	EBKES	Moderate	4
swCHNL007036	DSED		2
swCHNL007037	EBKES	Minor	3
swCHNL007038	VOG	Limited	1
swCHNL007039			0
swCHNL007040	OSED	50to75	4
swCHNL007041	VOG	Extensive	1
swCHNL007042	EBKES	Moderate	4
swCHNL007043	EBKES	Minor	3
swCHNL007045			0
swCHNL007046	EBMES	Moderate	4
swCHNL007047	VOG	Patchy	1
swCHNL007048	OSED	50to75	4

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL007049	DSED		2
swCHNL007050	VOG	Limited	1
swCHNL007051	DSED		2
swCHNL007054	VTB	Extensive	5
swCHNL007068	VOG		1
swCHNL007086	DSED		2
swCHNL007101	DWOD		2
swCHNL007105			0
swCHNL007107			0
swCHNL007108	DWOD		2
swCHNL007109	DSED		2
swCHNL007110	DWOD		2
swCHNL007112	EBKES	Minor	3
swCHNL007117			0
swCHNL007127	OBP	LT50	3
swCHNL007129	OSED	50to75	4
swCHNL007130	OWDD	GT75	5
swCHNL007131	OWDD	50to75	4
swCHNL007132	OBZ	GT75	5
swCHNL007133	OBB		5
swCHNL007137	DWOD		2
swCHNL007138			0
swCHNL007152	OWDD		0
swCHNL007153	OWDD	LT50	3
swCHNL007154			0
swCHNL007163			0
swCHNL007164	DSED		2
swCHNL007168			0
swCHNL007172	VTB	Extensive	5
swCHNL007173			0
swCHNL007174	VOG	Extensive	1
swCHNL007175	VTB	Extensive	5
swCHNL007176			0
swCHNL007181	VTB	Limited	3
swCHNL007184			0
swCHNL007186	VTB	Extensive	5
swCHNL007187			0
swCHNL007192			0
swCHNL007196	VOG	Patchy	1
swCHNL007197	DWOD		2
swCHNL007199			0
swCHNL007201			0
swCHNL007202	DSED		2
swCHNL007205			0
swCHNL007214			0
swCHNL990007		Moderate	0

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL990009	OWDD	LT50	3
swCHNL990010			0
swCHNL990012			0
swCHNL990017			0
swCHNL990023			0
swCHNL990024			0
swCHNL990025			0
swCHNL990026			0
swCHNL990027	VGS	Extensive	4
swCHNL990031	EBKES	Moderate	4
swCHNL990035			0
swCHNL990043	VOG	Patchy	1
swCHNL990044	DSED		2
swCHNL990045	OSED	50to75	4
swCHNL990046	VOG	Limited	1
swCHNL990047	DSED		2
swCHNL990051	OSED	GT75	5
swCHNL990052			0
swCHNL990053	VTB	Extensive	5
swCHNL990056	VTB	Extensive	5
swCHNL990057	DWOD		2
swCHNL990067			0
swCHNL990068	OWDD	GT75	5
swCHNL990069	OWDD	50to75	4
swCHNL990070			0
swCHNL990072	OSED	50to75	4
swCHNL990073	DSED		2
swCHNL990074	DWOD		2
swCHNL990075	OWDD	LT50	3
swCHNL990076	OSED	LT50	3
swCHNL990077	SMSW	25to50	3
swCHNL990088	ETRE	Minor	1
swCHNL990089	DSED		2
swCHNL990090	DSED		2
swCHNL990092	DSED		2
swCHNL990095	DWOD		2
swCHNL990096	DSED		2
swCHNL990098	DWOD		2
swCHNL990099	DSED		2
swCHNL990100			0
swCHNL990101			0
swCHNL990102			0
swCHNL990103			0
swCHNL990104			0
swCHNL990105			0
swCHNL990106			0

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCHNL990107			0
swCHNL990108			0
swCHNL990109			0
swCHNL990110	DWOD		2
swCHNL990111			0
swCHNL990112	DSED		2
swCHNL990113	DSED		2
swCHNL990117	DWOD		2
swCHNL990118	DWOD		2
swCHNL990122			0
swCHNL990125			0
swCHNL990126	VOG		1
swCHNL990132	EBKES	Moderate	4
swCHNL990133	EBKES	Moderate	4
swCHNL990134			0
swCHNL990135	OBN	GT75	5
swCHNL990137	VTB	Extensive	5
swCHNL990138	DSED		2
swCHNL990139	SMSW	25to50	3
swCHNL990140			0
swCHNL990141			0
swCHNL990142	OBRG	50to75	4
swCHNL990143			0
swCHNL990146	OSED	GT75	5
swCHNL990147	SMSW	25to50	3
swCHNL990148			0
swCHNL990149	SMSW	25to50	3
swCHNL990150	SMSW	25to50	3
swCHNL990151	OBRG	GT75	5
SWCHNL990152	OBRG	50to75	4
SWCHNL990154	VTB	Limited	3
swCHNL990514		Moderate	0
swCLVT000260	JS	Severe	5
swCLVT000262	SMSW	25to50	3
swCLVT000263	DSED		2
swCLVT000269	SMFW	LT25	1
swCLVT000270	SMFW	LT25	1
swCLVT000273			0
swCLVT000388	JO	Minor	2
swCLVT000389	DWOD		2
swCLVT000390	DSED		2
swCLVT000391	JS	Moderate	4
swCLVT000392	JS	Moderate	4
swCLVT000393	DSED		2
swCLVT000395	JO	Minor	2
swCLVT000418	SMSW	LT25	1

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCLVT000419	OBRG	LT50	3
swCLVT000420	DWOD		2
swCLVT000421	DWOD		2
swCLVT000422	DSED		2
swCLVT000423	DWOD		2
swCLVT000424	DSED		2
swCLVT000425	JO	Minor	2
swCLVT000426	OSED	LT50	3
swCLVT000427	DWOD		2
swCLVT000428	DWOD		2
swCLVT000429	JO	Minor	2
swCLVT000430	DWOD		2
swCLVT000435	VOG		1
swCLVT000439			0
swCLVT000440	OBRG	LT50	3
swCLVT000441			0
swCLVT000442			0
swCLVT000443			0
swCLVT000453	OSED	50to75	4
swCLVT000474			0
swCLVT000490	SMSW	25to50	3
swCLVT000508	DSED		2
swCLVT000532	JO	Moderate	3
swCLVT000544			0
swCLVT000545			0
swCLVT000546	OSED	50to75	4
swCLVT000547	OSED	GT75	5
swCLVT000549	OSED	50to75	4
swCLVT000550	JO	Minor	2
swCLVT000551	JO	Minor	2
swCLVT000555	OSED	50to75	4
swCLVT000556	OSED	GT75	5
swCLVT000557	DSED		2
swCLVT000563	DSED		2
swCLVT000566			0
swCLVT000567	JO	Minor	2
swCLVT000568	DSED		2
swCLVT000569	DSED		2
swCLVT000570	JO	Minor	2
swCLVT000571	SMSW	25to50	3
swCLVT000572	JO	Moderate	3
swCLVT000573	OSED	LT50	3
swCLVT000574		Moderate	0
swCLVT000576	OSED	GT75	5
swCLVT000577	OSED	LT50	3
swCLVT000578	DSED		2

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCLVT000579	JS	Moderate	4
swCLVT000580	JS	Minor	3
swCLVT000581	JO	Moderate	3
swCLVT000582	OSED	GT75	5
swCLVT000583	DSED		2
swCLVT000584	JO	Minor	2
swCLVT000591	JO	Moderate	3
swCLVT000593	DGAR		2
swCLVT000594	OSED	50to75	4
swCLVT000597	OBB	GT75	5
swCLVT000598	OBB	GT75	5
swCLVT000599	JO	Minor	2
swCLVT000600	JO	Minor	2
swCLVT000601	DSED		2
swCLVT000602	JO	Minor	2
swCLVT000607	JO	Minor	2
swCLVT000608	JO	Minor	2
swCLVT000609	JO	Minor	2
swCLVT000610	DSED		2
swCLVT000821			0
swCLVT000822	JO	Moderate	3
swCLVT000825			0
swCLVT000826	JO	Minor	2
swCLVT000827			0
swCLVT000828	JO	Minor	2
swCLVT000829	DSED		2
swCLVT000830	JO	Minor	2
swCLVT000831	JO	Minor	2
swCLVT000832	SMSW	25to50	3
swCLVT000833		Moderate	0
swCLVT000834	DSED		2
swCLVT000835	DSED		2
swCLVT000836	DSED		2
swCLVT000837	DSED		2
swCLVT000838	DSED		2
swCLVT000839	DSED		2
swCLVT000840	DSED		2
swCLVT000841	EBKES	Minor	3
swCLVT000842	OBRG	LT50	3
swCLVT000843	DSED		2
swCLVT000844	OSED	LT50	3
swCLVT000845	DSED		2
swCLVT000846			0
swCLVT000847	SMSW	25to50	3
swCLVT000848	SMSW	25to50	3
swCLVT000851	OSED	50to75	4

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCLVT000867	SMSW	GT50	5
swCLVT000921	JS	Minor	3
swCLVT000922	DWOD		2
swCLVT000923	OSED	LT50	3
swCLVT000924	OSED	LT50	3
swCLVT000925	OSED	LT50	3
swCLVT000926	OSED	LT50	3
swCLVT000927	OSED	LT50	3
swCLVT000928	DSED		2
swCLVT000930	JO	Moderate	3
swCLVT000931	JO	Moderate	3
swCLVT000932	DSED		2
swCLVT000933	OSED	GT75	5
swCLVT000934	DSED		2
swCLVT000936	OSED	GT75	5
swCLVT000937	OBB		5
swCLVT000938		Moderate	0
swCLVT000972	OSED	50to75	4
swCLVT000973	JS	Moderate	4
swCLVT000974	OBB		5
swCLVT000975	DSED		2
swCLVT000976	SMSW	LT25	1
swCLVT000977	JO	Moderate	3
swCLVT000978	DSED		2
swCLVT000979	OWDD	LT50	3
swCLVT000980	OWDD	50to75	4
swCLVT000981	DSED		2
swCLVT000982	DSED		2
swCLVT000983	OSED	50to75	4
swCLVT990018	JS	Moderate	4
swCLVT990019			0
swCLVT990021			0
swCLVT990022	JO	Minor	2
swCLVT990023			0
swCLVT990024	JO	Minor	2
swCLVT990025			0
swCLVT990028	JO	Minor	2
swCLVT990029	OSED	GT75	5
swCLVT990030	DSED		2
swCLVT990031	OSED	50to75	4
swCLVT990032			0
swCLVT990034	JO	Minor	2
swCLVT990035	OSED	50to75	4
swCLVT990038	OSED	50to75	4
swCLVT990039	OSED	LT50	3
swCLVT990040	OSED	50to75	4

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCLVT990045	OSED	50to75	4
swCLVT990048			0
swCLVT990049			0
swCLVT990051	OSED	LT50	3
swCLVT990052			0
swCLVT990053	JO	Moderate	3
swCLVT990065	JO	Severe	4
swCLVT990066	JS	Moderate	4
swCLVT990067			0
swCLVT990068			0
swCLVT990069	JO	Minor	2
swCLVT990070	DSED		2
swCLVT990071	DSED		2
swCLVT990072	OSED	LT50	3
swCLVT990073	DSED		2
swCLVT990074	OSED	50to75	4
swCLVT990075	JO	Minor	2
swCLVT990076	OSED	GT75	5
swCLVT990077			0
swCLVT990078	JO	Minor	2
swCLVT990079	OSED	LT50	3
swCLVT990080	JO	Severe	4
swCLVT990081	JO	Moderate	3
swCLVT990082	DSED		2
swCLVT990083	JO	Minor	2
swCLVT990084	DSED		2
swCLVT990085	DSED		2
swCLVT990086	DSED		2
swCLVT990087	SMSW	25to50	3
swCLVT990088	SMSW	25to50	3
swCLVT990089	SMSW	25to50	3
swCLVT990093		Moderate	0
swCLVT990094	DSED		2
swCLVT990095	DGAR		2
swCLVT990098	JO	Minor	2
swCLVT990099	DGAR		2
swCLVT990100	OSED	50to75	4
swCLVT990101	OSED	50to75	4
swCLVT990102	JO	Moderate	3
swCLVT990104	JS	Severe	5
swCLVT990105	JO	Minor	2
swCLVT990119	DSED		2
swCLVT990120	OSED	50to75	4
swCLVT990121	OSED	GT75	5
swCLVT990122	OBB		5
swCLVT990123	OBB		5

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swCLVT990124	OSED	LT50	3
swCLVT990125	OBB		5
swCLVT990126	OSED	50to75	4
swCLVT990127	OBB		5
swCLVT990128	OBZ	GT75	5
swCLVT990129	OSED	GT75	5
swCLVT990130	OBB		5
swCLVT990131	OWDD	50to75	4
swCLVT990132	DSED		2
swCLVT990135	DSED		2
swCLVT990136		Moderate	0
swCLVT990159	OSED	GT75	5
swCLVT990160	DSED		2
swCLVT990161	OSED	GT75	5
swCLVT990162	OSED	GT75	5
swCLVT990164	DSED		2
swCLVT990165	JO	Minor	2
swCLVT990167	DSED		2
swCLVT990168	DSED		2
swCLVT990169	DSED		2
swCLVT990170	SMSW	LT25	1
swCLVT990171	SMSW	GT50	5
swCLVT990172	DWOD		2
swCLVT990174	JO	Severe	4
swCLVT990176	JO	Minor	2
swCLVT990177			0
swCLVT990178	JO	Moderate	3
swCLVT990179	JO	Moderate	3
swCLVT990180	OSED	50to75	4
swCLVT990181	DSED		2
swCLVT990201	JO	Moderate	3
swCLVT990202			0
SWCLVT990203	SMSW	25to50	3
SWCLVT990204	OSED	50to75	4
swCLVT990500		Moderate	0
swCLVT990504	OSED	50to75	4
swPIPE002352	JO	Minor	2
swPIPE002353	JO	Severe	4
swPIPE002354			0
swPIPE002355			0
swPIPE002358			0
swPIPE002359	JO	Moderate	3
swPIPE010571	JO	Minor	2
swPIPE010580	DSED		2
swPIPE010581	JO	Moderate	3
swPIPE010582	DSED		2

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE010583	SMSW	25to50	3
swPIPE010590			0
swPIPE010672	JO	Minor	2
swPIPE010673			0
swPIPE010687			0
swPIPE010690	JO	Moderate	3
swPIPE010691	SMSW	LT25	1
swPIPE010692	JO	Minor	2
swPIPE010694			0
swPIPE010695	JO	Moderate	3
swPIPE010696	JO	Minor	2
swPIPE010697	DWOD		2
swPIPE010698	DSED		2
swPIPE010699	OSED	LT50	3
swPIPE010700	JS	Moderate	4
swPIPE010701	JS	Moderate	4
swPIPE010702	JO	Minor	2
swPIPE010703	SAG	LT30	2
swPIPE010705			0
swPIPE010706	JO	Moderate	3
swPIPE010754	SMSW	LT25	1
swPIPE010756	SMSW	25to50	3
swPIPE010757			0
swPIPE010809	DSED		2
swPIPE010810	JO	Minor	2
swPIPE010811	DSED		2
swPIPE010812	JO	Minor	2
swPIPE010813	JO	Minor	2
swPIPE010814	SMSW	LT25	1
swPIPE010815	DSED		2
swPIPE010816	SMSW	LT25	1
swPIPE010817	JS	Minor	3
swPIPE010818	SMSW	LT25	1
swPIPE010819	JO	Minor	2
swPIPE010820	SMSW	LT25	1
swPIPE010821	JO	Minor	2
swPIPE010822			0
swPIPE010823	SMSW	25to50	3
swPIPE010824	SMSW	25to50	3
swPIPE010825	SMSW	LT25	1
swPIPE010827	SMSW	LT25	1
swPIPE010828	SMSW	25to50	3
swPIPE010829	JO	Minor	2
swPIPE010973	JO	Minor	2
swPIPE010974	DWOD		2
swPIPE010975	SMSW	LT25	1

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE010976	JO	Moderate	3
swPIPE010977	JO	Minor	2
swPIPE010978		Minor	0
swPIPE010979	SMSW	LT25	1
swPIPE010980	SMSW	LT25	1
swPIPE010981	SMSW	LT25	1
swPIPE010982	SMSW	LT25	1
swPIPE010983			0
swPIPE010984	SMSW	25to50	3
swPIPE010988	JS	Moderate	4
swPIPE010989			0
swPIPE010993			0
swPIPE010994	DWOD		2
swPIPE010995	DWOD		2
swPIPE010997		Moderate	0
swPIPE011027			0
swPIPE011031	JO	Minor	2
swPIPE011032	JO	Minor	2
swPIPE011037	DZ		2
swPIPE011038			0
swPIPE011039	JO	Minor	2
swPIPE011040			0
swPIPE011041			0
swPIPE011042			0
swPIPE011043			0
swPIPE011045	JO	Minor	2
swPIPE011046	JO	Minor	2
swPIPE011048	SMSW	LT25	1
swPIPE011051			0
swPIPE011109	DSED		2
swPIPE011152			0
swPIPE011155	JO	Minor	2
swPIPE011156			0
swPIPE011170			0
swPIPE011174			0
swPIPE011205			0
swPIPE011206	SMSW	GT50	5
swPIPE011207	SMSW	GT50	5
swPIPE011235	SMSW	GT50	5
swPIPE011237	OSED	50to75	4
swPIPE011238	DSED		2
swPIPE011239	OSED	LT50	3
swPIPE011240	SMSW	25to50	3
swPIPE011241	JO	Minor	2
swPIPE011243	OSED	LT50	3
swPIPE011253	SMSW	GT50	5

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE011255	SMSW	25to50	3
swPIPE011258	DSED		2
swPIPE011260	DSED		2
swPIPE011261	DSED		2
swPIPE011262			0
swPIPE011264	JO	Moderate	3
swPIPE011267			0
swPIPE011269	DSED		2
swPIPE011270	SMSW	25to50	3
swPIPE011271			0
swPIPE011272			0
swPIPE011273	OWDD	50to75	4
swPIPE011274			0
swPIPE011276			0
swPIPE011277	JS	Minor	3
swPIPE011333			0
swPIPE011334			0
swPIPE011335			0
swPIPE011337	JS	Moderate	4
swPIPE011372	DSED		2
swPIPE011373	SMSW	LT25	1
swPIPE011388	DSED		2
swPIPE011401	JO	Moderate	3
swPIPE011409	JS	Minor	3
swPIPE011410			0
swPIPE011411	OSED	50to75	4
swPIPE011412	DSED		2
swPIPE011413	SMSW	LT25	1
swPIPE011414			0
swPIPE011416			0
swPIPE011417	SMSW	LT25	1
swPIPE011418	OSED	LT50	3
swPIPE011419	JO	Minor	2
swPIPE011420	OSED	LT50	3
swPIPE011421			0
swPIPE011422	JO	Minor	2
swPIPE011423	JO	Minor	2
swPIPE011424	JO	Minor	2
swPIPE011425	JO	Moderate	3
swPIPE011426			0
swPIPE011427	JO	Moderate	3
swPIPE011434	JO	Minor	2
swPIPE011435	JO	Minor	2
swPIPE011441	DSED		2
swPIPE011447		Moderate	0
swPIPE011515	OGAR	LT50	3

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE012033			0
swPIPE012034			0
swPIPE012041			0
swPIPE012042			0
swPIPE012049	DSED		2
swPIPE012050			0
swPIPE012051			0
swPIPE012052	JO	Minor	2
swPIPE012053			0
swPIPE012055			0
swPIPE012058			0
swPIPE012061			0
swPIPE012065			0
swPIPE012066	DWOD		2
swPIPE012070			0
swPIPE012072			0
swPIPE012073	DSED		2
swPIPE012090	JO	Minor	2
swPIPE012091			0
swPIPE012092	OSED	LT50	3
swPIPE012093			0
swPIPE012094	SMSW	25to50	3
swPIPE012101	JO	Minor	2
swPIPE012111	SMSW	25to50	3
swPIPE012112	OWDD	50to75	4
swPIPE012132			0
swPIPE012133			0
swPIPE012134	JS	Severe	5
swPIPE012147	JO	Moderate	3
swPIPE012151	SMSW	25to50	3
swPIPE012152			0
swPIPE012153			0
swPIPE012162	SMSW	GT50	5
swPIPE012163	OGAR	50to75	4
swPIPE012165	JS	Severe	5
swPIPE012178	JO	Moderate	3
swPIPE012196	RT		4
swPIPE012197	JO	Minor	2
swPIPE012198	DSED		2
swPIPE012199	DSED		2
swPIPE012200	SMSW	LT25	1
swPIPE012218	JO	Minor	2
swPIPE012219	SMSW	GT50	5
swPIPE012220	JO	Minor	2
swPIPE012221	JO	Minor	2
swPIPE012222	OWDD	50to75	4

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE012223	RB		5
swPIPE012224	SMSW	25to50	3
swPIPE012226	JS	Moderate	4
swPIPE013525	SMSW	25to50	3
swPIPE013526			0
swPIPE013527	JO	Minor	2
swPIPE013528			0
swPIPE013537	JO	Minor	2
swPIPE013586	DSED		2
swPIPE013598	DSED		2
swPIPE013602			0
swPIPE013603			0
swPIPE013614			0
swPIPE013615	OWDD	50to75	4
swPIPE013616			0
swPIPE013617	JO	Moderate	3
swPIPE013654			0
swPIPE013655	DSED		2
swPIPE013656			0
swPIPE013659	OSED	50to75	4
swPIPE013660	DSED		2
swPIPE013661			0
swPIPE013662	JS	Moderate	4
swPIPE013663			0
swPIPE013664			0
swPIPE013665	OBB	GT75	5
swPIPE013666			0
swPIPE013667			0
swPIPE013668			0
swPIPE013673	OBZ	GT75	5
swPIPE013674			0
swPIPE013677	OSED	LT50	3
swPIPE013696	OBN	GT75	5
swPIPE013701	SMSW	GT50	5
swPIPE013702		Moderate	0
swPIPE013721	JS	Minor	3
swPIPE013722	JS	Minor	3
swPIPE013723	DWOD		2
swPIPE013724	JO	Moderate	3
swPIPE013725	JS	Minor	3
swPIPE013726			0
swPIPE013727			0
swPIPE013728	JS	Moderate	4
swPIPE013729	JO	Minor	2
swPIPE013730	JS	Moderate	4
swPIPE013731	SMSW	25to50	3

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE013732			0
swPIPE013736	SMSW	25to50	3
swPIPE013738	SMSW	25to50	3
swPIPE013740	JO	Moderate	3
swPIPE013754	SMSW	LT25	1
swPIPE013755	JS	Moderate	4
swPIPE013756	SMSW	LT25	1
swPIPE013758	JO	Minor	2
swPIPE013762	JS	Moderate	4
swPIPE013765			0
swPIPE013766			0
swPIPE013767			0
swPIPE013768	OSED	GT75	5
swPIPE013769			0
swPIPE013771	DWOD		2
swPIPE013772	JS	Severe	5
swPIPE013774			0
swPIPE013783			0
swPIPE013784			0
swPIPE013785	JO	Minor	2
swPIPE013786	SMSW	GT50	5
swPIPE013787	SMSW	GT50	5
swPIPE013792	OSED	50to75	4
swPIPE013795	OSED	50to75	4
swPIPE013810	DSED		2
swPIPE013818	SMSW	25to50	3
swPIPE013819	DSED		2
swPIPE013820			0
swPIPE013821	JO	Severe	4
swPIPE013822			0
swPIPE013823			0
swPIPE013824	DGRV		2
swPIPE013825	DGRV		2
swPIPE013826	DGRV		2
swPIPE013828	JS	Severe	5
swPIPE013829	JO	Moderate	3
swPIPE013830	RB		5
swPIPE013831	JO	Moderate	3
swPIPE013834			0
swPIPE013835	JO	Minor	2
swPIPE013840	JS	Minor	3
swPIPE013849	SMSW	GT50	5
swPIPE013850	JO	Moderate	3
swPIPE013851			0
swPIPE013852	JO	Minor	2
swPIPE013853	DSED		2

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE013854	DSED		2
swPIPE013855	DSED		2
swPIPE013856			0
swPIPE013857	JO	Moderate	3
swPIPE013858	DSED		2
swPIPE013859	JO	Moderate	3
swPIPE013875	SMSW	LT25	1
swPIPE013879	SMSW	GT50	5
swPIPE013880	SMSW	GT50	5
swPIPE013883	DSED		2
swPIPE013884	DSED		2
swPIPE013885	DSED		2
swPIPE013906	JO	Minor	2
swPIPE013907	RB		5
swPIPE013910	JO	Minor	2
swPIPE013911			0
swPIPE013912			0
swPIPE990002	OSED	50to75	4
swPIPE990010	JO	Moderate	3
swPIPE990011			0
swPIPE990012			0
swPIPE990013			0
swPIPE990014			0
swPIPE990015	JS	Moderate	4
swPIPE990016	DSED		2
swPIPE990029	DSED		2
swPIPE990030	OSED	50to75	4
swPIPE990031			0
swPIPE990032			0
swPIPE990033			0
swPIPE990034			0
swPIPE990035			0
swPIPE990036			0
swPIPE990037			0
swPIPE990038	OBP	LT50	3
swPIPE990039	OBP	LT50	3
swPIPE990041			0
swPIPE990048			0
swPIPE990049			0
swPIPE990050			0
swPIPE990051	OBP	LT50	3
swPIPE990059			0
swPIPE990062			0
swPIPE990066	OBI	LT50	3
swPIPE990067	DSED		2
swPIPE990068	DSED		2

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE990069	DSED		2
swPIPE990071	JO	Moderate	3
swPIPE990075	JO	Moderate	3
swPIPE990077	SMSW	GT50	5
swPIPE990078	DSED		2
swPIPE990079	DSED		2
swPIPE990082	SMSW	GT50	5
swPIPE990083	VOG	Extensive	1
swPIPE990090	DSED		2
swPIPE990091	JO	Minor	2
swPIPE990096			0
swPIPE990097	DSED		2
swPIPE990098	DSED		2
swPIPE990099	JO	Minor	2
swPIPE990100	JS	Minor	3
swPIPE990101	DSED		2
swPIPE990102			0
swPIPE990103	DSED		2
swPIPE990104	DSED		2
swPIPE990112			0
swPIPE990113	DSED		2
swPIPE990114	DSED		2
swPIPE990115	JO	Minor	2
swPIPE990119			0
swPIPE990120	JO	Minor	2
swPIPE990130	OSED	LT50	3
swPIPE990131	JO	Severe	4
swPIPE990132	JO	Severe	4
swPIPE990133			0
swPIPE990134	JO	Minor	2
swPIPE990153	JO	Severe	4
swPIPE990154	OWDD	50to75	4
swPIPE990155	JO	Moderate	3
swPIPE990156	SMFW	LT25	1
swPIPE990157	OSED	50to75	4
swPIPE990158	JS	Moderate	4
swPIPE990159	SMSW	LT25	1
swPIPE990160	DSED		2
swPIPE990161	SMSW	LT25	1
swPIPE990162	SMSW	LT25	1
swPIPE990163	OSED	50to75	4
swPIPE990164	DSED		2
swPIPE990165	DSED		2
swPIPE990167	SMSW	GT50	5
swPIPE990168	SMSW	GT50	5
swPIPE990169	SMSW	25to50	3

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE990170		Moderate	0
swPIPE990171	SMSW	GT50	5
swPIPE990172	SMSW	GT50	5
swPIPE990173	OSED	LT50	3
swPIPE990174			0
swPIPE990175	OGAR	50to75	4
swPIPE990176	OGAR	50to75	4
swPIPE990177	SMSW	LT25	1
swPIPE990182	OSED	LT50	3
swPIPE990184	SMSW	GT50	5
swPIPE990186	SMSW	25to50	3
swPIPE990187	SMSW	25to50	3
swPIPE990188	SMSW	25to50	3
swPIPE990189	SMSW	25to50	3
swPIPE990190	JO	Minor	2
swPIPE990191	SMSW	25to50	3
swPIPE990192	SMSW	25to50	3
swPIPE990193	JO	Minor	2
swPIPE990196	SMSW	25to50	3
swPIPE990202	SMSW	GT50	5
swPIPE990203	SMSW	25to50	3
swPIPE990204	JO	Minor	2
swPIPE990205			0
swPIPE990207			0
swPIPE990208	OBN	LT50	3
swPIPE990209	DSED		2
swPIPE990210			0
swPIPE990211	JO	Minor	2
swPIPE990212	SMSW	25to50	3
swPIPE990213	DSED		2
swPIPE990216	DSED		2
swPIPE990217	OSED	GT75	5
swPIPE990218	DSED		2
swPIPE990219	DSED		2
swPIPE990220	SMFW	GT50	5
swPIPE990221	SMSW	GT50	5
swPIPE990223	SMSW	LT25	1
swPIPE990224	SMSW	LT25	1
swPIPE990225	SMSW	LT25	1
swPIPE990226	JS	Moderate	4
swPIPE990230	JO	Severe	4
swPIPE990231	OSED	50to75	4
swPIPE990232	JO	Minor	2
swPIPE990234	DSED		2
swPIPE990422	JO	Minor	2
swPIPE990423	DSED		2

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE990445	SMSW	LT25	1
swPIPE990446	DSED		2
swPIPE990448	DSED		2
swPIPE990450	JO	Minor	2
swPIPE990453	SMSW	LT25	1
swPIPE990454	SMSW	LT25	1
swPIPE990455	SMSW	LT25	1
swPIPE990456			0
swPIPE990458	DSED		2
swPIPE990461	DSED		2
swPIPE990463			0
swPIPE990465	SMSW	LT25	1
swPIPE990474	DSED		2
swPIPE990475		LT30	0
swPIPE990476	JO	Moderate	3
swPIPE990477	JO	Minor	2
swPIPE990479	JO	Moderate	3
swPIPE990480	SMSW	LT25	1
swPIPE990481	JO	Minor	2
swPIPE990482	SMSW	LT25	1
swPIPE990483	JO	Minor	2
swPIPE990484	JO	Minor	2
swPIPE990486			0
swPIPE990487	JO	Moderate	3
swPIPE990489	JO	Moderate	3
swPIPE990490	DWOD		2
swPIPE990492	DSED		2
swPIPE990496	SMSW	LT25	1
swPIPE990500	JS	Moderate	4
swPIPE990501			0
swPIPE990502	DSED		2
swPIPE990503	SMSW	25to50	3
swPIPE990507	JO	Minor	2
swPIPE990601			0
swPIPE990602	JO	Minor	2
swPIPE990605	DSED		2
swPIPE990606	SMSW	LT25	1
swPIPE990609	JO	Minor	2
swPIPE990610	JO	Minor	2
swPIPE990611	JO	Minor	2
swPIPE990619	SMSW	GT50	5
swPIPE990620	OSED	GT75	5
swPIPE990623	DSED		2
swPIPE990624	JO	Minor	2
swPIPE990626	SMSW	LT25	1
swPIPE990628	SMSW	25to50	3

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE990629	SMSW	25to50	3
swPIPE990630	DSED		2
swPIPE990631	SMSW		0
swPIPE990632	SMSW	25to50	3
swPIPE990633	JO	Severe	4
swPIPE990634	SMSW	25to50	3
swPIPE990635		30to50	3
swPIPE990636	SMSW	GT50	5
swPIPE990638	SMSW	GT50	5
swPIPE990639	SMSW	GT50	5
swPIPE990640	SMSW	25to50	3
swPIPE990641	SMSW	25to50	3
swPIPE990642	SMSW	GT50	5
swPIPE990643	SMSW	GT50	5
swPIPE990644			0
swPIPE990644			0
swPIPE990645	SMSW	GT50	5
swPIPE990646	SMSW	GT50	5
swPIPE990647	SMSW	GT50	5
swPIPE990648	SMSW	GT50	5
swPIPE990649	SMSW		0
swPIPE990650	SMSW	LT25	1
swPIPE990651	SMSW	LT25	1
swPIPE990652	SMSW	LT25	1
swPIPE990653	JO	Minor	2
swPIPE990654			0
swPIPE990655			0
swPIPE990657	SMSW	LT25	1
swPIPE990658			0
swPIPE990659	DSED		2
swPIPE990660	DSED		2
swPIPE990662	DSED		2
swPIPE990663	DSED		2
swPIPE990667	DSED		2
swPIPE990668	DSED		2
swPIPE990669			0
swPIPE990670	DSED		2
swPIPE990671	DSED		2
swPIPE990672	DSED		2
swPIPE990673	DSED		2
swPIPE990674	DSED		2
swPIPE990675			0
swPIPE990677	OSED	LT50	3
swPIPE990685	SMSW	LT25	1
swPIPE990686	DSED		2
swPIPE990687	DSED		2

Appendix M
Detailed Condition Assessment Scoring
Pipes, Culverts, and Channels

Asset ID	Description	Modifier	Condition Grade
swPIPE990689	DSED		2
swPIPE990700			0
swPIPE990702	SMSW	LT25	1
swPIPE990703			0
swPIPE990704			0
SWPIPE990708			0
SWPIPE990716	SMSW	25to50	3
SWPIPE990717	DSED		2
SWPIPE990718			0
SWPIPE990719	SMSW	25to50	3
SWPIPE990721	DSED		2
SWPIPE990722			0
SWPIPE990725	JS	Moderate	4

Appendix N Detailed Flood Resiliency Scoring Modeled Nodes

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_1	2.06	2.09	2.11	2.15	2.18	2.22			21	4			25
DuWapMH_10	-0.23	0.04	0.26	0.57	0.82	0.99			15	2			17
DuWapMH_101	-1.67	-1.58	-0.75	0.38	0.78	1.29			6	1			7
DuWapMH_103	0.82	1.10	1.29	1.50	1.74	2.22			21	3			24
DuWapMH_104	1.15	1.54	1.81	2.15	2.40	2.68			21	4			25
DuWapMH_105	0.54	0.90	1.16	1.47	1.70	1.94			21	3			24
DuWapMH_106	-2.09	-1.81	-1.62	-1.41	-1.19	-0.73			0	0			0
DuWapMH_107	0.58	1.34	1.93	2.21	2.36	2.62			21	4			25
DuWapMH_108	1.07	1.12	1.16	1.23	1.28	1.35			21	3			24
DuWapMH_109	-0.29	-0.17	-0.06	0.07	0.17	0.26			6	1			7
DuWapMH_11	-0.50	-0.22	-0.03	0.18	0.41	0.89	US Highway w/in 50'		6	1	10		17
DuWapMH_111	-5.19	-4.86	-4.61	-4.34	-4.13	-3.79			0	0			0
DuWapMH_112	-0.49	-0.22	-0.05	0.15	0.35	0.75			6	1			7
DuWapMH_113	2.09	2.18	2.22	2.28	2.33	2.38			21	4			25
DuWapMH_114	0.86	1.00	1.13	1.31	1.45	1.60			21	3			24
DuWapMH_115	-0.20	0.06	0.23	0.43	0.63	0.97			15	1			16
DuWapMH_116	0.77	1.06	1.27	1.51	1.81	2.54			21	3			24
DuWapMH_117	-0.82	-0.53	-0.33	-0.09	0.14	0.50			3	0			3
DuWapMH_118	-3.22	-3.13	-3.11	-3.08	-3.06	-3.04			0	0			0
DuWapMH_119	0.23	0.62	0.89	1.23	1.48	1.76			21	3			24
DuWapMH_12	-0.72	-0.44	-0.25	-0.04	0.19	0.65			3	0			3
DuWapMH_121	2.66	3.06	3.36	3.70	4.17	5.58			21	4			25
DuWapMH_123	0.88	1.20	1.33	1.52	1.67	1.84			21	3			24
DuWapMH_124	0.81	0.86	0.90	0.97	1.02	1.09			21	2			23
DuWapMH_128	-0.34	0.03	0.29	0.59	0.96	1.89			15	2			17
DuWapMH_129	-1.47	-1.12	-0.57	-0.17	0.23	1.07			3	0			3
DuWapMH_13	1.85	2.20	2.45	2.72	3.06	3.85			21	4			25
DuWapMH_130	2.85	3.14	3.35	3.60	3.87	4.41			21	4			25
DuWapMH_131	1.74	1.99	2.20	2.50	2.87	3.36			21	4			25
DuWapMH_132	-0.93	-0.67	-0.46	-0.16	0.25	0.78			3	0			3
DuWapMH_133	-0.84	-0.58	-0.33	0.00	0.40	0.96			3	1			4
DuWapMH_134	4.20	4.48	4.70	4.94	5.24	5.93			21	4			25
DuWapMH_135	0.67	1.00	1.24	1.51	1.72	2.05			21	3			24
DuWapMH_136	-1.53	-1.38	-0.76	0.34	0.72	1.18			6	1			7
DuWapMH_137	-1.64	-1.31	-1.07	-0.79	-0.49	0.19			1	0			1

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth 2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	Roadway	Critical Facilities	Scoring Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_14	0.13	0.48	0.70	0.96	1.27	1.95			21	2			23
DuWapMH_140	3.02	3.29	3.48	3.69	3.93	4.41			21	4			25
DuWapMH_141	-1.50	-0.79	0.18	1.32	1.73	2.25			10	3			13
DuWapMH_143	-0.31	0.03	0.27	0.57	0.78	1.00			15	2			17
DuWapMH_144	-3.37	-3.23	-3.15	-3.05	-2.98	-2.93			0	0			0
DuWapMH_146	-2.77	-2.77	-2.76	-2.73	-2.72	-2.70			0	0			0
DuWapMH_147	-3.01	-3.01	-2.98	-2.93	-2.90	-2.86	State Highway		0	0	10		10
DuWapMH_15	0.41	0.59	0.70	0.86	1.04	1.39			21	2			23
DuWapMH_151	0.16	0.32	0.45	0.64	0.81	1.01			21	2			23
DuWapMH_152	-0.83	-0.59	-0.42	-0.22	-0.03	0.34			1	0			1
DuWapMH_153	-0.31	-0.01	0.19	0.45	0.64	0.84			10	1			11
DuWapMH_154	0.44	0.71	0.89	1.09	1.32	1.73			21	3			24
DuWapMH_155	-4.80	-4.70	-4.63	-4.55	-4.47	-4.31			0	0			0
DuWapMH_156	-1.25	-0.98	-0.81	-0.61	-0.40	0.00			0	0			0
DuWapMH_157	-0.39	-0.25	-0.14	0.02	0.17	0.33			6	1			7
DuWapMH_158	0.46	0.62	0.78	0.93	1.05	1.17			21	2			23
DuWapMH_159	0.97	1.14	1.27	1.45	1.60	1.75	State Highway		21	3	10		34
DuWapMH_162	-2.88	-2.58	-2.38	-2.15	-1.93	-1.56			0	0			0
DuWapMH_17	0.15	0.49	0.72	0.99	1.20	1.48			21	2			23
DuWapMH_171	-0.35	0.01	0.26	0.54	0.90	1.79			15	2			17
DuWapMH_172	3.22	3.57	3.83	4.11	4.47	5.36			21	4			25
DuWapMH_173	1.50	2.01	2.39	2.59	2.76	3.00			21	4			25
DuWapMH_174	-0.83	-0.39	-0.03	0.15	0.30	0.55			6	1			7
DuWapMH_175	1.25	1.48	1.66	1.91	2.10	2.32			21	3			24
DuWapMH_177	1.17	1.34	1.46	1.67	1.91	2.21			21	3			24
DuWapMH_179	1.59	1.72	1.82	1.97	2.09	2.22			21	3			24
DuWapMH_180	-1.54	-1.10	-0.75	-0.34	0.32	2.42			3	0			3
DuWapMH_181	-2.70	-2.29	-1.95	-1.54	-0.87	1.22			1	0			1
DuWapMH_182	1.98	2.28	2.50	2.75	3.04	3.62			21	4			25
DuWapMH_184	3.23	3.59	3.85	4.15	4.52	5.45			21	4			25
DuWapMH_186	2.58	2.92	3.17	3.43	3.77	4.64			21	4			25
DuWapMH_188	-0.88	-0.80	-0.60	0.46	0.90	1.43			6	1			7
DuWapMH_189	-2.40	-2.13	-1.93	-1.69	-1.47	-1.11			0	0			0
DuWapMH_19	0.06	0.40	0.62	0.87	1.16	1.74			21	2			23
DuWapMH_190	0.97	1.07	1.36	1.74	1.96	2.21			21	3			24

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_191	2.72	3.16	3.51	3.92	4.59	6.69	US Highway		21	4	10		35
DuWapMH_192	0.33	0.85	1.23	1.46	1.66	2.04			21	3			24
DuWapMH_193	0.25	0.30	0.34	0.41	0.46	0.53			21	1			22
DuWapMH_194	-2.69	-2.61	-2.53	-2.42	-2.33	-2.24			0	0			0
DuWapMH_195	1.76	2.03	2.24	2.53	2.77	3.01			21	4			25
DuWapMH_196	-0.78	-0.49	-0.30	-0.05	0.17	0.53			3	0			3
DuWapMH_197	-2.62	-2.34	-2.21	-2.04	-1.86	-1.59			0	0			0
DuWapMH_198	0.87	1.00	1.11	1.26	1.38	1.51			21	3			24
DuWapMH_199	0.83	0.95	1.06	1.21	1.33	1.46			21	3			24
DuWapMH_20	-0.72	-0.56	-0.42	-0.24	-0.03	0.46			1	0			1
DuWapMH_206	1.89	2.28	2.56	2.90	3.15	3.43			21	4			25
DuWapMH_207	-2.76	-2.72	-2.69	-2.66	-2.64	-2.62		Education Facility	0	0		10	10
DuWapMH_21	-3.68	-3.62	-3.60	-3.58	-3.56	-3.55			0	0			0
DuWapMH_212	-2.12	-1.80	-1.57	-1.28	-1.02	-0.62			0	0			0
DuWapMH_213	2.10	2.40	2.59	2.82	3.04	3.41			21	4			25
DuWapMH_214	0.16	0.44	0.61	0.82	1.03	1.50			21	2			23
DuWapMH_218	2.81	3.23	3.56	3.94	4.53	6.32			21	4			25
DuWapMH_219	-0.07	0.21	0.39	0.60	0.82	1.28			15	2			17
DuWapMH_22	-2.90	-2.86	-2.84	-2.83	-2.82	-2.75			0	0			0
DuWapMH_220	-3.68	-3.63	-3.61	-3.59	-3.57	-3.46			0	0			0
DuWapMH_221	0.71	1.05	1.27	1.51	1.72	2.06			21	3			24
DuWapMH_222	3.68	4.03	4.28	4.55	4.90	5.77			21	4			25
DuWapMH_223	-0.49	0.19	0.74	1.00	1.10	1.22			15	3			18
DuWapMH_224	-3.25	-3.24	-3.23	-3.23	-3.23	-3.13			0	0			0
DuWapMH_225	0.74	0.77	0.81	0.87	0.94	1.02			21	2			23
DuWapMH_227	0.42	0.76	0.99	1.26	1.47	1.74			21	3			24
DuWapMH_228	3.89	4.24	4.48	4.75	5.10	5.96			21	4			25
DuWapMH_229	1.93	2.14	2.30	2.48	2.71	3.22			21	4			25
DuWapMH_23	1.97	2.25	2.46	2.74	2.97	3.21			21	4			25
DuWapMH_230	0.89	1.11	1.28	1.48	1.72	2.29			21	3			24
DuWapMH_231	1.34	1.57	1.75	1.96	2.21	2.80			21	3			24
DuWapMH_232	1.20	1.38	1.54	1.73	1.97	2.46	US Highway		21	3	10		34
DuWapMH_233	1.63	1.89	2.15	2.48	2.92	3.53			21	4			25
DuWapMH_235	1.08	1.23	1.35	1.54	1.70	1.88		Education Facility	21	3		10	34
DuWapMH_236	3.38	3.72	3.97	4.24	4.59	5.46			21	4			25

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_238	3.05	3.50	3.85	4.26	4.92	7.02			21	4			25
DuWapMH_24	-0.47	0.18	1.08	2.14	2.53	3.02			15	4			19
DuWapMH_240	1.41	1.85	2.20	2.61	3.27	5.37			21	4			25
DuWapMH_241	1.70	1.96	2.22	2.55	2.99	3.60			21	4			25
DuWapMH_243	4.17	4.53	4.79	5.07	5.43	6.35			21	4			25
DuWapMH_244	4.18	4.53	4.79	5.07	5.43	6.37			21	4			25
DuWapMH_245	3.53	3.89	4.15	4.45	4.81	5.74			21	4			25
DuWapMH_246	3.53	3.89	4.14	4.44	4.80	5.72			21	4			25
DuWapMH_248	2.51	2.86	3.12	3.42	3.78	4.70			21	4			25
DuWapMH_249	1.20	1.48	1.66	1.88	2.09	2.47			21	3			24
DuWapMH_250	1.59	2.06	2.35	2.59	2.81	3.10			21	4			25
DuWapMH_251	1.30	1.73	1.99	2.24	2.46	2.76			21	4			25
DuWapMH_252	1.01	1.41	1.66	1.90	2.12	2.45			21	3			24
DuWapMH_253	1.64	2.14	2.45	2.70	2.91	3.19			21	4			25
DuWapMH_254	2.30	2.86	3.21	3.46	3.67	3.92			21	4			25
DuWapMH_255	1.50	2.03	2.37	2.62	2.83	3.10			21	4			25
DuWapMH_256	3.08	3.67	4.04	4.29	4.50	4.74			21	4			25
DuWapMH_257	2.99	3.59	3.96	4.21	4.42	4.66			21	4			25
DuWapMH_258	1.00	1.32	1.52	1.76	1.97	2.32			21	3			24
DuWapMH_259	1.07	1.68	2.06	2.31	2.52	2.75			21	4			25
DuWapMH_260	0.46	1.08	1.46	1.71	1.92	2.15			21	3			24
DuWapMH_261	0.47	1.03	1.36	1.62	1.82	2.05			21	3			24
DuWapMH_262	0.33	0.76	1.01	1.27	1.47	1.70			21	3			24
DuWapMH_264	0.19	0.43	0.61	0.86	1.06	1.27			21	2			23
DuWapMH_267	-0.95	-0.67	-0.48	-0.26	-0.05	0.31			1	0			1
DuWapMH_268	-2.84	-2.68	-2.65	-2.63	-2.61	-2.59			0	0			0
DuWapMH_269	-1.79	-1.53	-1.49	-1.45	-1.41	-1.37			0	0			0
DuWapMH_27	1.10	1.15	1.20	1.27	1.34	1.41			21	3			24
DuWapMH_270	-1.31	-1.07	-1.01	-0.95	-0.89	-0.83			0	0			0
DuWapMH_271	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00			0	0			0
DuWapMH_272	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00			0	0			0
DuWapMH_273	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00			0	0			0
DuWapMH_274	1.45	1.55	1.84	2.22	2.44	2.69			21	4			25
DuWapMH_275	0.93	1.21	1.43	1.66	1.97	2.67			21	3			24
DuWapMH_276	-0.40	-0.12	0.10	0.33	0.64	1.34			10	1			11

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_277	-0.84	-0.56	-0.38	-0.18	0.04	0.54			3	0			3
DuWapMH_278	0.79	1.13	1.37	1.64	1.97	2.83			21	3			24
DuWapMH_279	-0.06	0.22	0.43	0.67	0.97	1.59			15	2			17
DuWapMH_28	0.52	0.68	0.82	1.03	1.19	1.35			21	3			24
DuWapMH_280	-0.57	-0.29	-0.08	0.16	0.46	1.08			6	1			7
DuWapMH_281	0.29	0.57	0.75	0.96	1.18	1.64			21	2			23
DuWapMH_282	-0.01	0.26	0.44	0.64	0.85	1.29			15	2			17
DuWapMH_287	4.68	5.02	5.27	5.54	5.87	6.74			21	4			25
DuWapMH_288	-2.44	-2.37	-2.32	-2.25	-2.20	-2.15			0	0			0
DuWapMH_289	-0.82	-0.45	-0.18	0.12	0.48	1.41			6	1			7
DuWapMH_290	-1.49	-1.19	-0.97	-0.70	-0.50	-0.33			0	0			0
DuWapMH_291	1.25	1.54	1.76	2.04	2.25	2.42			21	4			25
DuWapMH_292	-1.16	-0.88	-0.66	-0.37	-0.14	0.03			1	0			1
DuWapMH_293	-2.07	-1.80	-1.68	-1.51	-1.34	-1.08			0	0			0
DuWapMH_294	-0.59	-0.28	-0.08	0.18	0.37	0.54			6	1			7
DuWapMH_295	-0.98	-0.78	-0.64	-0.44	-0.28	-0.11			0	0			0
DuWapMH_296	-0.93	-0.67	-0.49	-0.27	-0.11	0.07			1	0			1
DuWapMH_297	-0.93	-0.77	-0.64	-0.45	-0.29	-0.12			0	0			0
DuWapMH_298	-1.61	-1.32	-1.12	-0.88	-0.64	-0.26			0	0			0
DuWapMH_299	-0.39	-0.13	0.05	0.25	0.47	0.87			10	1			11
DuWapMH_3	1.58	2.19	2.56	2.82	3.03	3.26			21	4			25
DuWapMH_30	-0.85	-0.51	-0.26	0.04	0.34	0.98			6	1			7
DuWapMH_301	-0.98	-0.68	-0.53	-0.33	-0.13	0.20			1	0			1
DuWapMH_302	1.02	1.34	1.47	1.66	1.82	1.98			21	3			24
DuWapMH_304	-1.33	-1.03	-0.83	-0.59	-0.34	0.04			1	0			1
DuWapMH_305	-1.00	-0.32	0.23	0.49	0.59	0.71			10	1			11
DuWapMH_306	-0.58	-0.28	-0.07	0.21	0.48	0.81			6	1			7
DuWapMH_307	-1.83	-1.55	-1.36	-1.13	-0.89	-0.51			0	0			0
DuWapMH_308	-0.59	-0.29	-0.08	0.19	0.45	0.79			6	1			7
DuWapMH_309	-1.81	-1.10	-0.13	1.02	1.45	1.98			6	3			9
DuWapMH_31	0.32	0.68	0.93	1.25	1.54	2.20			21	3			24
DuWapMH_310	-1.76	-1.06	-0.09	1.05	1.46	1.98			6	3			9
DuWapMH_311	-1.10	-0.43	0.49	1.57	1.97	2.47			10	3			13
DuWapMH_312	-0.81	-0.14	0.78	1.86	2.25	2.75			10	3			13
DuWapMH_313	2.84	3.28	3.63	4.04	4.71	6.81			21	4			25

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_315	1.39	1.60	1.69	1.81	1.90	1.99			21	3			24
DuWapMH_317	0.84	1.05	1.14	1.26	1.35	1.45			21	3			24
DuWapMH_318	-1.98	-1.88	-1.81	-1.73	-1.68	-1.63		Education Facility	0	0		10	10
DuWapMH_32	-2.10	-1.85	-1.65	-1.36	-1.09	-0.77			0	0			0
DuWapMH_322	-2.15	-1.88	-1.67	-1.36	-1.08	-0.76			0	0			0
DuWapMH_329	-3.22	-3.22	-3.19	-3.13	-3.09	-3.05	State Highway		0	0	10		10
DuWapMH_33	0.72	1.07	1.33	1.61	1.97	2.72			21	3			24
DuWapMH_330	-0.38	-0.10	0.10	0.35	0.57	0.93			10	1			11
DuWapMH_331	0.62	1.24	1.62	1.87	2.08	2.31			21	3			24
DuWapMH_332	2.67	3.28	3.66	3.91	4.12	4.35			21	4			25
DuWapMH_333	1.53	2.14	2.51	2.77	2.97	3.21			21	4			25
DuWapMH_334	-0.21	0.07	0.25	0.46	0.67	1.14			15	1			16
DuWapMH_335	2.23	2.59	2.85	3.15	3.52	4.45			21	4			25
DuWapMH_336	-2.13	-1.83	-1.63	-1.37	-1.18	-0.98			0	0			0
DuWapMH_337	1.26	1.57	1.77	2.02	2.21	2.41			21	4			25
DuWapMH_338	1.16	1.39	1.57	1.81	2.01	2.23			21	3			24
DuWapMH_339	-0.75	-0.44	-0.23	0.10	0.38	0.69			6	1			7
DuWapMH_34	0.52	0.87	1.13	1.41	1.77	2.52			21	3			24
DuWapMH_341	0.54	0.68	0.81	1.00	1.15	1.34			21	3			24
DuWapMH_342	-0.48	-0.13	0.13	0.41	0.77	1.67			10	1			11
DuWapMH_343	0.62	1.18	1.51	1.76	1.97	2.20			21	3			24
DuWapMH_344	0.37	0.81	1.06	1.31	1.52	1.74			21	3			24
DuWapMH_346	0.02	0.26	0.44	0.69	0.88	1.10			21	2			23
DuWapMH_351	1.27	1.60	1.82	2.11	2.37	2.78			21	4			25
DuWapMH_352	1.13	1.60	1.89	2.13	2.35	2.64			21	4			25
DuWapMH_353	0.97	1.40	1.66	1.91	2.12	2.43			21	3			24
DuWapMH_354	1.03	1.43	1.68	1.92	2.14	2.47			21	3			24
DuWapMH_355	1.12	1.61	1.93	2.18	2.39	2.67			21	4			25
DuWapMH_356	1.53	2.06	2.40	2.65	2.86	3.12			21	4			25
DuWapMH_357	1.92	2.47	2.83	3.08	3.29	3.54			21	4			25
DuWapMH_358	2.36	2.95	3.32	3.57	3.78	4.02			21	4			25
DuWapMH_359	2.18	2.78	3.15	3.40	3.61	3.85			21	4			25
DuWapMH_36	-0.18	0.07	0.27	0.44	0.58	0.81			15	1			16
DuWapMH_360	-1.87	-1.48	-1.21	-0.83	-0.54	-0.23			0	0			0
DuWapMH_361	-2.27	-2.10	-2.07	-2.05	-2.03	-2.01			0	0			0

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_362	-1.40	-1.15	-1.10	-1.06	-1.02	-0.98			0	0			0
DuWapMH_363	1.54	2.00	2.36	2.54	2.69	2.95			21	4			25
DuWapMH_364	-1.79	-1.51	-1.31	-1.09	-0.85	-0.46			0	0			0
DuWapMH_366	-0.40	-0.13	0.05	0.25	0.47	0.87			10	1			11
DuWapMH_367	-2.89	-2.58	-2.38	-2.15	-1.93	-1.56			0	0			0
DuWapMH_368	-2.72	-2.40	-2.26	-2.07	-1.89	-1.60			0	0			0
DuWapMH_369	-2.98	-2.68	-2.53	-2.33	-2.13	-1.80			0	0			0
DuWapMH_370	-0.44	-0.16	-0.07	0.06	0.18	0.30			6	1			7
DuWapMH_371	0.61	0.91	1.12	1.40	1.60	1.77			21	3			24
DuWapMH_372	0.52	0.80	1.02	1.33	1.58	1.74			21	3			24
DuWapMH_373	1.12	1.49	1.75	2.06	2.42	3.37			21	4			25
DuWapMH_374	3.73	4.09	4.35	4.65	5.01	5.94			21	4			25
DuWapMH_375	-0.38	-0.09	0.11	0.36	0.58	0.94			10	1			11
DuWapMH_377	0.39	0.70	0.84	1.03	1.18	1.35			21	3			24
DuWapMH_379	0.86	0.96	1.25	1.63	1.85	2.10			21	3			24
DuWapMH_380	3.65	3.75	4.04	4.42	4.64	4.89			21	4			25
DuWapMH_381	0.84	1.05	1.22	1.43	1.59	1.76			21	3			24
DuWapMH_382	1.65	2.00	2.26	2.54	2.90	3.79			21	4			25
DuWapMH_383	1.65	2.00	2.26	2.54	2.90	3.79			21	4			25
DuWapMH_384	-0.55	-0.20	0.06	0.34	0.70	1.59			10	1			11
DuWapMH_385	1.34	1.80	2.16	2.34	2.49	2.74			21	4			25
DuWapMH_386	-1.19	-0.94	-0.89	-0.82	-0.76	-0.70			0	0			0
DuWapMH_387	0.60	0.72	0.84	1.01	1.15	1.33			21	3			24
DuWapMH_388	0.08	0.20	0.30	0.46	0.58	0.71			21	1			22
DuWapMH_389	1.39	1.52	1.62	1.77	1.89	2.02			21	3			24
DuWapMH_390	-0.94	-0.67	-0.50	-0.28	-0.11	0.07			1	0			1
DuWapMH_391	-0.43	-0.23	-0.09	0.11	0.27	0.44			6	1			7
DuWapMH_392	-0.63	-0.47	-0.34	-0.15	0.00	0.17			1	0			1
DuWapMH_393	-1.80	-1.50	-1.29	-1.03	-0.85	-0.67			0	0			0
DuWapMH_394	-0.35	-0.06	0.15	0.45	0.68	0.84			10	1			11
DuWapMH_396	4.95	5.39	5.74	6.15	6.82	8.91			21	4			25
DuWapMH_397	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00			0	0			0
DuWapMH_398	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00			0	0			0
DuWapMH_399	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00			0	0			0
DuWapMH_40	-2.60	-2.47	-2.31	-2.05	-1.69	-0.58			0	0			0

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_400	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00			0	0			0
DuWapMH_402	-2.65	-2.53	-2.46	-2.37	-2.31	-2.26			0	0			0
DuWapMH_403	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00			0	0			0
DuWapMH_404	0.80	0.83	0.84	0.87	0.90	0.92			21	2			23
DuWapMH_405	0.68	0.71	0.74	0.77	0.80	0.84			21	2			23
DuWapMH_406	0.64	0.67	0.70	0.73	0.82	0.80			21	2			23
DuWapMH_407	0.61	0.64	0.67	0.70	0.74	0.77			21	2			23
DuWapMH_408	3.14	3.49	3.75	4.05	4.41	5.33			21	4			25
DuWapMH_409	-1.00	-0.33	0.59	1.67	2.07	2.57			10	3			13
DuWapMH_41	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00			0	0			0
DuWapMH_410	-2.06	-1.36	-0.38	0.77	1.20	1.74			6	2			8
DuWapMH_411	-1.66	-0.95	0.03	1.19	1.63	2.17			10	3			13
DuWapMH_412	-6.25	-5.90	-5.66	-5.41	-5.18	-4.75			0	0			0
DuWapMH_413	1.95	2.39	2.74	3.15	3.82	5.92			21	4			25
DuWapMH_414	6.46	6.90	7.25	7.66	8.33	10.42			21	4			25
DuWapMH_415	1.74	2.26	2.64	2.87	3.07	3.45			21	4			25
DuWapMH_416	-2.15	-1.99	-1.88	-1.74	-1.63	-1.53			0	0			0
DuWapMH_417	-0.77	-0.09	0.46	0.72	0.82	0.94			10	2			12
DuWapMH_418	-0.71	-0.04	0.88	1.96	2.35	2.85			10	3			13
DuWapMH_419	-2.27	-1.88	-1.60	-1.26	-1.01	-0.73			0	0			0
DuWapMH_42	2.15	2.19	2.22	2.27	2.32	2.36			21	4			25
DuWapMH_420	1.52	1.89	2.14	2.46	2.68	2.92			21	4			25
DuWapMH_421	2.17	2.52	2.76	3.01	3.24	3.68			21	4			25
DuWapMH_424	1.09	1.53	1.88	2.29	2.96	5.06			21	4			25
DuWapMH_425	3.46	3.90	4.25	4.66	5.33	7.43			21	4			25
DuWapMH_426	0.67	1.02	1.28	1.66	1.92	1.98			21	3			24
DuWapMH_429	3.70	4.05	4.30	4.57	4.93	5.80			21	4			25
DuWapMH_431	1.57	1.91	2.16	2.43	2.78	3.65			21	4			25
DuWapMH_432	-0.30	-0.02	0.16	0.38	0.59	0.97			10	1			11
DuWapMH_433	1.17	1.49	1.69	1.93	2.14	2.49			21	3			24
DuWapMH_434	1.22	1.56	1.78	2.01	2.23	2.57			21	4			25
DuWapMH_436	3.04	3.40	3.66	3.94	4.31	5.23			21	4			25
DuWapMH_437	0.38	0.69	0.92	1.24	1.48	1.72			21	3			24
DuWapMH_438	0.28	0.80	1.18	1.40	1.61	1.99			21	3			24
DuWapMH_441	1.57	1.91	2.16	2.43	2.78	3.65			21	4			25

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_444	0.26	0.61	0.86	1.14	1.49	2.39			21	3			24
DuWapMH_445	1.27	1.62	1.86	2.13	2.48	3.34			21	4			25
DuWapMH_446	-2.84	-2.61	-2.41	-2.14	-1.87	-1.55			0	0			0
DuWapMH_448	0.87	1.24	1.49	1.81	2.03	2.27			21	3			24
DuWapMH_449	0.53	0.77	0.91	1.10	1.27	1.49			21	3			24
DuWapMH_45	0.28	0.29	0.30	0.32	0.32	0.33			21	1			22
DuWapMH_454	-5.87	-5.52	-5.28	-5.03	-4.80	-4.37			0	0			0
DuWapMH_46	-0.65	0.01	0.92	1.99	2.38	2.88			15	3			18
DuWapMH_47	-1.02	-0.92	-0.83	-0.71	-0.61	-0.50			0	0			0
DuWapMH_48	0.34	0.38	0.42	0.48	0.54	0.59			21	1			22
DuWapMH_500	-2.32	-2.06	-1.88	-1.68	-1.45	-1.06			0	0			0
DuWapMH_51	0.93	0.98	1.01	1.07	1.12	1.19			21	3			24
DuWapMH_52	-0.53	-0.39	-0.31	-0.21	-0.14	-0.07			0	0			0
DuWapMH_53	0.63	0.82	0.92	1.05	1.19	1.38			21	3			24
DuWapMH_55	-0.68	-0.40	-0.20	0.01	0.24	0.72	US Highway		6	1	10		17
DuWapMH_56	2.39	2.70	2.92	3.19	3.44	3.86			21	4			25
DuWapMH_57	-0.70	-0.43	-0.23	-0.03	0.19	0.64			3	0			3
DuWapMH_59	-0.24	0.09	0.33	0.59	0.81	1.08			15	2			17
DuWapMH_60	1.21	1.54	1.78	2.03	2.30	2.76			21	4			25
DuWapMH_61	0.14	0.25	0.35	0.44	0.47	0.53		Education Facility	21	1		10	32
DuWapMH_62	-0.22	0.11	0.35	0.67	0.83	1.10			15	2			17
DuWapMH_63	0.58	0.97	1.22	1.48	1.76	2.28			21	3			24
DuWapMH_64	0.56	0.94	1.19	1.45	1.73	2.27			21	3			24
DuWapMH_65	0.50	0.84	1.06	1.32	1.61	2.20			21	3			24
DuWapMH_66	0.34	0.70	0.93	1.20	1.53	2.27			21	3			24
DuWapMH_69	2.99	3.10	3.19	3.30	3.42	3.64		Education Facility	21	4		10	35
DuWapMH_70	-3.88	-3.84	-3.83	-3.81	-3.78	-3.75			0	0			0
DuWapMH_71	1.24	1.56	1.78	2.03	2.35	3.12	State Highway		21	4	10		35
DuWapMH_73	-0.45	-0.13	0.10	0.35	0.66	1.46	State Highway		10	1	10		21
DuWapMH_74	0.39	0.46	0.53	0.67	0.80	1.03	State Highway		21	2	10		33
DuWapMH_75	-4.56	-4.47	-4.39	-4.31	-4.23	-4.07			0	0			0
DuWapMH_76	-3.42	-3.40	-3.38	-3.34	-3.32	-3.30			0	0			0
DuWapMH_77	4.24	4.45	4.61	4.81	4.97	5.13			21	4			25
DuWapMH_79	-1.69	-0.93	-0.37	-0.30	-0.25	-0.19			0	0			0
DuWapMH_8	-2.90	-2.90	-2.88	-2.84	-2.82	-2.79			0	0			0

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapMH_80	-2.16	-1.30	-0.66	-0.61	-0.56	-0.51			0	0			0
DuWapMH_81	-0.65	-0.35	-0.13	0.14	0.42	1.03			6	1			7
DuWapMH_82	-0.88	-0.53	-0.28	0.03	0.32	0.97	US Highway		6	1	10		17
DuWapMH_84	-0.34	0.01	0.27	0.55	0.90	1.71			15	2			17
DuWapMH_85	0.33	0.68	0.94	1.22	1.57	2.41			21	3			24
DuWapMH_86	2.18	2.65	2.95	3.12	3.34	3.90			21	4			25
DuWapMH_87	0.45	0.60	0.73	0.92	1.09	1.26			21	2			23
DuWapMH_88	-0.01	0.27	0.46	0.69	0.90	1.25			15	2			17
DuWapMH_900	-0.09	0.43	0.82	0.99	1.07	1.14			15	2			17
DuWapMH_92	-0.74	-0.45	-0.25	-0.01	0.22	0.58			3	0			3
DuWapMH_93	-1.22	-0.87	-0.61	-0.30	-0.01	0.65	US Highway		1	0	10		11
DuWapMH_95	-1.47	-1.13	-0.90	-0.54	-0.21	-0.03			0	0			0
DuWapMH_96	-0.18	-0.13	-0.09	-0.02	0.03	0.09			3	0			3
DuWapMH_97	0.08	0.13	0.17	0.24	0.29	0.36			21	1			22
DuWapMH_98	-0.81	-0.77	-0.74	-0.70	-0.66	-0.62			0	0			0
DuWapMH_99	0.98	1.21	1.39	1.64	1.83	2.05			21	3			24
DuWapN_1	0.65	0.70	0.74	0.80	0.86	0.92			21	2			23
DuWapN_10	0.29	0.63	0.87	1.14	1.35	1.62			21	3			24
DuWapN_101	-1.48	-1.06	-0.76	-0.37	0.04	0.97			3	0			3
DuWapN_102	-2.39	-1.50	-0.79	-0.47	-0.34	-0.17			0	0			0
DuWapN_103	0.78	0.82	0.86	0.93	0.98	1.05			21	2			23
DuWapN_105	-0.71	-0.42	-0.14	0.82	1.04	1.42			6	2			8
DuWapN_106	-2.28	-1.72	-1.29	-1.10	-1.02	-0.94			0	0			0
DuWapN_107	1.83	2.09	2.29	2.53	2.75	3.08			21	4			25
DuWapN_11a	-1.19	-1.06	-0.95	-0.81	-0.71	-0.60			0	0			0
DuWapN_11b	-1.06	-0.99	-0.59	0.00	0.03	0.06		Education Facility	3	1		10	14
DuWapN_12	0.41	0.58	0.72	0.91	1.07	1.23	State Highway		21	2	10		33
DuWapN_13	2.40	2.77	3.03	3.34	3.70	4.63			21	4			25
DuWapN_14	0.86	1.13	1.33	1.58	1.81	2.14			21	3			24
DuWapN_15	-0.14	0.05	0.12	0.24	0.52	1.13			15	1			16
DuWapN_16	-4.80	-4.34	-3.90	-3.26	-2.67	-1.94	State Highway		0	0	10		10
DuWapN_17	0.28	0.50	0.66	0.87	1.03	1.20			21	2			23
DuWapN_18	0.31	0.40	0.46	0.55	0.62	0.95			21	2			23
DuWapN_19a	0.05	0.10	0.15	0.22	0.29	0.57			21	1			22
DuWapN_19b	0.08	0.15	0.28	0.48	0.68	0.99			21	1			22

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

	Flood Depth								Scoring				
Model Node	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**	**Roadway**	**Critical Facilities**	**Flood Frequency**	**Flood Depth**	**Evac Routes**	**Crit Fac**	**Total score**
DuWapN_2	0.26	0.58	0.82	1.09	1.30	1.58			21	3			24
DuWapN_20	0.42	0.61	0.77	0.99	1.19	1.50			21	2			23
DuWapN_201	-1.60	-1.24	-0.89	-0.35	0.02	0.16			3	0			3
DuWapN_207b	-0.29	0.07	0.31	0.57	0.86	1.41			15	2			17
DuWapN_209b	0.90	1.26	1.52	1.82	2.20	3.12			21	3			24
DuWapN_21	0.93	1.28	1.54	1.82	2.18	3.07			21	3			24
DuWapN_210	0.20	0.29	0.36	0.44	0.51	0.66			21	1			22
DuWapN_211a	0.61	0.80	0.96	1.18	1.34	1.51	State Highway		21	3	10		34
DuWapN_211b	0.20	0.29	0.36	0.48	0.53	0.59		Education Facility	21	1		10	32
DuWapN_212	0.45	0.61	0.74	0.93	1.08	1.23	State Highway		21	2	10		33
DuWapN_216	0.14	0.25	0.35	0.48	0.60	0.73	State Highway		21	1	10		32
DuWapN_219a	0.59	0.86	1.04	1.24	1.45	1.89			21	3			24
DuWapN_219b	0.56	0.79	0.95	1.15	1.35	1.69			21	3			24
DuWapN_22	0.52	0.55	0.58	0.62	0.66	0.70	State Highway		21	2	10		33
DuWapN_222	-0.31	0.01	0.14	0.33	0.48	0.65			15	1			16
DuWapN_224	0.40	0.54	0.66	0.82	0.96	1.24			21	2			23
DuWapN_225	1.57	1.87	2.09	2.34	2.62	3.21			21	4			25
DuWapN_229	0.09	0.14	0.19	0.26	0.31	0.38			21	1			22
DuWapN_23	0.10	0.37	0.57	0.78	1.01	1.49			21	2			23
DuWapN_230	0.45	0.66	0.85	1.12	1.36	1.90			21	3			24
DuWapN_234	-1.43	-0.75	-0.20	0.06	0.16	0.28			6	1			7
DuWapN_238	-0.17	-0.03	0.07	0.23	0.35	0.48			10	1			11
DuWapN_24	0.02	0.10	0.19	0.32	0.48	0.93			21	1			22
DuWapN_240	1.62	1.91	2.10	2.32	2.53	2.91			21	4			25
DuWapN_241	1.62	1.88	2.06	2.25	2.46	2.90			21	4			25
DuWapN_25	1.05	1.40	1.64	1.95	2.18	2.44			21	3			24
DuWapN_250	-0.23	0.04	0.13	0.27	0.38	0.51			15	1			16
DuWapN_257	0.35	0.59	0.79	1.02	1.27	1.65		Education Facility	21	3		10	34
DuWapN_26	0.15	0.46	0.69	1.01	1.25	1.50			21	3			24
DuWapN_263	0.00	0.03	0.06	0.10	0.18	0.58			15	1			16
DuWapN_267	0.08	0.13	0.17	0.22	0.27	0.33			21	1			22
DuWapN_27	-1.25	-0.90	-0.64	-0.26	0.01	0.06			3	0			3
DuWapN_270	-0.23	0.10	0.34	0.61	0.82	1.09			15	2			17
DuWapN_273	0.16	0.29	0.41	0.57	0.72	0.88			21	2			23
DuWapN_274	0.08	0.23	0.36	0.55	0.71	0.88			21	2			23

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapN_28	3.31	3.75	4.10	4.52	5.18	7.28			21	4			25
DuWapN_29	0.06	0.11	0.14	0.20	0.25	0.31			21	1			22
DuWapN_3	0.03	0.07	0.10	0.15	0.19	0.23			21	1			22
DuWapN_30	0.10	0.17	0.23	0.33	0.42	0.58			21	1			22
DuWapN_31	0.31	0.47	0.59	0.75	0.91	1.19			21	2			23
DuWapN_312	0.26	0.38	0.48	0.61	0.72	0.83			21	2			23
DuWapN_32	-0.38	-0.10	0.08	0.28	0.50	1.00			10	1			11
DuWapN_324	-1.48	-1.12	-0.86	-0.55	-0.24	0.47			1	0			1
DuWapN_33	1.95	2.21	2.38	2.59	2.83	3.26			21	4			25
DuWapN_334	1.37	1.65	1.86	2.16	2.40	2.64			21	4			25
DuWapN_338	0.20	0.29	0.37	0.48	0.57	0.67			21	1			22
DuWapN_34	0.42	0.63	0.79	0.99	1.15	1.31			21	2			23
DuWapN_35a	0.30	0.62	0.75	0.94	1.09	1.26			21	2			23
DuWapN_35b	0.05	0.09	0.12	0.17	0.22	0.27			21	1			22
DuWapN_35c	0.04	0.07	0.10	0.14	0.17	0.20			21	1			22
DuWapN_36	0.23	0.33	0.41	0.54	0.65	0.76			21	2			23
DuWapN_37	0.17	0.26	0.33	0.43	0.52	0.62			21	1			22
DuWapN_38	-0.96	-0.93	-0.90	-0.86	-0.83	-0.80			0	0			0
DuWapN_4	0.06	0.10	0.14	0.20	0.25	0.32			21	1			22
DuWapN_40	0.05	0.09	0.12	0.16	0.20	0.25			21	1			22
DuWapN_41	0.27	0.41	0.54	0.73	0.89	1.07			21	2			23
DuWapN_42	-0.84	0.00	0.02	0.05	0.08	0.12		Education Facility	10	1		10	21
DuWapN_43	0.08	0.15	0.20	0.28	0.35	0.44	US Highway		21	1	10		32
DuWapN_44	-0.40	-0.19	-0.03	0.03	0.08	0.14			6	1			7
DuWapN_45	0.01	0.06	0.10	0.17	0.23	0.30			21	1			22
DuWapN_46	-3.48	-2.79	-2.07	-0.64	0.01	0.06			3	0			3
DuWapN_47	-2.15	-0.89	0.00	0.02	0.05	0.08			6	1			7
DuWapN_48	0.06	0.13	0.19	0.28	0.36	0.45			21	1			22
DuWapN_49	0.21	0.34	0.45	0.61	0.74	0.88			21	2			23
DuWapN_5	0.06	0.10	0.13	0.18	0.21	0.26			21	1			22
DuWapN_50	0.13	0.20	0.26	0.35	0.43	0.52			21	1			22
DuWapN_51	0.50	0.78	1.00	1.31	1.56	1.82			21	3			24
DuWapN_52	0.50	0.71	0.88	1.12	1.31	1.55			21	3			24
DuWapN_53	-0.50	-0.05	0.04	0.12	0.20	0.28			10	1			11
DuWapN_54	0.06	0.09	0.12	0.17	0.21	0.26			21	1			22

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapN_55	0.11	0.18	0.24	0.34	0.45	0.63			21	1			22
DuWapN_56	1.32	1.76	2.11	2.52	3.19	5.29			21	4			25
DuWapN_57	0.03	0.09	0.15	0.22	0.30	0.58		Education Facility	21	1		10	32
DuWapN_58	-20.00	-19.95	-19.91	-19.85	-19.80	-19.74			0	0			0
DuWapN_59	0.53	0.81	1.03	1.34	1.59	1.76			21	3			24
DuWapN_6	0.01	0.03	0.06	0.10	0.14	0.18			21	1			22
DuWapN_61	0.04	0.16	0.27	0.42	0.54	0.67			21	1			22
DuWapN_62	0.27	0.41	0.52	0.67	0.78	0.91			21	2			23
DuWapN_63	0.14	0.20	0.26	0.35	0.44	0.60		Education Facility	21	1		10	32
DuWapN_64	0.54	0.72	0.85	1.02	1.16	1.32		Education Facility	21	3		10	34
DuWapN_65	0.08	0.12	0.15	0.20	0.25	0.30			21	1			22
DuWapN_66	0.27	0.43	0.57	0.76	0.96	1.30			21	2			23
DuWapN_67	0.30	0.41	0.51	0.64	0.74	0.86			21	2			23
DuWapN_70	-0.22	0.20	0.36	0.54	0.67	0.95			15	2			17
DuWapN_71	1.08	1.35	1.54	1.77	1.98	2.34			21	3			24
DuWapN_72	0.17	0.26	0.34	0.45	0.55	0.64			21	1			22
DuWapN_73	0.01	0.04	0.07	0.11	0.14	0.18			21	1			22
DuWapN_74	0.64	0.83	0.98	1.17	1.30	1.44			21	3			24
DuWapN_76	3.14	3.38	3.57	3.78	4.02	4.58			21	4			25
DuWapN_77	2.77	3.11	3.34	3.61	3.82	4.10			21	4			25
DuWapN_78	1.48	1.82	2.06	2.33	2.54	2.81			21	4			25
DuWapN_79	-1.90	-1.61	-1.41	-1.14	-0.92	-0.70			0	0			0
DuWapN_7a	0.06	0.49	0.81	1.23	1.62	2.25			21	3			24
DuWapN_7b	-0.79	-0.48	-0.28	-0.03	0.26	0.82			3	0			3
DuWapN_80	-1.17	-1.09	-1.08	-1.07	-1.06	-1.05		Education Facility	0	0		10	10
DuWapN_82	0.18	0.43	0.57	0.76	0.92	1.13			21	2			23
DuWapN_84	5.00	5.36	5.62	5.92	6.30	7.22			21	4			25
DuWapN_9	0.00	0.07	0.16	0.29	0.41	0.61			15	1			16
DuWapN_90	1.18	1.54	2.02	2.50	2.70	2.91			21	4			25
DuWapN_91	1.92	2.23	2.47	2.70	2.99	3.83			21	4			25
DuWapN_93	-1.82	-1.57	-1.35	-1.09	-0.70	-0.20			0	0			0
DuWapN_94	-1.54	-1.29	-1.06	-0.73	-0.38	0.09			1	0			1
DuWapN_95	1.86	1.96	2.04	2.14	2.24	2.36			21	4			25
DuWapN_97	-0.24	0.13	0.38	0.69	0.92	1.15			15	2			17
DuWapN_98	-4.24	-3.84	-3.57	-3.23	-2.98	-2.70			0	0			0

Appendix N
Detailed Flood Resiliency Scoring
Modeled Nodes

Model Node	Flood Depth						Roadway	Critical Facilities	Scoring				
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr			Flood Frequency	Flood Depth	Evac Routes	Crit Fac	Total score
DuWapN_9b	0.33	0.51	0.66	0.85	1.03	1.31			21	2			23

Appendix N
Detailed Flood Resiliency Scoring
Structures

Assset ID	Model Node	Flood Score
swINLT001308	none	0
swINLT007868	DuWapMH_329	10
swINLT007869	DuWapN_36	23
swINLT007870	DuWapN_36	23
swINLT007915	DuWapMH_146	0
swINLT007926	none	0
swINLT007932	none	0
swINLT007933	none	0
swINLT007934	none	0
swINLT007936	none	0
swINLT007938	none	0
swINLT007939	none	0
swINLT007940	none	0
swINLT007964	none	0
swINLT007965	none	0
swINLT007966	none	0
swINLT007967	none	0
swINLT007996	none	0
swINLT007997	none	0
swINLT007998	none	0
swINLT007999	none	0
swINLT008000	none	0
swINLT008001	none	0
swINLT008002	none	0
swINLT008003	none	0
swINLT008004	none	0
swINLT008053	DuWapMH_92	3
swINLT008056	DuWapMH_88	17
swINLT008057	DuWapMH_88	17
swINLT008075	DuWapMH_140	25
swINLT008078	DuWapMH_10	17
swINLT008167	DuWapMH_95	0
swINLT008283	DuWapMH_195	25
swINLT008284	DuWapMH_23	25
swINLT008291	DuWapMH_24	19
swINLT008292	DuWapMH_46	18
swINLT008293	DuWapMH_46	18
swINLT008304	none	0
swINLT008305	none	0
swINLT008306	none	0
swINLT008307	none	0
swINLT008308	DuWapMH_159	34
swINLT008309	DuWapN_212	33
swINLT008312	DuWapMH_27	24
swINLT008316	DuWapMH_28	24
swINLT008319	DuWapMH_28	24

Appendix N
Detailed Flood Resiliency Scoring
Structures

Assset ID	Model Node	Flood Score
swINLT008354	DuWapMH_28	24
swINLT008360	DuWapN_71	24
swINLT008381	DuWapN_40	22
swINLT008418	DuWapN_250	16
swINLT008445	none	0
swINLT008463	none	0
swINLT008464	none	0
swINLT008478	DuWapMH_32	0
swINLT008479	DuWapMH_32	0
swINLT008480	DuWapMH_32	0
swINLT008481	DuWapMH_10	17
swINLT008482	DuWapMH_10	17
swINLT008483	DuWapMH_10	17
swINLT008484	DuWapMH_10	17
swINLT008486	DuWapMH_371	24
swINLT008487	DuWapMH_371	24
swINLT008488	DuWapMH_292	1
swINLT008489	DuWapMH_393	0
swINLT008490	DuWapMH_294	7
swINLT008491	DuWapMH_294	7
swINLT008492	DuWapMH_294	7
swINLT008496	DuWapMH_381	24
swINLT008499	DuWapN_216	32
swINLT008501	DuWapN_216	32
swINLT008505	DuWapMH_426	24
swINLT008506	DuWapN_27	3
swINLT008511	DuWapN_222	16
swINLT008512	DuWapN_222	16
swINLT008517	DuWapMH_302	24
swINLT008552	DuWapMH_296	1
swINLT008553	DuWapMH_296	1
swINLT008591	DuWapN_14	24
swINLT008601	DuWapN_66	23
swINLT008602	DuWapN_66	23
swINLT009034	DuWapMH_108	24
swINLT009035	DuWapMH_108	24
swINLT009045	DuWapMH_87	23
swINLT009046	DuWapN_274	23
swINLT009047	DuWapMH_338	24
swINLT009048	DuWapN_52	24
swINLT009051	DuWapMH_449	24
swINLT009052	DuWapMH_177	24
swINLT009053	DuWapN_74	24
swINLT009054	DuWapN_74	24
swINLT009055	DuWapN_74	24
swINLT009056	DuWapN_74	24

Appendix N
Detailed Flood Resiliency Scoring
Structures

Assset ID	Model Node	Flood Score
swINLT009058	DuWapN_74	24
swINLT009062	DuWapN_53	11
swINLT009109	DuWapMH_179	24
swINLT009115	DuWapMH_106	0
swINLT009126	DuWapN_57	32
swINLT009127	DuWapN_57	32
swINLT009128	DuWapN_257	34
swINLT009129	DuWapN_257	34
swINLT009130	DuWapN_63	32
swINLT009131	DuWapN_63	32
swINLT009132	DuWapN_63	32
swINLT009133	DuWapN_64	34
swINLT009134	DuWapN_64	34
swINLT009135	DuWapN_64	34
swINLT009136	DuWapMH_180	3
swINLT009141	DuWapMH_40	0
swINLT009164	DuWapN_65	22
swINLT009197	DuWapN_28	25
swINLT009202	none	0
swINLT009203	none	0
swINLT009204	none	0
swINLT009209	none	0
swINLT009210	none	0
swINLT009215	none	0
swINLT009216	none	0
swINLT009217	none	0
swINLT009218	none	0
swINLT009219	none	0
swINLT009239	DuWapMH_1	25
swINLT009242	DuWapMH_1	25
swINLT009282	DuWapN_56	25
swINLT009283	DuWapMH_191	35
swINLT009284	DuWapN_25	24
swINLT010719	DuWapMH_500	0
swINLT010726	DuWapMH_282	17
swINLT010734	DuWapMH_24	19
swINLT010737	none	0
swINLT010739	DuWapN_43	32
swINLT010742	DuWapN_225	25
swINLT010743	DuWapMH_446	0
swINLT010749	DuWapN_67	23
swINLT010750	DuWapN_67	23
swINLT010751	DuWapMH_47	0
swINLT010752	DuWapMH_47	0
swINLT010753	DuWapN_67	23
swINLT010754	DuWapN_67	23

Appendix N
Detailed Flood Resiliency Scoring
Structures

Assset ID	Model Node	Flood Score
swINLT010755	DuWapN_267	22
swINLT010756	DuWapN_267	22
swINLT010757	DuWapN_267	22
swINLT010758	DuWapN_79	0
swINLT010774	DuWapN_11a	0
swINLT010782	DuWapMH_48	22
swINLT010783	DuWapMH_193	22
swINLT010784	DuWapN_229	22
swINLT010803	DuWapMH_123	24
swINLT990002	DuWapMH_51	24
swINLT990003	DuWapMH_51	24
swINLT990004	DuWapMH_51	24
swINLT990009	DuWapMH_52	0
swINLT990010	DuWapMH_52	0
swINLT990019	DuWapN_48	22
swINLT990020	DuWapN_48	22
swINLT990021	DuWapN_59	24
swINLT990022	DuWapMH_10	17
swINLT990023	DuWapN_59	24
swINLT990036	DuWapN_17	23
swINLT990038	DuWapN_216	32
swINLT990039	DuWapN_250	16
swINLT990040	DuWapMH_53	24
swINLT990041	DuWapMH_53	24
swINLT990042	DuWapMH_53	24
swINLT990045	DuWapN_51	24
swINLT990048	DuWapMH_107	25
swINLT990049	DuWapMH_123	24
swINLT990050	DuWapN_222	16
swINLT990051	DuWapN_222	16
swINLT990052	DuWapMH_74	33
swINLT990053	DuWapMH_123	24
swINLT990054	DuWapMH_123	24
swINLT990056	DuWapN_57	32
swINLT990059	DuWapMH_55	17
swINLT990060	DuWapMH_55	17
swINLT990068	DuWapMH_56	25
swINLT990069	DuWapN_225	25
swINLT990070	none	0
swINLT990071	none	0
swINLT990072	none	0
swINLT990073	DuWapN_62	23
swINLT990075	DuWapN_97	17
swINLT990076	DuWapN_97	17
swINLT990077	DuWapMH_57	3
swINLT990078	DuWapMH_249	24

Appendix N
Detailed Flood Resiliency Scoring
Structures

Assset ID	Model Node	Flood Score
swINLT990081	none	0
swINLT990082	DuWapN_71	24
swINLT990083	DuWapMH_92	3
swINLT990084	DuWapMH_380	25
swINLT990086	DuWapMH_900	17
swINLT990087	DuWapMH_92	3
swINLT990088	DuWapN_67	23
swINLT990089	DuWapN_267	22
swINLT990090	DuWapMH_225	23
swINLT990157	DuWapMH_113	25
swINLT990158	DuWapN_3	22
swINLT990159	DuWapN_3	22
swINLT990160	DuWapMH_432	11
swINLT990164	DuWapMH_115	16
swINLT990165	DuWapMH_140	25
swINLT990167	DuWapN_40	22
swINLT990169	DuWapN_40	22
swINLT990171	none	0
swINLT990172	none	0
swINLT990173	none	0
swINLT990174	none	0
swINLT990175	DuWapN_225	25
swINLT990176	DuWapN_9b	23
swINLT990177	DuWapN_9b	23
swINLT990182	DuWapN_257	34
swINLT990183	DuWapN_257	34
swINLT990184	DuWapN_257	34
swINLT990185	DuWapN_57	32
swINLT990186	DuWapN_57	32
swINLT990187	DuWapN_64	34
swINLT990188	DuWapN_64	34
swINLT990189	DuWapN_64	34
swINLT990190	DuWapN_55	22
swINLT990191	DuWapN_63	32
swINLT990192	DuWapMH_69	35
swINLT990193	DuWapN_63	32
swINLT990194	DuWapN_64	34
swINLT990195	DuWapMH_131	25
swINLT990196	DuWapN_55	22
swINLT990197	DuWapN_91	25
swINLT990208	DuWapN_27	3
swINLT990209	DuWapN_27	3
swINLT990215	DuWapMH_61	32
swINLT990216	DuWapN_11b	14
swINLT990217	DuWapMH_61	32
swINLT990218	DuWapN_11b	14

Appendix N
Detailed Flood Resiliency Scoring
Structures

Assset ID	Model Node	Flood Score
swINLT990223	DuWapN_91	25
swINLT990224	DuWapN_63	32
swINLT990225	DuWapMH_69	35
SWINLT990231	DuWapMH_28	24
SWINLT990232	DuWapMH_28	24
swINLT990500	DuWapN_17	23
swINLT990502	DuWapMH_432	11
swMNHL000378	none	0
swMNHL000379	none	0
swMNHL001793	none	0
swMNHL001797	none	0
swMNHL001798	none	0
swMNHL001811	none	0
swMNHL001812	none	0
swMNHL001813	none	0
swMNHL001814	none	0
swMNHL001816	none	0
swMNHL001844	DuWapMH_77	25
swMNHL001845	DuWapN_334	25
swMNHL001853	none	0
swMNHL001854	DuWapN_11a	0
swMNHL001856	DuWapMH_88	17
swMNHL001865	DuWapMH_162	0
swMNHL001878	DuWapMH_32	0
swMNHL001880	DuWapN_250	16
swMNHL001881	DuWapN_216	32
swMNHL001887	DuWapMH_190	24
swMNHL001922	DuWapMH_87	23
swMNHL001927	DuWapN_53	11
swMNHL001943	DuWapMH_88	17
swMNHL001953	DuWapMH_88	17
swMNHL001954	DuWapMH_88	17
swMNHL001955	DuWapMH_92	3
swMNHL001960	DuWapMH_32	0
swMNHL002065	DuWapMH_101	7
swMNHL002066	DuWapMH_146	0
swMNHL002074	DuWapMH_192	24
swMNHL002075	DuWapMH_96	3
swMNHL002076	DuWapMH_97	22
swMNHL002077	DuWapMH_98	0
swMNHL002078	DuWapN_53	11
swMNHL990001	DuWapN_62	23
swMNHL990002	DuWapN_62	23
swMNHL990006	DuWapMH_99	24
swMNHL990007	DuWapMH_175	24
swMNHL990008	DuWapN_48	22

Appendix N
Detailed Flood Resiliency Scoring
Structures

Assset ID	Model Node	Flood Score
swMNHL990009	DuWapN_59	24
swMNHL990011	DuWapN_216	32
swMNHL990012	DuWapMH_381	24
swMNHL990013	DuWapMH_101	7
swMNHL990015	DuWapN_35c	22
swMNHL990016	DuWapN_222	16
swMNHL990025	none	0
swMNHL990026	none	0
swMNHL990027	none	0
swMNHL990028	DuWapMH_238	25
swMNHL990029	DuWapMH_104	25
swMNHL990030	DuWapMH_104	25
swMNHL990031	DuWapMH_105	24
swMNHL990032	DuWapMH_57	3
swMNHL990033	DuWapN_72	22
swMNHL990034	DuWapN_29	22
swMNHL990035	DuWapMH_107	25
swMNHL990036	DuWapMH_88	17
swMNHL990037	DuWapMH_92	3
swMNHL990038	DuWapMH_108	24
swMNHL990039	DuWapN_11a	0
swMNHL990040	DuWapMH_109	7
swMNHL990041	DuWapMH_207	10
swMNHL990042	DuWapN_11a	0
swMNHL990043	DuWapN_11a	0
swMNHL990044	DuWapN_211a	34
swMNHL990063	DuWapMH_113	25
swMNHL990065	DuWapN_3	22
swMNHL990066	DuWapMH_108	24
swMNHL990067	DuWapN_3	22
swMNHL990070	DuWapMH_140	25
swMNHL990071	DuWapMH_432	11
swMNHL990075	DuWapN_40	22
swMNHL990076	DuWapN_40	22
swMNHL990077	DuWapN_40	22
swMNHL990078	DuWapMH_115	16
swMNHL990080	DuWapMH_117	3
swMNHL990081	none	0
swMNHL990082	DuWapN_66	23
swMNHL990083	DuWapN_55	22
swMNHL990084	DuWapMH_318	10
swMNHL990500	DuWapMH_115	16
swMNHL990502	DuWapN_3	22
swMNHL990503	DuWapMH_114	24
swOUTL990002	DuWapN_48	22
swOUTL990003	DuWapMH_238	25

Appendix N
Detailed Flood Resiliency Scoring
Structures

Assset ID	Model Node	Flood Score
swOUTL990004	DuWapMH_900	17
swOUTL990005	DuWapMH_108	24
swOUTL990006	DuWapMH_130	25
swOUTL990012	DuWapMH_133	4
swOUTL990013	DuWapMH_121	25
swOUTL990014	DuWapMH_318	10
swOUTL990015	DuWapMH_402	0
swOUTL990016	DuWapN_80	10

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL002253	none	0
swCHNL002254	none	0
swCHNL002256	none	0
swCHNL002257	none	0
swCHNL002258	none	0
swCHNL002259	none	0
swCHNL002260	none	0
swCHNL002261	none	0
swCHNL002262	none	0
swCHNL002263	none	0
swCHNL005535	DuWapN_36	23
swCHNL005536	DuWapN_36	23
swCHNL005562	DuWapN_36	23
swCHNL005563	DuWapN_36	23
swCHNL005564	DuWapN_36	23
swCHNL005565	DuWapN_36	23
swCHNL005566	DuWapN_36	23
swCHNL005567	DuWapN_36	23
swCHNL005568	DuWapMH_329	10
swCHNL005569	DuWapMH_329	10
swCHNL005570	DuWapMH_329	10
swCHNL005571	DuWapMH_329	10
swCHNL005572	DuWapMH_146	0
swCHNL005573	DuWapMH_146	0
swCHNL005574	DuWapMH_146	0
swCHNL005575	DuWapMH_317	24
swCHNL005603	DuWapMH_146	0
swCHNL005617	none	0
swCHNL005643	none	0
swCHNL005644	none	0
swCHNL005645	none	0
swCHNL005646	none	0
swCHNL005674	DuWapMH_351	25
swCHNL005675	DuWapMH_351	25
swCHNL005676	DuWapMH_330	11
swCHNL005682	DuWapMH_88	17
swCHNL005683	DuWapMH_267	1
swCHNL005685	DuWapMH_334	16
swCHNL005686	DuWapMH_445	25
swCHNL005687	DuWapMH_429	25
swCHNL005688	DuWapMH_245	25
swCHNL005690	DuWapMH_289	7
swCHNL005691	DuWapN_241	25
swCHNL005693	DuWapMH_336	0
swCHNL005694	DuWapMH_336	0
swCHNL005695	DuWapMH_337	25

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL005696	DuWapMH_338	24
swCHNL005697	DuWapN_48	22
swCHNL005698	DuWapMH_339	7
swCHNL005699	DuWapMH_154	24
swCHNL005701	DuWapN_23	23
swCHNL005702	DuWapN_13	25
swCHNL005707	DuWapMH_140	25
swCHNL005711	DuWapN_32	11
swCHNL005721	DuWapMH_282	17
swCHNL005723	DuWapMH_282	17
swCHNL005724	DuWapMH_152	1
swCHNL005736	DuWapMH_281	23
swCHNL005744	DuWapN_21	24
swCHNL005757	DuWapMH_157	7
swCHNL005809	DuWapN_12	33
swCHNL005810	DuWapN_12	33
swCHNL005811	DuWapMH_28	24
swCHNL005812	DuWapMH_28	24
swCHNL005813	DuWapN_212	33
swCHNL005815	DuWapN_211a	34
swCHNL005816	DuWapN_211a	34
swCHNL005817	DuWapN_11a	0
swCHNL005819	DuWapN_11a	0
swCHNL005820	DuWapN_11a	0
swCHNL005823	DuWapMH_402	0
swCHNL005825	DuWapN_211a	34
swCHNL005826	DuWapN_211a	34
swCHNL005832	none	0
swCHNL005833	DuWapMH_196	3
swCHNL005873	none	0
swCHNL005895	DuWapMH_212	0
swCHNL005896	DuWapMH_351	25
swCHNL005897	DuWapMH_88	17
swCHNL005898	DuWapMH_196	3
swCHNL005899	DuWapMH_331	24
swCHNL005900	DuWapMH_331	24
swCHNL005901	DuWapMH_331	24
swCHNL005902	DuWapMH_88	17
swCHNL005903	DuWapMH_88	17
swCHNL005904	DuWapMH_88	17
swCHNL005905	DuWapMH_260	24
swCHNL005906	DuWapMH_343	24
swCHNL005907	DuWapMH_261	24
swCHNL005908	DuWapMH_88	17
swCHNL005913	DuWapMH_432	11
swCHNL005916	DuWapMH_258	24

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL005917	DuWapMH_221	24
swCHNL005950	DuWapMH_88	17
swCHNL005951	DuWapMH_88	17
swCHNL005952	DuWapMH_88	17
swCHNL005953	DuWapMH_196	3
swCHNL005954	DuWapMH_330	11
swCHNL005955	DuWapMH_196	3
swCHNL005956	DuWapMH_196	3
swCHNL005958	DuWapMH_330	11
swCHNL005959	DuWapMH_330	11
swCHNL005960	DuWapMH_330	11
swCHNL005961	DuWapMH_88	17
swCHNL005962	DuWapMH_88	17
swCHNL005964	DuWapMH_219	17
swCHNL005968	DuWapMH_152	1
swCHNL005969	DuWapMH_282	17
swCHNL005975	DuWapMH_249	24
swCHNL005976	DuWapMH_434	25
swCHNL005977	DuWapMH_221	24
swCHNL006002	DuWapMH_446	0
swCHNL006003	DuWapMH_449	24
swCHNL006004	DuWapN_52	24
swCHNL006009	DuWapMH_307	0
swCHNL006010	DuWapMH_366	11
swCHNL006011	DuWapMH_366	11
swCHNL006012	DuWapMH_367	0
swCHNL006013	DuWapMH_293	0
swCHNL006017	DuWapMH_370	7
swCHNL006019	DuWapN_234	7
swCHNL006021	DuWapMH_10	17
swCHNL006029	DuWapMH_10	17
swCHNL006030	DuWapMH_290	0
swCHNL006033	DuWapMH_372	24
swCHNL006034	DuWapN_59	24
swCHNL006036	DuWapMH_10	17
swCHNL006064	DuWapMH_436	25
swCHNL006066	DuWapMH_374	25
swCHNL006079	DuWapN_72	22
swCHNL006081	DuWapMH_189	0
swCHNL006086	none	0
swCHNL006088	none	0
swCHNL006106	DuWapMH_360	0
swCHNL006109	DuWapMH_95	0
swCHNL006110	DuWapMH_357	25
swCHNL006111	DuWapMH_254	25
swCHNL006112	DuWapMH_95	0

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL006151	DuWapMH_177	24
swCHNL006153	DuWapMH_294	7
swCHNL006160	DuWapMH_437	24
swCHNL006161	DuWapN_26	24
swCHNL006175	DuWapMH_381	24
swCHNL006180	DuWapMH_426	24
swCHNL006182	DuWapMH_426	24
swCHNL006183	DuWapMH_426	24
swCHNL006184	DuWapMH_426	24
swCHNL006185	DuWapMH_426	24
swCHNL006186	DuWapMH_426	24
swCHNL006187	DuWapN_27	3
swCHNL006188	DuWapN_27	3
swCHNL006189	DuWapMH_426	24
swCHNL006190	DuWapMH_426	24
swCHNL006194	DuWapN_27	3
swCHNL006195	DuWapN_27	3
swCHNL006196	DuWapN_27	3
swCHNL006197	DuWapN_27	3
swCHNL006212	DuWapMH_123	24
swCHNL006213	DuWapMH_377	24
swCHNL006214	DuWapMH_123	24
swCHNL006215	DuWapMH_123	24
swCHNL006216	DuWapMH_123	24
swCHNL006219	DuWapMH_377	24
swCHNL006221	DuWapN_35c	22
swCHNL006222	DuWapN_35c	22
swCHNL006223	DuWapMH_190	24
swCHNL006224	DuWapMH_190	24
swCHNL006225	DuWapMH_380	25
swCHNL006226	DuWapMH_190	24
swCHNL006227	DuWapMH_190	24
swCHNL006228	DuWapN_45	22
swCHNL006231	DuWapMH_190	24
swCHNL006232	DuWapN_51	24
swCHNL006234	DuWapN_17	23
swCHNL006235	DuWapN_17	23
swCHNL006236	DuWapN_17	23
swCHNL006237	DuWapN_35c	22
swCHNL006238	DuWapN_17	23
swCHNL006239	DuWapN_17	23
swCHNL006240	DuWapN_17	23
swCHNL006241	DuWapN_17	23
swCHNL006242	DuWapN_17	23
swCHNL006243	DuWapN_17	23
swCHNL006244	DuWapN_17	23

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL006254	DuWapN_17	23
swCHNL006255	DuWapN_17	23
swCHNL006256	DuWapN_35a	23
swCHNL006257	DuWapN_17	23
swCHNL006258	DuWapN_17	23
swCHNL006259	DuWapN_17	23
swCHNL006262	DuWapN_17	23
swCHNL006264	DuWapN_17	23
swCHNL006265	DuWapN_17	23
swCHNL006266	DuWapN_17	23
swCHNL006267	DuWapN_17	23
swCHNL006270	DuWapN_17	23
swCHNL006271	DuWapN_17	23
swCHNL006272	DuWapN_17	23
swCHNL006273	DuWapN_17	23
swCHNL006274	DuWapN_17	23
swCHNL006275	DuWapN_17	23
swCHNL006281	DuWapMH_380	25
swCHNL006444	DuWapMH_175	24
swCHNL006485	DuWapMH_387	24
swCHNL006486	DuWapMH_387	24
swCHNL006487	DuWapN_274	23
swCHNL006529	DuWapMH_153	11
swCHNL006556	DuWapMH_199	24
swCHNL006557	DuWapMH_389	24
swCHNL006580	DuWapN_48	22
swCHNL006581	DuWapN_48	22
swCHNL006583	DuWapN_59	24
swCHNL006584	DuWapMH_372	24
swCHNL006585	DuWapMH_390	1
swCHNL006586	DuWapMH_390	1
swCHNL006587	DuWapMH_390	1
swCHNL006588	DuWapMH_390	1
swCHNL006589	DuWapMH_295	0
swCHNL006590	DuWapMH_296	1
swCHNL006591	DuWapMH_295	0
swCHNL006592	DuWapMH_294	7
swCHNL006593	DuWapMH_297	0
swCHNL006594	DuWapMH_392	1
swCHNL006595	DuWapMH_392	1
swCHNL006596	DuWapMH_392	1
swCHNL006597	DuWapMH_392	1
swCHNL006598	DuWapMH_392	1
swCHNL006599	DuWapMH_392	1
swCHNL006600	DuWapMH_392	1
swCHNL006601	DuWapMH_392	1

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL006602	DuWapMH_294	7
swCHNL006603	DuWapMH_294	7
swCHNL006604	DuWapMH_294	7
swCHNL006606	DuWapMH_294	7
swCHNL006607	DuWapMH_294	7
swCHNL006608	DuWapMH_294	7
swCHNL006609	DuWapMH_292	1
swCHNL006612	DuWapMH_291	25
swCHNL006615	DuWapN_49	23
swCHNL006616	DuWapN_49	23
swCHNL006617	DuWapMH_297	0
swCHNL006633	DuWapMH_180	3
swCHNL006634	DuWapMH_181	1
swCHNL006635	DuWapN_230	24
swCHNL006636	DuWapN_30	22
swCHNL006646	DuWapMH_373	25
swCHNL006715	none	0
swCHNL006716	none	0
swCHNL006717	none	0
swCHNL006718	none	0
swCHNL006719	none	0
swCHNL006720	none	0
swCHNL006721	none	0
swCHNL006722	none	0
swCHNL006723	none	0
swCHNL006724	none	0
swCHNL006725	none	0
swCHNL006726	none	0
swCHNL006727	none	0
swCHNL006728	none	0
swCHNL006729	none	0
swCHNL006730	none	0
swCHNL006731	none	0
swCHNL006732	none	0
swCHNL006733	none	0
swCHNL006734	none	0
swCHNL006735	none	0
swCHNL006736	none	0
swCHNL006738	DuWapN_56	25
swCHNL006739	DuWapMH_238	25
swCHNL006772	DuWapMH_397	0
swCHNL006796	DuWapMH_403	0
swCHNL006805	none	0
swCHNL006806	none	0
swCHNL006807	none	0
swCHNL006808	none	0

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL006809	DuWapMH_191	35
swCHNL006810	DuWapMH_191	35
swCHNL006811	DuWapN_25	24
swCHNL006812	DuWapN_25	24
swCHNL006813	DuWapN_225	25
swCHNL006816	DuWapMH_329	10
swCHNL006904	DuWapMH_402	0
swCHNL006906	DuWapMH_402	0
swCHNL006911	DuWapMH_318	10
swCHNL006913	DuWapMH_207	10
swCHNL006961	DuWapMH_101	7
swCHNL006962	DuWapMH_101	7
swCHNL006963	DuWapMH_101	7
swCHNL006964	DuWapMH_101	7
swCHNL006965	DuWapMH_154	24
swCHNL006966	DuWapMH_154	24
swCHNL006967	DuWapMH_154	24
swCHNL006968	DuWapMH_154	24
swCHNL006969	DuWapMH_154	24
swCHNL006970	DuWapMH_154	24
swCHNL006971	DuWapMH_154	24
swCHNL006972	DuWapMH_154	24
swCHNL006973	DuWapMH_101	7
swCHNL006981	DuWapN_13	25
swCHNL006985	DuWapMH_408	25
swCHNL007014	DuWapN_17	23
swCHNL007018	DuWapMH_381	24
swCHNL007028	DuWapMH_177	24
swCHNL007029	DuWapMH_154	24
swCHNL007030	DuWapMH_154	24
swCHNL007031	DuWapMH_154	24
swCHNL007032	DuWapMH_154	24
swCHNL007034	DuWapMH_154	24
swCHNL007035	DuWapMH_154	24
swCHNL007036	DuWapMH_154	24
swCHNL007037	DuWapMH_154	24
swCHNL007038	DuWapMH_154	24
swCHNL007039	DuWapMH_154	24
swCHNL007040	DuWapMH_46	18
swCHNL007041	DuWapMH_46	18
swCHNL007042	DuWapMH_311	13
swCHNL007043	DuWapMH_310	9
swCHNL007045	DuWapMH_309	9
swCHNL007046	DuWapMH_188	7
swCHNL007047	DuWapMH_411	13
swCHNL007048	DuWapMH_101	7

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL007049	DuWapMH_101	7
swCHNL007050	DuWapMH_101	7
swCHNL007051	DuWapMH_101	7
swCHNL007054	DuWapMH_24	19
swCHNL007068	DuWapMH_381	24
swCHNL007086	DuWapMH_189	0
swCHNL007101	DuWapMH_47	0
swCHNL007105	DuWapMH_132	3
swCHNL007107	DuWapMH_240	25
swCHNL007108	DuWapN_28	25
swCHNL007109	DuWapN_28	25
swCHNL007110	DuWapN_28	25
swCHNL007112	DuWapMH_313	25
swCHNL007117	DuWapN_64	34
swCHNL007127	DuWapN_56	25
swCHNL007129	none	0
swCHNL007130	none	0
swCHNL007131	none	0
swCHNL007132	none	0
swCHNL007133	none	0
swCHNL007137	DuWapMH_225	23
swCHNL007138	DuWapMH_344	24
swCHNL007152	DuWapN_17	23
swCHNL007153	DuWapN_27	3
swCHNL007154	DuWapN_27	3
swCHNL007163	DuWapMH_192	24
swCHNL007164	DuWapMH_192	24
swCHNL007168	DuWapMH_415	25
swCHNL007172	DuWapMH_415	25
swCHNL007173	DuWapMH_192	24
swCHNL007174	DuWapMH_192	24
swCHNL007175	DuWapMH_192	24
swCHNL007176	DuWapMH_438	24
swCHNL007181	DuWapMH_194	0
swCHNL007184	DuWapMH_196	3
swCHNL007186	DuWapMH_117	3
swCHNL007187	DuWapMH_117	3
swCHNL007192	DuWapMH_375	11
swCHNL007196	DuWapN_51	24
swCHNL007197	DuWapMH_900	17
swCHNL007199	DuWapN_17	23
swCHNL007201	DuWapN_27	3
swCHNL007202	DuWapMH_381	24
swCHNL007205	DuWapMH_381	24
swCHNL007214	DuWapN_17	23
swCHNL990007	DuWapN_61	22

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL990009	DuWapMH_153	11
swCHNL990010	DuWapMH_153	11
swCHNL990012	DuWapMH_99	24
swCHNL990017	DuWapN_48	22
swCHNL990023	DuWapMH_291	25
swCHNL990024	DuWapN_27	3
swCHNL990025	DuWapMH_426	24
swCHNL990026	DuWapN_17	23
swCHNL990027	DuWapN_17	23
swCHNL990031	DuWapMH_223	18
swCHNL990035	DuWapN_17	23
swCHNL990043	DuWapMH_418	13
swCHNL990044	DuWapMH_154	24
swCHNL990045	DuWapMH_154	24
swCHNL990046	DuWapMH_154	24
swCHNL990047	DuWapMH_101	7
swCHNL990051	DuWapN_17	23
swCHNL990052	DuWapN_35a	23
swCHNL990053	DuWapMH_192	24
swCHNL990056	DuWapMH_419	0
swCHNL990057	DuWapN_57	32
swCHNL990067	none	0
swCHNL990068	none	0
swCHNL990069	none	0
swCHNL990070	none	0
swCHNL990072	none	0
swCHNL990073	none	0
swCHNL990074	none	0
swCHNL990075	DuWapMH_419	0
swCHNL990076	DuWapMH_206	25
swCHNL990077	DuWapMH_420	25
swCHNL990088	DuWapMH_261	24
swCHNL990089	DuWapMH_259	25
swCHNL990090	DuWapMH_259	25
swCHNL990092	DuWapMH_88	17
swCHNL990095	DuWapMH_225	23
swCHNL990096	DuWapMH_207	10
swCHNL990098	DuWapMH_207	10
swCHNL990099	DuWapMH_318	10
swCHNL990100	DuWapMH_318	10
swCHNL990101	DuWapMH_318	10
swCHNL990102	DuWapMH_318	10
swCHNL990103	DuWapMH_318	10
swCHNL990104	DuWapMH_318	10
swCHNL990105	DuWapMH_318	10
swCHNL990106	DuWapMH_318	10

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCHNL990107	DuWapMH_402	0
swCHNL990108	DuWapMH_402	0
swCHNL990109	DuWapMH_402	0
swCHNL990110	DuWapMH_402	0
swCHNL990111	DuWapN_11a	0
swCHNL990112	DuWapMH_159	34
swCHNL990113	DuWapMH_27	24
swCHNL990117	none	0
swCHNL990118	none	0
swCHNL990122	DuWapMH_329	10
swCHNL990125	DuWapN_241	25
swCHNL990126	none	0
swCHNL990132	DuWapMH_335	25
swCHNL990133	DuWapN_13	25
swCHNL990134	DuWapN_13	25
swCHNL990135	DuWapN_209b	24
swCHNL990137	none	0
swCHNL990138	DuWapN_9b	23
swCHNL990139	DuWapN_65	22
swCHNL990140	DuWapMH_233	25
swCHNL990141	DuWapMH_241	25
swCHNL990142	DuWapMH_240	25
swCHNL990143	DuWapMH_313	25
swCHNL990146	DuWapN_27	3
swCHNL990147	DuWapN_27	3
swCHNL990148	DuWapN_27	3
swCHNL990149	DuWapN_27	3
swCHNL990150	DuWapMH_426	24
swCHNL990151	DuWapN_57	32
SWCHNL990152	DuWapN_17	23
SWCHNL990154	DuWapN_230	24
swCHNL990514	DuWapMH_294	7
swCLVT000260	none	0
swCLVT000262	DuWapMH_275	24
swCLVT000263	DuWapMH_276	11
swCLVT000269	DuWapMH_154	24
swCLVT000270	DuWapMH_154	24
swCLVT000273	DuWapMH_444	24
swCLVT000388	DuWapMH_331	24
swCLVT000389	DuWapMH_331	24
swCLVT000390	DuWapMH_88	17
swCLVT000391	DuWapMH_88	17
swCLVT000392	DuWapMH_260	24
swCLVT000393	DuWapMH_261	24
swCLVT000395	DuWapMH_434	25
swCLVT000418	DuWapMH_196	3

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCLVT000419	DuWapMH_196	3
swCLVT000420	DuWapMH_88	17
swCLVT000421	DuWapMH_88	17
swCLVT000422	DuWapMH_196	3
swCLVT000423	DuWapMH_196	3
swCLVT000424	DuWapMH_330	11
swCLVT000425	DuWapMH_330	11
swCLVT000426	DuWapMH_330	11
swCLVT000427	DuWapMH_330	11
swCLVT000428	DuWapMH_330	11
swCLVT000429	DuWapMH_88	17
swCLVT000430	DuWapMH_88	17
swCLVT000435	DuWapMH_434	25
swCLVT000439	DuWapMH_298	0
swCLVT000440	DuWapMH_299	11
swCLVT000441	DuWapMH_500	0
swCLVT000442	DuWapMH_301	1
swCLVT000443	DuWapMH_370	7
swCLVT000453	DuWapMH_10	17
swCLVT000474	DuWapMH_246	25
swCLVT000490	none	0
swCLVT000508	DuWapMH_254	25
swCLVT000532	DuWapMH_437	24
swCLVT000544	DuWapMH_426	24
swCLVT000545	DuWapMH_426	24
swCLVT000546	DuWapMH_426	24
swCLVT000547	DuWapMH_426	24
swCLVT000549	DuWapMH_426	24
swCLVT000550	DuWapN_27	3
swCLVT000551	DuWapMH_426	24
swCLVT000555	DuWapN_27	3
swCLVT000556	DuWapN_27	3
swCLVT000557	DuWapN_27	3
swCLVT000563	DuWapMH_302	24
swCLVT000566	DuWapMH_377	24
swCLVT000567	DuWapN_35c	22
swCLVT000568	DuWapN_35c	22
swCLVT000569	DuWapN_35c	22
swCLVT000570	DuWapMH_274	25
swCLVT000571	DuWapMH_190	24
swCLVT000572	DuWapMH_190	24
swCLVT000573	DuWapMH_190	24
swCLVT000574	DuWapN_51	24
swCLVT000576	DuWapN_51	24
swCLVT000577	DuWapN_17	23
swCLVT000578	DuWapN_17	23

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCLVT000579	DuWapN_17	23
swCLVT000580	DuWapN_17	23
swCLVT000581	DuWapN_17	23
swCLVT000582	DuWapN_17	23
swCLVT000583	DuWapN_17	23
swCLVT000584	DuWapN_17	23
swCLVT000591	DuWapN_17	23
swCLVT000593	DuWapN_35a	23
swCLVT000594	DuWapN_17	23
swCLVT000597	DuWapN_17	23
swCLVT000598	DuWapN_17	23
swCLVT000599	DuWapN_17	23
swCLVT000600	DuWapN_17	23
swCLVT000601	DuWapN_17	23
swCLVT000602	DuWapN_17	23
swCLVT000607	DuWapN_17	23
swCLVT000608	DuWapN_17	23
swCLVT000609	DuWapN_17	23
swCLVT000610	DuWapN_17	23
swCLVT000821	DuWapN_48	22
swCLVT000822	DuWapN_59	24
swCLVT000825	DuWapN_59	24
swCLVT000826	DuWapMH_390	1
swCLVT000827	DuWapMH_294	7
swCLVT000828	DuWapMH_390	1
swCLVT000829	DuWapMH_390	1
swCLVT000830	DuWapMH_295	0
swCLVT000831	DuWapMH_392	1
swCLVT000832	DuWapMH_391	7
swCLVT000833	DuWapMH_392	1
swCLVT000834	DuWapMH_392	1
swCLVT000835	DuWapMH_392	1
swCLVT000836	DuWapMH_392	1
swCLVT000837	DuWapMH_392	1
swCLVT000838	DuWapMH_392	1
swCLVT000839	DuWapMH_392	1
swCLVT000840	DuWapMH_294	7
swCLVT000841	DuWapMH_294	7
swCLVT000842	DuWapMH_294	7
swCLVT000843	DuWapMH_294	7
swCLVT000844	DuWapMH_294	7
swCLVT000845	DuWapMH_294	7
swCLVT000846	DuWapMH_393	0
swCLVT000847	DuWapMH_371	24
swCLVT000848	DuWapMH_291	25
swCLVT000851	DuWapN_49	23

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCLVT000867	DuWapN_94	1
swCLVT000921	none	0
swCLVT000922	none	0
swCLVT000923	none	0
swCLVT000924	none	0
swCLVT000925	none	0
swCLVT000926	none	0
swCLVT000927	none	0
swCLVT000928	none	0
swCLVT000930	none	0
swCLVT000931	none	0
swCLVT000932	none	0
swCLVT000933	none	0
swCLVT000934	none	0
swCLVT000936	none	0
swCLVT000937	none	0
swCLVT000938	DuWapN_225	25
swCLVT000972	none	0
swCLVT000973	none	0
swCLVT000974	none	0
swCLVT000975	none	0
swCLVT000976	DuWapN_25	24
swCLVT000977	DuWapN_25	24
swCLVT000978	DuWapMH_329	10
swCLVT000979	DuWapN_36	23
swCLVT000980	DuWapN_36	23
swCLVT000981	DuWapN_36	23
swCLVT000982	DuWapN_36	23
swCLVT000983	DuWapN_36	23
swCLVT990018	DuWapMH_294	7
swCLVT990019	DuWapMH_294	7
swCLVT990021	DuWapMH_291	25
swCLVT990022	DuWapMH_449	24
swCLVT990023	DuWapMH_338	24
swCLVT990024	DuWapMH_449	24
swCLVT990025	DuWapN_52	24
swCLVT990028	DuWapMH_426	24
swCLVT990029	DuWapN_27	3
swCLVT990030	DuWapN_27	3
swCLVT990031	DuWapN_27	3
swCLVT990032	DuWapN_27	3
swCLVT990034	DuWapMH_426	24
swCLVT990035	DuWapMH_426	24
swCLVT990038	DuWapN_17	23
swCLVT990039	DuWapN_17	23
swCLVT990040	DuWapN_17	23

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCLVT990045	DuWapMH_10	17
swCLVT990048	DuWapMH_304	1
swCLVT990049	DuWapMH_305	11
swCLVT990051	DuWapMH_10	17
swCLVT990052	DuWapMH_197	0
swCLVT990053	DuWapMH_364	0
swCLVT990065	DuWapMH_309	9
swCLVT990066	DuWapMH_310	9
swCLVT990067	DuWapMH_311	13
swCLVT990068	DuWapMH_409	13
swCLVT990069	DuWapMH_46	18
swCLVT990070	DuWapMH_299	11
swCLVT990071	DuWapMH_154	24
swCLVT990072	DuWapMH_154	24
swCLVT990073	DuWapMH_154	24
swCLVT990074	DuWapMH_154	24
swCLVT990075	DuWapMH_154	24
swCLVT990076	DuWapMH_154	24
swCLVT990077	DuWapMH_154	24
swCLVT990078	DuWapMH_154	24
swCLVT990079	DuWapMH_154	24
swCLVT990080	DuWapMH_154	24
swCLVT990081	DuWapMH_154	24
swCLVT990082	DuWapMH_154	24
swCLVT990083	DuWapMH_154	24
swCLVT990084	DuWapMH_101	7
swCLVT990085	DuWapMH_101	7
swCLVT990086	DuWapMH_101	7
swCLVT990087	DuWapMH_101	7
swCLVT990088	DuWapMH_101	7
swCLVT990089	DuWapMH_101	7
swCLVT990093	DuWapN_17	23
swCLVT990094	DuWapN_17	23
swCLVT990095	DuWapN_35a	23
swCLVT990098	DuWapMH_192	24
swCLVT990099	DuWapMH_415	25
swCLVT990100	DuWapMH_192	24
swCLVT990101	DuWapMH_192	24
swCLVT990102	DuWapMH_288	0
swCLVT990104	DuWapMH_123	24
swCLVT990105	DuWapN_230	24
swCLVT990119	none	0
swCLVT990120	none	0
swCLVT990121	none	0
swCLVT990122	none	0
swCLVT990123	none	0

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swCLVT990124	none	0
swCLVT990125	none	0
swCLVT990126	none	0
swCLVT990127	none	0
swCLVT990128	none	0
swCLVT990129	none	0
swCLVT990130	none	0
swCLVT990131	none	0
swCLVT990132	none	0
swCLVT990135	DuWapN_71	24
swCLVT990136	DuWapMH_249	24
swCLVT990159	DuWapMH_157	7
swCLVT990160	DuWapMH_343	24
swCLVT990161	DuWapMH_344	24
swCLVT990162	DuWapMH_344	24
swCLVT990164	DuWapMH_88	17
swCLVT990165	DuWapMH_259	25
swCLVT990167	DuWapMH_254	25
swCLVT990168	none	0
swCLVT990169	none	0
swCLVT990170	none	0
swCLVT990171	DuWapN_212	33
swCLVT990172	DuWapMH_27	24
swCLVT990174	DuWapMH_329	10
swCLVT990176	none	0
swCLVT990177	none	0
swCLVT990178	none	0
swCLVT990179	none	0
swCLVT990180	none	0
swCLVT990181	DuWapN_15	16
swCLVT990201	DuWapMH_240	25
swCLVT990202	DuWapN_57	32
SWCLVT990203	DuWapN_17	23
SWCLVT990204	DuWapN_36	23
swCLVT990500	DuWapMH_446	0
swCLVT990504	DuWapMH_146	0
swPIPE002352	none	0
swPIPE002353	none	0
swPIPE002354	none	0
swPIPE002355	none	0
swPIPE002358	none	0
swPIPE002359	none	0
swPIPE010571	DuWapN_36	23
swPIPE010580	DuWapMH_329	10
swPIPE010581	DuWapMH_329	10
swPIPE010582	DuWapMH_317	24

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE010583	DuWapMH_146	0
swPIPE010590	DuWapMH_147	10
swPIPE010672	none	0
swPIPE010673	none	0
swPIPE010687	none	0
swPIPE010690	none	0
swPIPE010691	none	0
swPIPE010692	none	0
swPIPE010694	none	0
swPIPE010695	none	0
swPIPE010696	none	0
swPIPE010697	none	0
swPIPE010698	none	0
swPIPE010699	none	0
swPIPE010700	none	0
swPIPE010701	none	0
swPIPE010702	none	0
swPIPE010703	none	0
swPIPE010705	none	0
swPIPE010706	none	0
swPIPE010754	none	0
swPIPE010756	none	0
swPIPE010757	none	0
swPIPE010809	none	0
swPIPE010810	none	0
swPIPE010811	none	0
swPIPE010812	none	0
swPIPE010813	none	0
swPIPE010814	none	0
swPIPE010815	none	0
swPIPE010816	none	0
swPIPE010817	none	0
swPIPE010818	none	0
swPIPE010819	none	0
swPIPE010820	none	0
swPIPE010821	none	0
swPIPE010822	none	0
swPIPE010823	none	0
swPIPE010824	none	0
swPIPE010825	none	0
swPIPE010827	none	0
swPIPE010828	none	0
swPIPE010829	none	0
swPIPE010973	DuWapMH_92	3
swPIPE010974	DuWapMH_92	3
swPIPE010975	DuWapMH_330	11

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE010976	DuWapMH_92	3
swPIPE010977	DuWapMH_92	3
swPIPE010978	DuWapMH_88	17
swPIPE010979	DuWapMH_267	1
swPIPE010980	DuWapMH_267	1
swPIPE010981	DuWapMH_88	17
swPIPE010982	DuWapMH_88	17
swPIPE010983	DuWapMH_88	17
swPIPE010984	DuWapMH_3	25
swPIPE010988	DuWapMH_351	25
swPIPE010989	DuWapMH_351	25
swPIPE010993	DuWapMH_88	17
swPIPE010994	DuWapMH_92	3
swPIPE010995	DuWapMH_92	3
swPIPE010997	DuWapMH_357	25
swPIPE011027	DuWapMH_140	25
swPIPE011031	DuWapMH_140	25
swPIPE011032	DuWapMH_140	25
swPIPE011037	DuWapMH_52	0
swPIPE011038	DuWapMH_51	24
swPIPE011039	DuWapMH_51	24
swPIPE011040	DuWapMH_153	11
swPIPE011041	DuWapMH_99	24
swPIPE011042	DuWapMH_99	24
swPIPE011043	DuWapMH_99	24
swPIPE011045	DuWapMH_10	17
swPIPE011046	DuWapMH_394	11
swPIPE011048	DuWapMH_106	0
swPIPE011051	DuWapMH_55	17
swPIPE011109	DuWapMH_74	33
swPIPE011152	DuWapMH_156	0
swPIPE011155	DuWapMH_154	24
swPIPE011156	DuWapMH_154	24
swPIPE011170	DuWapMH_156	0
swPIPE011174	DuWapMH_156	0
swPIPE011205	DuWapMH_77	25
swPIPE011206	DuWapMH_195	25
swPIPE011207	DuWapN_334	25
swPIPE011235	none	0
swPIPE011237	none	0
swPIPE011238	none	0
swPIPE011239	DuWapMH_108	24
swPIPE011240	none	0
swPIPE011241	DuWapMH_159	34
swPIPE011243	DuWapMH_27	24
swPIPE011253	DuWapMH_28	24

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE011255	DuWapMH_28	24
swPIPE011258	DuWapN_11a	0
swPIPE011260	DuWapMH_61	32
swPIPE011261	DuWapN_211b	32
swPIPE011262	DuWapMH_318	10
swPIPE011264	DuWapN_312	23
swPIPE011267	DuWapN_11a	0
swPIPE011269	DuWapMH_351	25
swPIPE011270	none	0
swPIPE011271	DuWapMH_88	17
swPIPE011272	DuWapMH_88	17
swPIPE011273	DuWapMH_88	17
swPIPE011274	DuWapMH_88	17
swPIPE011276	DuWapN_71	24
swPIPE011277	DuWapMH_433	24
swPIPE011333	DuWapMH_162	0
swPIPE011334	DuWapMH_369	0
swPIPE011335	DuWapN_250	16
swPIPE011337	DuWapMH_10	17
swPIPE011372	none	0
swPIPE011373	none	0
swPIPE011388	none	0
swPIPE011401	DuWapMH_32	0
swPIPE011409	DuWapMH_32	0
swPIPE011410	DuWapMH_32	0
swPIPE011411	DuWapMH_10	17
swPIPE011412	DuWapMH_10	17
swPIPE011413	DuWapMH_10	17
swPIPE011414	DuWapMH_32	0
swPIPE011416	DuWapMH_10	17
swPIPE011417	DuWapMH_394	11
swPIPE011418	DuWapMH_371	24
swPIPE011419	DuWapMH_371	24
swPIPE011420	DuWapMH_292	1
swPIPE011421	DuWapMH_292	1
swPIPE011422	DuWapMH_393	0
swPIPE011423	DuWapMH_393	0
swPIPE011424	DuWapMH_294	7
swPIPE011425	DuWapMH_393	0
swPIPE011426	DuWapN_250	16
swPIPE011427	DuWapMH_437	24
swPIPE011434	DuWapMH_426	24
swPIPE011435	DuWapN_27	3
swPIPE011441	DuWapMH_302	24
swPIPE011447	DuWapN_26	24
swPIPE011515	DuWapN_66	23

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE012033	DuWapMH_108	24
swPIPE012034	DuWapMH_108	24
swPIPE012041	DuWapMH_175	24
swPIPE012042	DuWapMH_175	24
swPIPE012049	DuWapMH_337	25
swPIPE012050	DuWapMH_87	23
swPIPE012051	DuWapMH_87	23
swPIPE012052	DuWapN_274	23
swPIPE012053	DuWapN_274	23
swPIPE012055	DuWapMH_338	24
swPIPE012058	DuWapMH_338	24
swPIPE012061	DuWapN_52	24
swPIPE012065	DuWapMH_449	24
swPIPE012066	DuWapMH_449	24
swPIPE012070	DuWapMH_177	24
swPIPE012072	DuWapN_74	24
swPIPE012073	DuWapN_74	24
swPIPE012090	DuWapN_53	11
swPIPE012091	DuWapN_53	11
swPIPE012092	DuWapN_74	24
swPIPE012093	DuWapN_74	24
swPIPE012094	DuWapN_53	11
swPIPE012101	DuWapN_53	11
swPIPE012111	DuWapN_312	23
swPIPE012112	DuWapN_312	23
swPIPE012132	DuWapMH_179	24
swPIPE012133	DuWapN_59	24
swPIPE012134	DuWapN_59	24
swPIPE012147	DuWapN_29	22
swPIPE012151	DuWapMH_180	3
swPIPE012152	DuWapMH_180	3
swPIPE012153	DuWapMH_180	3
swPIPE012162	DuWapMH_40	0
swPIPE012163	DuWapMH_181	1
swPIPE012165	DuWapMH_40	0
swPIPE012178	DuWapN_65	22
swPIPE012196	none	0
swPIPE012197	none	0
swPIPE012198	none	0
swPIPE012199	none	0
swPIPE012200	DuWapN_225	25
swPIPE012218	DuWapMH_191	35
swPIPE012219	DuWapN_25	24
swPIPE012220	DuWapMH_191	35
swPIPE012221	DuWapN_25	24
swPIPE012222	DuWapN_25	24

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE012223	DuWapMH_56	25
swPIPE012224	DuWapMH_182	25
swPIPE012226	DuWapN_36	23
swPIPE013525	DuWapMH_101	7
swPIPE013526	DuWapMH_101	7
swPIPE013527	DuWapMH_101	7
swPIPE013528	DuWapMH_101	7
swPIPE013537	DuWapMH_130	25
swPIPE013586	DuWapMH_282	17
swPIPE013598	DuWapMH_282	17
swPIPE013602	DuWapMH_162	0
swPIPE013603	DuWapMH_500	0
swPIPE013614	DuWapN_216	32
swPIPE013615	DuWapN_216	32
swPIPE013616	DuWapMH_381	24
swPIPE013617	DuWapMH_381	24
swPIPE013654	DuWapMH_446	0
swPIPE013655	DuWapMH_446	0
swPIPE013656	DuWapMH_446	0
swPIPE013659	DuWapMH_46	18
swPIPE013660	DuWapMH_46	18
swPIPE013661	DuWapMH_46	18
swPIPE013662	DuWapMH_46	18
swPIPE013663	DuWapMH_24	19
swPIPE013664	DuWapMH_24	19
swPIPE013665	DuWapMH_188	7
swPIPE013666	DuWapMH_101	7
swPIPE013667	DuWapMH_101	7
swPIPE013668	DuWapMH_101	7
swPIPE013673	DuWapMH_223	18
swPIPE013674	DuWapMH_24	19
swPIPE013677	DuWapN_17	23
swPIPE013696	DuWapN_35c	22
swPIPE013701	DuWapMH_189	0
swPIPE013702	DuWapN_72	22
swPIPE013721	DuWapN_67	23
swPIPE013722	DuWapMH_47	0
swPIPE013723	DuWapMH_47	0
swPIPE013724	DuWapN_267	22
swPIPE013725	DuWapMH_47	0
swPIPE013726	DuWapN_67	23
swPIPE013727	DuWapN_67	23
swPIPE013728	DuWapN_67	23
swPIPE013729	DuWapN_267	22
swPIPE013730	DuWapN_267	22
swPIPE013731	DuWapN_51	24

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE013732	DuWapMH_132	3
swPIPE013736	DuWapMH_240	25
swPIPE013738	DuWapN_28	25
swPIPE013740	DuWapN_43	32
swPIPE013754	DuWapN_225	25
swPIPE013755	DuWapN_225	25
swPIPE013756	none	0
swPIPE013758	DuWapN_56	25
swPIPE013762	DuWapMH_446	0
swPIPE013765	DuWapN_74	24
swPIPE013766	DuWapN_74	24
swPIPE013767	DuWapN_74	24
swPIPE013768	DuWapN_74	24
swPIPE013769	DuWapMH_224	0
swPIPE013771	DuWapN_267	22
swPIPE013772	DuWapN_267	22
swPIPE013774	DuWapN_79	0
swPIPE013783	DuWapN_267	22
swPIPE013784	DuWapMH_360	0
swPIPE013785	none	0
swPIPE013786	none	0
swPIPE013787	none	0
swPIPE013792	DuWapN_17	23
swPIPE013795	DuWapN_17	23
swPIPE013810	DuWapN_27	3
swPIPE013818	DuWapMH_190	24
swPIPE013819	DuWapMH_190	24
swPIPE013820	DuWapN_45	22
swPIPE013821	DuWapMH_107	25
swPIPE013822	DuWapMH_192	24
swPIPE013823	DuWapMH_192	24
swPIPE013824	DuWapMH_107	25
swPIPE013825	DuWapMH_107	25
swPIPE013826	DuWapMH_380	25
swPIPE013828	DuWapMH_192	24
swPIPE013829	DuWapMH_192	24
swPIPE013830	DuWapMH_900	17
swPIPE013831	DuWapMH_900	17
swPIPE013834	DuWapMH_302	24
swPIPE013835	DuWapMH_302	24
swPIPE013840	DuWapMH_192	24
swPIPE013849	DuWapN_45	22
swPIPE013850	DuWapMH_48	22
swPIPE013851	DuWapN_29	22
swPIPE013852	DuWapMH_96	3
swPIPE013853	DuWapMH_97	22

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE013854	DuWapMH_193	22
swPIPE013855	DuWapMH_97	22
swPIPE013856	DuWapMH_193	22
swPIPE013857	DuWapN_229	22
swPIPE013858	DuWapMH_98	0
swPIPE013859	DuWapMH_194	0
swPIPE013875	DuWapMH_402	0
swPIPE013879	DuWapMH_23	25
swPIPE013880	DuWapMH_195	25
swPIPE013883	DuWapMH_117	3
swPIPE013884	DuWapMH_117	3
swPIPE013885	DuWapMH_117	3
swPIPE013906	DuWapMH_123	24
swPIPE013907	DuWapMH_123	24
swPIPE013910	DuWapMH_197	0
swPIPE013911	DuWapMH_53	24
swPIPE013912	DuWapMH_53	24
swPIPE990002	DuWapN_62	23
swPIPE990010	DuWapMH_198	24
swPIPE990011	DuWapMH_389	24
swPIPE990012	DuWapMH_389	24
swPIPE990013	DuWapMH_199	24
swPIPE990014	DuWapMH_389	24
swPIPE990015	DuWapMH_388	22
swPIPE990016	DuWapMH_52	0
swPIPE990029	DuWapMH_175	24
swPIPE990030	DuWapN_48	22
swPIPE990031	DuWapN_48	22
swPIPE990032	DuWapN_48	22
swPIPE990033	DuWapN_48	22
swPIPE990034	DuWapN_48	22
swPIPE990035	DuWapN_48	22
swPIPE990036	DuWapN_48	22
swPIPE990037	DuWapN_59	24
swPIPE990038	DuWapN_59	24
swPIPE990039	DuWapN_59	24
swPIPE990041	DuWapN_59	24
swPIPE990048	DuWapN_274	23
swPIPE990049	DuWapN_274	23
swPIPE990050	DuWapMH_87	23
swPIPE990051	DuWapN_74	24
swPIPE990059	DuWapN_17	23
swPIPE990062	DuWapMH_294	7
swPIPE990066	DuWapN_216	32
swPIPE990067	DuWapN_216	32
swPIPE990068	DuWapN_216	32

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE990069	DuWapMH_381	24
swPIPE990071	DuWapN_250	16
swPIPE990075	DuWapN_95	25
swPIPE990077	DuWapN_17	23
swPIPE990078	DuWapN_17	23
swPIPE990079	DuWapN_17	23
swPIPE990082	DuWapN_334	25
swPIPE990083	DuWapMH_136	7
swPIPE990090	DuWapN_35c	22
swPIPE990091	DuWapN_45	22
swPIPE990096	DuWapMH_123	24
swPIPE990097	DuWapN_222	16
swPIPE990098	DuWapN_222	16
swPIPE990099	DuWapN_222	16
swPIPE990100	DuWapN_222	16
swPIPE990101	DuWapMH_74	33
swPIPE990102	DuWapMH_123	24
swPIPE990103	DuWapMH_123	24
swPIPE990104	DuWapMH_123	24
swPIPE990112	DuWapN_57	32
swPIPE990113	DuWapMH_198	24
swPIPE990114	DuWapN_62	23
swPIPE990115	DuWapMH_294	7
swPIPE990119	DuWapMH_55	17
swPIPE990120	DuWapMH_103	24
swPIPE990130	DuWapN_222	16
swPIPE990131	DuWapMH_32	0
swPIPE990132	DuWapMH_446	0
swPIPE990133	DuWapMH_32	0
swPIPE990134	DuWapMH_32	0
swPIPE990153	DuWapMH_191	35
swPIPE990154	DuWapMH_191	35
swPIPE990155	DuWapMH_191	35
swPIPE990156	DuWapN_225	25
swPIPE990157	DuWapN_225	25
swPIPE990158	DuWapMH_238	25
swPIPE990159	none	0
swPIPE990160	none	0
swPIPE990161	none	0
swPIPE990162	none	0
swPIPE990163	none	0
swPIPE990164	none	0
swPIPE990165	none	0
swPIPE990167	none	0
swPIPE990168	none	0
swPIPE990169	none	0

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE990170	none	0
swPIPE990171	none	0
swPIPE990172	none	0
swPIPE990173	none	0
swPIPE990174	DuWapMH_238	25
swPIPE990175	none	0
swPIPE990176	none	0
swPIPE990177	none	0
swPIPE990182	DuWapMH_206	25
swPIPE990184	DuWapMH_104	25
swPIPE990186	DuWapMH_104	25
swPIPE990187	DuWapN_97	17
swPIPE990188	DuWapMH_105	24
swPIPE990189	DuWapMH_105	24
swPIPE990190	DuWapN_97	17
swPIPE990191	DuWapMH_57	3
swPIPE990192	DuWapMH_57	3
swPIPE990193	DuWapMH_106	0
swPIPE990196	DuWapMH_419	0
swPIPE990202	none	0
swPIPE990203	none	0
swPIPE990204	DuWapN_71	24
swPIPE990205	DuWapN_71	24
swPIPE990207	DuWapMH_88	17
swPIPE990208	DuWapMH_88	17
swPIPE990209	DuWapMH_88	17
swPIPE990210	DuWapMH_88	17
swPIPE990211	DuWapMH_88	17
swPIPE990212	DuWapMH_104	25
swPIPE990213	none	0
swPIPE990216	DuWapMH_254	25
swPIPE990217	none	
swPIPE990218	DuWapMH_108	24
swPIPE990219	DuWapMH_108	24
swPIPE990220	DuWapN_11a	0
swPIPE990221	DuWapN_11a	0
swPIPE990223	DuWapMH_109	7
swPIPE990224	DuWapMH_109	7
swPIPE990225	DuWapMH_207	10
swPIPE990226	DuWapN_11a	0
swPIPE990230	DuWapN_11a	0
swPIPE990231	DuWapN_11a	0
swPIPE990232	DuWapN_11a	0
swPIPE990234	DuWapN_211a	34
swPIPE990422	DuWapMH_329	10
swPIPE990423	DuWapN_36	23

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE990445	DuWapMH_114	24
swPIPE990446	DuWapMH_114	24
swPIPE990448	DuWapMH_113	25
swPIPE990450	DuWapMH_113	25
swPIPE990453	DuWapMH_113	25
swPIPE990454	DuWapN_3	22
swPIPE990455	DuWapN_3	22
swPIPE990456	DuWapN_3	22
swPIPE990458	DuWapN_3	22
swPIPE990461	DuWapMH_108	24
swPIPE990463	DuWapN_3	22
swPIPE990465	DuWapMH_212	0
swPIPE990474	DuWapMH_213	25
swPIPE990475	DuWapMH_115	16
swPIPE990476	DuWapMH_115	16
swPIPE990477	DuWapMH_115	16
swPIPE990479	DuWapMH_432	11
swPIPE990480	DuWapMH_432	11
swPIPE990481	DuWapMH_432	11
swPIPE990482	DuWapMH_432	11
swPIPE990483	DuWapMH_432	11
swPIPE990484	DuWapN_40	22
swPIPE990486	DuWapMH_432	11
swPIPE990487	DuWapN_40	22
swPIPE990489	DuWapN_40	22
swPIPE990490	DuWapN_40	22
swPIPE990492	DuWapMH_115	16
swPIPE990496	DuWapMH_115	16
swPIPE990500	none	0
swPIPE990501	DuWapMH_101	7
swPIPE990502	none	0
swPIPE990503	DuWapMH_114	24
swPIPE990507	DuWapMH_140	25
swPIPE990601	none	0
swPIPE990602	none	0
swPIPE990605	none	0
swPIPE990606	none	0
swPIPE990609	DuWapN_66	23
swPIPE990610	DuWapN_66	23
swPIPE990611	DuWapN_14	24
swPIPE990619	DuWapN_9b	23
swPIPE990620	DuWapN_209b	24
swPIPE990623	DuWapMH_1	25
swPIPE990624	DuWapMH_42	25
swPIPE990626	DuWapN_65	22
swPIPE990628	DuWapN_57	32

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE990629	DuWapN_57	32
swPIPE990630	DuWapN_57	32
swPIPE990631	DuWapN_257	34
swPIPE990632	DuWapN_257	34
swPIPE990633	DuWapN_257	34
swPIPE990634	DuWapN_257	34
swPIPE990635	DuWapN_257	34
swPIPE990636	DuWapN_257	34
swPIPE990638	DuWapN_64	34
swPIPE990639	DuWapN_64	34
swPIPE990640	DuWapN_64	34
swPIPE990641	DuWapN_64	34
swPIPE990642	DuWapN_64	34
swPIPE990643	DuWapN_64	34
swPIPE990644	DuWapN_64	34
swPIPE990645	DuWapN_63	32
swPIPE990646	DuWapN_63	32
swPIPE990647	DuWapMH_69	35
swPIPE990648	DuWapMH_69	35
swPIPE990649	DuWapN_63	32
swPIPE990650	DuWapN_63	32
swPIPE990651	DuWapMH_73	21
swPIPE990652	DuWapMH_73	21
swPIPE990653	DuWapMH_73	21
swPIPE990654	DuWapN_91	25
swPIPE990655	DuWapN_55	22
swPIPE990657	DuWapMH_121	25
swPIPE990658	DuWapN_55	22
swPIPE990659	DuWapMH_221	24
swPIPE990660	DuWapMH_221	24
swPIPE990662	DuWapMH_277	3
swPIPE990663	DuWapMH_277	3
swPIPE990667	DuWapMH_69	35
swPIPE990668	DuWapMH_113	25
swPIPE990669	DuWapMH_191	35
swPIPE990670	DuWapMH_232	34
swPIPE990671	DuWapMH_232	34
swPIPE990672	DuWapMH_232	34
swPIPE990673	DuWapMH_232	34
swPIPE990674	DuWapMH_191	35
swPIPE990675	DuWapN_27	3
swPIPE990677	DuWapMH_191	35
swPIPE990685	DuWapMH_61	32
swPIPE990686	DuWapMH_61	32
swPIPE990687	DuWapN_11b	14
swPIPE990689	DuWapN_11b	14

Appendix N
Detailed Flood Resiliency Scoring
Pipes, Culvert, and Channels

Asset ID	Model Node	Flood Score
swPIPE990700	DuWapMH_157	7
swPIPE990702	DuWapN_80	10
swPIPE990703	DuWapN_91	25
swPIPE990704	DuWapN_63	32
SWPIPE990708	DuWapN_53	11
SWPIPE990716	DuWapMH_390	1
SWPIPE990717	DuWapMH_296	1
SWPIPE990718	DuWapMH_296	1
SWPIPE990719	DuWapMH_315	24
SWPIPE990721	none	0
SWPIPE990722	none	0
SWPIPE990725	DuWapMH_27	24

Appendix O Total Condition Assessment/Resiliency Flood Scoring for Prioritization Structures

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Structures

Assset ID	Model Node	Condition Score	Flood Score	Total Score
swINLT001308	none	6	0	6
swINLT007868	DuWapMH_329	6	10	16
swINLT007869	DuWapN_36	6	23	29
swINLT007870	DuWapN_36	6	23	29
swINLT007915	DuWapMH_146	0	0	0
swINLT007926	none	3	0	3
swINLT007932	none	12	0	12
swINLT007933	none	6	0	6
swINLT007934	none	15	0	15
swINLT007936	none	9	0	9
swINLT007938	none	12	0	12
swINLT007939	none	6	0	6
swINLT007940	none	15	0	15
swINLT007964	none	6	0	6
swINLT007965	none	0	0	0
swINLT007966	none	3	0	3
swINLT007967	none	9	0	9
swINLT007996	none	3	0	3
swINLT007997	none	6	0	6
swINLT007998	none	3	0	3
swINLT007999	none	6	0	6
swINLT008000	none	6	0	6
swINLT008001	none	6	0	6
swINLT008002	none	6	0	6
swINLT008003	none	15	0	15
swINLT008004	none	0	0	0
swINLT008053	DuWapMH_92	0	3	3
swINLT008056	DuWapMH_88	0	17	17
swINLT008057	DuWapMH_88	0	17	17
swINLT008075	DuWapMH_140	0	25	25
swINLT008078	DuWapMH_10	9	17	26
swINLT008167	DuWapMH_95	3	0	3
swINLT008283	DuWapMH_195	6	25	31
swINLT008284	DuWapMH_23	6	25	31
swINLT008291	DuWapMH_24	6	19	25
swINLT008292	DuWapMH_46	0	18	18
swINLT008293	DuWapMH_46	0	18	18
swINLT008304	none	15	0	15
swINLT008305	none	9	0	9
swINLT008306	none	9	0	9
swINLT008307	none	3	0	3
swINLT008308	DuWapMH_159	6	34	40
swINLT008309	DuWapN_212	0	33	33
swINLT008312	DuWapMH_27	9	24	33
swINLT008316	DuWapMH_28	15	24	39
swINLT008319	DuWapMH_28	0	24	24

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Structures

Assset ID	Model Node	Condition Score	Flood Score	Total Score
swINLT008354	DuWapMH_28	9	24	33
swINLT008360	DuWapN_71	3	24	27
swINLT008381	DuWapN_40	3	22	25
swINLT008418	DuWapN_250	0	16	16
swINLT008445	none	0	0	0
swINLT008463	none	3	0	3
swINLT008464	none	12	0	12
swINLT008478	DuWapMH_32	0	0	0
swINLT008479	DuWapMH_32	6	0	6
swINLT008480	DuWapMH_32	6	0	6
swINLT008481	DuWapMH_10	6	17	23
swINLT008482	DuWapMH_10	9	17	26
swINLT008483	DuWapMH_10	0	17	17
swINLT008484	DuWapMH_10	9	17	26
swINLT008486	DuWapMH_371	9	24	33
swINLT008487	DuWapMH_371	6	24	30
swINLT008488	DuWapMH_292	9	1	10
swINLT008489	DuWapMH_393	0	0	0
swINLT008490	DuWapMH_294	0	7	7
swINLT008491	DuWapMH_294	9	7	16
swINLT008492	DuWapMH_294	0	7	7
swINLT008496	DuWapMH_381	6	24	30
swINLT008499	DuWapN_216	6	32	38
swINLT008501	DuWapN_216	6	32	38
swINLT008505	DuWapMH_426	12	24	36
swINLT008506	DuWapN_27	0	3	3
swINLT008511	DuWapN_222	6	16	22
swINLT008512	DuWapN_222	6	16	22
swINLT008517	DuWapMH_302	9	24	33
swINLT008552	DuWapMH_296	0	1	1
swINLT008553	DuWapMH_296	6	1	7
swINLT008591	DuWapN_14	6	24	30
swINLT008601	DuWapN_66	0	23	23
swINLT008602	DuWapN_66	6	23	29
swINLT009034	DuWapMH_108	0	24	24
swINLT009035	DuWapMH_108	15	24	39
swINLT009045	DuWapMH_87	0	23	23
swINLT009046	DuWapN_274	0	23	23
swINLT009047	DuWapMH_338	6	24	30
swINLT009048	DuWapN_52	6	24	30
swINLT009051	DuWapMH_449	6	24	30
swINLT009052	DuWapMH_177	0	24	24
swINLT009053	DuWapN_74	0	24	24
swINLT009054	DuWapN_74	6	24	30
swINLT009055	DuWapN_74	0	24	24
swINLT009056	DuWapN_74	9	24	33

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Structures

Assset ID	Model Node	Condition Score	Flood Score	Total Score
swINLT009058	DuWapN_74	6	24	30
swINLT009062	DuWapN_53	9	11	20
swINLT009109	DuWapMH_179	0	24	24
swINLT009115	DuWapMH_106	6	0	6
swINLT009126	DuWapN_57	9	32	41
swINLT009127	DuWapN_57	6	32	38
swINLT009128	DuWapN_257	6	34	40
swINLT009129	DuWapN_257	9	34	43
swINLT009130	DuWapN_63	0	32	32
swINLT009131	DuWapN_63	9	32	41
swINLT009132	DuWapN_63	3	32	35
swINLT009133	DuWapN_64	15	34	49
swINLT009134	DuWapN_64	15	34	49
swINLT009135	DuWapN_64	9	34	43
swINLT009136	DuWapMH_180	0	3	3
swINLT009141	DuWapMH_40	0	0	0
swINLT009164	DuWapN_65	6	22	28
swINLT009197	DuWapN_28	9	25	34
swINLT009202	none	6	0	6
swINLT009203	none	0	0	0
swINLT009204	none	6	0	6
swINLT009209	none	9	0	9
swINLT009210	none	9	0	9
swINLT009215	none	6	0	6
swINLT009216	none	6	0	6
swINLT009217	none	3	0	3
swINLT009218	none	3	0	3
swINLT009219	none	3	0	3
swINLT009239	DuWapMH_1	9	25	34
swINLT009242	DuWapMH_1	9	25	34
swINLT009282	DuWapN_56	6	25	31
swINLT009283	DuWapMH_191	6	35	41
swINLT009284	DuWapN_25	15	24	39
swINLT010719	DuWapMH_500	0	0	0
swINLT010726	DuWapMH_282	6	17	23
swINLT010734	DuWapMH_24	6	19	25
swINLT010737	none	6	0	6
swINLT010739	DuWapN_43	6	32	38
swINLT010742	DuWapN_225	6	25	31
swINLT010743	DuWapMH_446	6	0	6
swINLT010749	DuWapN_67	6	23	29
swINLT010750	DuWapN_67	6	23	29
swINLT010751	DuWapMH_47	6	0	6
swINLT010752	DuWapMH_47	0	0	0
swINLT010753	DuWapN_67	3	23	26
swINLT010754	DuWapN_67	6	23	29

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Structures

Assset ID	Model Node	Condition Score	Flood Score	Total Score
swINLT010755	DuWapN_267	3	22	25
swINLT010756	DuWapN_267	6	22	28
swINLT010757	DuWapN_267	6	22	28
swINLT010758	DuWapN_79	0	0	0
swINLT010774	DuWapN_11a	6	0	6
swINLT010782	DuWapMH_48	6	22	28
swINLT010783	DuWapMH_193	3	22	25
swINLT010784	DuWapN_229	0	22	22
swINLT010803	DuWapMH_123	9	24	33
swINLT990002	DuWapMH_51	9	24	33
swINLT990003	DuWapMH_51	0	24	24
swINLT990004	DuWapMH_51	0	24	24
swINLT990009	DuWapMH_52	0	0	0
swINLT990010	DuWapMH_52	0	0	0
swINLT990019	DuWapN_48	6	22	28
swINLT990020	DuWapN_48	0	22	22
swINLT990021	DuWapN_59	0	24	24
swINLT990022	DuWapMH_10	6	17	23
swINLT990023	DuWapN_59	0	24	24
swINLT990036	DuWapN_17	15	23	38
swINLT990038	DuWapN_216	6	32	38
swINLT990039	DuWapN_250	0	16	16
swINLT990040	DuWapMH_53	0	24	24
swINLT990041	DuWapMH_53	0	24	24
swINLT990042	DuWapMH_53	6	24	30
swINLT990045	DuWapN_51	0	24	24
swINLT990048	DuWapMH_107	0	25	25
swINLT990049	DuWapMH_123	6	24	30
swINLT990050	DuWapN_222	6	16	22
swINLT990051	DuWapN_222	0	16	16
swINLT990052	DuWapMH_74	6	33	39
swINLT990053	DuWapMH_123	6	24	30
swINLT990054	DuWapMH_123	6	24	30
swINLT990056	DuWapN_57	6	32	38
swINLT990059	DuWapMH_55	0	17	17
swINLT990060	DuWapMH_55	12	17	29
swINLT990068	DuWapMH_56	0	25	25
swINLT990069	DuWapN_225	6	25	31
swINLT990070	none	6	0	6
swINLT990071	none	12	0	12
swINLT990072	none	12	0	12
swINLT990073	DuWapN_62	6	23	29
swINLT990075	DuWapN_97	9	17	26
swINLT990076	DuWapN_97	0	17	17
swINLT990077	DuWapMH_57	3	3	6
swINLT990078	DuWapMH_249	0	24	24

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Structures

Assset ID	Model Node	Condition Score	Flood Score	Total Score
swINLT990081	none	9	0	9
swINLT990082	DuWapN_71	3	24	27
swINLT990083	DuWapMH_92	6	3	9
swINLT990084	DuWapMH_380	9	25	34
swINLT990086	DuWapMH_900	0	17	17
swINLT990087	DuWapMH_92	6	3	9
swINLT990088	DuWapN_67	6	23	29
swINLT990089	DuWapN_267	0	22	22
swINLT990090	DuWapMH_225	0	23	23
swINLT990157	DuWapMH_113	0	25	25
swINLT990158	DuWapN_3	0	22	22
swINLT990159	DuWapN_3	0	22	22
swINLT990160	DuWapMH_432	3	11	14
swINLT990164	DuWapMH_115	6	16	22
swINLT990165	DuWapMH_140	0	25	25
swINLT990167	DuWapN_40	0	22	22
swINLT990169	DuWapN_40	6	22	28
swINLT990171	none	0	0	0
swINLT990172	none	9	0	9
swINLT990173	none	3	0	3
swINLT990174	none	0	0	0
swINLT990175	DuWapN_225	6	25	31
swINLT990176	DuWapN_9b	15	23	38
swINLT990177	DuWapN_9b	9	23	32
swINLT990182	DuWapN_257	3	34	37
swINLT990183	DuWapN_257	12	34	46
swINLT990184	DuWapN_257	6	34	40
swINLT990185	DuWapN_57	0	32	32
swINLT990186	DuWapN_57	6	32	38
swINLT990187	DuWapN_64	15	34	49
swINLT990188	DuWapN_64	3	34	37
swINLT990189	DuWapN_64	0	34	34
swINLT990190	DuWapN_55	0	22	22
swINLT990191	DuWapN_63	15	32	47
swINLT990192	DuWapMH_69	9	35	44
swINLT990193	DuWapN_63	9	32	41
swINLT990194	DuWapN_64	3	34	37
swINLT990195	DuWapMH_131	9	25	34
swINLT990196	DuWapN_55	3	22	25
swINLT990197	DuWapN_91	15	25	40
swINLT990208	DuWapN_27	0	3	3
swINLT990209	DuWapN_27	0	3	3
swINLT990215	DuWapMH_61	3	32	35
swINLT990216	DuWapN_11b	3	14	17
swINLT990217	DuWapMH_61	3	32	35
swINLT990218	DuWapN_11b	3	14	17

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Structures

Assset ID	Model Node	Condition Score	Flood Score	Total Score
swINLT990223	DuWapN_91	15	25	40
swINLT990224	DuWapN_63	15	32	47
swINLT990225	DuWapMH_69	15	35	50
SWINLT990231	DuWapMH_28	0	24	24
SWINLT990232	DuWapMH_28	0	24	24
swINLT990500	DuWapN_17	0	23	23
swINLT990502	DuWapMH_432	3	11	14
swMNHL000378	none	6	0	6
swMNHL000379	none	3	0	3
swMNHL001793	none	0	0	0
swMNHL001797	none	3	0	3
swMNHL001798	none	6	0	6
swMNHL001811	none	6	0	6
swMNHL001812	none	9	0	9
swMNHL001813	none	3	0	3
swMNHL001814	none	3	0	3
swMNHL001816	none	6	0	6
swMNHL001844	DuWapMH_77	6	25	31
swMNHL001845	DuWapN_334	6	25	31
swMNHL001853	none	6	0	6
swMNHL001854	DuWapN_11a	3	0	3
swMNHL001856	DuWapMH_88	6	17	23
swMNHL001865	DuWapMH_162	0	0	0
swMNHL001878	DuWapMH_32	0	0	0
swMNHL001880	DuWapN_250	0	16	16
swMNHL001881	DuWapN_216	12	32	44
swMNHL001887	DuWapMH_190	6	24	30
swMNHL001922	DuWapMH_87	0	23	23
swMNHL001927	DuWapN_53	6	11	17
swMNHL001943	DuWapMH_88	6	17	23
swMNHL001953	DuWapMH_88	0	17	17
swMNHL001954	DuWapMH_88	0	17	17
swMNHL001955	DuWapMH_92	0	3	3
swMNHL001960	DuWapMH_32	0	0	0
swMNHL002065	DuWapMH_101	6	7	13
swMNHL002066	DuWapMH_146	0	0	0
swMNHL002074	DuWapMH_192	0	24	24
swMNHL002075	DuWapMH_96	6	3	9
swMNHL002076	DuWapMH_97	6	22	28
swMNHL002077	DuWapMH_98	6	0	6
swMNHL002078	DuWapN_53	12	11	23
swMNHL990001	DuWapN_62	0	23	23
swMNHL990002	DuWapN_62	6	23	29
swMNHL990006	DuWapMH_99	12	24	36
swMNHL990007	DuWapMH_175	0	24	24
swMNHL990008	DuWapN_48	0	22	22

Appendix O

Total Condition Assessment/Resiliency Flood Scoring for Prioritization

Structures

Assset ID	Model Node	Condition Score	Flood Score	Total Score
swMNHL990009	DuWapN_59	0	24	24
swMNHL990011	DuWapN_216	0	32	32
swMNHL990012	DuWapMH_381	0	24	24
swMNHL990013	DuWapMH_101	6	7	13
swMNHL990015	DuWapN_35c	9	22	31
swMNHL990016	DuWapN_222	6	16	22
swMNHL990025	none	6	0	6
swMNHL990026	none	0	0	0
swMNHL990027	none	6	0	6
swMNHL990028	DuWapMH_238	3	25	28
swMNHL990029	DuWapMH_104	0	25	25
swMNHL990030	DuWapMH_104	12	25	37
swMNHL990031	DuWapMH_105	9	24	33
swMNHL990032	DuWapMH_57	3	3	6
swMNHL990033	DuWapN_72	9	22	31
swMNHL990034	DuWapN_29	6	22	28
swMNHL990035	DuWapMH_107	12	25	37
swMNHL990036	DuWapMH_88	0	17	17
swMNHL990037	DuWapMH_92	0	3	3
swMNHL990038	DuWapMH_108	3	24	27
swMNHL990039	DuWapN_11a	9	0	9
swMNHL990040	DuWapMH_109	3	7	10
swMNHL990041	DuWapMH_207	3	10	13
swMNHL990042	DuWapN_11a	6	0	6
swMNHL990043	DuWapN_11a	6	0	6
swMNHL990044	DuWapN_211a	6	34	40
swMNHL990063	DuWapMH_113	0	25	25
swMNHL990065	DuWapN_3	3	22	25
swMNHL990066	DuWapMH_108	0	24	24
swMNHL990067	DuWapN_3	0	22	22
swMNHL990070	DuWapMH_140	6	25	31
swMNHL990071	DuWapMH_432	3	11	14
swMNHL990075	DuWapN_40	6	22	28
swMNHL990076	DuWapN_40	0	22	22
swMNHL990077	DuWapN_40	6	22	28
swMNHL990078	DuWapMH_115	3	16	19
swMNHL990080	DuWapMH_117	0	3	3
swMNHL990081	none	15	0	15
swMNHL990082	DuWapN_66	0	23	23
swMNHL990083	DuWapN_55	0	22	22
swMNHL990084	DuWapMH_318	3	10	13
swMNHL990500	DuWapMH_115	0	16	16
swMNHL990502	DuWapN_3	3	22	25
swMNHL990503	DuWapMH_114	9	24	33
swOUTL990002	DuWapN_48	0	22	22
swOUTL990003	DuWapMH_238	0	25	25

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Structures

Assset ID	Model Node	Condition Score	Flood Score	Total Score
swOUTL990004	DuWapMH_900	3	17	20
swOUTL990005	DuWapMH_108	9	24	33
swOUTL990006	DuWapMH_130	3	25	28
swOUTL990012	DuWapMH_133	9	4	13
swOUTL990013	DuWapMH_121	0	25	25
swOUTL990014	DuWapMH_318	0	10	10
swOUTL990015	DuWapMH_402	0	0	0
swOUTL990016	DuWapN_80	0	10	10

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL002253	none	3	0	9
swCHNL002254	none	6	0	18
swCHNL002256	none	3	0	9
swCHNL002257	none	3	0	9
swCHNL002258	none	3	0	9
swCHNL002259	none	0	0	0
swCHNL002260	none	3	0	9
swCHNL002261	none	6	0	18
swCHNL002262	none	6	0	18
swCHNL002263	none	6	0	18
swCHNL005535	DuWapN_36	3	23	32
swCHNL005536	DuWapN_36	12	23	59
swCHNL005562	DuWapN_36	0	23	23
swCHNL005563	DuWapN_36	6	23	41
swCHNL005564	DuWapN_36	6	23	41
swCHNL005565	DuWapN_36	6	23	41
swCHNL005566	DuWapN_36	0	23	23
swCHNL005567	DuWapN_36	0	23	23
swCHNL005568	DuWapMH_329	6	10	28
swCHNL005569	DuWapMH_329	6	10	28
swCHNL005570	DuWapMH_329	0	10	10
swCHNL005571	DuWapMH_329	9	10	37
swCHNL005572	DuWapMH_146	3	0	9
swCHNL005573	DuWapMH_146	9	0	27
swCHNL005574	DuWapMH_146	15	0	45
swCHNL005575	DuWapMH_317	0	24	24
swCHNL005603	DuWapMH_146	0	0	0
swCHNL005617	none	3	0	9
swCHNL005643	none	3	0	9
swCHNL005644	none	6	0	18
swCHNL005645	none	6	0	18
swCHNL005646	none	6	0	18
swCHNL005674	DuWapMH_351	3	25	34
swCHNL005675	DuWapMH_351	6	25	43
swCHNL005676	DuWapMH_330	6	11	29
swCHNL005682	DuWapMH_88	6	17	35
swCHNL005683	DuWapMH_267	3	1	10
swCHNL005685	DuWapMH_334	9	16	43
swCHNL005686	DuWapMH_445	9	25	52
swCHNL005687	DuWapMH_429	0	25	25
swCHNL005688	DuWapMH_245	9	25	52
swCHNL005690	DuWapMH_289	0	7	7
swCHNL005691	DuWapN_241	9	25	52
swCHNL005693	DuWapMH_336	0	0	0
swCHNL005694	DuWapMH_336	0	0	0
swCHNL005695	DuWapMH_337	6	25	43

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL005696	DuWapMH_338	9	24	51
swCHNL005697	DuWapN_48	6	22	40
swCHNL005698	DuWapMH_339	12	7	43
swCHNL005699	DuWapMH_154	12	24	60
swCHNL005701	DuWapN_23	6	23	41
swCHNL005702	DuWapN_13	3	25	34
swCHNL005707	DuWapMH_140	6	25	43
swCHNL005711	DuWapN_32	3	11	20
swCHNL005721	DuWapMH_282	3	17	26
swCHNL005723	DuWapMH_282	6	17	35
swCHNL005724	DuWapMH_152	9	1	28
swCHNL005736	DuWapMH_281	12	23	59
swCHNL005744	DuWapN_21	0	24	24
swCHNL005757	DuWapMH_157	0	7	7
swCHNL005809	DuWapN_12	3	33	42
swCHNL005810	DuWapN_12	12	33	69
swCHNL005811	DuWapMH_28	9	24	51
swCHNL005812	DuWapMH_28	3	24	33
swCHNL005813	DuWapN_212	0	33	33
swCHNL005815	DuWapN_211a	0	34	34
swCHNL005816	DuWapN_211a	3	34	43
swCHNL005817	DuWapN_11a	6	0	18
swCHNL005819	DuWapN_11a	6	0	18
swCHNL005820	DuWapN_11a	3	0	9
swCHNL005823	DuWapMH_402	6	0	18
swCHNL005825	DuWapN_211a	6	34	52
swCHNL005826	DuWapN_211a	6	34	52
swCHNL005832	none	6	0	18
swCHNL005833	DuWapMH_196	15	3	48
swCHNL005873	none	6	0	18
swCHNL005895	DuWapMH_212	3	0	9
swCHNL005896	DuWapMH_351	3	25	34
swCHNL005897	DuWapMH_88	6	17	35
swCHNL005898	DuWapMH_196	9	3	30
swCHNL005899	DuWapMH_331	0	24	24
swCHNL005900	DuWapMH_331	6	24	42
swCHNL005901	DuWapMH_331	0	24	24
swCHNL005902	DuWapMH_88	0	17	17
swCHNL005903	DuWapMH_88	12	17	53
swCHNL005904	DuWapMH_88	0	17	17
swCHNL005905	DuWapMH_260	0	24	24
swCHNL005906	DuWapMH_343	9	24	51
swCHNL005907	DuWapMH_261	3	24	33
swCHNL005908	DuWapMH_88	6	17	35
swCHNL005913	DuWapMH_432	3	11	20
swCHNL005916	DuWapMH_258	15	24	69

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL005917	DuWapMH_221	6	24	42
swCHNL005950	DuWapMH_88	0	17	17
swCHNL005951	DuWapMH_88	6	17	35
swCHNL005952	DuWapMH_88	6	17	35
swCHNL005953	DuWapMH_196	6	3	21
swCHNL005954	DuWapMH_330	6	11	29
swCHNL005955	DuWapMH_196	9	3	30
swCHNL005956	DuWapMH_196	6	3	21
swCHNL005958	DuWapMH_330	6	11	29
swCHNL005959	DuWapMH_330	6	11	29
swCHNL005960	DuWapMH_330	6	11	29
swCHNL005961	DuWapMH_88	6	17	35
swCHNL005962	DuWapMH_88	6	17	35
swCHNL005964	DuWapMH_219	3	17	26
swCHNL005968	DuWapMH_152	3	1	10
swCHNL005969	DuWapMH_282	3	17	26
swCHNL005975	DuWapMH_249	15	24	69
swCHNL005976	DuWapMH_434	6	25	43
swCHNL005977	DuWapMH_221	6	24	42
swCHNL006002	DuWapMH_446	3	0	9
swCHNL006003	DuWapMH_449	3	24	33
swCHNL006004	DuWapN_52	0	24	24
swCHNL006009	DuWapMH_307	12	0	36
swCHNL006010	DuWapMH_366	3	11	20
swCHNL006011	DuWapMH_366	0	11	11
swCHNL006012	DuWapMH_367	12	0	36
swCHNL006013	DuWapMH_293	3	0	9
swCHNL006017	DuWapMH_370	9	7	34
swCHNL006019	DuWapN_234	6	7	25
swCHNL006021	DuWapMH_10	0	17	17
swCHNL006029	DuWapMH_10	0	17	17
swCHNL006030	DuWapMH_290	3	0	9
swCHNL006033	DuWapMH_372	9	24	51
swCHNL006034	DuWapN_59	9	24	51
swCHNL006036	DuWapMH_10	3	17	26
swCHNL006064	DuWapMH_436	9	25	52
swCHNL006066	DuWapMH_374	12	25	61
swCHNL006079	DuWapN_72	9	22	49
swCHNL006081	DuWapMH_189	6	0	18
swCHNL006086	none	6	0	18
swCHNL006088	none	3	0	9
swCHNL006106	DuWapMH_360	15	0	45
swCHNL006109	DuWapMH_95	6	0	18
swCHNL006110	DuWapMH_357	6	25	43
swCHNL006111	DuWapMH_254	3	25	34
swCHNL006112	DuWapMH_95	3	0	9

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL006151	DuWapMH_177	12	24	60
swCHNL006153	DuWapMH_294	0	7	7
swCHNL006160	DuWapMH_437	0	24	24
swCHNL006161	DuWapN_26	12	24	60
swCHNL006175	DuWapMH_381	0	24	24
swCHNL006180	DuWapMH_426	0	24	24
swCHNL006182	DuWapMH_426	0	24	24
swCHNL006183	DuWapMH_426	0	24	24
swCHNL006184	DuWapMH_426	0	24	24
swCHNL006185	DuWapMH_426	12	24	60
swCHNL006186	DuWapMH_426	0	24	24
swCHNL006187	DuWapN_27	0	3	3
swCHNL006188	DuWapN_27	0	3	3
swCHNL006189	DuWapMH_426	0	24	24
swCHNL006190	DuWapMH_426	0	24	24
swCHNL006194	DuWapN_27	3	3	12
swCHNL006195	DuWapN_27	12	3	39
swCHNL006196	DuWapN_27	12	3	39
swCHNL006197	DuWapN_27	0	3	3
swCHNL006212	DuWapMH_123	3	24	33
swCHNL006213	DuWapMH_377	3	24	33
swCHNL006214	DuWapMH_123	15	24	69
swCHNL006215	DuWapMH_123	9	24	51
swCHNL006216	DuWapMH_123	0	24	24
swCHNL006219	DuWapMH_377	9	24	51
swCHNL006221	DuWapN_35c	6	22	40
swCHNL006222	DuWapN_35c	3	22	31
swCHNL006223	DuWapMH_190	3	24	33
swCHNL006224	DuWapMH_190	3	24	33
swCHNL006225	DuWapMH_380	9	25	52
swCHNL006226	DuWapMH_190	15	24	69
swCHNL006227	DuWapMH_190	3	24	33
swCHNL006228	DuWapN_45	0	22	22
swCHNL006231	DuWapMH_190	0	24	24
swCHNL006232	DuWapN_51	0	24	24
swCHNL006234	DuWapN_17	0	23	23
swCHNL006235	DuWapN_17	0	23	23
swCHNL006236	DuWapN_17	12	23	59
swCHNL006237	DuWapN_35c	3	22	31
swCHNL006238	DuWapN_17	9	23	50
swCHNL006239	DuWapN_17	0	23	23
swCHNL006240	DuWapN_17	3	23	32
swCHNL006241	DuWapN_17	0	23	23
swCHNL006242	DuWapN_17	0	23	23
swCHNL006243	DuWapN_17	0	23	23
swCHNL006244	DuWapN_17	0	23	23

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL006254	DuWapN_17	3	23	32
swCHNL006255	DuWapN_17	15	23	68
swCHNL006256	DuWapN_35a	0	23	23
swCHNL006257	DuWapN_17	0	23	23
swCHNL006258	DuWapN_17	6	23	41
swCHNL006259	DuWapN_17	12	23	59
swCHNL006262	DuWapN_17	0	23	23
swCHNL006264	DuWapN_17	0	23	23
swCHNL006265	DuWapN_17	6	23	41
swCHNL006266	DuWapN_17	0	23	23
swCHNL006267	DuWapN_17	0	23	23
swCHNL006270	DuWapN_17	6	23	41
swCHNL006271	DuWapN_17	0	23	23
swCHNL006272	DuWapN_17	6	23	41
swCHNL006273	DuWapN_17	6	23	41
swCHNL006274	DuWapN_17	12	23	59
swCHNL006275	DuWapN_17	6	23	41
swCHNL006281	DuWapMH_380	15	25	70
swCHNL006444	DuWapMH_175	0	24	24
swCHNL006485	DuWapMH_387	0	24	24
swCHNL006486	DuWapMH_387	0	24	24
swCHNL006487	DuWapN_274	0	23	23
swCHNL006529	DuWapMH_153	0	11	11
swCHNL006556	DuWapMH_199	0	24	24
swCHNL006557	DuWapMH_389	0	24	24
swCHNL006580	DuWapN_48	0	22	22
swCHNL006581	DuWapN_48	0	22	22
swCHNL006583	DuWapN_59	0	24	24
swCHNL006584	DuWapMH_372	0	24	24
swCHNL006585	DuWapMH_390	0	1	1
swCHNL006586	DuWapMH_390	0	1	1
swCHNL006587	DuWapMH_390	0	1	1
swCHNL006588	DuWapMH_390	0	1	1
swCHNL006589	DuWapMH_295	0	0	0
swCHNL006590	DuWapMH_296	0	1	1
swCHNL006591	DuWapMH_295	6	0	18
swCHNL006592	DuWapMH_294	0	7	7
swCHNL006593	DuWapMH_297	12	0	36
swCHNL006594	DuWapMH_392	6	1	19
swCHNL006595	DuWapMH_392	0	1	1
swCHNL006596	DuWapMH_392	0	1	1
swCHNL006597	DuWapMH_392	3	1	10
swCHNL006598	DuWapMH_392	6	1	19
swCHNL006599	DuWapMH_392	6	1	19
swCHNL006600	DuWapMH_392	0	1	1
swCHNL006601	DuWapMH_392	0	1	1

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL006602	DuWapMH_294	0	7	7
swCHNL006603	DuWapMH_294	0	7	7
swCHNL006604	DuWapMH_294	0	7	7
swCHNL006606	DuWapMH_294	0	7	7
swCHNL006607	DuWapMH_294	0	7	7
swCHNL006608	DuWapMH_294	3	7	16
swCHNL006609	DuWapMH_292	0	1	1
swCHNL006612	DuWapMH_291	0	25	25
swCHNL006615	DuWapN_49	6	23	41
swCHNL006616	DuWapN_49	6	23	41
swCHNL006617	DuWapMH_297	6	0	18
swCHNL006633	DuWapMH_180	6	3	21
swCHNL006634	DuWapMH_181	9	1	28
swCHNL006635	DuWapN_230	3	24	33
swCHNL006636	DuWapN_30	3	22	31
swCHNL006646	DuWapMH_373	12	25	61
swCHNL006715	none	9	0	27
swCHNL006716	none	0	0	0
swCHNL006717	none	12	0	36
swCHNL006718	none	12	0	36
swCHNL006719	none	0	0	0
swCHNL006720	none	12	0	36
swCHNL006721	none	12	0	36
swCHNL006722	none	9	0	27
swCHNL006723	none	0	0	0
swCHNL006724	none	3	0	9
swCHNL006725	none	6	0	18
swCHNL006726	none	15	0	45
swCHNL006727	none	12	0	36
swCHNL006728	none	0	0	0
swCHNL006729	none	0	0	0
swCHNL006730	none	6	0	18
swCHNL006731	none	15	0	45
swCHNL006732	none	6	0	18
swCHNL006733	none	9	0	27
swCHNL006734	none	6	0	18
swCHNL006735	none	15	0	45
swCHNL006736	none	15	0	45
swCHNL006738	DuWapN_56	15	25	70
swCHNL006739	DuWapMH_238	6	25	43
swCHNL006772	DuWapMH_397	6	0	18
swCHNL006796	DuWapMH_403	15	0	45
swCHNL006805	none	12	0	36
swCHNL006806	none	12	0	36
swCHNL006807	none	15	0	45
swCHNL006808	none	15	0	45

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL006809	DuWapMH_191	0	35	35
swCHNL006810	DuWapMH_191	0	35	35
swCHNL006811	DuWapN_25	12	24	60
swCHNL006812	DuWapN_25	6	24	42
swCHNL006813	DuWapN_225	6	25	43
swCHNL006816	DuWapMH_329	6	10	28
swCHNL006904	DuWapMH_402	3	0	9
swCHNL006906	DuWapMH_402	6	0	18
swCHNL006911	DuWapMH_318	9	10	37
swCHNL006913	DuWapMH_207	6	10	28
swCHNL006961	DuWapMH_101	0	7	7
swCHNL006962	DuWapMH_101	6	7	25
swCHNL006963	DuWapMH_101	6	7	25
swCHNL006964	DuWapMH_101	3	7	16
swCHNL006965	DuWapMH_154	6	24	42
swCHNL006966	DuWapMH_154	6	24	42
swCHNL006967	DuWapMH_154	3	24	33
swCHNL006968	DuWapMH_154	3	24	33
swCHNL006969	DuWapMH_154	12	24	60
swCHNL006970	DuWapMH_154	6	24	42
swCHNL006971	DuWapMH_154	0	24	24
swCHNL006972	DuWapMH_154	3	24	33
swCHNL006973	DuWapMH_101	6	7	25
swCHNL006981	DuWapN_13	0	25	25
swCHNL006985	DuWapMH_408	12	25	61
swCHNL007014	DuWapN_17	6	23	41
swCHNL007018	DuWapMH_381	6	24	42
swCHNL007028	DuWapMH_177	3	24	33
swCHNL007029	DuWapMH_154	9	24	51
swCHNL007030	DuWapMH_154	9	24	51
swCHNL007031	DuWapMH_154	12	24	60
swCHNL007032	DuWapMH_154	12	24	60
swCHNL007034	DuWapMH_154	6	24	42
swCHNL007035	DuWapMH_154	12	24	60
swCHNL007036	DuWapMH_154	6	24	42
swCHNL007037	DuWapMH_154	9	24	51
swCHNL007038	DuWapMH_154	3	24	33
swCHNL007039	DuWapMH_154	0	24	24
swCHNL007040	DuWapMH_46	12	18	54
swCHNL007041	DuWapMH_46	3	18	27
swCHNL007042	DuWapMH_311	12	13	49
swCHNL007043	DuWapMH_310	9	9	36
swCHNL007045	DuWapMH_309	0	9	9
swCHNL007046	DuWapMH_188	12	7	43
swCHNL007047	DuWapMH_411	3	13	22
swCHNL007048	DuWapMH_101	12	7	43

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL007049	DuWapMH_101	6	7	25
swCHNL007050	DuWapMH_101	3	7	16
swCHNL007051	DuWapMH_101	6	7	25
swCHNL007054	DuWapMH_24	15	19	64
swCHNL007068	DuWapMH_381	3	24	33
swCHNL007086	DuWapMH_189	6	0	18
swCHNL007101	DuWapMH_47	6	0	18
swCHNL007105	DuWapMH_132	0	3	3
swCHNL007107	DuWapMH_240	0	25	25
swCHNL007108	DuWapN_28	6	25	43
swCHNL007109	DuWapN_28	6	25	43
swCHNL007110	DuWapN_28	6	25	43
swCHNL007112	DuWapMH_313	9	25	52
swCHNL007117	DuWapN_64	0	34	34
swCHNL007127	DuWapN_56	9	25	52
swCHNL007129	none	12	0	36
swCHNL007130	none	15	0	45
swCHNL007131	none	12	0	36
swCHNL007132	none	15	0	45
swCHNL007133	none	15	0	45
swCHNL007137	DuWapMH_225	6	23	41
swCHNL007138	DuWapMH_344	0	24	24
swCHNL007152	DuWapN_17	0	23	23
swCHNL007153	DuWapN_27	9	3	30
swCHNL007154	DuWapN_27	0	3	3
swCHNL007163	DuWapMH_192	0	24	24
swCHNL007164	DuWapMH_192	6	24	42
swCHNL007168	DuWapMH_415	0	25	25
swCHNL007172	DuWapMH_415	15	25	70
swCHNL007173	DuWapMH_192	0	24	24
swCHNL007174	DuWapMH_192	3	24	33
swCHNL007175	DuWapMH_192	15	24	69
swCHNL007176	DuWapMH_438	0	24	24
swCHNL007181	DuWapMH_194	9	0	27
swCHNL007184	DuWapMH_196	0	3	3
swCHNL007186	DuWapMH_117	15	3	48
swCHNL007187	DuWapMH_117	0	3	3
swCHNL007192	DuWapMH_375	0	11	11
swCHNL007196	DuWapN_51	3	24	33
swCHNL007197	DuWapMH_900	6	17	35
swCHNL007199	DuWapN_17	0	23	23
swCHNL007201	DuWapN_27	0	3	3
swCHNL007202	DuWapMH_381	6	24	42
swCHNL007205	DuWapMH_381	0	24	24
swCHNL007214	DuWapN_17	0	23	23
swCHNL990007	DuWapN_61	0	22	22

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL990009	DuWapMH_153	9	11	38
swCHNL990010	DuWapMH_153	0	11	11
swCHNL990012	DuWapMH_99	0	24	24
swCHNL990017	DuWapN_48	0	22	22
swCHNL990023	DuWapMH_291	0	25	25
swCHNL990024	DuWapN_27	0	3	3
swCHNL990025	DuWapMH_426	0	24	24
swCHNL990026	DuWapN_17	0	23	23
swCHNL990027	DuWapN_17	12	23	59
swCHNL990031	DuWapMH_223	12	18	54
swCHNL990035	DuWapN_17	0	23	23
swCHNL990043	DuWapMH_418	3	13	22
swCHNL990044	DuWapMH_154	6	24	42
swCHNL990045	DuWapMH_154	12	24	60
swCHNL990046	DuWapMH_154	3	24	33
swCHNL990047	DuWapMH_101	6	7	25
swCHNL990051	DuWapN_17	15	23	68
swCHNL990052	DuWapN_35a	0	23	23
swCHNL990053	DuWapMH_192	15	24	69
swCHNL990056	DuWapMH_419	15	0	45
swCHNL990057	DuWapN_57	6	32	50
swCHNL990067	none	0	0	0
swCHNL990068	none	15	0	45
swCHNL990069	none	12	0	36
swCHNL990070	none	0	0	0
swCHNL990072	none	12	0	36
swCHNL990073	none	6	0	18
swCHNL990074	none	6	0	18
swCHNL990075	DuWapMH_419	9	0	27
swCHNL990076	DuWapMH_206	9	25	52
swCHNL990077	DuWapMH_420	9	25	52
swCHNL990088	DuWapMH_261	3	24	33
swCHNL990089	DuWapMH_259	6	25	43
swCHNL990090	DuWapMH_259	6	25	43
swCHNL990092	DuWapMH_88	6	17	35
swCHNL990095	DuWapMH_225	6	23	41
swCHNL990096	DuWapMH_207	6	10	28
swCHNL990098	DuWapMH_207	6	10	28
swCHNL990099	DuWapMH_318	6	10	28
swCHNL990100	DuWapMH_318	0	10	10
swCHNL990101	DuWapMH_318	0	10	10
swCHNL990102	DuWapMH_318	0	10	10
swCHNL990103	DuWapMH_318	0	10	10
swCHNL990104	DuWapMH_318	0	10	10
swCHNL990105	DuWapMH_318	0	10	10
swCHNL990106	DuWapMH_318	0	10	10

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCHNL990107	DuWapMH_402	0	0	0
swCHNL990108	DuWapMH_402	0	0	0
swCHNL990109	DuWapMH_402	0	0	0
swCHNL990110	DuWapMH_402	6	0	18
swCHNL990111	DuWapN_11a	0	0	0
swCHNL990112	DuWapMH_159	6	34	52
swCHNL990113	DuWapMH_27	6	24	42
swCHNL990117	none	6	0	18
swCHNL990118	none	6	0	18
swCHNL990122	DuWapMH_329	0	10	10
swCHNL990125	DuWapN_241	0	25	25
swCHNL990126	none	3	0	9
swCHNL990132	DuWapMH_335	12	25	61
swCHNL990133	DuWapN_13	12	25	61
swCHNL990134	DuWapN_13	0	25	25
swCHNL990135	DuWapN_209b	15	24	69
swCHNL990137	none	15	0	45
swCHNL990138	DuWapN_9b	6	23	41
swCHNL990139	DuWapN_65	9	22	49
swCHNL990140	DuWapMH_233	0	25	25
swCHNL990141	DuWapMH_241	0	25	25
swCHNL990142	DuWapMH_240	12	25	61
swCHNL990143	DuWapMH_313	0	25	25
swCHNL990146	DuWapN_27	15	3	48
swCHNL990147	DuWapN_27	9	3	30
swCHNL990148	DuWapN_27	0	3	3
swCHNL990149	DuWapN_27	9	3	30
swCHNL990150	DuWapMH_426	9	24	51
swCHNL990151	DuWapN_57	15	32	77
SWCHNL990152	DuWapN_17	12	23	59
SWCHNL990154	DuWapN_230	9	24	51
swCHNL990514	DuWapMH_294	0	7	7
swCLVT000260	none	15	0	45
swCLVT000262	DuWapMH_275	9	24	51
swCLVT000263	DuWapMH_276	6	11	29
swCLVT000269	DuWapMH_154	3	24	33
swCLVT000270	DuWapMH_154	3	24	33
swCLVT000273	DuWapMH_444	0	24	24
swCLVT000388	DuWapMH_331	6	24	42
swCLVT000389	DuWapMH_331	6	24	42
swCLVT000390	DuWapMH_88	6	17	35
swCLVT000391	DuWapMH_88	12	17	53
swCLVT000392	DuWapMH_260	12	24	60
swCLVT000393	DuWapMH_261	6	24	42
swCLVT000395	DuWapMH_434	6	25	43
swCLVT000418	DuWapMH_196	3	3	12

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCLVT000419	DuWapMH_196	9	3	30
swCLVT000420	DuWapMH_88	6	17	35
swCLVT000421	DuWapMH_88	6	17	35
swCLVT000422	DuWapMH_196	6	3	21
swCLVT000423	DuWapMH_196	6	3	21
swCLVT000424	DuWapMH_330	6	11	29
swCLVT000425	DuWapMH_330	6	11	29
swCLVT000426	DuWapMH_330	9	11	38
swCLVT000427	DuWapMH_330	6	11	29
swCLVT000428	DuWapMH_330	6	11	29
swCLVT000429	DuWapMH_88	6	17	35
swCLVT000430	DuWapMH_88	6	17	35
swCLVT000435	DuWapMH_434	3	25	34
swCLVT000439	DuWapMH_298	0	0	0
swCLVT000440	DuWapMH_299	9	11	38
swCLVT000441	DuWapMH_500	0	0	0
swCLVT000442	DuWapMH_301	0	1	1
swCLVT000443	DuWapMH_370	0	7	7
swCLVT000453	DuWapMH_10	12	17	53
swCLVT000474	DuWapMH_246	0	25	25
swCLVT000490	none	9	0	27
swCLVT000508	DuWapMH_254	6	25	43
swCLVT000532	DuWapMH_437	9	24	51
swCLVT000544	DuWapMH_426	0	24	24
swCLVT000545	DuWapMH_426	0	24	24
swCLVT000546	DuWapMH_426	12	24	60
swCLVT000547	DuWapMH_426	15	24	69
swCLVT000549	DuWapMH_426	12	24	60
swCLVT000550	DuWapN_27	6	3	21
swCLVT000551	DuWapMH_426	6	24	42
swCLVT000555	DuWapN_27	12	3	39
swCLVT000556	DuWapN_27	15	3	48
swCLVT000557	DuWapN_27	6	3	21
swCLVT000563	DuWapMH_302	6	24	42
swCLVT000566	DuWapMH_377	0	24	24
swCLVT000567	DuWapN_35c	6	22	40
swCLVT000568	DuWapN_35c	6	22	40
swCLVT000569	DuWapN_35c	6	22	40
swCLVT000570	DuWapMH_274	6	25	43
swCLVT000571	DuWapMH_190	9	24	51
swCLVT000572	DuWapMH_190	9	24	51
swCLVT000573	DuWapMH_190	9	24	51
swCLVT000574	DuWapN_51	0	24	24
swCLVT000576	DuWapN_51	15	24	69
swCLVT000577	DuWapN_17	9	23	50
swCLVT000578	DuWapN_17	6	23	41

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCLVT000579	DuWapN_17	12	23	59
swCLVT000580	DuWapN_17	9	23	50
swCLVT000581	DuWapN_17	9	23	50
swCLVT000582	DuWapN_17	15	23	68
swCLVT000583	DuWapN_17	6	23	41
swCLVT000584	DuWapN_17	6	23	41
swCLVT000591	DuWapN_17	9	23	50
swCLVT000593	DuWapN_35a	6	23	41
swCLVT000594	DuWapN_17	12	23	59
swCLVT000597	DuWapN_17	15	23	68
swCLVT000598	DuWapN_17	15	23	68
swCLVT000599	DuWapN_17	6	23	41
swCLVT000600	DuWapN_17	6	23	41
swCLVT000601	DuWapN_17	6	23	41
swCLVT000602	DuWapN_17	6	23	41
swCLVT000607	DuWapN_17	6	23	41
swCLVT000608	DuWapN_17	6	23	41
swCLVT000609	DuWapN_17	6	23	41
swCLVT000610	DuWapN_17	6	23	41
swCLVT000821	DuWapN_48	0	22	22
swCLVT000822	DuWapN_59	9	24	51
swCLVT000825	DuWapN_59	0	24	24
swCLVT000826	DuWapMH_390	6	1	19
swCLVT000827	DuWapMH_294	0	7	7
swCLVT000828	DuWapMH_390	6	1	19
swCLVT000829	DuWapMH_390	6	1	19
swCLVT000830	DuWapMH_295	6	0	18
swCLVT000831	DuWapMH_392	6	1	19
swCLVT000832	DuWapMH_391	9	7	34
swCLVT000833	DuWapMH_392	0	1	1
swCLVT000834	DuWapMH_392	6	1	19
swCLVT000835	DuWapMH_392	6	1	19
swCLVT000836	DuWapMH_392	6	1	19
swCLVT000837	DuWapMH_392	6	1	19
swCLVT000838	DuWapMH_392	6	1	19
swCLVT000839	DuWapMH_392	6	1	19
swCLVT000840	DuWapMH_294	6	7	25
swCLVT000841	DuWapMH_294	9	7	34
swCLVT000842	DuWapMH_294	9	7	34
swCLVT000843	DuWapMH_294	6	7	25
swCLVT000844	DuWapMH_294	9	7	34
swCLVT000845	DuWapMH_294	6	7	25
swCLVT000846	DuWapMH_393	0	0	0
swCLVT000847	DuWapMH_371	9	24	51
swCLVT000848	DuWapMH_291	9	25	52
swCLVT000851	DuWapN_49	12	23	59

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCLVT000867	DuWapN_94	15	1	46
swCLVT000921	none	9	0	27
swCLVT000922	none	6	0	18
swCLVT000923	none	9	0	27
swCLVT000924	none	9	0	27
swCLVT000925	none	9	0	27
swCLVT000926	none	9	0	27
swCLVT000927	none	9	0	27
swCLVT000928	none	6	0	18
swCLVT000930	none	9	0	27
swCLVT000931	none	9	0	27
swCLVT000932	none	6	0	18
swCLVT000933	none	15	0	45
swCLVT000934	none	6	0	18
swCLVT000936	none	15	0	45
swCLVT000937	none	15	0	45
swCLVT000938	DuWapN_225	0	25	25
swCLVT000972	none	12	0	36
swCLVT000973	none	12	0	36
swCLVT000974	none	15	0	45
swCLVT000975	none	6	0	18
swCLVT000976	DuWapN_25	3	24	33
swCLVT000977	DuWapN_25	9	24	51
swCLVT000978	DuWapMH_329	6	10	28
swCLVT000979	DuWapN_36	9	23	50
swCLVT000980	DuWapN_36	12	23	59
swCLVT000981	DuWapN_36	6	23	41
swCLVT000982	DuWapN_36	6	23	41
swCLVT000983	DuWapN_36	12	23	59
swCLVT990018	DuWapMH_294	12	7	43
swCLVT990019	DuWapMH_294	0	7	7
swCLVT990021	DuWapMH_291	0	25	25
swCLVT990022	DuWapMH_449	6	24	42
swCLVT990023	DuWapMH_338	0	24	24
swCLVT990024	DuWapMH_449	6	24	42
swCLVT990025	DuWapN_52	0	24	24
swCLVT990028	DuWapMH_426	6	24	42
swCLVT990029	DuWapN_27	15	3	48
swCLVT990030	DuWapN_27	6	3	21
swCLVT990031	DuWapN_27	12	3	39
swCLVT990032	DuWapN_27	0	3	3
swCLVT990034	DuWapMH_426	6	24	42
swCLVT990035	DuWapMH_426	12	24	60
swCLVT990038	DuWapN_17	12	23	59
swCLVT990039	DuWapN_17	9	23	50
swCLVT990040	DuWapN_17	12	23	59

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCLVT990045	DuWapMH_10	12	17	53
swCLVT990048	DuWapMH_304	0	1	1
swCLVT990049	DuWapMH_305	0	11	11
swCLVT990051	DuWapMH_10	9	17	44
swCLVT990052	DuWapMH_197	0	0	0
swCLVT990053	DuWapMH_364	9	0	27
swCLVT990065	DuWapMH_309	12	9	45
swCLVT990066	DuWapMH_310	12	9	45
swCLVT990067	DuWapMH_311	0	13	13
swCLVT990068	DuWapMH_409	0	13	13
swCLVT990069	DuWapMH_46	6	18	36
swCLVT990070	DuWapMH_299	6	11	29
swCLVT990071	DuWapMH_154	6	24	42
swCLVT990072	DuWapMH_154	9	24	51
swCLVT990073	DuWapMH_154	6	24	42
swCLVT990074	DuWapMH_154	12	24	60
swCLVT990075	DuWapMH_154	6	24	42
swCLVT990076	DuWapMH_154	15	24	69
swCLVT990077	DuWapMH_154	0	24	24
swCLVT990078	DuWapMH_154	6	24	42
swCLVT990079	DuWapMH_154	9	24	51
swCLVT990080	DuWapMH_154	12	24	60
swCLVT990081	DuWapMH_154	9	24	51
swCLVT990082	DuWapMH_154	6	24	42
swCLVT990083	DuWapMH_154	6	24	42
swCLVT990084	DuWapMH_101	6	7	25
swCLVT990085	DuWapMH_101	6	7	25
swCLVT990086	DuWapMH_101	6	7	25
swCLVT990087	DuWapMH_101	9	7	34
swCLVT990088	DuWapMH_101	9	7	34
swCLVT990089	DuWapMH_101	9	7	34
swCLVT990093	DuWapN_17	0	23	23
swCLVT990094	DuWapN_17	6	23	41
swCLVT990095	DuWapN_35a	6	23	41
swCLVT990098	DuWapMH_192	6	24	42
swCLVT990099	DuWapMH_415	6	25	43
swCLVT990100	DuWapMH_192	12	24	60
swCLVT990101	DuWapMH_192	12	24	60
swCLVT990102	DuWapMH_288	9	0	27
swCLVT990104	DuWapMH_123	15	24	69
swCLVT990105	DuWapN_230	6	24	42
swCLVT990119	none	6	0	18
swCLVT990120	none	12	0	36
swCLVT990121	none	15	0	45
swCLVT990122	none	15	0	45
swCLVT990123	none	15	0	45

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swCLVT990124	none	9	0	27
swCLVT990125	none	15	0	45
swCLVT990126	none	12	0	36
swCLVT990127	none	15	0	45
swCLVT990128	none	15	0	45
swCLVT990129	none	15	0	45
swCLVT990130	none	15	0	45
swCLVT990131	none	12	0	36
swCLVT990132	none	6	0	18
swCLVT990135	DuWapN_71	6	24	42
swCLVT990136	DuWapMH_249	0	24	24
swCLVT990159	DuWapMH_157	15	7	52
swCLVT990160	DuWapMH_343	6	24	42
swCLVT990161	DuWapMH_344	15	24	69
swCLVT990162	DuWapMH_344	15	24	69
swCLVT990164	DuWapMH_88	6	17	35
swCLVT990165	DuWapMH_259	6	25	43
swCLVT990167	DuWapMH_254	6	25	43
swCLVT990168	none	6	0	18
swCLVT990169	none	6	0	18
swCLVT990170	none	3	0	9
swCLVT990171	DuWapN_212	15	33	78
swCLVT990172	DuWapMH_27	6	24	42
swCLVT990174	DuWapMH_329	12	10	46
swCLVT990176	none	6	0	18
swCLVT990177	none	0	0	0
swCLVT990178	none	9	0	27
swCLVT990179	none	9	0	27
swCLVT990180	none	12	0	36
swCLVT990181	DuWapN_15	6	16	34
swCLVT990201	DuWapMH_240	9	25	52
swCLVT990202	DuWapN_57	0	32	32
SWCLVT990203	DuWapN_17	9	23	50
SWCLVT990204	DuWapN_36	12	23	59
swCLVT990500	DuWapMH_446	0	0	0
swCLVT990504	DuWapMH_146	12	0	36
swPIPE002352	none	6	0	18
swPIPE002353	none	12	0	36
swPIPE002354	none	0	0	0
swPIPE002355	none	0	0	0
swPIPE002358	none	0	0	0
swPIPE002359	none	9	0	27
swPIPE010571	DuWapN_36	6	23	41
swPIPE010580	DuWapMH_329	6	10	28
swPIPE010581	DuWapMH_329	9	10	37
swPIPE010582	DuWapMH_317	6	24	42

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE010583	DuWapMH_146	9	0	27
swPIPE010590	DuWapMH_147	0	10	10
swPIPE010672	none	6	0	18
swPIPE010673	none	0	0	0
swPIPE010687	none	0	0	0
swPIPE010690	none	9	0	27
swPIPE010691	none	3	0	9
swPIPE010692	none	6	0	18
swPIPE010694	none	0	0	0
swPIPE010695	none	9	0	27
swPIPE010696	none	6	0	18
swPIPE010697	none	6	0	18
swPIPE010698	none	6	0	18
swPIPE010699	none	9	0	27
swPIPE010700	none	12	0	36
swPIPE010701	none	12	0	36
swPIPE010702	none	6	0	18
swPIPE010703	none	6	0	18
swPIPE010705	none	0	0	0
swPIPE010706	none	9	0	27
swPIPE010754	none	3	0	9
swPIPE010756	none	9	0	27
swPIPE010757	none	0	0	0
swPIPE010809	none	6	0	18
swPIPE010810	none	6	0	18
swPIPE010811	none	6	0	18
swPIPE010812	none	6	0	18
swPIPE010813	none	6	0	18
swPIPE010814	none	3	0	9
swPIPE010815	none	6	0	18
swPIPE010816	none	3	0	9
swPIPE010817	none	9	0	27
swPIPE010818	none	3	0	9
swPIPE010819	none	6	0	18
swPIPE010820	none	3	0	9
swPIPE010821	none	6	0	18
swPIPE010822	none	0	0	0
swPIPE010823	none	9	0	27
swPIPE010824	none	9	0	27
swPIPE010825	none	3	0	9
swPIPE010827	none	3	0	9
swPIPE010828	none	9	0	27
swPIPE010829	none	6	0	18
swPIPE010973	DuWapMH_92	6	3	21
swPIPE010974	DuWapMH_92	6	3	21
swPIPE010975	DuWapMH_330	3	11	20

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE010976	DuWapMH_92	9	3	30
swPIPE010977	DuWapMH_92	6	3	21
swPIPE010978	DuWapMH_88	0	17	17
swPIPE010979	DuWapMH_267	3	1	10
swPIPE010980	DuWapMH_267	3	1	10
swPIPE010981	DuWapMH_88	3	17	26
swPIPE010982	DuWapMH_88	3	17	26
swPIPE010983	DuWapMH_88	0	17	17
swPIPE010984	DuWapMH_3	9	25	52
swPIPE010988	DuWapMH_351	12	25	61
swPIPE010989	DuWapMH_351	0	25	25
swPIPE010993	DuWapMH_88	0	17	17
swPIPE010994	DuWapMH_92	6	3	21
swPIPE010995	DuWapMH_92	6	3	21
swPIPE010997	DuWapMH_357	0	25	25
swPIPE011027	DuWapMH_140	0	25	25
swPIPE011031	DuWapMH_140	6	25	43
swPIPE011032	DuWapMH_140	6	25	43
swPIPE011037	DuWapMH_52	6	0	18
swPIPE011038	DuWapMH_51	0	24	24
swPIPE011039	DuWapMH_51	6	24	42
swPIPE011040	DuWapMH_153	0	11	11
swPIPE011041	DuWapMH_99	0	24	24
swPIPE011042	DuWapMH_99	0	24	24
swPIPE011043	DuWapMH_99	0	24	24
swPIPE011045	DuWapMH_10	6	17	35
swPIPE011046	DuWapMH_394	6	11	29
swPIPE011048	DuWapMH_106	3	0	9
swPIPE011051	DuWapMH_55	0	17	17
swPIPE011109	DuWapMH_74	6	33	51
swPIPE011152	DuWapMH_156	0	0	0
swPIPE011155	DuWapMH_154	6	24	42
swPIPE011156	DuWapMH_154	0	24	24
swPIPE011170	DuWapMH_156	0	0	0
swPIPE011174	DuWapMH_156	0	0	0
swPIPE011205	DuWapMH_77	0	25	25
swPIPE011206	DuWapMH_195	15	25	70
swPIPE011207	DuWapN_334	15	25	70
swPIPE011235	none	15	0	45
swPIPE011237	none	12	0	36
swPIPE011238	none	6	0	18
swPIPE011239	DuWapMH_108	9	24	51
swPIPE011240	none	9	0	27
swPIPE011241	DuWapMH_159	6	34	52
swPIPE011243	DuWapMH_27	9	24	51
swPIPE011253	DuWapMH_28	15	24	69

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE011255	DuWapMH_28	9	24	51
swPIPE011258	DuWapN_11a	6	0	18
swPIPE011260	DuWapMH_61	6	32	50
swPIPE011261	DuWapN_211b	6	32	50
swPIPE011262	DuWapMH_318	0	10	10
swPIPE011264	DuWapN_312	9	23	50
swPIPE011267	DuWapN_11a	0	0	0
swPIPE011269	DuWapMH_351	6	25	43
swPIPE011270	none	9	0	27
swPIPE011271	DuWapMH_88	0	17	17
swPIPE011272	DuWapMH_88	0	17	17
swPIPE011273	DuWapMH_88	12	17	53
swPIPE011274	DuWapMH_88	0	17	17
swPIPE011276	DuWapN_71	0	24	24
swPIPE011277	DuWapMH_433	9	24	51
swPIPE011333	DuWapMH_162	0	0	0
swPIPE011334	DuWapMH_369	0	0	0
swPIPE011335	DuWapN_250	0	16	16
swPIPE011337	DuWapMH_10	12	17	53
swPIPE011372	none	6	0	18
swPIPE011373	none	3	0	9
swPIPE011388	none	6	0	18
swPIPE011401	DuWapMH_32	9	0	27
swPIPE011409	DuWapMH_32	9	0	27
swPIPE011410	DuWapMH_32	0	0	0
swPIPE011411	DuWapMH_10	12	17	53
swPIPE011412	DuWapMH_10	6	17	35
swPIPE011413	DuWapMH_10	3	17	26
swPIPE011414	DuWapMH_32	0	0	0
swPIPE011416	DuWapMH_10	0	17	17
swPIPE011417	DuWapMH_394	3	11	20
swPIPE011418	DuWapMH_371	9	24	51
swPIPE011419	DuWapMH_371	6	24	42
swPIPE011420	DuWapMH_292	9	1	28
swPIPE011421	DuWapMH_292	0	1	1
swPIPE011422	DuWapMH_393	6	0	18
swPIPE011423	DuWapMH_393	6	0	18
swPIPE011424	DuWapMH_294	6	7	25
swPIPE011425	DuWapMH_393	9	0	27
swPIPE011426	DuWapN_250	0	16	16
swPIPE011427	DuWapMH_437	9	24	51
swPIPE011434	DuWapMH_426	6	24	42
swPIPE011435	DuWapN_27	6	3	21
swPIPE011441	DuWapMH_302	6	24	42
swPIPE011447	DuWapN_26	0	24	24
swPIPE011515	DuWapN_66	9	23	50

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE012033	DuWapMH_108	0	24	24
swPIPE012034	DuWapMH_108	0	24	24
swPIPE012041	DuWapMH_175	0	24	24
swPIPE012042	DuWapMH_175	0	24	24
swPIPE012049	DuWapMH_337	6	25	43
swPIPE012050	DuWapMH_87	0	23	23
swPIPE012051	DuWapMH_87	0	23	23
swPIPE012052	DuWapN_274	6	23	41
swPIPE012053	DuWapN_274	0	23	23
swPIPE012055	DuWapMH_338	0	24	24
swPIPE012058	DuWapMH_338	0	24	24
swPIPE012061	DuWapN_52	0	24	24
swPIPE012065	DuWapMH_449	0	24	24
swPIPE012066	DuWapMH_449	6	24	42
swPIPE012070	DuWapMH_177	0	24	24
swPIPE012072	DuWapN_74	0	24	24
swPIPE012073	DuWapN_74	6	24	42
swPIPE012090	DuWapN_53	6	11	29
swPIPE012091	DuWapN_53	0	11	11
swPIPE012092	DuWapN_74	9	24	51
swPIPE012093	DuWapN_74	0	24	24
swPIPE012094	DuWapN_53	9	11	38
swPIPE012101	DuWapN_53	6	11	29
swPIPE012111	DuWapN_312	9	23	50
swPIPE012112	DuWapN_312	12	23	59
swPIPE012132	DuWapMH_179	0	24	24
swPIPE012133	DuWapN_59	0	24	24
swPIPE012134	DuWapN_59	15	24	69
swPIPE012147	DuWapN_29	9	22	49
swPIPE012151	DuWapMH_180	9	3	30
swPIPE012152	DuWapMH_180	0	3	3
swPIPE012153	DuWapMH_180	0	3	3
swPIPE012162	DuWapMH_40	15	0	45
swPIPE012163	DuWapMH_181	12	1	37
swPIPE012165	DuWapMH_40	15	0	45
swPIPE012178	DuWapN_65	9	22	49
swPIPE012196	none	12	0	36
swPIPE012197	none	6	0	18
swPIPE012198	none	6	0	18
swPIPE012199	none	6	0	18
swPIPE012200	DuWapN_225	3	25	34
swPIPE012218	DuWapMH_191	6	35	53
swPIPE012219	DuWapN_25	15	24	69
swPIPE012220	DuWapMH_191	6	35	53
swPIPE012221	DuWapN_25	6	24	42
swPIPE012222	DuWapN_25	12	24	60

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE012223	DuWapMH_56	15	25	70
swPIPE012224	DuWapMH_182	9	25	52
swPIPE012226	DuWapN_36	12	23	59
swPIPE013525	DuWapMH_101	9	7	34
swPIPE013526	DuWapMH_101	0	7	7
swPIPE013527	DuWapMH_101	6	7	25
swPIPE013528	DuWapMH_101	0	7	7
swPIPE013537	DuWapMH_130	6	25	43
swPIPE013586	DuWapMH_282	6	17	35
swPIPE013598	DuWapMH_282	6	17	35
swPIPE013602	DuWapMH_162	0	0	0
swPIPE013603	DuWapMH_500	0	0	0
swPIPE013614	DuWapN_216	0	32	32
swPIPE013615	DuWapN_216	12	32	68
swPIPE013616	DuWapMH_381	0	24	24
swPIPE013617	DuWapMH_381	9	24	51
swPIPE013654	DuWapMH_446	0	0	0
swPIPE013655	DuWapMH_446	6	0	18
swPIPE013656	DuWapMH_446	0	0	0
swPIPE013659	DuWapMH_46	12	18	54
swPIPE013660	DuWapMH_46	6	18	36
swPIPE013661	DuWapMH_46	0	18	18
swPIPE013662	DuWapMH_46	12	18	54
swPIPE013663	DuWapMH_24	0	19	19
swPIPE013664	DuWapMH_24	0	19	19
swPIPE013665	DuWapMH_188	15	7	52
swPIPE013666	DuWapMH_101	0	7	7
swPIPE013667	DuWapMH_101	0	7	7
swPIPE013668	DuWapMH_101	0	7	7
swPIPE013673	DuWapMH_223	15	18	63
swPIPE013674	DuWapMH_24	0	19	19
swPIPE013677	DuWapN_17	9	23	50
swPIPE013696	DuWapN_35c	15	22	67
swPIPE013701	DuWapMH_189	15	0	45
swPIPE013702	DuWapN_72	0	22	22
swPIPE013721	DuWapN_67	9	23	50
swPIPE013722	DuWapMH_47	9	0	27
swPIPE013723	DuWapMH_47	6	0	18
swPIPE013724	DuWapN_267	9	22	49
swPIPE013725	DuWapMH_47	9	0	27
swPIPE013726	DuWapN_67	0	23	23
swPIPE013727	DuWapN_67	0	23	23
swPIPE013728	DuWapN_67	12	23	59
swPIPE013729	DuWapN_267	6	22	40
swPIPE013730	DuWapN_267	12	22	58
swPIPE013731	DuWapN_51	9	24	51

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE013732	DuWapMH_132	0	3	3
swPIPE013736	DuWapMH_240	9	25	52
swPIPE013738	DuWapN_28	9	25	52
swPIPE013740	DuWapN_43	9	32	59
swPIPE013754	DuWapN_225	3	25	34
swPIPE013755	DuWapN_225	12	25	61
swPIPE013756	none	3	0	9
swPIPE013758	DuWapN_56	6	25	43
swPIPE013762	DuWapMH_446	12	0	36
swPIPE013765	DuWapN_74	0	24	24
swPIPE013766	DuWapN_74	0	24	24
swPIPE013767	DuWapN_74	0	24	24
swPIPE013768	DuWapN_74	15	24	69
swPIPE013769	DuWapMH_224	0	0	0
swPIPE013771	DuWapN_267	6	22	40
swPIPE013772	DuWapN_267	15	22	67
swPIPE013774	DuWapN_79	0	0	0
swPIPE013783	DuWapN_267	0	22	22
swPIPE013784	DuWapMH_360	0	0	0
swPIPE013785	none	6	0	18
swPIPE013786	none	15	0	45
swPIPE013787	none	15	0	45
swPIPE013792	DuWapN_17	12	23	59
swPIPE013795	DuWapN_17	12	23	59
swPIPE013810	DuWapN_27	6	3	21
swPIPE013818	DuWapMH_190	9	24	51
swPIPE013819	DuWapMH_190	6	24	42
swPIPE013820	DuWapN_45	0	22	22
swPIPE013821	DuWapMH_107	12	25	61
swPIPE013822	DuWapMH_192	0	24	24
swPIPE013823	DuWapMH_192	0	24	24
swPIPE013824	DuWapMH_107	6	25	43
swPIPE013825	DuWapMH_107	6	25	43
swPIPE013826	DuWapMH_380	6	25	43
swPIPE013828	DuWapMH_192	15	24	69
swPIPE013829	DuWapMH_192	9	24	51
swPIPE013830	DuWapMH_900	15	17	62
swPIPE013831	DuWapMH_900	9	17	44
swPIPE013834	DuWapMH_302	0	24	24
swPIPE013835	DuWapMH_302	6	24	42
swPIPE013840	DuWapMH_192	9	24	51
swPIPE013849	DuWapN_45	15	22	67
swPIPE013850	DuWapMH_48	9	22	49
swPIPE013851	DuWapN_29	0	22	22
swPIPE013852	DuWapMH_96	6	3	21
swPIPE013853	DuWapMH_97	6	22	40

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE013854	DuWapMH_193	6	22	40
swPIPE013855	DuWapMH_97	6	22	40
swPIPE013856	DuWapMH_193	0	22	22
swPIPE013857	DuWapN_229	9	22	49
swPIPE013858	DuWapMH_98	6	0	18
swPIPE013859	DuWapMH_194	9	0	27
swPIPE013875	DuWapMH_402	3	0	9
swPIPE013879	DuWapMH_23	15	25	70
swPIPE013880	DuWapMH_195	15	25	70
swPIPE013883	DuWapMH_117	6	3	21
swPIPE013884	DuWapMH_117	6	3	21
swPIPE013885	DuWapMH_117	6	3	21
swPIPE013906	DuWapMH_123	6	24	42
swPIPE013907	DuWapMH_123	15	24	69
swPIPE013910	DuWapMH_197	6	0	18
swPIPE013911	DuWapMH_53	0	24	24
swPIPE013912	DuWapMH_53	0	24	24
swPIPE990002	DuWapN_62	12	23	59
swPIPE990010	DuWapMH_198	9	24	51
swPIPE990011	DuWapMH_389	0	24	24
swPIPE990012	DuWapMH_389	0	24	24
swPIPE990013	DuWapMH_199	0	24	24
swPIPE990014	DuWapMH_389	0	24	24
swPIPE990015	DuWapMH_388	12	22	58
swPIPE990016	DuWapMH_52	6	0	18
swPIPE990029	DuWapMH_175	6	24	42
swPIPE990030	DuWapN_48	12	22	58
swPIPE990031	DuWapN_48	0	22	22
swPIPE990032	DuWapN_48	0	22	22
swPIPE990033	DuWapN_48	0	22	22
swPIPE990034	DuWapN_48	0	22	22
swPIPE990035	DuWapN_48	0	22	22
swPIPE990036	DuWapN_48	0	22	22
swPIPE990037	DuWapN_59	0	24	24
swPIPE990038	DuWapN_59	9	24	51
swPIPE990039	DuWapN_59	9	24	51
swPIPE990041	DuWapN_59	0	24	24
swPIPE990048	DuWapN_274	0	23	23
swPIPE990049	DuWapN_274	0	23	23
swPIPE990050	DuWapMH_87	0	23	23
swPIPE990051	DuWapN_74	9	24	51
swPIPE990059	DuWapN_17	0	23	23
swPIPE990062	DuWapMH_294	0	7	7
swPIPE990066	DuWapN_216	9	32	59
swPIPE990067	DuWapN_216	6	32	50
swPIPE990068	DuWapN_216	6	32	50

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE990069	DuWapMH_381	6	24	42
swPIPE990071	DuWapN_250	9	16	43
swPIPE990075	DuWapN_95	9	25	52
swPIPE990077	DuWapN_17	15	23	68
swPIPE990078	DuWapN_17	6	23	41
swPIPE990079	DuWapN_17	6	23	41
swPIPE990082	DuWapN_334	15	25	70
swPIPE990083	DuWapMH_136	3	7	16
swPIPE990090	DuWapN_35c	6	22	40
swPIPE990091	DuWapN_45	6	22	40
swPIPE990096	DuWapMH_123	0	24	24
swPIPE990097	DuWapN_222	6	16	34
swPIPE990098	DuWapN_222	6	16	34
swPIPE990099	DuWapN_222	6	16	34
swPIPE990100	DuWapN_222	9	16	43
swPIPE990101	DuWapMH_74	6	33	51
swPIPE990102	DuWapMH_123	0	24	24
swPIPE990103	DuWapMH_123	6	24	42
swPIPE990104	DuWapMH_123	6	24	42
swPIPE990112	DuWapN_57	0	32	32
swPIPE990113	DuWapMH_198	6	24	42
swPIPE990114	DuWapN_62	6	23	41
swPIPE990115	DuWapMH_294	6	7	25
swPIPE990119	DuWapMH_55	0	17	17
swPIPE990120	DuWapMH_103	6	24	42
swPIPE990130	DuWapN_222	9	16	43
swPIPE990131	DuWapMH_32	12	0	36
swPIPE990132	DuWapMH_446	12	0	36
swPIPE990133	DuWapMH_32	0	0	0
swPIPE990134	DuWapMH_32	6	0	18
swPIPE990153	DuWapMH_191	12	35	71
swPIPE990154	DuWapMH_191	12	35	71
swPIPE990155	DuWapMH_191	9	35	62
swPIPE990156	DuWapN_225	3	25	34
swPIPE990157	DuWapN_225	12	25	61
swPIPE990158	DuWapMH_238	12	25	61
swPIPE990159	none	3	0	9
swPIPE990160	none	6	0	18
swPIPE990161	none	3	0	9
swPIPE990162	none	3	0	9
swPIPE990163	none	12	0	36
swPIPE990164	none	6	0	18
swPIPE990165	none	6	0	18
swPIPE990167	none	15	0	45
swPIPE990168	none	15	0	45
swPIPE990169	none	9	0	27

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE990170	none	0	0	0
swPIPE990171	none	15	0	45
swPIPE990172	none	15	0	45
swPIPE990173	none	9	0	27
swPIPE990174	DuWapMH_238	0	25	25
swPIPE990175	none	12	0	36
swPIPE990176	none	12	0	36
swPIPE990177	none	3	0	9
swPIPE990182	DuWapMH_206	9	25	52
swPIPE990184	DuWapMH_104	15	25	70
swPIPE990186	DuWapMH_104	9	25	52
swPIPE990187	DuWapN_97	9	17	44
swPIPE990188	DuWapMH_105	9	24	51
swPIPE990189	DuWapMH_105	9	24	51
swPIPE990190	DuWapN_97	6	17	35
swPIPE990191	DuWapMH_57	9	3	30
swPIPE990192	DuWapMH_57	9	3	30
swPIPE990193	DuWapMH_106	6	0	18
swPIPE990196	DuWapMH_419	9	0	27
swPIPE990202	none	15	0	45
swPIPE990203	none	9	0	27
swPIPE990204	DuWapN_71	6	24	42
swPIPE990205	DuWapN_71	0	24	24
swPIPE990207	DuWapMH_88	0	17	17
swPIPE990208	DuWapMH_88	9	17	44
swPIPE990209	DuWapMH_88	6	17	35
swPIPE990210	DuWapMH_88	0	17	17
swPIPE990211	DuWapMH_88	6	17	35
swPIPE990212	DuWapMH_104	9	25	52
swPIPE990213	none	6	0	18
swPIPE990216	DuWapMH_254	6	25	43
swPIPE990217	none	15		45
swPIPE990218	DuWapMH_108	6	24	42
swPIPE990219	DuWapMH_108	6	24	42
swPIPE990220	DuWapN_11a	15	0	45
swPIPE990221	DuWapN_11a	15	0	45
swPIPE990223	DuWapMH_109	3	7	16
swPIPE990224	DuWapMH_109	3	7	16
swPIPE990225	DuWapMH_207	3	10	19
swPIPE990226	DuWapN_11a	12	0	36
swPIPE990230	DuWapN_11a	12	0	36
swPIPE990231	DuWapN_11a	12	0	36
swPIPE990232	DuWapN_11a	6	0	18
swPIPE990234	DuWapN_211a	6	34	52
swPIPE990422	DuWapMH_329	6	10	28
swPIPE990423	DuWapN_36	6	23	41

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE990445	DuWapMH_114	3	24	33
swPIPE990446	DuWapMH_114	6	24	42
swPIPE990448	DuWapMH_113	6	25	43
swPIPE990450	DuWapMH_113	6	25	43
swPIPE990453	DuWapMH_113	3	25	34
swPIPE990454	DuWapN_3	3	22	31
swPIPE990455	DuWapN_3	3	22	31
swPIPE990456	DuWapN_3	0	22	22
swPIPE990458	DuWapN_3	6	22	40
swPIPE990461	DuWapMH_108	6	24	42
swPIPE990463	DuWapN_3	0	22	22
swPIPE990465	DuWapMH_212	3	0	9
swPIPE990474	DuWapMH_213	6	25	43
swPIPE990475	DuWapMH_115	0	16	16
swPIPE990476	DuWapMH_115	9	16	43
swPIPE990477	DuWapMH_115	6	16	34
swPIPE990479	DuWapMH_432	9	11	38
swPIPE990480	DuWapMH_432	3	11	20
swPIPE990481	DuWapMH_432	6	11	29
swPIPE990482	DuWapMH_432	3	11	20
swPIPE990483	DuWapMH_432	6	11	29
swPIPE990484	DuWapN_40	6	22	40
swPIPE990486	DuWapMH_432	0	11	11
swPIPE990487	DuWapN_40	9	22	49
swPIPE990489	DuWapN_40	9	22	49
swPIPE990490	DuWapN_40	6	22	40
swPIPE990492	DuWapMH_115	6	16	34
swPIPE990496	DuWapMH_115	3	16	25
swPIPE990500	none	12	0	36
swPIPE990501	DuWapMH_101	0	7	7
swPIPE990502	none	6	0	18
swPIPE990503	DuWapMH_114	9	24	51
swPIPE990507	DuWapMH_140	6	25	43
swPIPE990601	none	0	0	0
swPIPE990602	none	6	0	18
swPIPE990605	none	6	0	18
swPIPE990606	none	3	0	9
swPIPE990609	DuWapN_66	6	23	41
swPIPE990610	DuWapN_66	6	23	41
swPIPE990611	DuWapN_14	6	24	42
swPIPE990619	DuWapN_9b	15	23	68
swPIPE990620	DuWapN_209b	15	24	69
swPIPE990623	DuWapMH_1	6	25	43
swPIPE990624	DuWapMH_42	6	25	43
swPIPE990626	DuWapN_65	3	22	31
swPIPE990628	DuWapN_57	9	32	59

Appendix O
Total Condition Assessment/Resiliency Flood Scoring for Prioritization
Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE990629	DuWapN_57	9	32	59
swPIPE990630	DuWapN_57	6	32	50
swPIPE990631	DuWapN_257	0	34	34
swPIPE990632	DuWapN_257	9	34	61
swPIPE990633	DuWapN_257	12	34	70
swPIPE990634	DuWapN_257	9	34	61
swPIPE990635	DuWapN_257	9	34	61
swPIPE990636	DuWapN_257	15	34	79
swPIPE990638	DuWapN_64	15	34	79
swPIPE990639	DuWapN_64	15	34	79
swPIPE990640	DuWapN_64	9	34	61
swPIPE990641	DuWapN_64	9	34	61
swPIPE990642	DuWapN_64	15	34	79
swPIPE990643	DuWapN_64	15	34	79
swPIPE990644	DuWapN_64	0	34	34
swPIPE990645	DuWapN_63	15	32	77
swPIPE990646	DuWapN_63	15	32	77
swPIPE990647	DuWapMH_69	15	35	80
swPIPE990648	DuWapMH_69	15	35	80
swPIPE990649	DuWapN_63	0	32	32
swPIPE990650	DuWapN_63	3	32	41
swPIPE990651	DuWapMH_73	3	21	30
swPIPE990652	DuWapMH_73	3	21	30
swPIPE990653	DuWapMH_73	6	21	39
swPIPE990654	DuWapN_91	0	25	25
swPIPE990655	DuWapN_55	0	22	22
swPIPE990657	DuWapMH_121	3	25	34
swPIPE990658	DuWapN_55	0	22	22
swPIPE990659	DuWapMH_221	6	24	42
swPIPE990660	DuWapMH_221	6	24	42
swPIPE990662	DuWapMH_277	6	3	21
swPIPE990663	DuWapMH_277	6	3	21
swPIPE990667	DuWapMH_69	6	35	53
swPIPE990668	DuWapMH_113	6	25	43
swPIPE990669	DuWapMH_191	0	35	35
swPIPE990670	DuWapMH_232	6	34	52
swPIPE990671	DuWapMH_232	6	34	52
swPIPE990672	DuWapMH_232	6	34	52
swPIPE990673	DuWapMH_232	6	34	52
swPIPE990674	DuWapMH_191	6	35	53
swPIPE990675	DuWapN_27	0	3	3
swPIPE990677	DuWapMH_191	9	35	62
swPIPE990685	DuWapMH_61	3	32	41
swPIPE990686	DuWapMH_61	6	32	50
swPIPE990687	DuWapN_11b	6	14	32
swPIPE990689	DuWapN_11b	6	14	32

Appendix O

Total Condition Assessment/Resiliency Flood Scoring for Prioritization

Pipes, Channels, and Culverts

Asset ID	Model Node	Condition Grade	Flood Score	Total Score
swPIPE990700	DuWapMH_157	0	7	7
swPIPE990702	DuWapN_80	3	10	19
swPIPE990703	DuWapN_91	0	25	25
swPIPE990704	DuWapN_63	0	32	32
SWPIPE990708	DuWapN_53	0	11	11
SWPIPE990716	DuWapMH_390	9	1	28
SWPIPE990717	DuWapMH_296	6	1	19
SWPIPE990718	DuWapMH_296	0	1	1
SWPIPE990719	DuWapMH_315	9	24	51
SWPIPE990721	none	6	0	18
SWPIPE990722	none	0	0	0
SWPIPE990725	DuWapMH_27	12	24	60

Appendix P Improved Node Maximum Stage Result Summary

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_1	17.22	19.33
25 Year 24 Hour_SS_SLR	DuWapMH_10	12.11	11.75
25 Year 24 Hour_SS_SLR	DuWapMH_101	13.18	12.06
25 Year 24 Hour_SS_SLR	DuWapMH_103	7	8.13
25 Year 24 Hour_SS_SLR	DuWapMH_104	7.99	9.18
25 Year 24 Hour_SS_SLR	DuWapMH_105	8.5	9.09
25 Year 24 Hour_SS_SLR	DuWapMH_106	9.97	8.4
25 Year 24 Hour_SS_SLR	DuWapMH_107	7.8	8.29
25 Year 24 Hour_SS_SLR	DuWapMH_108	17.18	17.45
25 Year 24 Hour_SS_SLR	DuWapMH_109	12.31	12.38
25 Year 24 Hour_SS_SLR	DuWapMH_11	8.33	8.16
25 Year 24 Hour_SS_SLR	DuWapMH_111	13.09	8.3
25 Year 24 Hour_SS_SLR	DuWapMH_112	8.68	8.81
25 Year 24 Hour_SS_SLR	DuWapMH_113	13.2	15.36
25 Year 24 Hour_SS_SLR	DuWapMH_114	10.14	11.07
25 Year 24 Hour_SS_SLR	DuWapMH_115	8.62	8.99
25 Year 24 Hour_SS_SLR	DuWapMH_116	6.91	7.93
25 Year 24 Hour_SS_SLR	DuWapMH_117	9.24	9.68
25 Year 24 Hour_SS_SLR	DuWapMH_118	18.7	16.82
25 Year 24 Hour_SS_SLR	DuWapMH_119	8.92	9.22
25 Year 24 Hour_SS_SLR	DuWapMH_12	8.58	8.28
25 Year 24 Hour_SS_SLR	DuWapMH_121	5.24	9.16
25 Year 24 Hour_SS_SLR	DuWapMH_123	7.64	9.05
25 Year 24 Hour_SS_SLR	DuWapMH_124	17.44	17.45
25 Year 24 Hour_SS_SLR	DuWapMH_128	8.06	7.93
25 Year 24 Hour_SS_SLR	DuWapMH_129	9.21	8.84
25 Year 24 Hour_SS_SLR	DuWapMH_13	6.24	7.82
25 Year 24 Hour_SS_SLR	DuWapMH_130	4.76	7.94
25 Year 24 Hour_SS_SLR	DuWapMH_131	6.67	9.23
25 Year 24 Hour_SS_SLR	DuWapMH_132	9.28	9.17
25 Year 24 Hour_SS_SLR	DuWapMH_133	9.17	9.18
25 Year 24 Hour_SS_SLR	DuWapMH_134	3.15	7.67
25 Year 24 Hour_SS_SLR	DuWapMH_135	7.04	8
25 Year 24 Hour_SS_SLR	DuWapMH_136	13.25	12.31
25 Year 24 Hour_SS_SLR	DuWapMH_137	9.28	7.92
25 Year 24 Hour_SS_SLR	DuWapMH_14	7.57	7.82
25 Year 24 Hour_SS_SLR	DuWapMH_140	7.8	8.06
25 Year 24 Hour_SS_SLR	DuWapMH_141	12.23	11.98
25 Year 24 Hour_SS_SLR	DuWapMH_143	9.25	8.75
25 Year 24 Hour_SS_SLR	DuWapMH_144	16.45	13.4
25 Year 24 Hour_SS_SLR	DuWapMH_146	21.1	18.87
25 Year 24 Hour_SS_SLR	DuWapMH_147	19.8	17.9
25 Year 24 Hour_SS_SLR	DuWapMH_15	8.03	8.83
25 Year 24 Hour_SS_SLR	DuWapMH_151	9.28	9.92
25 Year 24 Hour_SS_SLR	DuWapMH_152	9.4	9.18
25 Year 24 Hour_SS_SLR	DuWapMH_153	12.6	11.27

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_154	8	9.15
25 Year 24 Hour_SS_SLR	DuWapMH_155	14.96	10.79
25 Year 24 Hour_SS_SLR	DuWapMH_156	9.64	9.04
25 Year 24 Hour_SS_SLR	DuWapMH_157	13.51	13.14
25 Year 24 Hour_SS_SLR	DuWapMH_158	12.76	13.44
25 Year 24 Hour_SS_SLR	DuWapMH_159	16.4	17.36
25 Year 24 Hour_SS_SLR	DuWapMH_162	11.5	9.27
25 Year 24 Hour_SS_SLR	DuWapMH_17	7.67	8.19
25 Year 24 Hour_SS_SLR	DuWapMH_171	8.1	7.97
25 Year 24 Hour_SS_SLR	DuWapMH_172	6.3	7.97
25 Year 24 Hour_SS_SLR	DuWapMH_174	10.09	8.95
25 Year 24 Hour_SS_SLR	DuWapMH_175	10.51	11.16
25 Year 24 Hour_SS_SLR	DuWapMH_177	10.64	10.79
25 Year 24 Hour_SS_SLR	DuWapMH_180	9.5	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_181	10.7	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_182	5.25	6.88
25 Year 24 Hour_SS_SLR	DuWapMH_184	4.5	7.94
25 Year 24 Hour_SS_SLR	DuWapMH_186	5.2	8.01
25 Year 24 Hour_SS_SLR	DuWapMH_188	13.14	12.66
25 Year 24 Hour_SS_SLR	DuWapMH_189	10.85	9.75
25 Year 24 Hour_SS_SLR	DuWapMH_19	7.65	7.82
25 Year 24 Hour_SS_SLR	DuWapMH_190	10.09	9.8
25 Year 24 Hour_SS_SLR	DuWapMH_191	5.22	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_192	7.76	8.21
25 Year 24 Hour_SS_SLR	DuWapMH_193	16.87	17.28
25 Year 24 Hour_SS_SLR	DuWapMH_194	16.75	14.33
25 Year 24 Hour_SS_SLR	DuWapMH_195	13.4	14.37
25 Year 24 Hour_SS_SLR	DuWapMH_196	9.2	9.68
25 Year 24 Hour_SS_SLR	DuWapMH_197	12	9.77
25 Year 24 Hour_SS_SLR	DuWapMH_199	11.25	11.15
25 Year 24 Hour_SS_SLR	DuWapMH_20	9.13	8.51
25 Year 24 Hour_SS_SLR	DuWapMH_206	7.25	9.2
25 Year 24 Hour_SS_SLR	DuWapMH_207	14.22	11.56
25 Year 24 Hour_SS_SLR	DuWapMH_21	15.51	12.72
25 Year 24 Hour_SS_SLR	DuWapMH_212	10.9	10.18
25 Year 24 Hour_SS_SLR	DuWapMH_213	6.1	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_214	8	8.8
25 Year 24 Hour_SS_SLR	DuWapMH_218	5.12	9.43
25 Year 24 Hour_SS_SLR	DuWapMH_219	8.26	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_22	14.58	12.41
25 Year 24 Hour_SS_SLR	DuWapMH_220	15.74	13.22
25 Year 24 Hour_SS_SLR	DuWapMH_221	8.21	8.97
25 Year 24 Hour_SS_SLR	DuWapMH_222	4.08	7.99
25 Year 24 Hour_SS_SLR	DuWapMH_223	11.06	10.9
25 Year 24 Hour_SS_SLR	DuWapMH_224	16.4	13.77
25 Year 24 Hour_SS_SLR	DuWapMH_225	11.69	12.69

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_227	7.4	8.19
25 Year 24 Hour_SS_SLR	DuWapMH_228	3.88	8
25 Year 24 Hour_SS_SLR	DuWapMH_229	5.63	7.82
25 Year 24 Hour_SS_SLR	DuWapMH_23	13.4	14.22
25 Year 24 Hour_SS_SLR	DuWapMH_230	6.69	7.84
25 Year 24 Hour_SS_SLR	DuWapMH_231	6.25	7.86
25 Year 24 Hour_SS_SLR	DuWapMH_232	7.15	8.93
25 Year 24 Hour_SS_SLR	DuWapMH_233	6.65	9.18
25 Year 24 Hour_SS_SLR	DuWapMH_235	8.53	10.06
25 Year 24 Hour_SS_SLR	DuWapMH_236	4.39	8
25 Year 24 Hour_SS_SLR	DuWapMH_238	4.89	6.82
25 Year 24 Hour_SS_SLR	DuWapMH_24	11.15	11.29
25 Year 24 Hour_SS_SLR	DuWapMH_240	6.58	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_241	6.58	9.18
25 Year 24 Hour_SS_SLR	DuWapMH_243	3.57	7.96
25 Year 24 Hour_SS_SLR	DuWapMH_244	3.57	7.96
25 Year 24 Hour_SS_SLR	DuWapMH_245	4.2	7.94
25 Year 24 Hour_SS_SLR	DuWapMH_246	4.21	7.95
25 Year 24 Hour_SS_SLR	DuWapMH_248	5.23	7.95
25 Year 24 Hour_SS_SLR	DuWapMH_249	7	8.93
25 Year 24 Hour_SS_SLR	DuWapMH_250	8.5	9.08
25 Year 24 Hour_SS_SLR	DuWapMH_251	8.48	9.04
25 Year 24 Hour_SS_SLR	DuWapMH_252	8.46	9.01
25 Year 24 Hour_SS_SLR	DuWapMH_253	8.8	9.11
25 Year 24 Hour_SS_SLR	DuWapMH_254	8.75	9.19
25 Year 24 Hour_SS_SLR	DuWapMH_255	9.26	9.15
25 Year 24 Hour_SS_SLR	DuWapMH_256	8.26	9.24
25 Year 24 Hour_SS_SLR	DuWapMH_257	8.5	9.29
25 Year 24 Hour_SS_SLR	DuWapMH_258	7.67	8.95
25 Year 24 Hour_SS_SLR	DuWapMH_259	10.6	9.43
25 Year 24 Hour_SS_SLR	DuWapMH_260	11.26	12.2
25 Year 24 Hour_SS_SLR	DuWapMH_261	11.4	12.25
25 Year 24 Hour_SS_SLR	DuWapMH_262	11.8	12.44
25 Year 24 Hour_SS_SLR	DuWapMH_264	12.3	12.69
25 Year 24 Hour_SS_SLR	DuWapMH_267	9.2	8.95
25 Year 24 Hour_SS_SLR	DuWapMH_268	17.48	14.85
25 Year 24 Hour_SS_SLR	DuWapMH_269	17.89	16.44
25 Year 24 Hour_SS_SLR	DuWapMH_27	17.1	17.44
25 Year 24 Hour_SS_SLR	DuWapMH_270	19.23	18.28
25 Year 24 Hour_SS_SLR	DuWapMH_271	7.86	6.86
25 Year 24 Hour_SS_SLR	DuWapMH_272	8.03	7.03
25 Year 24 Hour_SS_SLR	DuWapMH_273	8.14	7.14
25 Year 24 Hour_SS_SLR	DuWapMH_274	9.6	9.8
25 Year 24 Hour_SS_SLR	DuWapMH_275	7	8.3
25 Year 24 Hour_SS_SLR	DuWapMH_276	8.33	8.3
25 Year 24 Hour_SS_SLR	DuWapMH_277	9	8.81

APPENDIX-P Improved Node Maximum Stage Result Summary

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_278	7	8.02
25 Year 24 Hour_SS_SLR	DuWapMH_279	8	8.31
25 Year 24 Hour_SS_SLR	DuWapMH_28	16.44	17.47
25 Year 24 Hour_SS_SLR	DuWapMH_280	8.51	8.31
25 Year 24 Hour_SS_SLR	DuWapMH_281	7.9	8.87
25 Year 24 Hour_SS_SLR	DuWapMH_282	8.3	8.94
25 Year 24 Hour_SS_SLR	DuWapMH_287	3.1	8.01
25 Year 24 Hour_SS_SLR	DuWapMH_288	14.5	12.22
25 Year 24 Hour_SS_SLR	DuWapMH_289	8.54	7.93
25 Year 24 Hour_SS_SLR	DuWapMH_290	14.2	12.5
25 Year 24 Hour_SS_SLR	DuWapMH_291	13.3	12.41
25 Year 24 Hour_SS_SLR	DuWapMH_292	13.43	12.31
25 Year 24 Hour_SS_SLR	DuWapMH_293	11.5	9.79
25 Year 24 Hour_SS_SLR	DuWapMH_294	13.59	12.91
25 Year 24 Hour_SS_SLR	DuWapMH_295	15.25	14.45
25 Year 24 Hour_SS_SLR	DuWapMH_296	14.6	13.75
25 Year 24 Hour_SS_SLR	DuWapMH_297	15.6	14.91
25 Year 24 Hour_SS_SLR	DuWapMH_298	10.26	10.06
25 Year 24 Hour_SS_SLR	DuWapMH_299	8.87	9.18
25 Year 24 Hour_SS_SLR	DuWapMH_3	10.05	9.35
25 Year 24 Hour_SS_SLR	DuWapMH_30	8.58	7.96
25 Year 24 Hour_SS_SLR	DuWapMH_301	10	9.48
25 Year 24 Hour_SS_SLR	DuWapMH_302	7.5	9.05
25 Year 24 Hour_SS_SLR	DuWapMH_304	9.98	10.11
25 Year 24 Hour_SS_SLR	DuWapMH_305	10.88	10.78
25 Year 24 Hour_SS_SLR	DuWapMH_306	9.28	10.36
25 Year 24 Hour_SS_SLR	DuWapMH_307	10.43	9.8
25 Year 24 Hour_SS_SLR	DuWapMH_308	9.28	10.31
25 Year 24 Hour_SS_SLR	DuWapMH_309	12.55	12.11
25 Year 24 Hour_SS_SLR	DuWapMH_31	7.46	7.99
25 Year 24 Hour_SS_SLR	DuWapMH_310	12.5	11.98
25 Year 24 Hour_SS_SLR	DuWapMH_311	11.8	11.8
25 Year 24 Hour_SS_SLR	DuWapMH_312	11.5	11.64
25 Year 24 Hour_SS_SLR	DuWapMH_313	5.12	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_315	21.53	22.65
25 Year 24 Hour_SS_SLR	DuWapMH_317	22.08	22.65
25 Year 24 Hour_SS_SLR	DuWapMH_318	13	11.28
25 Year 24 Hour_SS_SLR	DuWapMH_32	11	10.7
25 Year 24 Hour_SS_SLR	DuWapMH_322	10.96	10.62
25 Year 24 Hour_SS_SLR	DuWapMH_329	20.4	18.49
25 Year 24 Hour_SS_SLR	DuWapMH_33	7.62	7.98
25 Year 24 Hour_SS_SLR	DuWapMH_330	8.8	9.67
25 Year 24 Hour_SS_SLR	DuWapMH_331	11.1	12.2
25 Year 24 Hour_SS_SLR	DuWapMH_332	9	9.42
25 Year 24 Hour_SS_SLR	DuWapMH_333	10.1	9.35
25 Year 24 Hour_SS_SLR	DuWapMH_334	8.4	8.87

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_335	5.5	7.94
25 Year 24 Hour_SS_SLR	DuWapMH_336	14.1	11.28
25 Year 24 Hour_SS_SLR	DuWapMH_337	10.7	11.25
25 Year 24 Hour_SS_SLR	DuWapMH_338	10.4	11.15
25 Year 24 Hour_SS_SLR	DuWapMH_339	9.5	10.62
25 Year 24 Hour_SS_SLR	DuWapMH_34	7.62	7.98
25 Year 24 Hour_SS_SLR	DuWapMH_341	9.07	10.06
25 Year 24 Hour_SS_SLR	DuWapMH_342	8.23	7.97
25 Year 24 Hour_SS_SLR	DuWapMH_343	11.25	12.25
25 Year 24 Hour_SS_SLR	DuWapMH_344	11.75	12.44
25 Year 24 Hour_SS_SLR	DuWapMH_346	12.47	12.69
25 Year 24 Hour_SS_SLR	DuWapMH_351	7.5	10.18
25 Year 24 Hour_SS_SLR	DuWapMH_352	8.96	9.07
25 Year 24 Hour_SS_SLR	DuWapMH_353	8.81	9.04
25 Year 24 Hour_SS_SLR	DuWapMH_354	8.44	9.01
25 Year 24 Hour_SS_SLR	DuWapMH_355	9.32	9.11
25 Year 24 Hour_SS_SLR	DuWapMH_356	9.23	9.15
25 Year 24 Hour_SS_SLR	DuWapMH_357	9.13	9.19
25 Year 24 Hour_SS_SLR	DuWapMH_358	8.98	9.23
25 Year 24 Hour_SS_SLR	DuWapMH_359	9.31	9.29
25 Year 24 Hour_SS_SLR	DuWapMH_36	9.78	9.55
25 Year 24 Hour_SS_SLR	DuWapMH_360	12.25	11.54
25 Year 24 Hour_SS_SLR	DuWapMH_361	16.9	14.85
25 Year 24 Hour_SS_SLR	DuWapMH_362	17.5	16.44
25 Year 24 Hour_SS_SLR	DuWapMH_363	7.7	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_364	10.38	9.79
25 Year 24 Hour_SS_SLR	DuWapMH_366	8.87	9.17
25 Year 24 Hour_SS_SLR	DuWapMH_367	11.5	9.27
25 Year 24 Hour_SS_SLR	DuWapMH_368	12	9.74
25 Year 24 Hour_SS_SLR	DuWapMH_369	12	9.48
25 Year 24 Hour_SS_SLR	DuWapMH_370	11.25	11.08
25 Year 24 Hour_SS_SLR	DuWapMH_371	12.1	12.5
25 Year 24 Hour_SS_SLR	DuWapMH_372	11.4	12.02
25 Year 24 Hour_SS_SLR	DuWapMH_373	6.6	7.93
25 Year 24 Hour_SS_SLR	DuWapMH_374	4	7.95
25 Year 24 Hour_SS_SLR	DuWapMH_375	8.8	9.75
25 Year 24 Hour_SS_SLR	DuWapMH_377	8.14	9.06
25 Year 24 Hour_SS_SLR	DuWapMH_379	10.2	9.8
25 Year 24 Hour_SS_SLR	DuWapMH_380	7.4	9.8
25 Year 24 Hour_SS_SLR	DuWapMH_381	8.25	9.57
25 Year 24 Hour_SS_SLR	DuWapMH_382	6.1	7.97
25 Year 24 Hour_SS_SLR	DuWapMH_383	6.1	7.97
25 Year 24 Hour_SS_SLR	DuWapMH_384	8.3	7.97
25 Year 24 Hour_SS_SLR	DuWapMH_385	7.9	8.86
25 Year 24 Hour_SS_SLR	DuWapMH_386	19.1	18.28
25 Year 24 Hour_SS_SLR	DuWapMH_388	12	11.15

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_390	14.6	13.74
25 Year 24 Hour_SS_SLR	DuWapMH_391	14.7	14.44
25 Year 24 Hour_SS_SLR	DuWapMH_392	15.3	14.91
25 Year 24 Hour_SS_SLR	DuWapMH_393	14.8	12.91
25 Year 24 Hour_SS_SLR	DuWapMH_394	12.61	12.31
25 Year 24 Hour_SS_SLR	DuWapMH_396	3	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_397	7.81	6.81
25 Year 24 Hour_SS_SLR	DuWapMH_398	8.26	7.26
25 Year 24 Hour_SS_SLR	DuWapMH_399	8.03	7.03
25 Year 24 Hour_SS_SLR	DuWapMH_40	11.93	10.28
25 Year 24 Hour_SS_SLR	DuWapMH_400	7.97	6.97
25 Year 24 Hour_SS_SLR	DuWapMH_402	13.6	11.24
25 Year 24 Hour_SS_SLR	DuWapMH_403	8.54	7.54
25 Year 24 Hour_SS_SLR	DuWapMH_404	12	12.95
25 Year 24 Hour_SS_SLR	DuWapMH_405	18.6	19.33
25 Year 24 Hour_SS_SLR	DuWapMH_406	18.64	19.33
25 Year 24 Hour_SS_SLR	DuWapMH_407	18.67	19.33
25 Year 24 Hour_SS_SLR	DuWapMH_408	4.6	7.95
25 Year 24 Hour_SS_SLR	DuWapMH_409	11.7	11.8
25 Year 24 Hour_SS_SLR	DuWapMH_41	8.44	7.44
25 Year 24 Hour_SS_SLR	DuWapMH_410	12.8	12.1
25 Year 24 Hour_SS_SLR	DuWapMH_411	12.4	12.22
25 Year 24 Hour_SS_SLR	DuWapMH_412	14.01	8.03
25 Year 24 Hour_SS_SLR	DuWapMH_413	4	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_414	4	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_415	8.3	8.21
25 Year 24 Hour_SS_SLR	DuWapMH_416	16	14.26
25 Year 24 Hour_SS_SLR	DuWapMH_417	9.7	10.9
25 Year 24 Hour_SS_SLR	DuWapMH_418	11.4	11.63
25 Year 24 Hour_SS_SLR	DuWapMH_419	11.41	9.2
25 Year 24 Hour_SS_SLR	DuWapMH_42	16.56	18.37
25 Year 24 Hour_SS_SLR	DuWapMH_420	7.51	9.07
25 Year 24 Hour_SS_SLR	DuWapMH_421	6.78	8.02
25 Year 24 Hour_SS_SLR	DuWapMH_424	6.9	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_425	4.5	9.64
25 Year 24 Hour_SS_SLR	DuWapMH_426	10.8	10.88
25 Year 24 Hour_SS_SLR	DuWapMH_429	4.06	7.99
25 Year 24 Hour_SS_SLR	DuWapMH_431	6.2	8
25 Year 24 Hour_SS_SLR	DuWapMH_432	8.5	8.93
25 Year 24 Hour_SS_SLR	DuWapMH_433	7.5	8.95
25 Year 24 Hour_SS_SLR	DuWapMH_434	7.7	8.97
25 Year 24 Hour_SS_SLR	DuWapMH_436	4.7	7.96
25 Year 24 Hour_SS_SLR	DuWapMH_437	11	10.98
25 Year 24 Hour_SS_SLR	DuWapMH_438	7.81	8.21
25 Year 24 Hour_SS_SLR	DuWapMH_441	6.2	8
25 Year 24 Hour_SS_SLR	DuWapMH_444	7.5	7.98

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_445	6.5	8
25 Year 24 Hour_SS_SLR	DuWapMH_446	11.8	10.79
25 Year 24 Hour_SS_SLR	DuWapMH_448	8.16	9.07
25 Year 24 Hour_SS_SLR	DuWapMH_45	11.96	12.3
25 Year 24 Hour_SS_SLR	DuWapMH_454	13.63	8.03
25 Year 24 Hour_SS_SLR	DuWapMH_46	11.34	11.49
25 Year 24 Hour_SS_SLR	DuWapMH_47	15.76	15.05
25 Year 24 Hour_SS_SLR	DuWapMH_48	17.11	17.59
25 Year 24 Hour_SS_SLR	DuWapMH_500	10.8	9.18
25 Year 24 Hour_SS_SLR	DuWapMH_51	14.7	12.86
25 Year 24 Hour_SS_SLR	DuWapMH_52	17.38	12.86
25 Year 24 Hour_SS_SLR	DuWapMH_53	10.3	11.22
25 Year 24 Hour_SS_SLR	DuWapMH_55	8.5	8.15
25 Year 24 Hour_SS_SLR	DuWapMH_56	5.23	7.29
25 Year 24 Hour_SS_SLR	DuWapMH_57	8.61	8.42
25 Year 24 Hour_SS_SLR	DuWapMH_59	8.1	8.23
25 Year 24 Hour_SS_SLR	DuWapMH_60	8.05	7.99
25 Year 24 Hour_SS_SLR	DuWapMH_61	14.18	14.61
25 Year 24 Hour_SS_SLR	DuWapMH_62	8.05	8.2
25 Year 24 Hour_SS_SLR	DuWapMH_63	7.48	7.88
25 Year 24 Hour_SS_SLR	DuWapMH_64	7.25	7.85
25 Year 24 Hour_SS_SLR	DuWapMH_65	7.32	7.82
25 Year 24 Hour_SS_SLR	DuWapMH_66	7.6	7.82
25 Year 24 Hour_SS_SLR	DuWapMH_69	6.21	9.2
25 Year 24 Hour_SS_SLR	DuWapMH_70	19.9	17.15
25 Year 24 Hour_SS_SLR	DuWapMH_71	6.53	8
25 Year 24 Hour_SS_SLR	DuWapMH_73	8.28	8.06
25 Year 24 Hour_SS_SLR	DuWapMH_74	8.02	8.55
25 Year 24 Hour_SS_SLR	DuWapMH_75	14.77	10.8
25 Year 24 Hour_SS_SLR	DuWapMH_76	16.89	14.85
25 Year 24 Hour_SS_SLR	DuWapMH_77	14.34	16.37
25 Year 24 Hour_SS_SLR	DuWapMH_79	15.74	15.34
25 Year 24 Hour_SS_SLR	DuWapMH_8	19.09	17.24
25 Year 24 Hour_SS_SLR	DuWapMH_80	16.36	15.67
25 Year 24 Hour_SS_SLR	DuWapMH_81	8.61	8.14
25 Year 24 Hour_SS_SLR	DuWapMH_82	8.63	7.97
25 Year 24 Hour_SS_SLR	DuWapMH_84	8.1	7.98
25 Year 24 Hour_SS_SLR	DuWapMH_85	7.88	7.98
25 Year 24 Hour_SS_SLR	DuWapMH_86	6.38	8.05
25 Year 24 Hour_SS_SLR	DuWapMH_87	13.3	13.19
25 Year 24 Hour_SS_SLR	DuWapMH_88	8.27	8.98
25 Year 24 Hour_SS_SLR	DuWapMH_900	9.06	10.02
25 Year 24 Hour_SS_SLR	DuWapMH_92	9.15	9.67
25 Year 24 Hour_SS_SLR	DuWapMH_93	8.99	7.98
25 Year 24 Hour_SS_SLR	DuWapMH_95	11.72	11.5
25 Year 24 Hour_SS_SLR	DuWapMH_96	17.49	17.47

APPENDIX-P Improved Node Maximum Stage Result Summary

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapMH_97	17.13	17.37
25 Year 24 Hour_SS_SLR	DuWapMH_98	17.15	16.45
25 Year 24 Hour_SS_SLR	DuWapMH_99	10.37	11.19
25 Year 24 Hour_SS_SLR	DuWapN_1	19.32	20.12
25 Year 24 Hour_SS_SLR	DuWapN_10	7.53	8.19
25 Year 24 Hour_SS_SLR	DuWapN_101	8.5	7.73
25 Year 24 Hour_SS_SLR	DuWapN_102	11.02	9.79
25 Year 24 Hour_SS_SLR	DuWapN_103	17.5	18.04
25 Year 24 Hour_SS_SLR	DuWapN_105	12.94	13.1
25 Year 24 Hour_SS_SLR	DuWapN_106	11.39	10.26
25 Year 24 Hour_SS_SLR	DuWapN_107	5.73	8
25 Year 24 Hour_SS_SLR	DuWapN_11a	13.6	12.79
25 Year 24 Hour_SS_SLR	DuWapN_11b	16.17	15.57
25 Year 24 Hour_SS_SLR	DuWapN_12	17.02	17.57
25 Year 24 Hour_SS_SLR	DuWapN_13	5.32	7.93
25 Year 24 Hour_SS_SLR	DuWapN_14	6.72	8.05
25 Year 24 Hour_SS_SLR	DuWapN_15	8.48	8.55
25 Year 24 Hour_SS_SLR	DuWapN_16	13.24	9.86
25 Year 24 Hour_SS_SLR	DuWapN_17	8.81	9.58
25 Year 24 Hour_SS_SLR	DuWapN_18	13.41	13.96
25 Year 24 Hour_SS_SLR	DuWapN_19a	8.87	9.07
25 Year 24 Hour_SS_SLR	DuWapN_19b	8.36	8.81
25 Year 24 Hour_SS_SLR	DuWapN_2	7.62	8.26
25 Year 24 Hour_SS_SLR	DuWapN_20	8.5	9.37
25 Year 24 Hour_SS_SLR	DuWapN_201	11.82	11.66
25 Year 24 Hour_SS_SLR	DuWapN_207b	7.24	7.83
25 Year 24 Hour_SS_SLR	DuWapN_209b	6.82	7.91
25 Year 24 Hour_SS_SLR	DuWapN_21	6.82	7.97
25 Year 24 Hour_SS_SLR	DuWapN_210	8.5	8.94
25 Year 24 Hour_SS_SLR	DuWapN_211a	16.36	17.04
25 Year 24 Hour_SS_SLR	DuWapN_211b	14.11	14.59
25 Year 24 Hour_SS_SLR	DuWapN_212	16.72	17.25
25 Year 24 Hour_SS_SLR	DuWapN_216	9.51	9.9
25 Year 24 Hour_SS_SLR	DuWapN_219a	7.58	8.8
25 Year 24 Hour_SS_SLR	DuWapN_219b	7.68	8.81
25 Year 24 Hour_SS_SLR	DuWapN_22	9.33	9.95
25 Year 24 Hour_SS_SLR	DuWapN_222	8.83	9.05
25 Year 24 Hour_SS_SLR	DuWapN_224	8.56	9.26
25 Year 24 Hour_SS_SLR	DuWapN_225	5.66	6.88
25 Year 24 Hour_SS_SLR	DuWapN_229	16.94	17.2
25 Year 24 Hour_SS_SLR	DuWapN_23	7.7	8.06
25 Year 24 Hour_SS_SLR	DuWapN_230	9.69	11.36
25 Year 24 Hour_SS_SLR	DuWapN_234	10.36	10.77
25 Year 24 Hour_SS_SLR	DuWapN_238	7.34	7.58
25 Year 24 Hour_SS_SLR	DuWapN_24	8.68	8.85
25 Year 24 Hour_SS_SLR	DuWapN_240	6.57	8.87

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapN_241	6.7	8.96
25 Year 24 Hour_SS_SLR	DuWapN_25	7.05	7.72
25 Year 24 Hour_SS_SLR	DuWapN_250	11.05	11.08
25 Year 24 Hour_SS_SLR	DuWapN_257	8.09	9.18
25 Year 24 Hour_SS_SLR	DuWapN_26	11.23	10.98
25 Year 24 Hour_SS_SLR	DuWapN_263	9.5	9.61
25 Year 24 Hour_SS_SLR	DuWapN_267	13.91	14.13
25 Year 24 Hour_SS_SLR	DuWapN_27	10.72	10.88
25 Year 24 Hour_SS_SLR	DuWapN_270	8.09	8.24
25 Year 24 Hour_SS_SLR	DuWapN_273	12.96	13.14
25 Year 24 Hour_SS_SLR	DuWapN_274	11.94	12.54
25 Year 24 Hour_SS_SLR	DuWapN_28	4.64	9.64
25 Year 24 Hour_SS_SLR	DuWapN_29	17.53	17.73
25 Year 24 Hour_SS_SLR	DuWapN_3	17.18	17.33
25 Year 24 Hour_SS_SLR	DuWapN_30	11.8	11.93
25 Year 24 Hour_SS_SLR	DuWapN_31	7.21	7.78
25 Year 24 Hour_SS_SLR	DuWapN_312	17.9	17.94
25 Year 24 Hour_SS_SLR	DuWapN_32	8.53	8.8
25 Year 24 Hour_SS_SLR	DuWapN_324	9.26	7.98
25 Year 24 Hour_SS_SLR	DuWapN_33	5.11	7.45
25 Year 24 Hour_SS_SLR	DuWapN_334	13.52	14.51
25 Year 24 Hour_SS_SLR	DuWapN_338	15.5	16.28
25 Year 24 Hour_SS_SLR	DuWapN_34	18.3	17.43
25 Year 24 Hour_SS_SLR	DuWapN_35a	8.23	9.06
25 Year 24 Hour_SS_SLR	DuWapN_35b	10.35	10.52
25 Year 24 Hour_SS_SLR	DuWapN_35c	10.67	10.81
25 Year 24 Hour_SS_SLR	DuWapN_36	23.18	23.71
25 Year 24 Hour_SS_SLR	DuWapN_37	23.26	23.66
25 Year 24 Hour_SS_SLR	DuWapN_38	20.24	19.34
25 Year 24 Hour_SS_SLR	DuWapN_4	18.24	18.31
25 Year 24 Hour_SS_SLR	DuWapN_40	10.1	10.26
25 Year 24 Hour_SS_SLR	DuWapN_41	9.34	10.06
25 Year 24 Hour_SS_SLR	DuWapN_42	16.92	16.97
25 Year 24 Hour_SS_SLR	DuWapN_43	9.63	9.9
25 Year 24 Hour_SS_SLR	DuWapN_44	9.76	9.79
25 Year 24 Hour_SS_SLR	DuWapN_45	10.73	10.89
25 Year 24 Hour_SS_SLR	DuWapN_46	17.75	17.11
25 Year 24 Hour_SS_SLR	DuWapN_47	16.9	16.92
25 Year 24 Hour_SS_SLR	DuWapN_48	12.98	13.25
25 Year 24 Hour_SS_SLR	DuWapN_49	15.7	16.31
25 Year 24 Hour_SS_SLR	DuWapN_5	11.96	12.14
25 Year 24 Hour_SS_SLR	DuWapN_50	13.02	13.36
25 Year 24 Hour_SS_SLR	DuWapN_51	9.87	10.58
25 Year 24 Hour_SS_SLR	DuWapN_52	10.45	11.12
25 Year 24 Hour_SS_SLR	DuWapN_53	24.41	24.15
25 Year 24 Hour_SS_SLR	DuWapN_54	10.4	10.56

Simulation	Node Name	Warning Stage [ft]	Maximum Stage [ft]
25 Year 24 Hour_SS_SLR	DuWapN_55	8.51	8.86
25 Year 24 Hour_SS_SLR	DuWapN_56	6.64	9.64
25 Year 24 Hour_SS_SLR	DuWapN_57	9.17	9.19
25 Year 24 Hour_SS_SLR	DuWapN_58	18.5	14.64
25 Year 24 Hour_SS_SLR	DuWapN_59	11.39	12.02
25 Year 24 Hour_SS_SLR	DuWapN_6	13.41	13.5
25 Year 24 Hour_SS_SLR	DuWapN_61	12.04	11.15
25 Year 24 Hour_SS_SLR	DuWapN_62	11.86	11.58
25 Year 24 Hour_SS_SLR	DuWapN_63	9.3	9.3
25 Year 24 Hour_SS_SLR	DuWapN_64	7.71	8.68
25 Year 24 Hour_SS_SLR	DuWapN_65	10.77	10.97
25 Year 24 Hour_SS_SLR	DuWapN_66	8.22	8.97
25 Year 24 Hour_SS_SLR	DuWapN_67	14.52	15.16
25 Year 24 Hour_SS_SLR	DuWapN_70	8.24	8.68
25 Year 24 Hour_SS_SLR	DuWapN_71	7.17	8.94
25 Year 24 Hour_SS_SLR	DuWapN_72	10.57	10.78
25 Year 24 Hour_SS_SLR	DuWapN_73	15.46	15.57
25 Year 24 Hour_SS_SLR	DuWapN_74	22.47	22.73
25 Year 24 Hour_SS_SLR	DuWapN_76	3.99	7.47
25 Year 24 Hour_SS_SLR	DuWapN_77	7	8.23
25 Year 24 Hour_SS_SLR	DuWapN_78	7.5	8.18
25 Year 24 Hour_SS_SLR	DuWapN_79	12.34	12.17
25 Year 24 Hour_SS_SLR	DuWapN_7a	7.78	7.83
25 Year 24 Hour_SS_SLR	DuWapN_7b	8.56	7.82
25 Year 24 Hour_SS_SLR	DuWapN_80	15.4	14.33
25 Year 24 Hour_SS_SLR	DuWapN_82	10.37	11.22
25 Year 24 Hour_SS_SLR	DuWapN_84	2.72	7.91
25 Year 24 Hour_SS_SLR	DuWapN_9	9.94	10.04
25 Year 24 Hour_SS_SLR	DuWapN_90	8.67	11.14
25 Year 24 Hour_SS_SLR	DuWapN_91	6.12	8.77
25 Year 24 Hour_SS_SLR	DuWapN_93	10.21	9.18
25 Year 24 Hour_SS_SLR	DuWapN_94	9.98	9.25
25 Year 24 Hour_SS_SLR	DuWapN_95	10.8	12.87
25 Year 24 Hour_SS_SLR	DuWapN_97	9.26	9.04
25 Year 24 Hour_SS_SLR	DuWapN_98	13.38	9.22
25 Year 24 Hour_SS_SLR	DuWapN_9b	7.48	7.88

Appendix Q Improved Link Maximum Flow Result Summary

APPENDIX Q - Improved Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
Channel_1	25 Year 24 Hour_SS_SLR	DuWapMH_146	DuWapMH_329	28.97
Channel_100	25 Year 24 Hour_SS_SLR	DuWapMH_454	DuWapMH_412	66.14
Channel_101	25 Year 24 Hour_SS_SLR	DuWapN_28	DuWapMH_413	680.92
Channel_102	25 Year 24 Hour_SS_SLR	DuWapN_56	DuWapMH_414	232.72
Channel_103	25 Year 24 Hour_SS_SLR	DuWapMH_192	DuWapMH_415	27.08
Channel_104	25 Year 24 Hour_SS_SLR	DuWapMH_194	DuWapMH_416	27.15
Channel_105	25 Year 24 Hour_SS_SLR	DuWapMH_223	DuWapMH_417	151.55
Channel_106	25 Year 24 Hour_SS_SLR	DuWapMH_312	DuWapMH_418	27.76
Channel_107	25 Year 24 Hour_SS_SLR	DuWapMH_288	DuWapMH_119	12.47
Channel_108	25 Year 24 Hour_SS_SLR	DuWapMH_419	DuWapMH_206	30.01
Channel_109	25 Year 24 Hour_SS_SLR	DuWapMH_420	DuWapMH_448	42.63
Channel_11	25 Year 24 Hour_SS_SLR	DuWapMH_153	DuWapMH_337	34.81
Channel_110	25 Year 24 Hour_SS_SLR	DuWapMH_412	DuWapMH_421	15.87
Channel_111	25 Year 24 Hour_SS_SLR	DuWapN_209b	DuWapN_84	25.15
Channel_112	25 Year 24 Hour_SS_SLR	DuWapMH_233	DuWapMH_241	29.79
Channel_114	25 Year 24 Hour_SS_SLR	DuWapMH_240	DuWapMH_424	395.37
Channel_115	25 Year 24 Hour_SS_SLR	DuWapMH_313	DuWapMH_425	28.97
Channel_116	25 Year 24 Hour_SS_SLR	DuWapN_27	DuWapMH_426	3.93
Channel_118	25 Year 24 Hour_SS_SLR	DuWapMH_267	DuWapN_71	34.71
Channel_119	25 Year 24 Hour_SS_SLR	DuWapMH_186	DuWapMH_445	250.8
Channel_12	25 Year 24 Hour_SS_SLR	DuWapMH_175	DuWapMH_338	21.74
Channel_120	25 Year 24 Hour_SS_SLR	DuWapMH_222	DuWapMH_429	297.98
Channel_121	25 Year 24 Hour_SS_SLR	DuWapMH_156	DuWapN_241	226.85
Channel_122	25 Year 24 Hour_SS_SLR	DuWapN_23	DuWapMH_140	76.46
Channel_123	25 Year 24 Hour_SS_SLR	DuWapMH_445	DuWapMH_431	267.07
Channel_124	25 Year 24 Hour_SS_SLR	DuWapMH_444	DuWapN_21	296.82
Channel_125	25 Year 24 Hour_SS_SLR	DuWapMH_249	DuWapMH_432	67.98
Channel_126	25 Year 24 Hour_SS_SLR	DuWapMH_258	DuWapMH_433	58.04
Channel_127	25 Year 24 Hour_SS_SLR	DuWapMH_221	DuWapMH_434	9.51
Channel_128	25 Year 24 Hour_SS_SLR	DuWapMH_305	DuWapN_234	26.66
Channel_129	25 Year 24 Hour_SS_SLR	DuWapMH_244	DuWapMH_243	145.91
Channel_13	25 Year 24 Hour_SS_SLR	DuWapMH_322	DuWapMH_339	57.56
Channel_130	25 Year 24 Hour_SS_SLR	DuWapMH_243	DuWapMH_436	365.67
Channel_131	25 Year 24 Hour_SS_SLR	DuWapN_26	DuWapMH_437	18.9
Channel_132	25 Year 24 Hour_SS_SLR	DuWapMH_180	DuWapMH_413	71.26
Channel_133	25 Year 24 Hour_SS_SLR	DuWapMH_415	DuWapMH_438	30.3
Channel_134	25 Year 24 Hour_SS_SLR	DuWapMH_335	DuWapN_13	377.49
Channel_135	25 Year 24 Hour_SS_SLR	DuWapMH_191	DuWapMH_396	513.57
Channel_136	25 Year 24 Hour_SS_SLR	DuWapMH_396	DuWapMH_413	595.92
Channel_137	25 Year 24 Hour_SS_SLR	DuWapMH_413	DuWapMH_414	1164.47
Channel_138	25 Year 24 Hour_SS_SLR	DuWapMH_414	DuWapMH_425	1251.37
Channel_139	25 Year 24 Hour_SS_SLR	DuWapMH_425	DuWapMH_424	1320.99
Channel_14	25 Year 24 Hour_SS_SLR	DuWapMH_366	DuWapMH_154	106.64
Channel_147	25 Year 24 Hour_SS_SLR	DuWapMH_228	DuWapMH_445	11.78
Channel_148	25 Year 24 Hour_SS_SLR	DuWapMH_431	DuWapMH_441	265.14
Channel_15	25 Year 24 Hour_SS_SLR	DuWapMH_277	DuWapN_32	225.45
Channel_16	25 Year 24 Hour_SS_SLR	DuWapN_241	DuWapMH_282	264.17
Channel_17	25 Year 24 Hour_SS_SLR	DuWapMH_235	DuWapN_41	22.35

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
Channel_18	25 Year 24 Hour_SS_SLR	DuWapN_41	DuWapMH_341	52.29
Channel_19	25 Year 24 Hour_SS_SLR	DuWapMH_383	DuWapMH_342	152.99
Channel_2	25 Year 24 Hour_SS_SLR	DuWapMH_317	DuWapMH_315	20.35
Channel_20	25 Year 24 Hour_SS_SLR	DuWapMH_261	DuWapMH_343	37.46
Channel_201	25 Year 24 Hour_SS_SLR	DuWapN_21	DuWapMH_383	347.38
Channel_202	25 Year 24 Hour_SS_SLR	DuWapMH_408	DuWapMH_374	384.01
Channel_203	25 Year 24 Hour_SS_SLR	DuWapN_61	DuWapMH_199	17.37
Channel_204	25 Year 24 Hour_SS_SLR	DuWapMH_293	DuWapMH_197	42.98
Channel_205	25 Year 24 Hour_SS_SLR	DuWapMH_281	DuWapMH_334	14.07
Channel_207	25 Year 24 Hour_SS_SLR	DuWapMH_236	DuWapMH_222	450.33
Channel_208	25 Year 24 Hour_SS_SLR	DuWapMH_441	DuWapMH_236	357.01
Channel_209	25 Year 24 Hour_SS_SLR	DuWapMH_278	DuWapMH_287	239.17
Channel_21	25 Year 24 Hour_SS_SLR	DuWapMH_262	DuWapMH_344	36.44
Channel_210	25 Year 24 Hour_SS_SLR	DuWapMH_287	DuWapMH_186	244.75
Channel_211	25 Year 24 Hour_SS_SLR	DuWapMH_119	DuWapMH_419	12.03
Channel_212	25 Year 24 Hour_SS_SLR	DuWapMH_424	DuWapMH_440	1418.32
Channel_213	25 Year 24 Hour_SS_SLR	DuWapMH_184	DuWapMH_335	1270.46
Channel_214	25 Year 24 Hour_SS_SLR	DuWapMH_289	DuWapN_13	87.36
Channel_22	25 Year 24 Hour_SS_SLR	DuWapMH_264	DuWapMH_346	67.12
Channel_26	25 Year 24 Hour_SS_SLR	DuWapMH_157	DuWapN_273	21.03
Channel_28	25 Year 24 Hour_SS_SLR	DuWapMH_212	DuWapMH_351	69.83
Channel_29	25 Year 24 Hour_SS_SLR	DuWapMH_250	DuWapMH_352	8.75
Channel_3	25 Year 24 Hour_SS_SLR	DuWapMH_196	DuWapMH_330	17.04
Channel_30	25 Year 24 Hour_SS_SLR	DuWapMH_251	DuWapMH_353	15.89
Channel_31	25 Year 24 Hour_SS_SLR	DuWapMH_252	DuWapMH_354	16.36
Channel_32	25 Year 24 Hour_SS_SLR	DuWapMH_253	DuWapMH_355	22.94
Channel_33	25 Year 24 Hour_SS_SLR	DuWapMH_255	DuWapMH_356	7.82
Channel_34	25 Year 24 Hour_SS_SLR	DuWapMH_254	DuWapMH_357	8.45
Channel_35	25 Year 24 Hour_SS_SLR	DuWapMH_256	DuWapMH_358	8.32
Channel_36	25 Year 24 Hour_SS_SLR	DuWapMH_257	DuWapMH_359	8.94
Channel_37	25 Year 24 Hour_SS_SLR	DuWapMH_144	DuWapMH_360	20.39
Channel_38	25 Year 24 Hour_SS_SLR	DuWapMH_268	DuWapMH_361	9.96
Channel_39	25 Year 24 Hour_SS_SLR	DuWapMH_269	DuWapMH_362	13.2
Channel_4	25 Year 24 Hour_SS_SLR	DuWapMH_260	DuWapMH_331	33.45
Channel_40	25 Year 24 Hour_SS_SLR	DuWapMH_219	DuWapMH_334	77.83
Channel_41	25 Year 24 Hour_SS_SLR	DuWapMH_174	DuWapMH_363	14.36
Channel_42	25 Year 24 Hour_SS_SLR	DuWapMH_177	DuWapMH_446	34.7
Channel_43	25 Year 24 Hour_SS_SLR	DuWapMH_307	DuWapMH_364	73.51
Channel_44	25 Year 24 Hour_SS_SLR	DuWapMH_500	DuWapMH_299	85.42
Channel_45	25 Year 24 Hour_SS_SLR	DuWapMH_299	DuWapMH_366	214
Channel_46	25 Year 24 Hour_SS_SLR	DuWapMH_162	DuWapMH_367	59.4
Channel_47	25 Year 24 Hour_SS_SLR	DuWapMH_197	DuWapMH_368	49.73
Channel_48	25 Year 24 Hour_SS_SLR	DuWapMH_301	DuWapMH_369	113.41
Channel_49	25 Year 24 Hour_SS_SLR	DuWapN_250	DuWapMH_370	92.33
Channel_5	25 Year 24 Hour_SS_SLR	DuWapMH_259	DuWapMH_332	7.35
Channel_51	25 Year 24 Hour_SS_SLR	DuWapMH_290	DuWapMH_371	9.11
Channel_52	25 Year 24 Hour_SS_SLR	DuWapN_59	DuWapMH_372	35.72
Channel_53	25 Year 24 Hour_SS_SLR	DuWapN_13	DuWapMH_373	484.02

APPENDIX Q - Improved Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
Channel_54	25 Year 24 Hour_SS_SLR	DuWapMH_246	DuWapMH_408	366.18
Channel_55	25 Year 24 Hour_SS_SLR	DuWapMH_189	DuWapMH_375	20.06
Channel_57	25 Year 24 Hour_SS_SLR	DuWapMH_302	DuWapMH_123	3.77
Channel_58	25 Year 24 Hour_SS_SLR	DuWapN_35a	DuWapMH_377	40.86
Channel_59	25 Year 24 Hour_SS_SLR	DuWapMH_123	DuWapN_222	5.28
Channel_6	25 Year 24 Hour_SS_SLR	DuWapMH_3	DuWapMH_333	7.7
Channel_61	25 Year 24 Hour_SS_SLR	DuWapMH_190	DuWapMH_379	30.18
Channel_62	25 Year 24 Hour_SS_SLR	DuWapMH_274	DuWapMH_380	19.85
Channel_63	25 Year 24 Hour_SS_SLR	DuWapN_17	DuWapMH_381	73.04
Channel_64	25 Year 24 Hour_SS_SLR	DuWapMH_384	DuWapMH_382	41.37
Channel_65	25 Year 24 Hour_SS_SLR	DuWapMH_382	DuWapMH_383	41.49
Channel_66	25 Year 24 Hour_SS_SLR	DuWapMH_171	DuWapMH_384	44.63
Channel_67	25 Year 24 Hour_SS_SLR	DuWapMH_172	DuWapMH_383	28.12
Channel_69	25 Year 24 Hour_SS_SLR	DuWapMH_363	DuWapMH_385	35.11
Channel_7	25 Year 24 Hour_SS_SLR	DuWapMH_282	DuWapMH_334	181.1
Channel_70	25 Year 24 Hour_SS_SLR	DuWapMH_270	DuWapMH_386	14.54
Channel_71	25 Year 24 Hour_SS_SLR	DuWapMH_224	DuWapMH_87	69
Channel_72	25 Year 24 Hour_SS_SLR	DuWapMH_336	DuWapMH_153	16.25
Channel_73	25 Year 24 Hour_SS_SLR	DuWapMH_199	DuWapMH_388	11.16
Channel_75	25 Year 24 Hour_SS_SLR	DuWapMH_296	DuWapMH_390	7.7
Channel_76	25 Year 24 Hour_SS_SLR	DuWapMH_295	DuWapMH_391	11.29
Channel_77	25 Year 24 Hour_SS_SLR	DuWapMH_297	DuWapMH_392	8.72
Channel_78	25 Year 24 Hour_SS_SLR	DuWapMH_294	DuWapMH_393	7.22
Channel_79	25 Year 24 Hour_SS_SLR	DuWapMH_292	DuWapMH_394	11.03
Channel_8	25 Year 24 Hour_SS_SLR	DuWapMH_245	DuWapMH_184	392.57
Channel_80	25 Year 24 Hour_SS_SLR	DuWapMH_181	DuWapMH_414	27.67
Channel_81	25 Year 24 Hour_SS_SLR	DuWapMH_238	DuWapMH_396	53.37
Channel_82	25 Year 24 Hour_SS_SLR	DuWapMH_397	DuWapMH_462	0
Channel_83	25 Year 24 Hour_SS_SLR	DuWapMH_398	DuWapMH_273	0
Channel_84	25 Year 24 Hour_SS_SLR	DuWapMH_272	DuWapMH_399	0
Channel_85	25 Year 24 Hour_SS_SLR	DuWapMH_400	DuWapMH_271	0
Channel_86	25 Year 24 Hour_SS_SLR	DuWapMH_182	DuWapN_225	23.68
Channel_87	25 Year 24 Hour_SS_SLR	DuWapMH_318	DuWapMH_402	20.37
Channel_88	25 Year 24 Hour_SS_SLR	DuWapMH_207	DuWapMH_318	11.96
Channel_89	25 Year 24 Hour_SS_SLR	DuWapN_238	DuWapMH_403	0
Channel_9	25 Year 24 Hour_SS_SLR	DuWapMH_128	DuWapMH_289	27.03
Channel_91	25 Year 24 Hour_SS_SLR	DuWapMH_405	DuWapMH_1	54.01
Channel_92	25 Year 24 Hour_SS_SLR	DuWapMH_406	DuWapMH_405	99.46
Channel_93	25 Year 24 Hour_SS_SLR	DuWapMH_407	DuWapMH_406	104.98
Channel_94	25 Year 24 Hour_SS_SLR	DuWapN_38	DuWapMH_407	118.61
Channel_95	25 Year 24 Hour_SS_SLR	DuWapMH_248	DuWapMH_408	21.54
Channel_96	25 Year 24 Hour_SS_SLR	DuWapMH_311	DuWapMH_409	28.59
Channel_97	25 Year 24 Hour_SS_SLR	DuWapMH_310	DuWapMH_141	32.42
Channel_98	25 Year 24 Hour_SS_SLR	DuWapMH_309	DuWapMH_410	39.21
Channel_99	25 Year 24 Hour_SS_SLR	DuWapMH_188	DuWapMH_411	20.71
DS_101	25 Year 24 Hour_SS_SLR	~~D~DS_101~N	DuWapMH_137	2.93
DS_102	25 Year 24 Hour_SS_SLR	~~D~DS_102~N	DuWapMH_107	20.26
DS_103	25 Year 24 Hour_SS_SLR	~~D~DS_103~N	DuWapMH_108	6.81

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
DS_105	25 Year 24 Hour_SS_SLR	~~D~DS_105~N	DuWapMH_136	2.04
DS_106	25 Year 24 Hour_SS_SLR	~~D~DS_106~N	DuWapMH_900	2.68
DS_107	25 Year 24 Hour_SS_SLR	~~D~DS_107~N	DuWapMH_130	5.7
DS_76	25 Year 24 Hour_SS_SLR	~~D~DS_76~N	DuWapMH_134	6.02
DS_77	25 Year 24 Hour_SS_SLR	~~D~DS_77~N	DuWapN_78	27.63
DS_78	25 Year 24 Hour_SS_SLR	~~D~DS_78~N	DuWapMH_135	24.32
DS_80	25 Year 24 Hour_SS_SLR	~~D~DS_80~N	DuWapMH_235	22.71
DS_84	25 Year 24 Hour_SS_SLR	~~D~DS_84~N	DuWapMH_128	22.18
DS_90	25 Year 24 Hour_SS_SLR	~~D~DS_90~N	DuWapMH_129	10.32
DS_91	25 Year 24 Hour_SS_SLR	~~D~DS_91~N	DuWapMH_121	9.03
DS_93a	25 Year 24 Hour_SS_SLR	~~D~DS_93a~N	DuWapMH_132	27.1
DS_93b	25 Year 24 Hour_SS_SLR	~~D~DS_93b~N	DuWapMH_131	7.12
DS_94	25 Year 24 Hour_SS_SLR	~~D~DS_94~N	DuWapMH_133	10.71
DS_95	25 Year 24 Hour_SS_SLR	~~D~DS_95~N	DuWapMH_53	11.15
DS_97	25 Year 24 Hour_SS_SLR	~~D~DS_97~N	DuWapMH_143	12.14
DS_98	25 Year 24 Hour_SS_SLR	~~D~DS_98~N	DuWapMH_119	1.3
L-0100P	25 Year 24 Hour_SS_SLR	DuWapN_4	DuWapN_103	7.29
L-0120P	25 Year 24 Hour_SS_SLR	DuWapMH_101	DuWapMH_310	2.05
L-0130P	25 Year 24 Hour_SS_SLR	DuWapN_18	DuWapN_105	2.27
L-0150P	25 Year 24 Hour_SS_SLR	DuWapN_42	DuWapN_80	21.29
L-0160P	25 Year 24 Hour_SS_SLR	DuWapN_44	DuWapN_101	14.29
L-0180P	25 Year 24 Hour_SS_SLR	DuWapN_55	DuWapN_91	4.86
L-0200P	25 Year 24 Hour_SS_SLR	DuWapN_64	DuWapN_91	4.95
L-0270P	25 Year 24 Hour_SS_SLR	DuWapN_35c	DuWapN_106	4.16
L-0280P	25 Year 24 Hour_SS_SLR	DuWapMH_380	DuWapN_102	14.63
L-0290P	25 Year 24 Hour_SS_SLR	DuWapN_45	DuWapN_102	24.9
L-0340P	25 Year 24 Hour_SS_SLR	DuWapN_50	DuWapN_95	14.34
L-0360P	25 Year 24 Hour_SS_SLR	DuWapN_274	DuWapN_82	52.33
L-0380P	25 Year 24 Hour_SS_SLR	DuWapN_52	DuWapN_82	26.85
L-0390P	25 Year 24 Hour_SS_SLR	DuWapN_58	DuWapMH_51	20.06
L-0400P	25 Year 24 Hour_SS_SLR	DuWapN_58	DuWapMH_52	23.15
L-0420P	25 Year 24 Hour_SS_SLR	DuWapMH_225	DuWapN_79	9.39
L-0430P	25 Year 24 Hour_SS_SLR	DuWapN_46	DuWapMH_144	18.46
L-0440P	25 Year 24 Hour_SS_SLR	DuWapMH_448	DuWapN_97	12.14
L-0450P	25 Year 24 Hour_SS_SLR	DuWapN_54	DuWapN_97	10.78
L-0490P	25 Year 24 Hour_SS_SLR	DuWapMH_158	DuWapN_273	11.64
L-0500P	25 Year 24 Hour_SS_SLR	DuWapN_5	DuWapN_90	16.86
L-0570P	25 Year 24 Hour_SS_SLR	DuWapN_33	DuWapN_76	5.63
L-0580P	25 Year 24 Hour_SS_SLR	DuWapMH_134	DuWapMH_287	6.03
L-0590P	25 Year 24 Hour_SS_SLR	DuWapMH_66	DuWapMH_13	35.38
L-0600P	25 Year 24 Hour_SS_SLR	DuWapMH_13	DuWapN_21	35.54
L-0680P	25 Year 24 Hour_SS_SLR	DuWapMH_900	DuWapMH_123	2.68
L-0690P	25 Year 24 Hour_SS_SLR	DuWapN_35b	DuWapMH_123	6.54
L-0830P	25 Year 24 Hour_SS_SLR	DuWapMH_227	DuWapN_78	26.84
L-1130P	25 Year 24 Hour_SS_SLR	DuWapN_263	DuWapN_94	9.56
L-1140P	25 Year 24 Hour_SS_SLR	DuWapN_338	DuWapMH_404	4.07
L-142	25 Year 24 Hour_SS_SLR	DuWapMH_429	DuWapMH_444	1444.51
P_1	25 Year 24 Hour_SS_SLR	DuWapMH_147	DuWapMH_8	28.92

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_10	25 Year 24 Hour_SS_SLR	DuWapMH_88	DuWapMH_267	15.88
P_100	25 Year 24 Hour_SS_SLR	DuWapMH_381	DuWapN_216	22.35
P_101	25 Year 24 Hour_SS_SLR	DuWapMH_418	DuWapMH_46	21.01
P_102	25 Year 24 Hour_SS_SLR	DuWapMH_23	DuWapMH_188	20.71
P_103	25 Year 24 Hour_SS_SLR	DuWapN_72	DuWapMH_189	22.76
P_104	25 Year 24 Hour_SS_SLR	DuWapMH_47	DuWapN_267	4.45
P_105	25 Year 24 Hour_SS_SLR	DuWapN_51	DuWapMH_190	35.57
P_106	25 Year 24 Hour_SS_SLR	DuWapMH_232	DuWapMH_191	6.03
P_107	25 Year 24 Hour_SS_SLR	DuWapN_47	DuWapMH_80	12.07
P_108	25 Year 24 Hour_SS_SLR	DuWapMH_107	DuWapMH_192	20.28
P_109	25 Year 24 Hour_SS_SLR	DuWapMH_438	DuWapMH_103	19.99
P_11	25 Year 24 Hour_SS_SLR	DuWapMH_88	DuWapMH_267	15.88
P_110	25 Year 24 Hour_SS_SLR	DuWapN_29	DuWapMH_48	10.7
P_111	25 Year 24 Hour_SS_SLR	DuWapMH_48	DuWapMH_96	10.67
P_112	25 Year 24 Hour_SS_SLR	DuWapMH_96	DuWapMH_97	10.67
P_113	25 Year 24 Hour_SS_SLR	DuWapMH_97	DuWapMH_193	11.37
P_114	25 Year 24 Hour_SS_SLR	DuWapMH_193	DuWapN_229	14.04
P_115	25 Year 24 Hour_SS_SLR	DuWapN_229	DuWapMH_98	27.16
P_116	25 Year 24 Hour_SS_SLR	DuWapMH_98	DuWapMH_194	27.16
P_117	25 Year 24 Hour_SS_SLR	DuWapMH_195	DuWapMH_23	20.71
P_118	25 Year 24 Hour_SS_SLR	DuWapN_334	DuWapMH_195	20.71
P_119	25 Year 24 Hour_SS_SLR	DuWapMH_117	DuWapMH_196	18.14
P_12	25 Year 24 Hour_SS_SLR	DuWapMH_92	DuWapMH_88	3.12
P_120	25 Year 24 Hour_SS_SLR	DuWapMH_375	DuWapMH_117	18.15
P_121	25 Year 24 Hour_SS_SLR	DuWapMH_53	DuWapMH_197	11.13
P_125	25 Year 24 Hour_SS_SLR	DuWapMH_388	DuWapMH_99	8.08
P_126	25 Year 24 Hour_SS_SLR	DuWapMH_52	DuWapMH_336	17.31
P_127	25 Year 24 Hour_SS_SLR	DuWapN_48	DuWapN_59	17.56
P_128	25 Year 24 Hour_SS_SLR	DuWapN_48	DuWapN_59	17.56
P_13	25 Year 24 Hour_SS_SLR	DuWapMH_341	DuWapMH_151	12.57
P_131	25 Year 24 Hour_SS_SLR	DuWapMH_136	DuWapMH_101	2.05
P_133	25 Year 24 Hour_SS_SLR	DuWapMH_11	DuWapMH_55	12.16
P_134	25 Year 24 Hour_SS_SLR	DuWapMH_446	DuWapMH_32	17.42
P_135	25 Year 24 Hour_SS_SLR	DuWapMH_446	DuWapMH_322	42.28
P_136	25 Year 24 Hour_SS_SLR	DuWapMH_32	DuWapMH_322	17.42
P_138	25 Year 24 Hour_SS_SLR	DuWapMH_206	DuWapMH_104	13.87
P_139	25 Year 24 Hour_SS_SLR	DuWapMH_104	DuWapMH_105	12.11
P_14	25 Year 24 Hour_SS_SLR	DuWapMH_151	DuWapMH_152	12.57
P_140	25 Year 24 Hour_SS_SLR	DuWapMH_105	DuWapMH_420	13.36
P_141	25 Year 24 Hour_SS_SLR	DuWapMH_57	DuWapMH_143	0
P_142	25 Year 24 Hour_SS_SLR	DuWapMH_57	DuWapMH_106	12.15
P_143	25 Year 24 Hour_SS_SLR	DuWapMH_124	DuWapMH_108	0.12
P_144	25 Year 24 Hour_SS_SLR	DuWapN_11a	DuWapMH_109	11.96
P_145	25 Year 24 Hour_SS_SLR	DuWapMH_109	DuWapMH_207	11.96
P_146	25 Year 24 Hour_SS_SLR	DuWapN_2	DuWapN_77	19.19
P_148	25 Year 24 Hour_SS_SLR	DuWapN_270	DuWapMH_59	53.11
P_149	25 Year 24 Hour_SS_SLR	DuWapMH_59	DuWapN_77	53.07
P_15	25 Year 24 Hour_SS_SLR	DuWapMH_51	DuWapMH_153	22.37

APPENDIX Q - Improved Link Maximum Flow Result Summary

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_150	25 Year 24 Hour_SS_SLR	DuWapMH_135	DuWapMH_60	24.33
P_151	25 Year 24 Hour_SS_SLR	DuWapMH_421	DuWapMH_60	16.3
P_152	25 Year 24 Hour_SS_SLR	DuWapMH_60	DuWapMH_63	35.25
P_153	25 Year 24 Hour_SS_SLR	DuWapN_10	DuWapMH_17	36.38
P_154	25 Year 24 Hour_SS_SLR	DuWapMH_62	DuWapN_10	12.77
P_155	25 Year 24 Hour_SS_SLR	DuWapN_216	DuWapN_241	34.83
P_156	25 Year 24 Hour_SS_SLR	DuWapMH_113	DuWapMH_114	113.77
P_157	25 Year 24 Hour_SS_SLR	DuWapN_3	DuWapMH_113	113.77
P_158	25 Year 24 Hour_SS_SLR	DuWapMH_114	DuWapMH_212	72.47
P_159	25 Year 24 Hour_SS_SLR	DuWapN_40	DuWapMH_115	16.24
P_16	25 Year 24 Hour_SS_SLR	DuWapMH_337	DuWapMH_99	16.85
P_160	25 Year 24 Hour_SS_SLR	DuWapMH_115	DuWapMH_213	16.19
P_161	25 Year 24 Hour_SS_SLR	DuWapN_210	DuWapMH_62	13.02
P_162	25 Year 24 Hour_SS_SLR	DuWapMH_63	DuWapMH_64	35.26
P_163	25 Year 24 Hour_SS_SLR	DuWapMH_64	DuWapN_207b	35.27
P_164	25 Year 24 Hour_SS_SLR	DuWapN_207b	DuWapMH_65	35.28
P_165	25 Year 24 Hour_SS_SLR	DuWapMH_19	DuWapMH_65	9.2
P_166	25 Year 24 Hour_SS_SLR	DuWapMH_14	DuWapMH_66	35.32
P_167	25 Year 24 Hour_SS_SLR	DuWapN_7a	DuWapMH_66	9.63
P_168	25 Year 24 Hour_SS_SLR	DuWapN_7b	DuWapMH_19	19.96
P_169	25 Year 24 Hour_SS_SLR	DuWapN_70	DuWapN_270	32.54
P_17	25 Year 24 Hour_SS_SLR	DuWapMH_337	DuWapMH_99	16.82
P_170	25 Year 24 Hour_SS_SLR	DuWapMH_15	DuWapMH_112	11.16
P_171	25 Year 24 Hour_SS_SLR	DuWapN_19a	DuWapMH_15	11.29
P_172	25 Year 24 Hour_SS_SLR	DuWapN_219b	DuWapMH_112	17.69
P_173	25 Year 24 Hour_SS_SLR	DuWapN_19b	DuWapN_219b	11.86
P_174	25 Year 24 Hour_SS_SLR	DuWapN_219a	DuWapMH_214	31.94
P_175	25 Year 24 Hour_SS_SLR	DuWapN_9b	DuWapN_209b	16.35
P_176	25 Year 24 Hour_SS_SLR	DuWapMH_1	DuWapMH_42	11.21
P_177	25 Year 24 Hour_SS_SLR	DuWapMH_42	DuWapN_338	11.11
P_178	25 Year 24 Hour_SS_SLR	DuWapN_57	DuWapN_257	19.11
P_179	25 Year 24 Hour_SS_SLR	DuWapN_257	DuWapN_93	27.35
P_18	25 Year 24 Hour_SS_SLR	DuWapMH_394	DuWapMH_10	7.18
P_180	25 Year 24 Hour_SS_SLR	DuWapN_63	DuWapMH_69	18.58
P_181	25 Year 24 Hour_SS_SLR	DuWapMH_69	DuWapN_93	18.53
P_182	25 Year 24 Hour_SS_SLR	DuWapMH_121	DuWapMH_218	9.08
P_184	25 Year 24 Hour_SS_SLR	DuWapMH_103	DuWapN_23	26.46
P_185	25 Year 24 Hour_SS_SLR	DuWapMH_432	DuWapMH_219	32.2
P_186	25 Year 24 Hour_SS_SLR	DuWapMH_403	DuWapMH_41	0
P_187	25 Year 24 Hour_SS_SLR	DuWapMH_372	DuWapMH_10	29.23
P_188	25 Year 24 Hour_SS_SLR	DuWapMH_12	DuWapMH_11	12.15
P_189	25 Year 24 Hour_SS_SLR	DuWapMH_76	DuWapMH_220	55.6
P_19	25 Year 24 Hour_SS_SLR	DuWapMH_106	DuWapMH_12	12.15
P_190	25 Year 24 Hour_SS_SLR	DuWapMH_118	DuWapMH_76	54.66
P_191	25 Year 24 Hour_SS_SLR	DuWapMH_433	DuWapN_71	7.3
P_192	25 Year 24 Hour_SS_SLR	DuWapMH_354	DuWapMH_221	6.48
P_194	25 Year 24 Hour_SS_SLR	DuWapMH_338	DuWapN_52	23.47
P_195	25 Year 24 Hour_SS_SLR	DuWapMH_140	DuWapMH_222	29.48

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_196	25 Year 24 Hour_SS_SLR	DuWapMH_46	DuWapMH_24	20.99
P_197	25 Year 24 Hour_SS_SLR	DuWapMH_24	DuWapMH_223	21
P_198	25 Year 24 Hour_SS_SLR	DuWapN_67	DuWapMH_47	4.24
P_199	25 Year 24 Hour_SS_SLR	DuWapN_74	DuWapMH_224	64.79
P_2	25 Year 24 Hour_SS_SLR	DuWapMH_8	DuWapMH_70	36.93
P_20	25 Year 24 Hour_SS_SLR	DuWapMH_55	DuWapMH_103	12.18
P_200	25 Year 24 Hour_SS_SLR	DuWapN_267	DuWapMH_225	9.87
P_201	25 Year 24 Hour_SS_SLR	DuWapMH_360	DuWapN_201	12.06
P_202	25 Year 24 Hour_SS_SLR	DuWapMH_95	DuWapN_201	12.69
P_203	25 Year 24 Hour_SS_SLR	DuWapN_201	DuWapMH_111	32.46
P_204	25 Year 24 Hour_SS_SLR	DuWapMH_111	DuWapN_77	23.98
P_205	25 Year 24 Hour_SS_SLR	DuWapMH_111	DuWapMH_454	15.43
P_206	25 Year 24 Hour_SS_SLR	DuWapMH_17	DuWapMH_227	36.31
P_207	25 Year 24 Hour_SS_SLR	DuWapMH_432	DuWapMH_219	32.19
P_208	25 Year 24 Hour_SS_SLR	DuWapMH_231	DuWapMH_116	9.12
P_209	25 Year 24 Hour_SS_SLR	DuWapMH_116	DuWapMH_228	9.12
P_21	25 Year 24 Hour_SS_SLR	DuWapMH_112	DuWapN_219a	19.77
P_210	25 Year 24 Hour_SS_SLR	DuWapMH_65	DuWapMH_14	35.3
P_211	25 Year 24 Hour_SS_SLR	DuWapN_31	DuWapMH_229	9.11
P_212	25 Year 24 Hour_SS_SLR	DuWapMH_229	DuWapMH_230	9.12
P_213	25 Year 24 Hour_SS_SLR	DuWapMH_230	DuWapMH_231	9.12
P_214	25 Year 24 Hour_SS_SLR	DuWapN_66	DuWapMH_232	6.03
P_215	25 Year 24 Hour_SS_SLR	DuWapMH_132	DuWapMH_233	27.13
P_216	25 Year 24 Hour_SS_SLR	DuWapN_211b	DuWapMH_318	9.1
P_217	25 Year 24 Hour_SS_SLR	DuWapN_11b	DuWapMH_61	16.32
P_219	25 Year 24 Hour_SS_SLR	DuWapMH_71	DuWapMH_236	29.98
P_22	25 Year 24 Hour_SS_SLR	DuWapMH_31	DuWapN_324	11.78
P_220	25 Year 24 Hour_SS_SLR	DuWapMH_140	DuWapMH_71	29.94
P_222	25 Year 24 Hour_SS_SLR	DuWapN_225	DuWapMH_238	34.41
P_223	25 Year 24 Hour_SS_SLR	DuWapN_30	DuWapN_230	29.88
P_224	25 Year 24 Hour_SS_SLR	DuWapMH_241	DuWapMH_240	38.8
P_225	25 Year 24 Hour_SS_SLR	DuWapMH_133	DuWapMH_241	10.76
P_226	25 Year 24 Hour_SS_SLR	DuWapMH_131	DuWapN_94	7.14
P_227	25 Year 24 Hour_SS_SLR	DuWapMH_373	DuWapMH_191	488.65
P_228	25 Year 24 Hour_SS_SLR	DuWapMH_383	DuWapMH_243	117.32
P_229	25 Year 24 Hour_SS_SLR	DuWapMH_342	DuWapMH_244	118.58
P_23	25 Year 24 Hour_SS_SLR	DuWapN_24	DuWapMH_20	11.28
P_230	25 Year 24 Hour_SS_SLR	DuWapMH_383	DuWapMH_243	117.27
P_231	25 Year 24 Hour_SS_SLR	DuWapMH_374	DuWapMH_245	370.93
P_232	25 Year 24 Hour_SS_SLR	DuWapMH_436	DuWapMH_246	760.12
P_233	25 Year 24 Hour_SS_SLR	DuWapN_14	DuWapN_107	8.49
P_234	25 Year 24 Hour_SS_SLR	DuWapMH_129	DuWapMH_248	10.32
P_238	25 Year 24 Hour_SS_SLR	DuWapN_71	DuWapMH_249	59.51
P_24	25 Year 24 Hour_SS_SLR	DuWapN_224	DuWapN_24	8.56
P_240	25 Year 24 Hour_SS_SLR	DuWapMH_355	DuWapMH_250	6.72
P_241	25 Year 24 Hour_SS_SLR	DuWapMH_352	DuWapMH_251	6.64
P_242	25 Year 24 Hour_SS_SLR	DuWapMH_353	DuWapMH_252	6.55
P_243	25 Year 24 Hour_SS_SLR	DuWapMH_356	DuWapMH_253	6.8

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_244	25 Year 24 Hour_SS_SLR	DuWapMH_358	DuWapMH_254	6.99
P_245	25 Year 24 Hour_SS_SLR	DuWapMH_357	DuWapMH_255	6.89
P_246	25 Year 24 Hour_SS_SLR	DuWapMH_359	DuWapMH_256	7.1
P_247	25 Year 24 Hour_SS_SLR	DuWapMH_333	DuWapMH_257	7.21
P_248	25 Year 24 Hour_SS_SLR	DuWapMH_434	DuWapMH_258	6.4
P_249	25 Year 24 Hour_SS_SLR	DuWapMH_331	DuWapN_79	22.37
P_25	25 Year 24 Hour_SS_SLR	DuWapN_43	DuWapN_224	8.84
P_250	25 Year 24 Hour_SS_SLR	DuWapMH_343	DuWapMH_260	34.03
P_251	25 Year 24 Hour_SS_SLR	DuWapMH_344	DuWapMH_261	34.62
P_252	25 Year 24 Hour_SS_SLR	DuWapMH_346	DuWapMH_262	34.84
P_255	25 Year 24 Hour_SS_SLR	DuWapN_273	DuWapMH_264	37.37
P_26	25 Year 24 Hour_SS_SLR	DuWapN_222	DuWapMH_74	4.93
P_260	25 Year 24 Hour_SS_SLR	DuWapMH_361	DuWapMH_144	6.66
P_261	25 Year 24 Hour_SS_SLR	DuWapMH_362	DuWapMH_268	6.67
P_262	25 Year 24 Hour_SS_SLR	DuWapMH_386	DuWapMH_269	6.73
P_263	25 Year 24 Hour_SS_SLR	DuWapN_1	DuWapMH_270	10.21
P_264	25 Year 24 Hour_SS_SLR	DuWapMH_271	DuWapMH_397	0
P_265	25 Year 24 Hour_SS_SLR	DuWapMH_272	DuWapMH_400	0
P_266	25 Year 24 Hour_SS_SLR	DuWapMH_399	DuWapMH_273	0
P_267	25 Year 24 Hour_SS_SLR	DuWapMH_379	DuWapMH_274	25.05
P_268	25 Year 24 Hour_SS_SLR	DuWapMH_279	DuWapMH_275	120.04
P_269	25 Year 24 Hour_SS_SLR	DuWapMH_280	DuWapMH_276	119.86
P_27	25 Year 24 Hour_SS_SLR	DuWapN_22	DuWapMH_74	15.57
P_270	25 Year 24 Hour_SS_SLR	DuWapMH_334	DuWapMH_277	112.96
P_271	25 Year 24 Hour_SS_SLR	DuWapMH_334	DuWapMH_277	112.14
P_272	25 Year 24 Hour_SS_SLR	DuWapMH_214	DuWapN_32	31.89
P_273	25 Year 24 Hour_SS_SLR	DuWapMH_275	DuWapMH_278	119.6
P_274	25 Year 24 Hour_SS_SLR	DuWapMH_276	DuWapMH_278	119.46
P_275	25 Year 24 Hour_SS_SLR	DuWapN_32	DuWapMH_279	119.59
P_276	25 Year 24 Hour_SS_SLR	DuWapN_32	DuWapMH_280	119.45
P_277	25 Year 24 Hour_SS_SLR	DuWapN_240	DuWapMH_281	12.96
P_278	25 Year 24 Hour_SS_SLR	DuWapMH_152	DuWapMH_282	12.58
P_279	25 Year 24 Hour_SS_SLR	DuWapMH_154	DuWapMH_156	81.01
P_28	25 Year 24 Hour_SS_SLR	DuWapMH_74	DuWapMH_73	10.14
P_280	25 Year 24 Hour_SS_SLR	DuWapMH_154	DuWapMH_156	81.09
P_288	25 Year 24 Hour_SS_SLR	DuWapMH_416	DuWapMH_288	12.49
P_289	25 Year 24 Hour_SS_SLR	DuWapN_15	DuWapMH_289	118.72
P_29	25 Year 24 Hour_SS_SLR	DuWapN_16	DuWapMH_154	102.74
P_290	25 Year 24 Hour_SS_SLR	DuWapN_20	DuWapMH_243	11.09
P_291	25 Year 24 Hour_SS_SLR	DuWapMH_393	DuWapMH_290	7.04
P_292	25 Year 24 Hour_SS_SLR	DuWapMH_371	DuWapMH_291	7.14
P_293	25 Year 24 Hour_SS_SLR	DuWapMH_291	DuWapMH_292	7.14
P_294	25 Year 24 Hour_SS_SLR	DuWapMH_370	DuWapMH_293	43.97
P_295	25 Year 24 Hour_SS_SLR	DuWapMH_426	DuWapN_26	4.55
P_296	25 Year 24 Hour_SS_SLR	DuWapMH_390	DuWapMH_294	7.59
P_297	25 Year 24 Hour_SS_SLR	DuWapMH_392	DuWapMH_295	7.82
P_298	25 Year 24 Hour_SS_SLR	DuWapMH_391	DuWapMH_296	7.79
P_299	25 Year 24 Hour_SS_SLR	DuWapN_49	DuWapMH_297	8.23

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_3	25 Year 24 Hour_SS_SLR	DuWapMH_70	DuWapMH_118	28.93
P_30	25 Year 24 Hour_SS_SLR	DuWapMH_402	DuWapMH_75	20.25
P_300	25 Year 24 Hour_SS_SLR	DuWapMH_306	DuWapMH_298	29.77
P_301	25 Year 24 Hour_SS_SLR	DuWapMH_364	DuWapMH_299	73.08
P_302	25 Year 24 Hour_SS_SLR	DuWapMH_367	DuWapMH_500	48.32
P_303	25 Year 24 Hour_SS_SLR	DuWapMH_368	DuWapMH_301	63.1
P_304	25 Year 24 Hour_SS_SLR	DuWapMH_377	DuWapMH_302	6.04
P_305	25 Year 24 Hour_SS_SLR	DuWapN_234	DuWapMH_339	60.63
P_306	25 Year 24 Hour_SS_SLR	DuWapMH_308	DuWapMH_304	44.34
P_307	25 Year 24 Hour_SS_SLR	DuWapMH_417	DuWapMH_305	20.97
P_308	25 Year 24 Hour_SS_SLR	DuWapMH_339	DuWapMH_306	29.77
P_309	25 Year 24 Hour_SS_SLR	DuWapMH_298	DuWapMH_307	29.76
P_31	25 Year 24 Hour_SS_SLR	DuWapMH_21	DuWapMH_155	38.09
P_310	25 Year 24 Hour_SS_SLR	DuWapMH_304	DuWapMH_307	44.34
P_311	25 Year 24 Hour_SS_SLR	DuWapMH_339	DuWapMH_308	44.35
P_312	25 Year 24 Hour_SS_SLR	DuWapMH_411	DuWapMH_309	20.62
P_313	25 Year 24 Hour_SS_SLR	DuWapMH_410	DuWapMH_310	20.15
P_314	25 Year 24 Hour_SS_SLR	DuWapMH_141	DuWapMH_311	21.46
P_315	25 Year 24 Hour_SS_SLR	DuWapMH_409	DuWapMH_312	21.2
P_316	25 Year 24 Hour_SS_SLR	DuWapMH_218	DuWapMH_313	9.75
P_318	25 Year 24 Hour_SS_SLR	DuWapN_37	DuWapMH_315	17.2
P_32	25 Year 24 Hour_SS_SLR	DuWapMH_75	DuWapMH_155	4.55
P_320	25 Year 24 Hour_SS_SLR	DuWapN_36	DuWapMH_317	20.39
P_33	25 Year 24 Hour_SS_SLR	DuWapMH_155	DuWapMH_156	34.81
P_333	25 Year 24 Hour_SS_SLR	DuWapMH_30	DuWapMH_82	1.5
P_334	25 Year 24 Hour_SS_SLR	DuWapMH_30	DuWapMH_82	1.54
P_337	25 Year 24 Hour_SS_SLR	DuWapMH_82	DuWapMH_93	1.49
P_338	25 Year 24 Hour_SS_SLR	DuWapMH_82	DuWapMH_93	1.49
P_34	25 Year 24 Hour_SS_SLR	DuWapMH_75	DuWapMH_156	36.01
P_35	25 Year 24 Hour_SS_SLR	DuWapMH_22	DuWapMH_75	21.17
P_36	25 Year 24 Hour_SS_SLR	DuWapMH_220	DuWapMH_21	36.37
P_37	25 Year 24 Hour_SS_SLR	DuWapMH_220	DuWapMH_22	21.31
P_38	25 Year 24 Hour_SS_SLR	DuWapN_34	DuWapMH_77	56.61
P_39	25 Year 24 Hour_SS_SLR	DuWapMH_77	DuWapN_334	55.64
P_4	25 Year 24 Hour_SS_SLR	DuWapMH_315	DuWapMH_146	28.99
P_40	25 Year 24 Hour_SS_SLR	DuWapN_73	DuWapMH_157	18.53
P_41	25 Year 24 Hour_SS_SLR	DuWapMH_80	DuWapMH_79	11.75
P_42	25 Year 24 Hour_SS_SLR	DuWapMH_79	DuWapMH_158	11.65
P_43	25 Year 24 Hour_SS_SLR	DuWapMH_27	DuWapMH_159	6.8
P_44	25 Year 24 Hour_SS_SLR	DuWapMH_159	DuWapN_212	12.41
P_45	25 Year 24 Hour_SS_SLR	DuWapN_212	DuWapN_211a	17.83
P_46	25 Year 24 Hour_SS_SLR	DuWapN_12	DuWapMH_159	6.82
P_47	25 Year 24 Hour_SS_SLR	DuWapN_211a	DuWapMH_28	13.2
P_48	25 Year 24 Hour_SS_SLR	DuWapMH_28	DuWapN_312	13.2
P_49	25 Year 24 Hour_SS_SLR	DuWapMH_61	DuWapN_211b	8.18
P_5	25 Year 24 Hour_SS_SLR	DuWapMH_329	DuWapMH_147	28.91
P_50	25 Year 24 Hour_SS_SLR	DuWapMH_61	DuWapN_211b	8.12
P_51	25 Year 24 Hour_SS_SLR	DuWapN_312	DuWapMH_118	34.9

Link Name	Simulation	From Node Name	To Node Name	Maximum Flow Rate [cfs]
P_52	25 Year 24 Hour_SS_SLR	DuWapMH_332	DuWapMH_3	7.3
P_53	25 Year 24 Hour_SS_SLR	DuWapMH_385	DuWapMH_86	25.65
P_54	25 Year 24 Hour_SS_SLR	DuWapMH_369	DuWapMH_162	48.26
P_55	25 Year 24 Hour_SS_SLR	DuWapMH_10	DuWapMH_446	34.2
P_56	25 Year 24 Hour_SS_SLR	DuWapMH_137	DuWapMH_30	2.94
P_59	25 Year 24 Hour_SS_SLR	DuWapMH_93	DuWapMH_31	3.25
P_60	25 Year 24 Hour_SS_SLR	DuWapMH_20	DuWapMH_81	11.16
P_61	25 Year 24 Hour_SS_SLR	DuWapMH_81	DuWapMH_31	11.06
P_64	25 Year 24 Hour_SS_SLR	DuWapMH_437	DuWapN_250	17.01
P_65	25 Year 24 Hour_SS_SLR	DuWapMH_33	DuWapMH_85	23.36
P_66	25 Year 24 Hour_SS_SLR	DuWapN_324	DuWapMH_33	23.4
P_67	25 Year 24 Hour_SS_SLR	DuWapN_324	DuWapMH_34	23.34
P_69	25 Year 24 Hour_SS_SLR	DuWapMH_34	DuWapMH_84	23.29
P_7	25 Year 24 Hour_SS_SLR	DuWapMH_351	DuWapMH_92	24.85
P_70	25 Year 24 Hour_SS_SLR	DuWapMH_84	DuWapMH_171	23.26
P_71	25 Year 24 Hour_SS_SLR	DuWapMH_85	DuWapMH_171	23.32
P_72	25 Year 24 Hour_SS_SLR	DuWapMH_86	DuWapMH_172	25.64
P_73	25 Year 24 Hour_SS_SLR	DuWapN_6	DuWapMH_363	22.46
P_74	25 Year 24 Hour_SS_SLR	DuWapMH_36	DuWapMH_174	12.61
P_75	25 Year 24 Hour_SS_SLR	DuWapN_9	DuWapMH_36	12.61
P_76	25 Year 24 Hour_SS_SLR	DuWapMH_108	DuWapMH_27	6.81
P_77	25 Year 24 Hour_SS_SLR	DuWapMH_99	DuWapMH_175	10.57
P_78	25 Year 24 Hour_SS_SLR	DuWapMH_99	DuWapMH_175	10.81
P_8	25 Year 24 Hour_SS_SLR	DuWapMH_330	DuWapMH_92	11.3
P_80	25 Year 24 Hour_SS_SLR	DuWapMH_87	DuWapN_274	90.12
P_81	25 Year 24 Hour_SS_SLR	DuWapN_82	DuWapMH_177	34.38
P_82	25 Year 24 Hour_SS_SLR	DuWapN_53	DuWapN_74	19.68
P_84	25 Year 24 Hour_SS_SLR	DuWapN_62	DuWapMH_199	8.42
P_85	25 Year 24 Hour_SS_SLR	DuWapN_30	DuWapMH_180	39.45
P_86	25 Year 24 Hour_SS_SLR	DuWapN_230	DuWapMH_40	12.15
P_87	25 Year 24 Hour_SS_SLR	DuWapMH_40	DuWapMH_181	12.16
P_88	25 Year 24 Hour_SS_SLR	DuWapN_65	DuWapN_43	2.88
P_89	25 Year 24 Hour_SS_SLR	DuWapMH_41	DuWapMH_398	0
P_9	25 Year 24 Hour_SS_SLR	DuWapMH_92	DuWapMH_88	28.16
P_91	25 Year 24 Hour_SS_SLR	DuWapN_25	DuWapMH_56	17.13
P_92	25 Year 24 Hour_SS_SLR	DuWapMH_56	DuWapMH_182	17.11
P_93	25 Year 24 Hour_SS_SLR	DuWapMH_45	DuWapN_238	4.07
P_94	25 Year 24 Hour_SS_SLR	DuWapMH_404	DuWapMH_45	4.07
P_95	25 Year 24 Hour_SS_SLR	DuWapMH_130	DuWapMH_184	5.71
P_98	25 Year 24 Hour_SS_SLR	DuWapMH_73	DuWapMH_186	10.09
P_99	25 Year 24 Hour_SS_SLR	DuWapMH_213	DuWapN_240	9.34

Appendix R Capital Improvements Cost Estimate

Appendix R - Link Improvements

Area	Asset	Length	Dia-Pre	Dia-Post	Count-Pre	Count-Post	Flow-Direction-Pre	Flow-Direction-Post	US-Elev-Pre	US-Elev-Post	DS-Elev-Pre	DS-Elev-Post	Weir L Pre	Weir L Post	Remarks
1	Channel_125	124 ft													See Channel Improvements
1	Channel_126	38 ft													See Channel Improvements
1	Channel_127	51 ft													See Channel Improvements
1	Channel_67	413 ft													See Channel Improvements
1	Channel_29	30 ft													See Channel Improvements
1	Channel_30	33 ft													See Channel Improvements
1	Channel_31	15 ft													See Channel Improvements
1	Channel_32	31 ft													See Channel Improvements
1	Channel_33	34 ft													See Channel Improvements
1	Channel_34	47 ft													See Channel Improvements
1	Channel_35	38 ft													See Channel Improvements
1	Channel_36	28 ft													See Channel Improvements
1	Channel_40	75 ft													See Channel Improvements
1	Channel_6	65 ft													See Channel Improvements
1	**TOTAL Channels Area-1**	**1022 ft**													
1	P_191	62 ft	1.25 ft	3.00 ft	1	2									
1	P_192	77 ft	1.25 ft	2.50 ft											
1	P_238	64 ft	4.00 ft	5.00 ft	2	3									
1	P_240	32 ft	1.25 ft	2.50 ft											
1	P_241	27 ft	1.25 ft	2.50 ft											
1	P_242	24 ft	1.25 ft	2.50 ft											
1	P_243	28 ft	1.25 ft	2.50 ft											
1	P_244	21 ft	1.25 ft	2.50 ft											
1	P_245	19 ft	1.25 ft	2.50 ft											
1	P_246	24 ft	1.50 ft	2.50 ft											
1	P_247	22 ft	1.50 ft	2.50 ft											
1	P_248	12 ft	1.25 ft	2.50 ft											
1	P_249	49 ft	2.00 ft	3.00 ft	1	2									
1	P_250	16 ft	2.00 ft	3.00 ft	1	2									
1	P_251	17 ft	2.00 ft	3.00 ft											
1	P_252	45 ft	2.00 ft	3.00 ft											
1	P_255	100 ft	2.00 ft	3.00 ft											
1	P_52	22 ft	2.00 ft	3.00 ft											
1	P_9	542 ft	3.00 ft	3.50 ft											
1	P_12	544 ft	3.00 ft	3.50 ft											
1	**TOTAL Pipes Area-1**	**661 ft**													
2	DS_102 Weir Width	Weir											4.00 ft	2.00 ft	
2	L-0280P	237 ft							10.60 ft	4.89 ft					Changed upstream invert
2	P_105	160 ft	2.00 ft	3.00 ft											
2	P_108	251 ft	2.00 ft	4.00 ft											
2	P_109	230 ft	2.00 ft	4.00 ft											
2	P_184	14 ft	3.50 ft	4.00 ft											
2	P_195	895 ft	3.50 ft	3.50 ft			Bi-Directional	Positive Only							
2	P_219	249 ft	4.00 ft	4.00 ft			Bi-Directional	Positive Only							
2	P_267	48 ft	3.00 ft	4.00 ft											
2	**TOTAL Pipes Area-2**	**2084 ft**													
3	DS_78 Weir Width	Weir	4.00 ft	2.00 ft											
3	L-0600P	578 ft			1	2	Bi-Directional	Positive Only							
3	P_53	816 ft			1	2									
3	P_72	32 ft	1.50 ft	2.50 ft	1	2									
3	P_150	85 ft	2.50 ft	4.00 ft											
3	P_151	24 ft	3.00 ft	4.00 ft											
3	P_152	294 ft	3.00 ft	4.00 ft											
3	P_162	139 ft	3.50 ft	4.00 ft											
3	Channel_67	413 ft													
3	**TOTAL Pipes Area-3**	**1968 ft**													
4	Channel_65	28 ft					Bi-Directional	Positive Only							
4	**TOTAL Channels Area-4**	**28 ft**													
4	P_228	376 ft					Bi-Directional	Positive Only							
4	P_229	320 ft					Bi-Directional	Positive Only							
4	P_230	377 ft					Bi-Directional	Positive Only							
4	P_68	DELETED													Deleted 2.55 to 2.56 @ 15 ft and 1.5 ft diameter
4	**TOTAL Pipes Area -4**	**1073 ft**													
5	Channel_12	325 ft							7.60 ft	8.63 ft					See Channel Improvements
5	**TOTAL Channels Area-5**	**325 ft**													
5	L-0380P	304 ft	2.00 ft	3.00 ft	1	2	Bi-Directional	Positive Only							
5	P_125	118 ft					Bi-Directional	Positive Only							
5	P_15	127 ft	2.00 ft	3.00 ft											
5	P_16	79 ft	1.50 ft	3.00 ft											

Appendix R - Link Improvements

Area	Asset	Length	Dia-Pre	Dia-Post	Count-Pre	Count-Post	Flow-Direction-Pre	Flow-Direction-Post	US-Elev-Pre	US-Elev-Post	DS-Elev-Pre	DS-Elev-Post	Weir L Pre	Weir L Post	Remarks
5	P_17	79 ft	1.50 ft	3.00 ft											
5	P_194	66 ft	2.00 ft	3.00 ft	1	2									
5	P_80	124 ft			1	2									
5	P_81	223 ft	2.00 ft	3.00 ft											
5	P_77	61 ft	2.00 ft	3.00 ft											
5	P_78	60 ft	2.00 ft	3.00 ft											
5	**TOTAL Pipes Area-5**	**1241 ft**													
6	Channel_13	795 ft							6.87 ft	6.25 ft	5.34 ft	5.34 ft			
6	Channel_42	732 ft							7.12 ft	7.12 ft	7.41 ft	6.32 ft			
6	**TOTAL Channels Area-6**	**1527 ft**													
6	L-0360P	277 ft	2.00 ft	3.00 ft											
6	P_134	49 ft							4.19 ft	6.32 ft	6.79 ft	6.28 ft			
6	P_135	103 ft							7.41 ft	6.32 ft	6.86 ft	6.25 ft			
6	P_136	54 ft							6.77 ft	6.28 ft	6.86 ft	6.25 ft			
6	P_136	54 ft	2.50 ft	3.00 ft											
6	P_199	260 ft	2.00 ft	3.00 ft											
6	P_79	Deleted													DELETED. L= 9 ft; 36"; 11.13 to 10.00 ft
6	P_80	124 ft	2.00 ft	3.00 ft											
6	P_81	223 ft	2.00 ft	2.00 ft	1	2									
6	**TOTAL Pipes Area-6**	**1144 ft**													
7	Channel_99	42 ft													See Channel Improvements
7	**TOTAL Channels Area-7**	**42 ft**													
7	P_101	22 ft	2.50 ft	3.00 ft											
7	P_102	23 ft	2.00 ft	3.00 ft											
7	P_117	27 ft	2.00 ft	3.00 ft											
7	P_118	17 ft	2.00 ft	3.00 ft											
7	P_196	72 ft	2.50 ft	3.00 ft											
7	P_197	305 ft	2.00 ft	3.00 ft											
7	P_305	43 ft	2.00 ft	3.00 ft			Bi-Directional	Positive Only							
7	P_307	24 ft	2.00 ft	3.00 ft											
7	P_312	21 ft	2.50 ft	3.00 ft											
7	P_313	25 ft	2.50 ft	3.00 ft											
7	P_314	44 ft	2.50 ft	3.00 ft											
7	P_315	38 ft	2.00 ft	3.00 ft											
7	P_39	178 ft	2.50 ft	3.00 ft											Upstream pipe is 4'
7	P_79	Deleted													DELETED. L= 9 ft; 36"; 11.13 to 10.00 ft
7	**TOTAL Pipes Area-7**	**839 ft**													
8	DS_103 Weir Width	Weir											4.00 ft	2.00 ft	
8	L-0100P	54 ft	1.50 ft	3.00 ft											
8	P_143	15 ft	1.50 ft	3.00 ft											
8	P_43	398 ft	1.50 ft	3.00 ft											
8	P_44	53 ft	1.50 ft	3.00 ft											
8	P_45	68 ft	1.50 ft	3.00 ft											
8	P_47	139 ft	2.00 ft	3.00 ft											
8	P_48	294 ft	1.50 ft	3.00 ft											
8	P_51	305 ft	2.50 ft	3.00 ft											
8	P_76	35 ft	1.25 ft	3.00 ft											
8	P_47	139 ft								15.05 ft		14.90 ft			
8	P_48	294 ft								14.90 ft		14.40 ft			
8	P_51	305 ft								14.40 ft		13.92 ft			
8	**TOTAL Pipes Area-8**	**1361 ft**													
9	Channel_52	64 ft							8.37 ft	8.45 ft	8.45 ft	8.40 ft			See Channel Improvements
9	**TOTAL Channels Area-9**	**64 ft**													
9	P_127	241 ft							8.54 ft	8.54 ft	8.37 ft	8.45 ft			
9	P_128	245 ft							8.54 ft	8.54 ft	8.37 ft	8.45 ft			
9	P_187	114 ft	2.00 ft	3.00 ft					8.45 ft	8.40 ft	8.32 ft	8.32 ft			
9	P_292	19 ft	1.50 ft	2.00 ft											
9	P_293	26 ft	1.50 ft	2.00 ft											
9	P_55	358 ft	1.50 ft	3.00 ft											
9	**TOTAL Pipes Area-9**	**1003 ft**													
10	Channel_81	254 ft					Bi-Directional	Positive Only							
10	**TOTAL Channels Area-10**	**254 ft**													
10	P_106	1315 ft					Bi-Directional	Positive Only							
10	P_227	179 ft					Bi-Directional	Positive Only							
10	**TOTAL Pipes Area-10**	**1494 ft**													
11	Channel_114	254 ft							5.11 ft	2.00 ft					
11	**TOTAL Channels Area-11**	**254 ft**													
11	DS_93a Weir Width	Weir											4.00 ft	2.00 ft	
11	DS_93b Weir Width	Weir											4.00 ft	2.00 ft	

Area	Asset	Length	Dia-Pre	Dia-Post	Count-Pre	Count-Post	Flow-Direction-Pre	Flow-Direction-Post	US-Elev-Pre	US-Elev-Post	DS-Elev-Pre	DS-Elev-Post	Weir L Pre	Weir L Post	Remarks
11	DS_94 Weir Width	Weir											3.00 ft	2.00 ft	
11	P_178	313 ft	2.00 ft	3.00 ft											
11	P_179	408 ft	2.50 ft	3.00 ft											
11	P_180	106 ft	2.00 ft	2.00 ft											
11	P_181	139 ft	2.00 ft	3.00 ft											
11	P_215	94 ft	2.00 ft	3.00 ft											
11	P_224	32 ft	1.50 ft	3.00 ft			Bi-Directional	Positive Only			5.11 ft	2.00 ft			Significant adverse slope
11	P_225	59 ft	2.00 ft	3.00 ft							4.23 ft	3.87 ft			
11	P_226	77 ft	2.00 ft	3.00 ft											
11	**TOTAL Pipes Area-11**	**1228 ft**													
	All Pipe Improvements	**14096 ft**													
	All Channel Improvements	**3516 ft**													

		Before				After			
	Area	Order	Station	Elevation (ft)	Mannings	Order	Station	Elevation (ft)	Mannings
Channel_6	1	2	15.34	10.431	0.035	2	15.34	10.431	0.035
	1	3	23	8.844	0.035	3	23	7.8	0.035
	1	4	30.67	8.277	0.035	4	30.67	7.8	0.035
	1	5	38.34	8.692	0.035	5	38.34	9	0.035
	1	6	46.01	8.884	0.035	6	46.01	9	0.035
	1	7	53.68	8.852	0.035	7	53.68	9	0.035
Channel_36	1	3	17.62	9.146	0.035	3	17.62	9	0.028
	1	4	23.5	7.5	0.035	4	23.5	7.5	0.028
	1	5	29.37	7.5	0.035	5	29.37	7	0.028
	1	6	35.25	8.5	0.035	6	35.25	7.5	0.028
	1	7	41.12	8.5	0.035	7	41.12	9	0.028
Channel_35	1	4	23.21	8.595	0.035	4	23.21	9	0.028
	1	5	29.01	7.4	0.035	5	29.01	7.5	0.028
	1	6	34.82	7.4	0.035	6	34.82	7	0.028
	1	7	40.62	8.3	0.035	7	40.62	7.5	0.028
	1	8	46.42	8.3	0.035	8	46.42	9	0.028
Channel_34	1	4	20.7	8.768	0.035	4	20.7	9	0.028
	1	5	25.87	8	0.035	5	25.87	7.5	0.028
	1	6	31.05	8	0.035	6	31.05	7	0.028
	1	7	36.22	8.531	0.035	7	36.22	7.5	0.028
	1	8	41.39	8.583	0.035	8	41.39	9	0.028
Channel_33	1	3	15.36	8.893	0.035	3	15.36	8.893	0.035
	1	4	20.48	8.699	0.035	4	20.48	7.2	0.035
	1	5	25.6	8.855	0.035	5	25.6	7.2	0.035
	1	6	30.72	8.925	0.035	6	30.72	8.925	0.035
	1	7	35.84	8.909	0.035	7	35.84	8.909	0.035
Channel_32	1	1	8.32	8.615	0.035	1	8.32	8.615	0.035
	1	2	16.65	8.271	0.035	2	16.65	7	0.035
	1	3	24.97	8.433	0.035	3	24.97	7	0.035
	1	4	33.3	8.581	0.035	4	33.3	8.581	0.035
Channel_29	1	3	15.7	8.486	0.035	3	15.7	8.486	0.035
	1	4	20.93	7.733	0.035	4	20.93	6.8	0.035
	1	5	26.16	7.838	0.035	5	26.16	6.8	0.035

		Before				After			
	Area	Order	Station	Elevation (ft)	Mannings	Order	Station	Elevation (ft)	Mannings
	1	6	31.39	7.933	0.035	6	31.39	7.933	0.035
	1	7	36.62	7.843	0.035	7	36.62	7.843	0.035
Channel_30	1	0	0	9.08	0.035	0	0	9.08	0.035
	1	1	9.05	8.866	0.035	1	9.05	8.866	0.035
	1	2	18.09	8.054	0.035	2	18.09	7	0.035
	1	3	27.14	8.392	0.035	3	27.14	7	0.035
	1	4	36.18	8.586	0.035	4	36.18	8.586	0.035
Channel_31	1	3	15.79	8.732	0.035	3	15.79	8.732	0.035
	1	4	21.05	8.618	0.035	4	21.05	8.618	0.035
	1	5	26.31	8.529	0.035	5	26.31	6.5	0.035
	1	6	31.58	8.544	0.035	6	31.58	6.5	0.035
	1	7	36.84	8.582	0.035	7	36.84	8.582	0.035
	1	8	42.1	8.636	0.035	8	42.1	8.636	0.035
Channel_127	1	3	18.67	8.201	0.035	3	18.67	8.201	0.035
	1	4	24.89	7.816	0.035	4	24.89	7.816	0.035
	1	5	31.11	7.192	0.035	5	31.11	7.192	0.035
	1	6	37.34	6.668	0.035	6	37.34	6.1	0.035
	1	7	43.56	7.495	0.035	7	43.56	6.1	0.035
	1	8	49.78	7.931	0.035	8	49.78	7.931	0.035
Channel_126	1	3	20.72	7.371	0.035	3	20.72	7.371	0.035
	1	4	27.63	7.308	0.035	4	27.63	7.308	0.035
	1	5	34.54	6.918	0.035	5	34.54	6.9	0.035
	1	6	41.45	6.994	0.035	6	41.45	6.9	0.035
	1	7	48.36	7.323	0.035	7	48.36	6.9	0.035
	1	8	55.27	7.441	0.035	8	55.27	7.441	0.035
Channel_61	2	1	7.62	9.846	0.028	1	7.62	9.846	0.028
	2	2	15.25	10.001	0.028	2	15.25	10.001	0.028
	2	3	22.87	9.268	0.028	3	22.87	8.5	0.028
	2	4	30.49	8.57	0.028	4	30.49	8.5	0.028
	2	5	38.12	8.416	0.028	5	38.12	8.5	0.028
	2	6	45.74	9.265	0.028	6	45.74	9.265	0.028
	2	7	53.37	9.792	0.028	7	53.37	9.792	0.028
	2	8	60.99	10.219	0.028	8	60.99	10.219	0.028

		Before				After			
	Area	Order	Station	Elevation (ft)	Mannings	Order	Station	Elevation (ft)	Mannings
Channel_122	2	2	17.68	7.393	0.035	2	17.68	7.393	0.035
	2	3	26.52	6.754	0.035	3	26.52	6.754	0.035
	2	4	35.35	4.042	0.035	4	35.35	3.5	0.035
	2	5	44.19	4.249	0.035	5	44.19	3.5	0.035
	2	6	53.03	6.424	0.035	6	53.03	5	0.035
	2	7	61.87	7.547	0.035	7	61.87	7.547	0.035
Channel_99	7	2	12.31	11.792	0.035	2	12.31	11.792	0.035
	7	3	18.46	10.813	0.035	3	18.46	10	0.035
	7	4	24.62	11.423	0.035	4	23	10	0.035
	7	5	30.77	11.68	0.035	5	30.77	11.68	0.035
	7	6	36.93	11.708	0.035	6	36.93	11.708	0.035
Channel_52	9	3	21.42	11.122	0.035	3	21.42	11.122	0.035
	9	4	28.56	11.087	0.035	4	28.56	11.087	0.035
	9	5	35.7	10.786	0.035	5	35.7	10	0.035
	9	6	42.83	10.607	0.035	6	42.83	10	0.035
	9	7	49.97	11.044	0.035	7	49.97	11.044	0.035
	9	8	57.11	11.371	0.035	8	57.11	11.371	0.035
Channel_40	1	6	42.11	6.984	0.035	6	42.11	6.984	0.035
		7	49.13	4.572	0.035	7	49.13	4.572	0.035
		8	56.15	2.037	0.035	8	56.15	2.037	0.035
		9	63.17	3.133	0.035	9	63.17	2.037	0.035
		10	70.19	5.594	0.035	10	70.19	2.037	0.035
		11	77.2	7.127	0.035	11	77.2	2.037	0.035
		12	84.22	7.267	0.035	12	84.22	7.267	0.035
		13	91.24	6.783	0.035	13	91.24	6.783	0.035
Channel_125	1	1	7	6.974	0.035	1	7	6.974	0.035
		2	13.99	6.856	0.035	2	13.99	6.856	0.035
		3	20.99	6.656	0.035	3	20.99	4.2	0.035
		4	27.99	4.843	0.035	4	27.99	4.2	0.035
		5	34.98	4.243	0.035	5	34.98	4.2	0.035
		6	41.98	7.149	0.035	6	41.98	7.149	0.035
Channel_12	5	6	37.5	10.5	0.028	6	37.5	11	0.028
	5	7	43.75	8.8	0.028	7	43.75	9	0.028

		Before				After			
	Area	Order	Station	Elevation (ft)	Mannings	Order	Station	Elevation (ft)	Mannings
	5	8	50	8.8	0.028	8	50	8	0.028
	5	9	56.25	8.855	0.028	9	56.25	8	0.028
	5	10	62.5	10.066	0.028	10	62.5	9	0.028
	5	11	68.75	10.389	0.028	11	68.75	11	0.028
Channel_69	3	2	12.76	8.042	0.035	2	12.76	8.042	0.028
	3	3	19.14	7.728	0.035	3	19.14	7.728	0.028
	3	4	25.52	7.285	0.035	4	25.52	7.285	0.028
	3	5	31.9	6.579	0.035	5	31.9	6	0.028
	3	6	38.28	6.018	0.035	6	38.28	6	0.028
	3	7	44.66	6.001	0.035	7	44.66	6	0.028
	3	8	51.04	6.792	0.035	8	51.04	6	0.028
	3	9	57.42	7.221	0.035	9	57.42	7.221	0.028
	3	10	63.8	7.423	0.035	10	63.8	7.423	0.028
	3	11	70.18	7.489	0.035	11	70.18	8	0.028
Channel_67	3	0	0	7.611	0.035	0	0	7.6	0.028
	3	1	8.7	7.471	0.035	1	8.7	7	0.028
	3	2	17.39	4.726	0.035	2	17.39	2.8	0.028
	3	3	26.09	2.845	0.035	3	26.09	2.8	0.028
	3	4	34.79	4.872	0.035	4	34.79	2.8	0.028
	3	5	43.49	6.43	0.035	5	43.49	6.2	0.028
	3	6	52.18	6.188	0.035	6	52.18	7.6	0.028
Channel_11	5	6	37.64	12.109	0.035	6	37.64	12.109	0.028
	5	7	43.92	12.168	0.035	7	43.92	12.168	0.028
	5	8	50.19	11.637	0.035	8	50.19	11.637	0.028
	5	9	56.47	10.826	0.035	9	56.47	9	0.028
	5	10	62.74	9.86	0.035	10	62.74	9	0.028
	5	11	69.02	10.345	0.035	11	69.02	9	0.028
	5	12	75.29	10.968	0.035	12	75.29	10.968	0.028
	5	13	81.56	10.967	0.035	13	81.56	12	0.028
	5	14	87.84	11.042	0.035	14	87.84	12	0.028

Appendix R - Addition of Storage

		Before		After	
	Area	**Elevation**	**Area**	**Elevation**	**Area**
DuWapN_59	1	11.39	9.85	11.39	10.25
	1	12.39	12.39	12.39	12.39
	1	13.39	13.27	13.39	13.27
	1	14.39	13.56	14.39	13.56
DuWapN_93	11	5.56	0.01	5.56	0.09
	11	6.06	0.04	6.06	0.18
	11	7.06	0.06	7.06	0.2
	11	8.06	0.08	8.06	0.23
	11	9.06	0.12	9.06	0.25
	11	10.21	0.27	10.21	0.27
DuWapN_94		7.42	0.001	7.42	0.1
		8.42	0.06	8.42	0.16
		9.42	0.15	9.42	0.18
		9.98	0.2	9.98	0.2
DuWapMH_249	1	4.67	0.14	2.63	0.14
		5.67	0.22	3.63	0.22
		6.67	0.38	4.67	0.38
				5.67	0.5
				6.67	0.8
DuWapMH_257		None		7.64	0.01
				8.5	0.05
DuWapMH_256		None		7.48	0.01
				8.26	0.05
DuWapMH_254		None		7.3	0.01
				8.75	0.05
DuWapMH_255		None		7.22	0.01
				9.26	0.05
DuWapMH_253		None		7.03	0.01
				8.8	0.05
DuWapMH_250		None		6.84	0.01
				8.5	0.05
DuWapMH_251		None		6.67	0.01
				8.48	0.05
DuWapMH_252		None		6.5	0.01
				8.46	0.05
DuWapMH_221		None		6.22	0.01
				8.21	0.05
DuWapMH_258		None		5.72	0.01
				7.67	0.05
DuWapN_51		8.63	0.25	8.63	0.25
		9.132	0.4	9.132	0.4
		10.13	0.6	10.13	1
		11.13	2.4	11.13	2.5
		12.13	2.7	12.13	3
		13.13	3.47	13.13	4

		Before		After	
	Area	**Elevation**	**Area**	**Elevation**	**Area**
		14.13	4.6	14.13	5
DuWapMH_190		None		7.17	0.1
				10.09	0.2
DuWapMH_379				6.8	0.1
				10.2	0.2
DuWapMH_274				6.69	0.1
				9.6	0.2
DuWapMH_380				4.89	0.1
				7.4	0.2
DuWapN_82		6.95	0.63	6.95	0.8
		7.95	0.7	7.95	0.9
		8.95	0.7	8.95	1
		9.95	0.72	9.95	1.2
		10.37	0.74	10.37	1.3
DuWapN_34		18.3	1.64	14.8	0.002
		19.3	3.75	15.3	0.096
		20.3	6.46	16.3	0.409
		21.3	11.14	17.3	0.879
				18.3	1.644
				19.3	3.751
				20.3	6.455
				21.3	11.141
DuWapN_12		17.02	1.46	16.02	0.66
		18.02	2.41	17.02	1.46
		19.02	3.74	18.02	2.41
		20.02	5.41	19.02	3.74
				20.02	5.41
DuWapN_25		7.05	3.93	4.55	0.422
		8.05	5.48	5.55	0.971
		9.05	9.02	6.55	2.39
		10.05	14.41	7.55	3.93
				8.55	5.48
				9.55	9.022
				10.55	14.41
DuWapN_225		5.66	1.26	2.66	0.037
		6.66	2.18	3.66	0.179
		7.66	4.45	4.66	0.693
		8.66	7.64	5.66	1.256
				6.66	2.181
				7.66	4.454
				8.66	7.635
DuWapMH_238		3.55	0.35	0.96	0.1
		4.55	0.73	3.55	0.35
				4.55	0.73
DuWapMH_182		4.55	0.73	3.06	0.1

		Before		After	
	Area	Elevation	Area	Elevation	Area
		5.55	1.86	4.55	0.73
				5.55	1.86
DuWapMH_188		None		11.96	0.01
				13.14	0.05
DuWapMH_309		None		8.37	0.01
				12.55	0.05
DuWapMH_310		None		9.01	0.01
				12.5	0.05
DuWapMH_311		None		8.56	0.01
				11.8	0.05
DuWapMH_312		None		7.41	0.01
				11.5	0.05
DuWapMH_199		None		8.91	0.01
				11.25	0.05
DuWapMH_337				8.9	0.1
				9.9	0.2
				10.7	0.3
DuWapN_274		11.94	1.56	9.94	0.27
		12.94	1.84	10.94	0.88
		13.94	2.03	11.94	1.56
		14.94	2.18	12.94	1.84
				13.94	2.03
				14.94	2.18
DuWapN_103		14.89	0.001	14.89	0.05
		15.89	0.03	15.89	0.1
		16.89	0.03	16.89	0.15
		17.5	0.04	17.5	0.2
DuWapMH_77		None		10.13	0.01
				14.34	0.05
DuWapN_79	1	8.94	0.001	8.00	0.25
	1	9.44	0.94	9.44	0.75
	1	10.44	0.98	10.44	1.25
	1	11.44	1.04	11.44	1.75
	1	12.34	1.09	12.34	2.00
DuWapN_77		3.37	0.001	3.3	0.5
		3.87	2.92	4	3
		5.08	2.92	5	4
				6	5
DuWapN_78		4.75	0.5	4.75	0.5
		5.25	1.1	5.25	1.5
		6.33	1.3	6.33	2.25
				7.5	2.5
DuWapMH_99	5	10.54	1.65	8.05	2
		11.54	6.49	9	3
				10.54	4

APPENDIX-R Capital Improvements Cost Estimate

Area	Asset	Length	Dia-Pre	Dia-Post*	Crew Days	Crew Costs/Day	Pipe Costs (per foot dia)	Erosion Control Mat (per LF)	Gate	OH+Contingency	Total	Comments**
						4,000	110	10	1000	20%		
1	P_191	51 ft	1.25 ft	2.50 ft	1.13	$ 4,533	$ 14,453	$ 510		$ 2,993	$ 22,489	
1	P_192	77 ft	1.25 ft	2.50 ft	1.71	$ 6,844	$ 21,821	$ 770		$ 4,518	$ 33,953	
1	P_238	126 ft	4.00 ft	4.00 ft	8.40	$ 33,600	$ 54,049	$ 1,260		$ 11,062	$ 99,971	***Parallel Pipes***
1	P_240	32 ft	1.25 ft	2.50 ft	0.71	$ 2,844	$ 9,068	$ 320		$ 1,878	$ 14,110	
1	P_241	27 ft	1.25 ft	2.50 ft	0.60	$ 2,400	$ 7,651	$ 270		$ 1,584	$ 11,906	
1	P_242	24 ft	1.25 ft	2.50 ft	0.53	$ 2,133	$ 6,801	$ 240		$ 1,408	$ 10,583	
1	P_243	28 ft	1.25 ft	2.50 ft	0.62	$ 2,489	$ 7,935	$ 280		$ 1,643	$ 12,347	
1	P_244	21 ft	1.25 ft	2.50 ft	0.47	$ 1,867	$ 5,951	$ 210		$ 1,232	$ 9,260	
1	P_245	19 ft	1.25 ft	2.50 ft	0.42	$ 1,689	$ 5,384	$ 190		$ 1,115	$ 8,378	
1	P_246	24 ft	1.50 ft	2.50 ft	0.53	$ 2,133	$ 6,801	$ 240		$ 1,408	$ 10,583	
1	P_247	22 ft	1.50 ft	2.50 ft	0.49	$ 1,956	$ 6,235	$ 220		$ 1,291	$ 9,701	
1	P_248	12 ft	1.25 ft	2.50 ft	0.27	$ 1,067	$ 3,401	$ 120		$ 704	$ 5,291	
1	P_249	49 ft	2.00 ft	3.00 ft	1.23	$ 4,900	$ 15,490	$ 490		$ 3,196	$ 24,076	
1	P_250	16 ft	2.00 ft	3.00 ft	0.40	$ 1,600	$ 5,058	$ 160		$ 1,044	$ 7,862	
1	P_251	17 ft	2.00 ft	3.00 ft	0.43	$ 1,700	$ 5,374	$ 170		$ 1,109	$ 8,353	
1	P_252	53 ft	2.00 ft	3.00 ft	1.33	$ 5,300	$ 16,754	$ 530		$ 3,457	$ 26,041	
1	P_255	93 ft	2.00 ft	3.00 ft	2.33	$ 9,300	$ 29,399	$ 930		$ 6,066	$ 45,695	
1	P_52	22 ft	2.00 ft	3.00 ft	0.55	$ 2,200	$ 6,955	$ 220		$ 1,435	$ 10,810	
1	**TOTAL Pipes Area-1**	**713 ft**									**$ 371,408**	
2	L-0280P	251 ft			6.28	$ 25,100	$ -	$ 2,510		$ 502	$ 28,112	***Changed upstream invert, Pipe relaying to change slope***
2	P_105	153 ft	2.00 ft	3.00 ft	3.83	$ 15,300	$ 48,367	$ 1,530		$ 9,979	$ 75,176	
2	P_108	236 ft	2.00 ft	4.00 ft	7.9	$ 31,467	$ 101,235	$ 2,360		$ 20,719	$ 155,780	
2	P_109	230 ft	2.00 ft	4.00 ft	7.7	$ 30,667	$ 98,661	$ 2,300		$ 20,192	$ 151,820	
2	P_184	7 ft	3.50 ft	4.00 ft	0.2	$ 933	$ 3,003	$ 70		$ 615	$ 4,621	
2	P_195	879 ft	3.50 ft	3.50 ft	4.0	$ 16,000	$ -	$ -	$ 3,500	$ -	$ 19,500	***Gate***
2	P_219	249 ft	4.00 ft	4.00 ft	4.0	$ 16,000	$ -	$ -	$ 4,000	$ -	$ 20,000	***Gate***
2	P_267	32 ft	3.00 ft	4.00 ft	1.1	$ 4,267	$ 13,727	$ 320		$ 2,809	$ 21,123	
2	**TOTAL Pipes Area-2**	**2037 ft**									**$ 476,131**	
3	L-0600P	590 ft	4.50 ft	4.50 ft	16.9	$ 67,429	$ 313,254	$ 5,900	$ 8,000	$ 63,831	$ 458,413	***Parallel Pipes & 2 Gate Valves***
3	P_72	16 ft			4.00	$ 16,000	$ -	$ -	$ 6,000	$ -	$ 22,000	***Gate***
3	P_150	85 ft	2.50 ft	4.00 ft	2.8	$ 11,333	$ 36,462	$ 850		$ 7,462	$ 56,107	
3	P_151	24 ft	3.00 ft	4.00 ft	0.8	$ 3,200	$ 10,295	$ 240		$ 2,107	$ 15,842	
3	P_152	294 ft	3.00 ft	4.00 ft	9.8	$ 39,200	$ 126,114	$ 2,940		$ 25,811	$ 194,065	
3	P_162	139 ft	3.50 ft	4.00 ft	4.6	$ 18,533	$ 59,625	$ 1,390		$ 12,203	$ 91,752	
3	**TOTAL Pipes Area-3**	**1148 ft**	**Gate**								**$ 838,179**	
4	P_70	16 ft			4.00	$ 16,000	$ -	$ -	$ 6,000	$ -	$ 22,000	***Gate***
4	P_71	16 ft			4.00	$ 16,000	$ -	$ -	$ 6,000	$ -	$ 22,000	***Gate***
4	P_228	376 ft			4.00	$ 16,000	$ -	$ -	$ 6,000	$ -	$ 22,000	***Gate***
4	P_229	320 ft			4.00	$ 16,000	$ -	$ -	$ 6,000	$ -	$ 22,000	***Gate***
4	P_230	377 ft			4.00	$ 16,000	$ -	$ -	$ 6,000	$ -	$ 22,000	***Gate***
4	**TOTAL Pipes Area -4**	**1073 ft**									**$ 110,000**	
5	L-0380P	231 ft	2.00 ft	3.00 ft	5.78	$ 23,100	$ 73,024	$ 2,310	$ 6,000	$ 15,067	$ 119,501	***2 Gate***
5	P_125	16 ft			2.00	$ 8,000	$ -	$ -	$ 3,000	$ -	$ 11,000	***Gate***
5	P_15	127 ft	2.00 ft	3.00 ft	3.18	$ 12,700	$ 40,147	$ 1,270		$ 8,283	$ 62,401	
5	P_16	57 ft	1.50 ft	3.00 ft	1.43	$ 5,700	$ 18,019	$ 570		$ 3,718	$ 28,007	
5	P_17	58 ft	1.50 ft	3.00 ft	1.45	$ 5,800	$ 18,335	$ 580		$ 3,783	$ 28,498	
5	P_194	61 ft	2.00 ft	3.00 ft	1.53	$ 6,100	$ 19,283	$ 610		$ 3,979	$ 29,972	
5	P_77	61 ft	2.00 ft	3.00 ft	1.53	$ 6,100	$ 19,283	$ 610		$ 3,979	$ 29,972	
5	P_78	60 ft	2.00 ft	3.00 ft	1.50	$ 6,000	$ 18,967	$ 600		$ 3,913	$ 29,481	
5	**TOTAL Pipes Area-5**	**671 ft**									**$ 338,832**	
6	L-0360P	143 ft	2.00 ft	3.00 ft	3.58	$ 14,300	$ 45,205	$ 1,430		$ 9,327	$ 70,263	
6	P_134	45 ft	2.50 ft	3.00 ft	1.13	$ 4,500	$ 14,225	$ 450		$ 2,935	$ 22,111	
6	P_135	70 ft	2.50 ft	4.00 ft	1.75	$ 7,000	$ 30,027	$ 700		$ 6,145	$ 43,873	
6	P_136	26 ft	2.50 ft	3.00 ft	0.65	$ 2,600	$ 8,219	$ 260		$ 1,696	$ 12,775	
6	P_199	259 ft	2.00 ft	3.00 ft	6.48	$ 25,900	$ 81,876	$ 2,590		$ 16,893	$ 127,259	
6	P_80	121 ft	2.00 ft	3.00 ft	3.03	$ 12,100	$ 38,251	$ 1,210		$ 7,892	$ 59,453	
6	P_81	130 ft	2.00 ft	2.00 ft	2.60	$ 10,400	$ 32,741	$ 1,300		$ 6,808	$ 51,250	***Parallel Pipes***

APPENDIX-R Capital Improvements Cost Estimate

Area	Asset	Length	Dia-Pre	Dia-Post*	Crew Days	Crew Costs/Day	Pipe Costs (per foot dia)	Erosion Control Mat (per LF)	Gate	OH+Contingency	Total	Comments**
6	**TOTAL Pipes Area-6**	**794 ft**									**$ 386,982**	
7	P_101	22 ft	2.50 ft	3.00 ft	0.55	$ 2,200	$ 6,955	$ 220		$ 1,435	$ 10,810	
7	P_102	23 ft	2.00 ft	3.00 ft	0.58	$ 2,300	$ 7,271	$ 230		$ 1,500	$ 11,301	
7	P_117	27 ft	2.00 ft	3.00 ft	0.68	$ 2,700	$ 8,535	$ 270		$ 1,761	$ 13,266	
7	P_118	17 ft	2.00 ft	3.00 ft	0.43	$ 1,700	$ 5,374	$ 170		$ 1,109	$ 8,353	
7	P_196	72 ft	2.50 ft	3.00 ft	1.80	$ 7,200	$ 22,761	$ 720		$ 4,696	$ 35,377	
7	P_197	305 ft	2.00 ft	3.00 ft	7.63	$ 30,500	$ 96,417	$ 3,050		$ 19,893	$ 149,861	
7	P_305	24 ft	2.00 ft	3.00 ft	0.60	$ 2,400	$ 7,587	$ 240	$ 3,000	$ 1,565	$ 14,792	***Gate***
7	P_307	24 ft	2.00 ft	3.00 ft	0.60	$ 2,400	$ 7,587	$ 240		$ 1,565	$ 11,792	
7	P_312	21 ft	2.50 ft	3.00 ft	0.53	$ 2,100	$ 6,639	$ 210		$ 1,370	$ 10,318	
7	P_313	25 ft	2.50 ft	3.00 ft	0.63	$ 2,500	$ 7,903	$ 250		$ 1,631	$ 12,284	
7	P_314	44 ft	2.50 ft	3.00 ft	1.10	$ 4,400	$ 13,909	$ 440		$ 2,870	$ 21,619	
7	P_315	38 ft	2.00 ft	3.00 ft	0.95	$ 3,800	$ 12,013	$ 380		$ 2,479	$ 18,671	
7	P_39	178 ft	2.50 ft	3.00 ft	4.45	$ 17,800	$ 56,270	$ 1,780		$ 11,610	$ 87,460	***Upstream pipe is 4'***
7	**TOTAL Pipes Area-7**	**820 ft**									**$ 405,904**	
8	L-0100P	42 ft	1.50 ft	3.00 ft	1.05	$ 4,200	$ 13,277	$ 420		$ 2,739	$ 20,637	
8	P_143	19 ft	1.50 ft	3.00 ft	0.48	$ 1,900	$ 6,006	$ 190		$ 1,239	$ 9,336	
8	P_43	398 ft	1.50 ft	3.00 ft	9.95	$ 39,800	$ 125,817	$ 3,980		$ 25,959	$ 195,556	
8	P_44	53 ft	1.50 ft	3.00 ft	1.33	$ 5,300	$ 16,754	$ 530		$ 3,457	$ 26,041	
8	P_45	68 ft	1.50 ft	3.00 ft	1.70	$ 6,800	$ 21,496	$ 680		$ 4,435	$ 33,412	
8	P_47	139 ft	2.00 ft	3.00 ft	3.48	$ 13,900	$ 43,941	$ 1,390		$ 9,066	$ 68,297	
8	P_48	294 ft	1.50 ft	3.00 ft	7.35	$ 29,400	$ 92,940	$ 2,940		$ 19,176	$ 144,456	
8	P_51	305 ft	2.50 ft	3.00 ft	7.63	$ 30,500	$ 96,417	$ 3,050		$ 19,893	$ 149,861	
8	P_76	35 ft	1.25 ft	3.00 ft	0.88	$ 3,500	$ 11,064	$ 350		$ 2,283	$ 17,197	
8	**TOTAL Pipes Area-8**	**1353 ft**									**$ 664,792**	
9	P_127	182 ft	2.00 ft	3.00 ft	4.55	$ 18,200	$ 57,534	$ 1,820		$ 11,871	$ 89,425	
9	P_128	182 ft	2.00 ft	3.00 ft	4.55	$ 18,200	$ 57,534	$ 1,820		$ 11,871	$ 89,425	
9	P_187	83 ft	2.00 ft	3.00 ft	2.08	$ 8,300	$ 26,238	$ 830		$ 5,414	$ 40,782	
9	P_292	19 ft	1.50 ft	2.00 ft	0.38	$ 1,520	$ 4,785	$ 190		$ 995	$ 7,490	
9	P_293	26 ft	1.50 ft	2.00 ft	0.52	$ 2,080	$ 6,548	$ 260		$ 1,362	$ 10,250	
9	P_55	357 ft	1.50 ft	3.00 ft	8.93	$ 35,700	$ 112,856	$ 3,570		$ 23,285	$ 175,411	
9	**TOTAL Pipes Area-9**	**849 ft**									**$ 412,783**	
10	P_106	1313 ft		3.00 ft	2.00	$ 8,000	$ -	$ -	$ 3,000	$ -	$ 11,000	***Gate***
10	P_222	16 ft			4.00	$ 16,000	$ -	$ -	$ 6,000	$ -	$ 22,000	***Gate***
10	P_227	127 ft		3.00 ft	4.00	$ 16,000	$ -	$ -	$ 3,000	$ -	$ 19,000	***Gate***
10	**TOTAL Pipes Area-10**	**1456 ft**									**$ 52,000**	
	All Pipe Improvements	**10914 ft**								TOTAL	$ 4,057,011	
											$ 372	**cost per LF of pipe**

APPENDIX-R Capital Improvements Cost Estimate

			Before				After										TOTAL
	Area	Length	Order	Station	Elevation (ft)	Mannings	Order	Station	Elevation (ft)	Mannings	δWidth (ft)	δElev (ft)	Regrade?	Average Width (ft)	Area (ac)	Volume Displaced (CY)	$ 20,000
Channel_6	1	65	2	15.34	10.431	0.035	2	15.34	10.431	0.035	0	0.00	FALSE	34.507	0.051	28.98	$ 1,000
	1		3	23.00	8.844	0.035	3	23.00	7.8	0.035	0	1.04	TRUE				
	1		4	30.67	8.277	0.035	4	30.67	7.8	0.035	0	0.48	TRUE				
	1		5	38.34	8.692	0.035	5	38.34	9	0.035	0	0.31	TRUE				
	1		6	46.01	8.884	0.035	6	46.01	9	0.035	0	0.12	TRUE				
	1		7	53.68	8.852	0.035	7	53.68	9	0.035	0	0.15	TRUE				
Channel_36	1	28	3	17.62	9.146	0.035	3	17.62	9.146	0.035	0	0.00	FALSE	29.372	0.019	5.64	$ 400
	1		4	23.50	7.711	0.035	4	23.50	7.5	0.035	0	0.21	TRUE				
	1		5	29.37	7.835	0.035	5	29.37	7.5	0.035	0	0.34	TRUE				
	1		6	35.25	8.287	0.035	6	35.25	8.5	0.035	0	0.21	TRUE				
	1		7	41.12	8.333	0.035	7	41.12	8.5	0.035	0	0.17	TRUE				
Channel_35	1	38	4	23.21	8.595	0.035	4	23.21	8.595	0.035	0	0.00	FALSE	34.816	0.030	11.63	$ 600
	1		5	29.01	7.736	0.035	5	29.01	7.4	0.035	0	0.34	TRUE				
	1		6	34.82	8.079	0.035	6	34.82	7.4	0.035	0	0.68	TRUE				
	1		7	40.62	8.258	0.035	7	40.62	8.3	0.035	0	0.04	TRUE				
	1		8	46.42	8.17	0.035	8	46.42	8.3	0.035	0	0.13	TRUE				
Channel_34	1	47	4	20.70	8.768	0.035	4	20.70	8.768	0.035	0	0.00	FALSE	31.046	0.033	10.18	$ 700
	1		5	25.87	8.527	0.035	5	25.87	8	0.035	0	0.53	TRUE				
	1		6	31.05	8.415	0.035	6	31.05	8	0.035	0	0.41	TRUE				
	1		7	36.22	8.531	0.035	7	36.22	8.531	0.035	0	0.00	FALSE				
	1		8	41.39	8.583	0.035	8	41.39	8.583	0.035	0	0.00	FALSE				
Channel_33	1	34	3	15.36	8.893	0.035	3	15.36	8.893	0.035	0	0.00	FALSE	25.600	0.020	20.34	$ 400
	1		4	20.48	8.699	0.035	4	20.48	7.2	0.035	0	1.50	TRUE				
	1		5	25.60	8.855	0.035	5	25.60	7.2	0.035	0	1.66	TRUE				
	1		6	30.72	8.925	0.035	6	30.72	8.925	0.035	0	0.00	FALSE				
	1		7	35.84	8.909	0.035	7	35.84	8.909	0.035	0	0.00	FALSE				
Channel_32	1	31	1	8.32	8.615	0.035	1	8.32	8.615	0.035	0	0.00	FALSE	20.81	0.015	12.92	$ 300
	1		2	16.65	8.271	0.035	2	16.65	7	0.035	0	1.27	TRUE				
	1		3	24.97	8.433	0.035	3	24.97	7	0.035	0	1.43	TRUE				
	1		4	33.30	8.581	0.035	4	33.30	8.581	0.035	0	0.00	FALSE				
Channel_29	1	30	3	15.70	8.486	0.035	3	15.70	8.486	0.035	0	0.00	FALSE	26.16	0.018	11.46	$ 400
	1		4	20.93	7.733	0.035	4	20.93	6.8	0.035	0	0.93	TRUE				
	1		5	26.16	7.838	0.035	5	26.16	6.8	0.035	0	1.04	TRUE				
	1		6	31.39	7.933	0.035	6	31.39	7.933	0.035	0	0.00	FALSE				
	1		7	36.62	7.843	0.035	7	36.62	7.843	0.035	0	0.00	FALSE				
++	1	33	0	0.00	9.08	0.035	0	0.00	9.08	0.035	0	0.00	FALSE	18.092	0.014	10.82	$ 300
	1		1	9.05	8.866	0.035	1	9.05	8.866	0.035	0	0.00	FALSE				
	1		2	18.09	8.054	0.035	2	18.09	7	0.035	0	1.05	TRUE				
	1		3	27.14	8.392	0.035	3	27.14	7	0.035	0	1.39	TRUE				
	1		4	36.18	8.586	0.035	4	36.18	8.586	0.035	0	0.00	FALSE				
Channel_31	1	15	3	15.79	8.732	0.035	3	15.79	8.732	0.035	0	0.00	FALSE	28.945	0.010	10.92	$ 200
	1		4	21.05	8.618	0.035	4	21.05	8.618	0.035	0	0.00	FALSE				
	1		5	26.31	8.529	0.035	5	26.31	6.5	0.035	0	2.03	TRUE				
	1		6	31.58	8.544	0.035	6	31.58	6.5	0.035	0	2.04	TRUE				
	1		7	36.84	8.582	0.035	7	36.84	8.582	0.035	0	0.00	FALSE				
	1		8	42.10	8.636	0.035	8	42.10	8.636	0.035	0	0.00	FALSE				
Channel_127	1	51	3	18.67	8.201	0.035	3	18.67	8.201	0.035	0	0.00	FALSE	34.225	0.040	21.15	$ 800
	1		4	24.89	7.816	0.035	4	24.89	7.816	0.035	0	0.00	FALSE				
	1		5	31.11	7.192	0.035	5	31.11	7.192	0.035	0	0.00	FALSE				
	1		6	37.34	6.668	0.035	6	37.34	6.1	0.035	0	0.57	TRUE				
	1		7	43.56	7.495	0.035	7	43.56	6.1	0.035	0	1.40	TRUE				
	1		8	49.78	7.931	0.035	8	49.78	7.931	0.035	0	0.00	FALSE				
Channel_126	1	47	3	20.72	7.371	0.035	3	20.72	7.371	0.035	0	0.00	FALSE	37.995	0.041	5.90	$ 800
	1		4	27.63	7.308	0.035	4	27.63	7.308	0.035	0	0.00	FALSE				
	1		5	34.54	6.918	0.035	5	34.54	6.9	0.035	0	0.02	TRUE				
	1		6	41.45	6.994	0.035	6	41.45	6.9	0.035	0	0.09	TRUE				
	1		7	48.36	7.323	0.035	7	48.36	6.9	0.035	0	0.42	TRUE				

APPENDIX-R Capital Improvements Cost Estimate

			Before				After										TOTAL
	Area	Length	Order	Station	Elevation (ft)	Mannings	Order	Station	Elevation (ft)	Mannings	δWidth (ft)	δElev (ft)	Regrade?	Average Width (ft)	Area (ac)	Volume Displaced (CY)	$ 20,000
	1		8	55.27	7.441	0.035	8	55.27	7.441	0.035	0	0.00	FALSE				
Channel_61	2		1	7.62	9.846	0.028	1	7.62	9.846	0.028	0	0.00	FALSE				
	2		2	15.25	10.001	0.028	2	15.25	10.001	0.028	0	0.00	FALSE				
	2		3	22.87	9.268	0.028	3	22.87	8.5	0.028	0	0.77	TRUE				
	2		4	30.49	8.57	0.028	4	30.49	8.5	0.028	0	0.07	TRUE				
	2	210	5	38.12	8.416	0.028	5	38.12	8.5	0.028	0	0.08	TRUE	34.306	0.165	30.75	$ 3,300
	2		6	45.74	9.265	0.028	6	45.74	9.265	0.028	0	0.00	FALSE				
	2		7	53.37	9.792	0.028	7	53.37	9.792	0.028	0	0.00	FALSE				
	2		8	60.99	10.219	0.028	8	60.99	10.219	0.028	0	0.00	FALSE				
Channel_122	2		2	17.68	7.393	0.035	2	17.68	7.393	0.035	0	0.00	FALSE				
	2		3	26.52	6.754	0.035	3	26.52	6.754	0.035	0	0.00	FALSE				
	2	400	4	35.35	4.042	0.035	4	35.35	3.5	0.035	0	0.54	TRUE	39.773	0.365	266.63	$ 7,300
	2		5	44.19	4.249	0.035	5	44.19	3.5	0.035	0	0.75	TRUE				
	2		6	53.03	6.424	0.035	6	53.03	5	0.035	0	1.42	TRUE				
	2		7	61.87	7.547	0.035	7	61.87	7.547	0.035	0	0.00	FALSE				
Channel_99	7		2	12.31	11.792	0.035	2	12.31	11.792	0.035	0	0.00	FALSE				
	7		3	18.46	10.813	0.035	3	18.46	10	0.035	0	0.81	TRUE				
	7	42	4	24.62	11.423	0.035	4	23.00	10	0.035	-1.62	1.42	TRUE	24.618	0.024	17.13	$ 500
	7		5	30.77	11.68	0.035	5	30.77	11.68	0.035	0	0.00	FALSE				
	7		6	36.93	11.708	0.035	6	36.93	11.708	0.035	0	0.00	FALSE				
Channel_52	9		3	21.42	11.122	0.035	3	21.42	11.122	0.035	0	0.00	FALSE				
	9		4	28.56	11.087	0.035	4	28.56	11.087	0.035	0	0.00	FALSE				
	9	65	5	35.70	10.786	0.035	5	35.70	10	0.035	0	0.79	TRUE	39.265	0.059	21.95	$ 1,200
	9		6	42.83	10.607	0.035	6	42.83	10	0.035	0	0.61	TRUE				
	9		7	49.97	11.044	0.035	7	49.97	11.044	0.035	0	0.00	FALSE				
	9		8	57.11	11.371	0.035	8	57.11	11.371	0.035	0	0.00	FALSE				
Channel_40	1		6	42.11	6.984	0.035	6	42.11	6.984	0.035	0	0.00	FALSE				
	1		7	49.13	4.572	0.035	7	49.13	4.572	0.035	0	0.00	FALSE				
	1		8	56.15	2.037	0.035	8	56.15	2.037	0.035	0	0.00	FALSE				
	1	75	9	63.17	3.133	0.035	9	63.17	2.037	0.035	0	1.10	TRUE	66.676	0.115	225.56	$ 2,300
	1		10	70.19	5.594	0.035	10	70.19	2.037	0.035	0	3.56	TRUE				
	1		11	77.20	7.127	0.035	11	77.20	2.037	0.035	0	5.09	TRUE				
	1		12	84.22	7.267	0.035	12	84.22	7.267	0.035	0	0.00	FALSE				
	1		13	91.24	6.783	0.035	13	91.24	6.783	0.035	0	0.00	FALSE				
Channel_125	1		1	7.00	6.974	0.035	1	7.00	6.974	0.035	0	0.00	FALSE				
	1		2	13.99	6.856	0.035	2	13.99	6.856	0.035	0	0.00	FALSE				
	1	124	3	20.99	6.656	0.035	3	20.99	4.2	0.035	0	2.46	TRUE	24.488	0.070	58.89	$ 1,400
	1		4	27.99	4.843	0.035	4	27.99	4.2	0.035	0	0.64	TRUE				
	1		5	34.98	4.243	0.035	5	34.98	4.2	0.035	0	0.04	TRUE				
	1		6	41.98	7.149	0.035	6	41.98	7.149	0.035	0	0.00	FALSE				
Channel_12	5		6	37.50	9.813	0.028	6	37.50	10.5	0.028	0	0.69	TRUE				
	5		7	43.75	10.025	0.028	7	43.75	8.8	0.028	0	1.23	TRUE				
	5	325	8	50.00	9.111	0.028	8	50.00	8.8	0.028	0	0.31	TRUE	53.125	0.396	236.92	$ 7,900
	5		9	56.25	8.855	0.028	9	56.25	8.855	0.028	0	0.00	FALSE				
	5		10	62.50	10.066	0.028	10	62.50	10.066	0.028	0	0.00	FALSE				
	5		11	68.75	10.389	0.028	11	68.75	10.389	0.028	0	0.00	FALSE				
Channel_13	7	844	1	20.0	6.866			20.00	6.250		0	0.62	TRUE	40	0.775	387.61	$ 15,500
	7		2	20.0	5.344			20.00	5.340		0	0.00	TRUE				
Channel_42	6	742	1	20.0	7.120			20.00	7.120		0	0.00	FALSE	40	0.681	596.51	$ 13,600
	6		2	20.0	7.410			20.00	6.325		0	1.09	TRUE				
Channel_65	4	28	1	20.0				20.00			0	0.00	FALSE	40	0.026	0.00	$ -
	4		2	20.0				20.00			0	0.00	FALSE				
Channel_81	10	276	1	20.0				20.00			0	0.00	FALSE	40	0.253	0.00	$ -
	10		2	20.0				20.00			0	0.00	FALSE				

APPENDIX-R Capital Improvements Cost Estimate

		Before		After						Cost/Ac
Node	Area	Elevation	Area	Elevation	Area	δArea (ac)	δDepth (	δVolume (CY)	Largest Area (ac)	$ 6,000
DuWapN_59	1	11.39	9.85	11.39	10.25	0.4	0.0	647		
	1	12.39	12.39	12.39	12.39	0.0	0.0	0	13.56	$ 81,360
	1	13.39	13.27	13.39	13.27	0.0	0.0	0		
	1	14.39	13.56	14.39	13.56	0.0	0.0	0		
DuWapMH_249	1	2.63	0	2.63	0.14	0.1	0.0	226		
	1	3.63	0	3.63	0.22	0.2	0.0	356		
	1	4.67	0.14	4.67	0.38	0.2	0.0	388	0.8	$ 4,800
	1	5.67	0.22	5.67	0.5	0.3	0.0	453		
	1	6.67	0.38	6.67	0.8	0.4	0.0	679		
DuWapN_51	2	8.63	0.25	8.63	0.25	0.0	0.0	0		
	2	9.132	0.4	9.132	0.4	0.0	0.0	0		
	2	10.13	0.6	10.13	1	0.4	0.0	647		
	2	11.13	2.4	11.13	2.5	0.1	0.0	162	5	$ 30,000
	2	12.13	2.7	12.13	3	0.3	0.0	485		
	2	13.13	3.47	13.13	4	0.5	0.0	857		
	2	14.13	4.6	14.13	5	0.4	0.0	647		
DuWapN_82	5	6.95	0.63	6.95	0.8	0.2	0.0	275		
	5	7.95	0.7	7.95	0.9	0.2	0.0	323		
	5	8.95	0.7	8.95	1	0.3	0.0	485	1.3	$ 7,800
	5	9.95	0.72	9.95	1.2	0.5	0.0	776		
	5	10.37	0.74	10.37	1.3	0.6	0.0	905		
DuWapN_34	7	14.8	0	14.8	0.002	0.0	0.0	3		
	7	15.3	0	15.3	0.096	0.1	0.0	155		
	7	16.3	0	16.3	0.409	0.4	0.0	661		
	7	17.3	0	17.3	0.879	0.9	0.0	1421	11.14	$ 66,846
	7	18.3	1.64	18.3	1.644	0.0	0.0	6		
	7	19.3	3.75	19.3	3.751	0.0	0.0	2		
	7	20.3	6.46	20.3	6.455	0.0	0.0	-8		
	7	21.3	11.14	21.3	11.141	0.0	0.0	2		
DuWapN_12	8	16.02	0	16.02	0.66	0.7	0.0	1061		
	8	17.02	1.46	17.02	1.46	0.0	0.0	0		
	8	18.02	2.41	18.02	2.41	0.0	0.0	-7	5.41	$ 32,466
	8	19.02	3.74	19.02	3.74	0.0	0.0	-4		
	8	20.02	5.41	20.02	5.41	0.0	0.0	1		
DuWapN_25	10	4.55	0	4.55	0.422	0.4	0.0	682		
	10	5.55	0	5.55	0.971	1.0	0.0	1570		
	10	6.55	0	6.55	2.39	2.4	0.0	3864		
	10	7.55	3.93	7.55	3.93	0.0	0.0	0	14.41	$ 86,460
	10	8.55	5.48	8.55	5.48	0.0	0.0	0		
	10	9.55	9.02	9.55	9.022	0.0	0.0	3		
	10	10.55	14.41	10.55	14.41	0.0	0.0	0		
DuWapN_225	10	2.66	0	2.66	0.037	0.0	0.0	59		
	10	3.66	0	3.66	0.179	0.2	0.0	289		
	10	4.66	0	4.66	0.693	0.7	0.0	1121		
	10	5.66	1.26	5.66	1.256	0.0	0.0	-7	7.64	$ 45,813
	10	6.66	2.18	6.66	2.181	0.0	0.0	1		
	10	7.66	4.45	7.66	4.454	0.0	0.0	6		
	10	8.66	7.64	8.66	7.635	0.0	0.0	-7		
DuWapMH_238	10	0.96	0	0.96	0.1	0.1	0.0	162		
	10	3.55	0.35	3.55	0.35	0.0	0.0	0	0.73	$ 4,380
	10	4.55	0.73	4.55	0.73	0.0	0.0	0		
DuWapMH_182	10	3.06	0	3.06	0.1	0.1	0.0	162		
	10	4.55	0.73	4.55	0.73	0.0	0.0	0	1.86	$ 11,160
	10	5.55	1.86	5.55	1.86	0.0	0.0	0		
DuWapN_78	3	4.75	0	4.75	0.5	0.5	0.0	808		
	3	5.25	1.1	5.25	1.1	0.0	0.0	0	1.3	$ 7,800
	3	6.33	1.1	6.33	1.3	0.2	0.0	323		
DuWapN_274	6	9.94	0	9.94	0.27	0.3	0.0	438		
	6	10.94	0	10.94	0.88	0.9	0.0	1418		
	6	11.94	1.56	11.94	1.56	0.0	0.0	-6		
	6	12.94	1.84	12.94	1.84	0.0	0.0	-2	2.18	$ 13,058
	6	13.94	2.03	13.94	2.03	0.0	0.0	-1		
	6	14.94	2.18	14.94	2.18	0.0	0.0	-6		
DuWapN_103	8	14.89	0.001	14.89	0.05	0.0	0.0	79		
	8	15.89	0.03	15.89	0.1	0.1	0.0	113		
	8	16.89	0.03	16.89	0.15	0.1	0.0	194	0.2	$ 1,200
	8	17.5	0.04	17.5	0.2	0.2	0.0	259		
									TOTAL	$ 393,142

AREA 5 High Cost Improvements		
Area/Pond Dimensions		
Pond Area =	4 acres	= 174240 sq ft
Pond Depth =	3 ft	
Pond Volume =	522720 cf	
Total Available Area =	7.5 acres	= 326700 sq ft

Cost Estimate					
Item	Qty	Unit	Cost per unit	Total	Notes
Buying Houses	12	houses	$ 321,000	$ 3,852,000	Zillow 2019 median home price (Charleston SC), 37 total houses
Demo houses	12	houses	$ 20,000		
Grubbing	4	acre	$ 11,400	$ 45,600	
Excavating	19360	CY	$ 10	$ 193,600	
Hauling fill	19360	CY	$ 5	$ 96,800	
Grading	4	acre	$ 3,000	$ 12,000	
Grassing/Fertilizing	4	acre	$ 5,000	$ 20,000	

Subtotal		$ 4,220,000
Legal & Engineering	30%	$ 1,266,000
Contingency	50%	$ 2,110,000
	Total	**$ 7,596,000**

AREA 10 High Cost Improvements

Trapezoidal Berm	
Height	8 ft
Width (top)	8 ft
Side Ratio	3:1
Width (bottom)	56 ft
Cross Section Area	256 ft
Length	1200 ft
Volume	**307200 cf**

Pond Area 10 P_222 From Hydrograph:		
Time	12 hr	= 43200 sec
Average Flow	18 cfs	
Total Volume of Water	777600 cf	= 17.9 ac-ft
Pump Flow Rate	18 cfs	
Excess Volume	388800 cf	= 2908224 gal
Area needed for 3 ft Pond	129600 sq-ft	= 2.98 ac

Cost Estimate

Item	**Qty**	**Unit**	**Cost per unit**	**Total**	**Notes**
Pond					
Purchase condos	30	condos	$ 150,000	$ 4,500,000	
Demo condos	30	condos	$ 20,000	$ 600,000	
Clearing	2.97	acre	$ 11,400	$ 33,910	
Excavating	14400	CY of dirt	$ 10	$ 144,000	
Grading	2.98	acre	$ 3,000	$ 8,926	
Hauling fill	14400	CY of dirt	$ 5	$ 72,000	
Grassing	2.97	acre	$ 5,000	$ 14,873	
Pump Station				$ -	18 cfs capacity
Pumps/Motors	2		$ 100,000	$ 200,000	
Piping	1		$ 25,000	$ 25,000	
Electrical	1		$ 50,000	$ 50,000	
Structural	1		$ 100,000	$ 100,000	
Generator	1		$ 50,000	$ 50,000	
Sitework	1		$ 200,000	$ 200,000	
Berm					
Purchase Land					
Innundated land	20	acre	$ 50,000	$ 1,000,000	
Berm	3.1	acre	$ 50,000	$ 154,270	
Purchase Homes	15	homes	$ 300,000	$ 4,500,000	
Demo Homes	15	homes	$ 20,000	$ 300,000	
Road/Utility Relocation	1	lump sum	$ 5,000,000	$ 5,000,000	
Clearing and Grubbing	3.1	acre	$ 11,400	$ 35,174	
Purchase and Haul Borrow	11378	CY	$ 30	$ 341,333	
Placing Fill/Compaction	11378	CY	$ 10	$ 113,778	
Grading Berm	3.1	acre	$ 3,000	$ 9,256	
Grassing/Fertilizing	3.1	acre	$ 5,000	$ 15,427	

Subtotal		$ 17,467,946
Legal & Engineering	30%	$ 5,240,384
Contingency	50%	$ 8,733,973
Total For Area 10		**$ 31,442,302**
Total For Area 5		**$ 7,596,000**
Total for Area 5 and Area 10		**$ 39,038,302**

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