3 Data and Methodology

3.1 Meetings with the City and Available Data

A kickoff meeting was conducted with the City to introduce the Arcadis project team and review the City's drainage system, historical problems, recent projects, management issues, and identify data available for the master planning effort. The City had extensive hard copy files of previous master plans and previous project documentation, but there were no previous model files of the stormwater system. In addition, the only topographic information available was the Florida Division of Emergency Management (FDEM) Coastal Program 2007 Light Detection and Ranging (LiDAR) elevation data of Indian River County in vertical datum NAVD88.

After reviewing available documentation and several discussions with City staff, it was determined that a new GIS map of the major components of the City's stormwater system would be needed for the hydraulic and hydrologic modeling effort and to satisfy MS4 permit requirements. In order to make the GIS map as accurate as possible, Arcadis reviewed and digitized more than 280 as-built drawings, permits, sketches, and other documentation of the drainage features within the City's stormwater system. A field crew was mobilized and spent more than three weeks in the City locating, identifying, measuring, and surveying elevations for more than 4,400 stormwater drainage components to populate the GIS map.

3.2 Stormwater System GIS Map Development

The stormwater system GIS Map was developed to provide a geospatial database of the City of Sebastian stormwater system incorporating the best available information. The City provided several stormwater-related GIS layers and record drawings as noted in section 3.1. The database incorporated available City of Sebastian information such as CAD drawings, GIS layers including the ditches feature class and Weirs Dams feature class and georeferenced PDFs including "2015 – Ditch Location Map.pdf" and Plan view figures from the 2018 City of Sebastian Stormwater Master Plan. The GIS database and subsequent H&H modeling was completed in vertical Datum NAVD 88. Information collected from record drawings, PDF's, etc. in vertical datum NGVD 29 were converted to NAVD 88 by subtracting 1.463ft based on the NOAA National Geodetic Survey Coordinate Conversion and Transformation Tool (NCAT), see Appendix F for conversion documentation.

The information provided by the City of Sebastian was utilized as a starting point. The team utilized aerial imagery, surface topography, and Google Street View to identify stormwater assets not provided in the City of Sebastian data. Through desktop analysis, approximately 2,381 nodes and 1,875 pipes, culverts and open channels were identified. 75% of stormwater assets were missing critical parameters such as pipe size, invert elevation and rim elevation. Therefore, an ArcGIS online map was created for the survey crew to take measurements via Collector or Field Maps application while in the field.

Two shapefiles were created to represent the stormwater system: a point layer for stormwater structures and a polyline layer for closed pipes and open channels. Additional spot elevations were collected in areas with documented historic flooding. Private driveway culverts and cross pipes were also included in the geodatabase where drawings were available; however, these assets were not included in the modeling work, which focused on infrastructure owned by the City of Sebastian.

Due to survey time limitations, a priority ranking from 1 to 6 was assigned to all nodes and conduits. The highest priority for survey, Rank 1, was given if there was missing information necessary for the H&H modeling work such as conduit type, pipe material, pipe size, invert elevations, rim elevations and blockage conditions. Rank 2 was assigned to ditches that are adjacent to high priority Rank 1 nodes and conduits, and were missing cross-section dimensions, invert elevations and vegetation conditions. Rank 3 was assigned to nodes and conduits which had at least one critical attribute identified from information provided by the City of Sebastian. Ranks 4-6 were low priority nodes and conduits that were not in critical locations for the H&H model development but were identified as part of the stormwater system.

Of the 2,381 nodes and 1,875 conduits identified for the field survey activities 2,170 nodes and 1,539 conduits were inspected. ~~Of the 2,381 nodes and 1,875 conduits identified for the field survey activities 2,360 nodes and 1,854 conduits were inspected.~~

Arcadis developed a stormwater system asset geospatial database in ArcGIS with the best available information from the desktop analysis, field inspections and survey and the H&H stormwater model development. The database is provided in Appendix J Stormwater Asset GIS Database.

3.3 Infrastructure Asset Survey and Assessment

3.3.1 Asset Assessment Goals, Criteria and Methodology

Arcadis reviewed available stormwater system information as mentioned in Section 1, 3.1, and 3.2. A GIS based inventory of stormwater assets was first developed using desktop analysis followed by a site visit stormwater inspection and field survey.

The infrastructure asset assessment included inspections of over 4,500 stormwater assets including:

- 756 bulkheads,
- 2,170 nodes which include culvert inlets/outlets, outfalls, baffle boxes, curb inlets, yard inlets, and manholes, and
- 1,539 conduits which include pipes, canals, and ditches.

In addition, 111 point elevations were taken at low points that were in flood hazard areas. The complete GIS database also includes inlets and conduits that were provided by the City or located in as-built drawings. The total asset inventory developed for field inspections and survey is comprised of 756 bulkheads, 2,381 inlets/nodes, 1,875 conduits (canals, ditches, etc.), and 27 outfalls for a total of 5,039 features.

3.3.2 Inspection Methodology

The inspections were performed using a Trimble R2 GNSS receiver and a mobile based application that allowed the inspectors to update the inventory of the stormwater conveyance system by taking elevations, dimension measurements, taking note of the material/size, uploading pictures of the asset, and writing down any comments specific to the asset to include condition assessments. The Trimble units were tested with Keynet VRS correction and the ESRI Field Maps App to verify the vertical and horizontal accuracy. The vertical accuracy was documented as +/- 0.2ft and the horizontal accuracy was documented +/-0.1ft. Previously unknown or undocumented assets which were discovered during the inspections were recorded and located with GPS coordinates.

3.3.3 SWMS Components

3.3.3.1 Canals

The City's Stormwater Management System (SWMS) includes approximately eight miles of canals, which have bulkheads on both sides for most of their length. The canals themselves showed varying amounts of vegetation and shoaling, and generally appeared to be in need of vegetation removal and maintenance dredging to reset their flow areas to their original design configurations. The bulkheads along the canal banks are constructed of a variety of materials, primarily concrete or steel sheet piling. The canals themselves are within the City's drainage easement and are maintained by the City, but the majority of the bulkheads are privately owned and maintained.

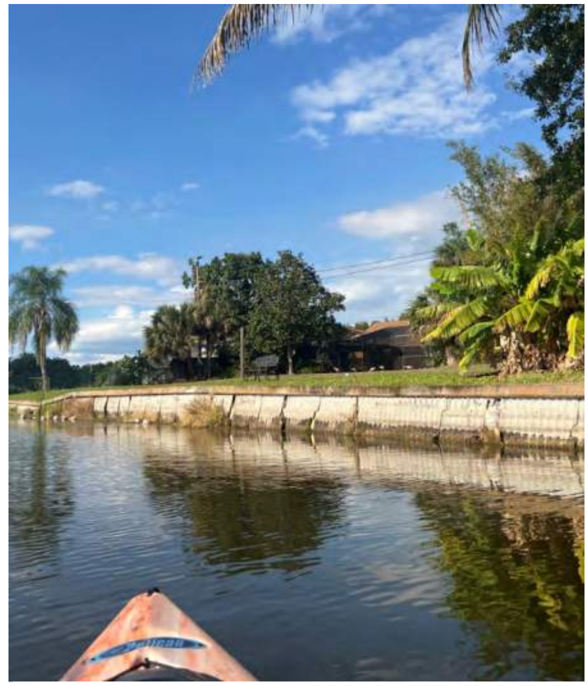

Figure 3-1. Bulkhead Toe Failure

As indicated above, a total of 756 bulkheads were inspected and about 85% were generally found to be structurally sound, but many of those showed signs of deterioration (i.e., cracks along the bulkhead face, concrete cap, etc.) and need maintenance. At the time of the inspections, 108 bulkheads had structurally failed and need to be replaced immediately, especially in the Schumann Lake area. An example of the observed bulkhead failures is shown in Figure 3-1, a bulkhead toe failure that occurred over multiple properties.

The bulkheads that were constructed of metal were consistently in better condition with fewer cases of failure, but that is likely because they are newer than the concrete bulkheads. Many of the properties with bulkheads also have moderate to high amounts of vegetation growing around and on top of the structures, which blocked the view for inspections and, if left unchecked, could cause future failures due to erosion and uplift from tree roots. For these reasons, no trees, shrubs or other vegetation with substantial root systems should be present within 20 feet of a bulkhead structure.

3.3.3.2 Green Infrastructure

The City's SWMS relies primarily on Green Infrastructure, a network of interconnected roadside swales, side yard swales, and backyard ditches, for conveyance of stormwater to canals and outfall points. Due to the sheer number of swales and ditches, our inspections were limited to the major flow paths for use in H&H model development. The thousands of roadside swale sections, though not specifically included in our inspections, were observed throughout the City during the field work and generally appeared to be in good condition, with some exceptions. However, the large number of roadside swale sections and their connecting driveway culverts in series create a collection system with a high probability for operational difficulties. A detailed inspection and hydraulic analysis of the roadside swale systems throughout the City should be performed in the future.

The GIS infrastructure database developed to facilitate the field inspections and survey activities described in Section 3.3.1 included 473 line features representing roadside swales, side yard swales, and backyard ditches. For each asset, the inspection data and a photo documenting its condition at the time of inspection was entered into the GIS database. Per City code, the private property owners are the responsible party for maintenance of swales and ditches. The City completes limited ditch regrading in association with road repaving projects. Approximately 60% of these swales and ditches were either in good condition or had evidence of being recently cleared and regraded by the City. Approximately 40% of them had moderate to high amounts of vegetation that could potentially impede the stormwater drainage. A map of the drainage conditions observed during the inspections is shown in Figure 3-2.

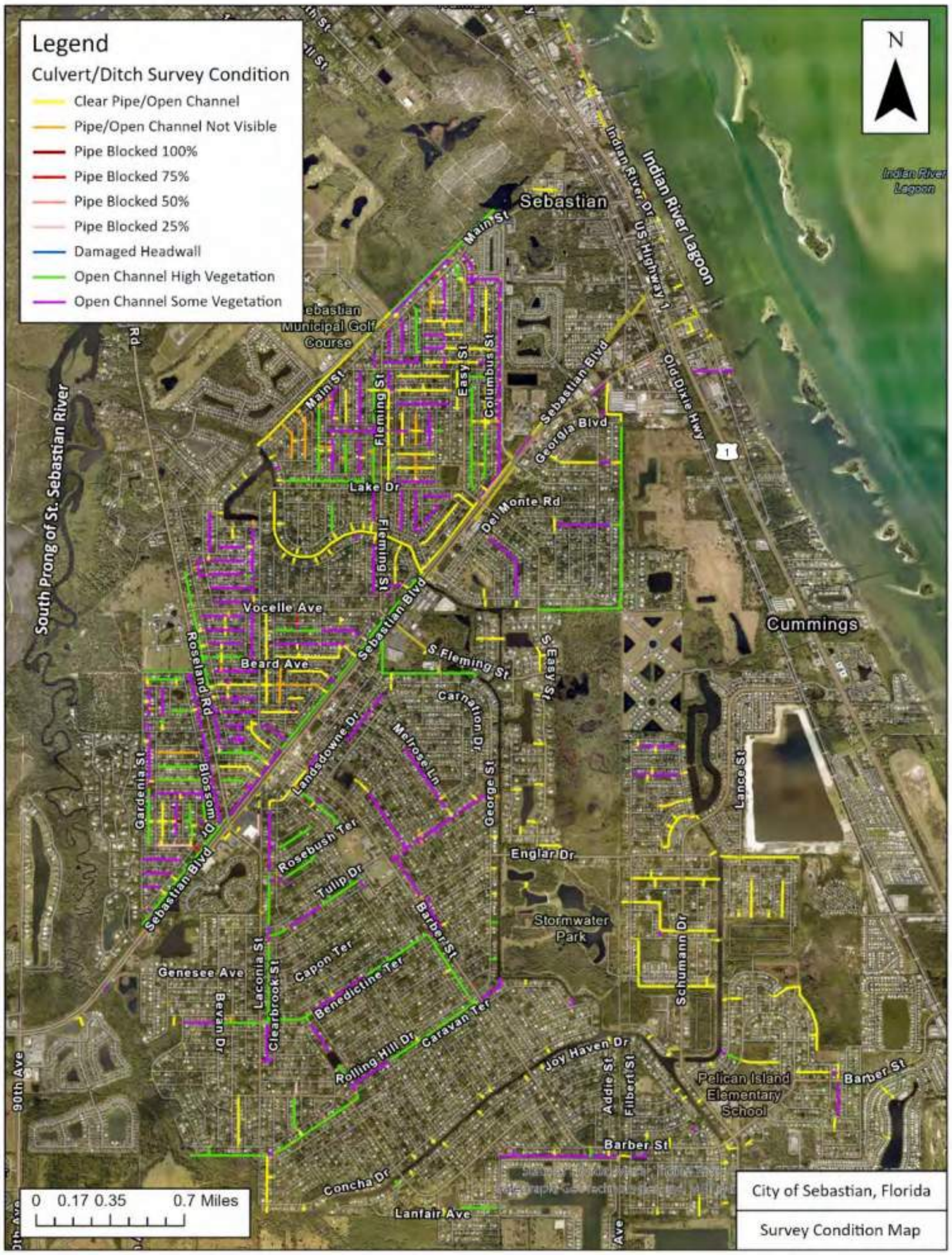

Figure 3-2. Observed Drainage Conditions

Note: The stormwater survey was focused on City-owned stormwater infrastructure.
Private stormwater infrastructure including driveway culverts were not included in the surveying effort.

3.3.3.3 Conveyance Structures

The remainder of the stormwater inspections consisted of assessing the physical and operation condition of the conveyance structures, such as culvert inlets/outlets, outfalls, baffle boxes, curb inlets, yard inlets, manholes, and pipes. Except as noted, all accessible structures identified during the desktop analysis discussed in Section 3.2 were inspected and surveyed. Elevations were taken at the rim and invert(s) of these stormwater structures, when accessible. For pipes, additional field measurements were taken to document the pipe diameter and length, and the pipe material was noted. For each asset, the inspection data and a photo documenting its condition at the time of inspection was entered into the GIS database.

Note that the thousands of driveway culverts in the SWMS were not included in these inspections, as they are part of the residential roadside swale network and not specifically included in the hydraulic model due to a lack of survey and physical data. Note that the thousands of driveway culverts in the SWMS were not included in these inspections, as they are part of the residential roadside swale network and not specifically included in the hydraulic model due to a lack of survey and physical data. However, as mentioned in the previous section, the large number of roadside swale sections and their connecting driveway culverts in series create a collection system with a high probability for operational difficulties. A detailed inspection and hydraulic analysis of the roadside swale systems throughout the City should be performed in the future.

In all, 2,165 nodes were included in the GIS map for these conveyance structures. In all, 2,381 node features and 1,440 line features were included in the GIS map for these conveyance structures. Their condition was determined based on the amount of sediment inside the asset, whether the asset was blocked due to vegetation, or if the asset was damaged or collapsed. In most cases these assets were in good condition, with little or no sediment blocking the flow. However, there were a few locations in which sediment and vegetation blocked enough of the structure to prevent water from flowing at their intended levels.

The GIS infrastructure database developed to facilitate the field inspections and survey activities described in Section 3.3.1 included 473 line features representing roadside swales, side yard swales, and backyard ditches.

3.4 Hydrologic and Hydraulic Modeling

3.4.1 H&H Model Goals and Limitations

A dynamic 1D Hydrologic and Hydraulic (H&H) computer model of the City of Sebastian stormwater network was developed to evaluate the system performance in response to various conditions. The H&H model also supported capital improvement project development, permitting, grant funding applications and stormwater system performance evaluations.

3.4.2 Software Selection

Arcadis worked with the City of Sebastian to select a modeling software for the stormwater analysis that met the needs of the City. Arcadis completed a technical review of the existing City of Sebastian modeling approach and the capabilities of standard software programs and commonly applied modeling approaches. The existing City of Sebastian stormwater model files created in modeling software Interconnected Pond Routing model (ICPR) version 3 developed by Streamline Technologies Inc. were not available for review and therefore Arcadis reviewed the model documentation provided in the *Master Stormwater Management Plan Report, 2004*[7] and the

[7] CDM Smith. *Master Stormwater Management Plan*. City of Sebastian, Florida. February 2004.

Stormwater Management Plan Update, 2018[8]. Based on discussions with the City of Sebastian the top priorities when selecting the modeling software were low cost, wide software usage, model accessibility, and suitability for use on stormwater planning projects. The Team reviewed stormwater modeling software ICPR version 4, PCSWMM provided by Computational Hydraulics Int., and InfoWorks ICM by Innovyze. The software selected with input from the City of Sebastian for the hydrologic and hydraulic evaluation was PCSWMM which uses the EPA's public domain Stormwater Management Model (SWMM) engine. A summary of the PCSWMM software attributes is provided below:

- Relatively low cost
- High accessibility – PCSWMM model files can be accessed using the publicly available EPA SWMM5 software.
- Flexibility across projects - PCSWMM model network can be exported to GIS for easy data management and review in support of ancillary City of Sebastian objectives.
- Support and Software Usage - PCSWMM software and EPA SWMM5 is used throughout the US and has an extensive user group and online community.
- Suitability – PCSWMM is a dynamic hydrologic and hydraulic model software developed to support stormwater management.

The City of Sebastian is interested in 2D stormwater modeling capabilities. 2D modeling is helpful when evaluating surface flooding extents and complex overland flow paths associated with various design storm events. Arcadis recommended InfoWorks ICM as the software of choice for 2D modeling. PCSWMM software has a recommended maximum 2D area of 500 acres which would not support a system-wide 2D model of the City of Sebastian (7,243 ac). The City of Sebastian selected PCSWMM over InfoWorks ICM based on software costs and accessibility which are higher priorities to the City compared to 2D modeling capabilities. Utilizing the PCSWMM software the City of Sebastian will have the ability to create individual 2D models for areas of concern within the stormwater network with a total 2D surface areas less than 500 acres as necessary.

3.4.3 Model Extents and Level of Detail

The model extents were developed based on discussions with the City of Sebastian and are provided in Figure 3-3. The modeled network is focused on the pipes, culverts, and open channels owned by the City of Sebastian. In some locations roadside swales were included in the model extents in order to maintain system connectivity between City owned infrastructure. The model includes 2,210 conduits (pipes, culverts, open channels, swales, canals, etc.), 2,150 junctions (culvert inlets/outlets, catch basins, manholes, open channel confluence points, etc.), and 46 storage nodes (detention basins, ponds, GI features, etc.). There are an additional 57 storage nodes in the model that track and store runoff from Planned Unit Development (PUD) areas where stormwater runoff is managed onsite and disconnected from areas without stormwater infrastructure that are not tributary to the City of Sebastian stormwater network.

[8] CWT Engineering, LLC. Stormwater *Management Master Plan update*. City of Sebastian, Florida. August 2018.

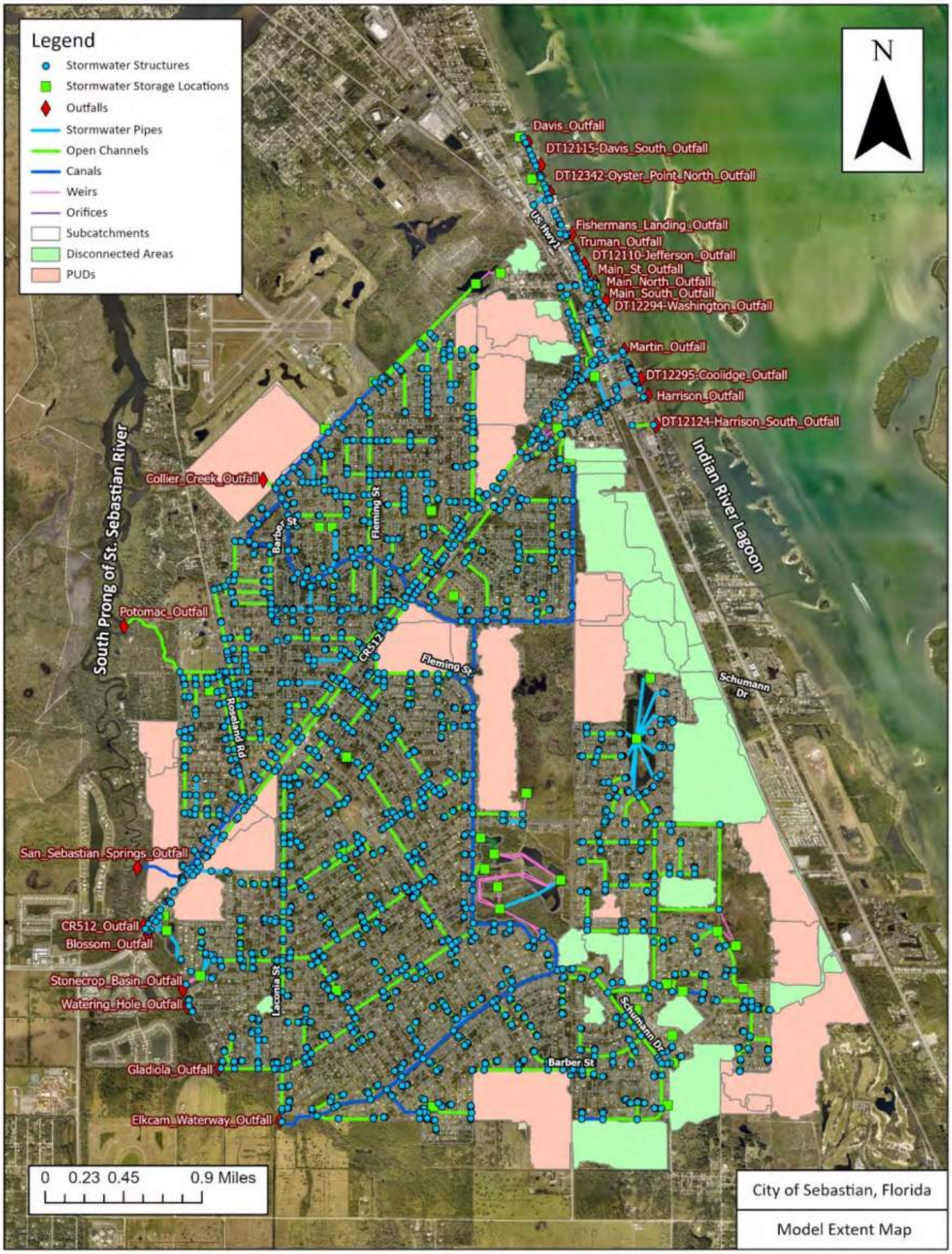

Figure 3-3. Hydrologic and Hydraulic Modeling Extents

There are a total of 27 outfall locations in the City of Sebastian, the locations are described in Table 3-1. Fourteen of the outfalls drain to the Indian River Lagoon, the outfalls are managed by the FDOT and the City of Sebastian as described in Table 3-1. Thirteen of the outfalls drain to the South Prong of the St. Sebastian River, the outfalls are managed by the City of Sebastian, Indian River County, and a private entity as described in Table 3-1. Two of the outfalls drain to Collier Creek which is tributary to the South Prong of the St. Sebastian River, the outfalls are managed by the City of Sebastian. There are 23 outfall locations included in the H&H model, as shown in Figure 3-3. The modeled outfalls are not a direct match to the outfalls documented in Table 3-1. The model includes a single outfall along Collier Creek labeled Collier Creek Outfall located 375ft downstream of the Hardee Dam and receives flow from the Twin Ditches Outfall and Hardee Outfall. Also, the model includes a single outfall along the Elkcam Waterway labeled Elkcam Waterway Outfall located 1,500ft downstream of the Elkcam Dam and includes flow from the Elkcam outfall, Laconia outfall and Lanfair outfall. Finally, the Sunport outfall is not included in the H&H model due to a lack of available information.

Table 3-1. Outfall Locations

Outfall Name	Responsible Party	Tributary Waterbody
Davis Outfall	City of Sebastian	Indian River Lagoon
DT12110-Jefferson Outfall	FDOT	Indian River Lagoon
DT12115-Davis South Outfall	FDOT	Indian River Lagoon
DT12124-Harrison South Outfall	FDOT	Indian River Lagoon
DT12294-Washington Outfall	FDOT	Indian River Lagoon
DT12295-Coolidge Outfall	City of Sebastian	Indian River Lagoon
DT12342-Oyster Point North Outfall	FDOT	Indian River Lagoon
Fisherman’s Landing Outfall	City of Sebastian	Indian River Lagoon
Harrison Outfall	City of Sebastian	Indian River Lagoon
Main North Outfall	City of Sebastian	Indian River Lagoon
Main South Outfall	City of Sebastian	Indian River Lagoon
Main St Outfall	City of Sebastian	Indian River Lagoon
Martin Outfall	City of Sebastian	Indian River Lagoon
Truman Outfall	City of Sebastian	Indian River Lagoon
Hardee Dam Outfall	City of Sebastian	Collier Creek
Twin Ditches Outfall	City of Sebastian	Collier Creek
Blossom Outfall	City of Sebastian	South Prong of the St. Sebastian River
CR512 Outfall	Indian River County	South Prong of the St. Sebastian River
Elkcam Outfall	City of Sebastian	South Prong of the St. Sebastian River
Gladiola Outfall	City of Sebastian	South Prong of the St. Sebastian River
Laconia Outfall	City of Sebastian	South Prong of the St. Sebastian River
Lanfair Outfall	City of Sebastian	South Prong of the St. Sebastian River
Potomac Outfall	Indian River County / City of Sebastian	South Prong of the St. Sebastian River
San Sebastian Springs Outfall	Private	South Prong of the St. Sebastian River
Stonecrop Basin Outfall	City of Sebastian	South Prong of the St. Sebastian River

Table 3-1. Outfall Locations

Outfall Name	Responsible Party	Tributary Waterbody
Sunport Outfall	City of Sebastian	South Prong of the St. Sebastian River
Watering Hole Outfall	City of Sebastian	South Prong of the St. Sebastian River

Note 1: The Potomac Outfall is owned by Indian River County. The City of Sebastian has historically maintained the outfall and placed a Baffle Box at this location in coordination with Indian River County.

3.4.4 Hydraulic Parameters

The 1D hydraulic stormwater network was developed from limited GIS data provided by the City of Sebastian, digitized record drawings, field investigations, survey data and photos. The network includes closed pipe and open channel stormwater conveyance and is represented in the model with a collection of nodes and links. As discussed in Section *3.2 Stormwater System GIS Map Development* a desktop analysis was completed to create the City of Sebastian existing stormwater network geospatial database which included a review of available GIS data and record drawings, aerial imagery and Google Street View to identify open channels and pipes not included in the GIS data and record drawings. 75% of the stormwater assets identified during the desktop analysis were missing hydraulic attributes (pipe diameter, open channel geometry, invert elevations, rim elevations, pipe material, and open channel vegetation). Pipe and open channel attributes were collected by survey crews in 2022, as documented in Section 3.2. Open channel cross-section geometry and channel slope was based on surveyed cross-sections and channel elevations supplemented with surface topography. The Florida Division of Emergency Management (FDEM) Coastal Program 2007 Light Detection and Ranging (LiDAR) elevation data of Indian River County with a vertical accuracy of +/- 4 inches was used for the analysis and is in vertical datum NAVD88. An average open channel geometry is assigned to the length of the modeled open channel sections.

As part of the hydraulic data quality review the surveyed invert elevations were compared against the LiDAR topography and adjacent invert elevations documented in record drawings. The hand-held GPS unit has a documented vertical accuracy of +/-0.2ft. A limited number of surveyed invert elevations were found to have a larger range of accuracy than expected, approximately +/-1.5ft. The hand-held GPS unit used for survey data collection can result in less accurate data if satellite connectivity issues occur. Locations with inaccuracies in the surveyed elevations were determined based on the following criteria: negatively sloped pipes and open channels, invert elevations that exceeded the ground surface elevations derived from LiDAR or survey data. Locations with the invert elevation inaccuracies or missing invert elevations were either estimated based on the LiDAR topography or interpolated based upstream and downstream invert elevations while assuming constant slope. The invert elevation adjustments were focused on the larger pipes and open channels that were significant to stormwater conveyance. Due to limited existing system information and the flat nature of the City of Sebastian topography flow directions of the pipes and open channels were determined by reviewing invert elevations and pipe sizes under the assumption that smaller pipes flow to larger pipes.

The team reviewed the stormwater network following the surveying effort and identified gaps in the system connectivity; pipes, roadside ditches, and open channels not included in the hydraulic network developed through desktop analyses from available information. The roadside swales are not maintained by the City of Sebastian but were included as necessary to connect the City of Sebastian culverts, open channels, etc. in the stormwater model. For the assets not included or inaccessible during the surveying effort, hydraulic attributes were assumed based on topography, Google Street View, and upstream and downstream stormwater infrastructure. The open channels with missing cross-section geometry were grouped into 6 categories according to vegetation condition and size of the channel according to 2007 LiDAR data and recent aerial imagery provided by Indian River County dated June 2021. Roadside ditches were grouped as one category assuming they have similar cross-section geometry. The average cross-section geometry was calculated for each category and was applied to each open channel and roadside ditch lacking cross-section geometry. Cross-section geometry for the large open channels was developed individually based on the 2007 LiDAR elevation data.

The Manning's, n, roughness coefficients for pipes and culverts were adjusted according to material type as noted in the record drawings and field survey. Open channel Manning's, n, roughness coefficients used in PCSWMM were based on existing conditions documented in field surveyed vegetation, site photographs, aerial imagery, and Manning's, n, roughness coefficients for channels[9]. Table 3-2 summarizes the Manning's, n, roughness coefficients used in the PCSWMM modeled pipes and open channels. In locations where detailed information regarding pipe material or open channel conditions was unavailable a default Manning's, n, roughness coefficient of 0.015 and 0.035 was assigned for pipes and open channels respectively.

Table 3-2. Manning's, n, Roughness Coefficients

Pipe Material / Open Channel Condition	Manning's Roughness Coefficient
Reinforced Concrete Pipe - Default	**0.015**
Polyvinyl Chloride and Cured In Place Pipe Lining	0.01
Concrete	0.015
Corrugated Metal/Aluminum Pipe	0.02
HDPE	0.012
Excavated Channel - Earth, straight, and uniform with short grass, few weeds	0.027
Clean, straight, full stage, no rifts, or deep pools, with some stones and weeds (Default or Clear)	**0.035**
Channels not maintained, weeds and brush uncut, clean bottom, brush on sides (Some vegetation)	0.05
Channels not maintained, weeds and brush uncut, dense weeds, high as flow depth (High vegetation)	0.08

Pipe blockages documented in the field survey efforts, Section 3.2 and 3.3, were not included in the existing conditions model. The H&H model assumes that pipe blockages have been addressed through regular O&M activities. This condition allows for identification of undersized infrastructure and supports the identification of CIP projects. System maintenance to remove sedimentation and pipe blockages is critical to the operation of the stormwater system as sedimentation and blockages negatively impact the conveyance capacity of the existing stormwater infrastructure and can increase the severity and frequency of surface flooding within the City.

The stormwater storage structures including detention basins and ponds were represented in the model as storage nodes. The storage nodes are assigned a stage-storage curve based on available record drawings or LiDAR topography. Specialty hydraulic features including weirs and orifices were included in the model to represent outlet control structures at the canals, outfalls, detention basins, etc. The Stormwater Park pump station is included in the

9 Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill.

PCSWMM model but based on discussions with the City of Sebastian staff the pump is not operated during wet-weather events and is therefore the pump station is turned off in the design storm simulations.

3.4.4.1 Outfall Boundary Conditions

There are 23 outfall locations included in the H&H model, as shown in Figure 3-3. Fourteen of the outfalls drain to the Indian River Lagoon and the remaining nine outfalls drain to the South Prong of the St. Sebastian River. The boundary conditions of the outfalls in the Indian River Lagoon are based on the mean sea level elevation data collected at the Trident Pier Station at Port Canaveral (Station No. 8721604) which is the closest National Oceanic and Atmospheric Administration (NOAA) Tide Station to the City of Sebastian. According to Figure 5-1 in Section 5 – Sea Level Rise Assessment, data collected at this station from 1994 to 2022 show the maximum of mean sea level elevation is 2.15ft NAVD 88 (1.2 MSL ft). The fixed stage water surface elevation of 2.15 ft was assigned to the 14 Indian River Lagoon outfalls for the 10-year, 25-year, and 100-year design storm events. The Indian River Lagoon boundary condition set to the maximum mean sea level allows for review of the capacity of the stormwater conveyance system. There are additional risks to stormwater infrastructure draining to the Indian River Lagoon which are present during periods of elevated water levels such as King Tides, Hurricanes, etc. The outfalls tributary to the South Prong of the St. Sebastian River were assigned a fixed stage elevation based on the FEMA Flood Insurance Study (FIS) for Indian River County, Florida[10] and incorporated areas revised on December 4, 2012. The FIS provides still water elevations by transect for 10-, 50-, 100-, 500-year recurrence intervals for use in floodplain management. The 25-year storm event at each transect was interpolated from the provided recurrence interval floodplain data. The location of each City of Sebastian outfall to the South Prong of the St. Sebastian River in relation to the FIS transects along the stream centerline was used to interpolate the water surface elevations for the 10-, 25-, and 100-year recurrence interval events. The boundary conditions at each outfall location are summarized in Table 3-2.

Table 3-3. Outfall Boundary Conditions

Outfall Name	10-year Water Surface Elevation, ft	25-year Water Surface Elevation, ft	100-year Water Surface Elevation, ft	Invert Elevation, ft
Blossom Outfall	6.27	7.37	8.94	8.54
Collier Creek Outfall[2]	12.30	13.12	14.20	5
CR512 Outfall[3]	6.34	7.43	9.00	0
Davis Outfall	2.15	2.15	2.15	-1
DT12110-Jefferson Outfall	2.15	2.15	2.15	-2.1
DT12115-Davis South Outfall	2.15	2.15	2.15	-1
DT12124-Harrison South Outfall	2.15	2.15	2.15	-3.8
DT12294-Washington Outfall	2.15	2.15	2.15	0.46
DT12295-Coolidge Outfall	2.15	2.15	2.15	-1.5
DT12342-Oyster Point North Outfall	2.15	2.15	2.15	-1.42
Elkcam Waterway Outfall[5]	7.97	8.91	10.47	5.54
Fisherman’s Landing Outfall	2.15	2.15	2.15	-1
Gladiola Outfall	6.90	7.94	9.67	-1

[10] Federal Emergency Management Agency, Flood Insurance Study Indian River County, Florida and Incorporated Areas, 4 December 2012.

Table 3-3. Outfall Boundary Conditions

Outfall Name	10-year Water Surface Elevation, ft	25-year Water Surface Elevation, ft	100-year Water Surface Elevation, ft	Invert Elevation, ft
Harrison Outfall	2.15	2.15	2.15	-1
Main North Outfall	2.15	2.15	2.15	-1.46
Main South Outfall	2.15	2.15	2.15	2.54
Main St Outfall	2.15	2.15	2.15	3.94
Martin Outfall	2.15	2.15	2.15	-2
Potomac Outfall	1.98	3.13	4.85	7.56
San Sebastian Springs Outfall	5.26	6.38	8.00	6.15
Stonecrop Basin Outfall	6.60	7.67	9.32	0.54
Truman Outfall	2.15	2.15	2.15	0
Watering Hole Outfall	6.72	7.77	9.46	8.1

Note 1: Elevations are provided in vertical datum NAVD88

Note 2: The modeled Collier Creek outfall is located 375ft downstream of the Hardee Dam and includes flow from the Twin Ditches outfall and Hardee outfall

Note 3: The CoR512 outfall included in the H&H model is not owned by the City but receives flow from City property along CoR512. The outfall is located South of CoR512 and drains to the South Prong of the St. Sebastian River.

Note 4: The Sunport outfall is not included in the H&H model due to a lack of available information.

Note 5: The modeled Elkham Waterway outfall is located 1,500ft downstream of the Elkham Dam and includes flow from the Elkham outfall, Laconia outfall and Lanfair outfall

3.4.5 Hydrologic Parameters

Hydrologic parameters for the area tributary to the stormwater collection system were developed to define the PCSWMM calculations which convert rainfall into stormwater runoff and infiltration.

3.4.5.1 Subcatchment Delineation

Site topography, storm sewer inlet locations, site survey and visual inspections were used to delineate drainage areas throughout the system. The total modeled drainage area is 7,243 acres and was split into 1,898 subcatchments (see Figure 3-3). The City provided a map of locations and boundaries of Planned Unit Development (PUD) areas where stormwater runoff is managed onsite and these areas were delineated as individual subcatchments. Additionally, areas not identified as PUD's without stormwater infrastructure that were not tributary to the City of Sebastian stormwater network were delineated as individual subcatchments and are noted as a "Disconnected area" in Figure 3-3. There are 28 PUD subcatchments and 29 disconnected area subcatchments with a total acreage of 1,087 ac and 734 ac respectively.

The calculated subcatchment hydrologic parameters developed for the stormwater model are listed below.

- Subcatchment Parameters
  - Area
  - Average Flow Path Length
  - Average Subcatchment Slope

- Impervious Area
- Infiltration Parameters

Subcatchment parameters affect stormwater runoff volume and peak flow rates. Site topography is based on Florida Division of Emergency Management (FDEM) Coastal Program 2007 Light Detection and Ranging (LiDAR) elevation data of Indian River County with a vertical accuracy of +/- 4 inches. The LiDAR data along with the stormwater inlet locations identified through the review of record drawings, survey activities, and publicly available aerial/street-view imagery were used to calculate the subcatchment area in Arc Geographic Information System (ArcGIS). The subcatchment flow path length is defined by the distance runoff travels within a subcatchment to reach the outlet. The flow paths were developed in ArcGIS for each subcatchment based on the existing topography. The slope for each subcatchment is determined based on the average slope of the subcatchment and was calculated based on the existing topography.

The subcatchment impervious area was calculated in ArcGIS based on geospatial information regarding building footprints and roadway extents. The building footprint information was developed from the Indian River County building footprint shp file and was reviewed and updated. The *IRC_Building_Footprints_poly* file was compared against recent aerial imagery provided by Indian River County dated June 2021 and buildings identified as missing in the building footprint file were added and buildings that were not present in the aerial imagery were removed. The updated *IRC_Building_Footprints_poly* file is provided for reference in Appendix J Stormwater Asset GIS Database. When calculating the percentage of impervious area within the subcatchments the building impervious areas were increased by 25% to account for driveways. The roadway impervious area shp file was developed using a buffer of the street centerline file provided by the City of Sebastian. The existing system percent impervious is approximately 20%.

The modified Green-Ampt Infiltration method was selected for modeling the infiltration of rainfall into the pervious surfaces within the drainage area. Infiltration parameters are based on physical soil attributes and include the initial moisture deficit of the soil, soil hydraulic conductivity (infiltration rate), and the suction head at the wetting front. The stormwater infiltration within the City of Sebastian functions differently East versus West of the coastal divide. Detailed City of Sebastian soils information is provided in Section 2.1 - Geology and Soils. West of the coastal divide the groundwater is noted as within 1ft of the ground surface and there is a documented hardpan layer, both of which limit the infiltration potential. East of the coastal divide infiltration functions based on the physical characteristics of the soils. Two different approaches were used to develop infiltration parameters for the varied hydrogeology East and West of the coastal divide in the City of Sebastian.

East of the coastal divide the subcatchment Green-Ampt infiltration parameters were developed from a composite of the soils documented in the NRCS Web Soil Survey. The documented soil types were assigned Green-Ampt parameters based on the relative soil texture, as referenced from *Rawls (1983)*[11], the NRCS provided soil hydraulic conductivity ranges and the most hydraulically restrictive layer within each soil type. The Green-Ampt parameters for the various soil types are provided in Table 3-3.

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11 Rawls, W.J. et al. 1983. J. Hyd. Engr., 109:1316.

Table 3-4. Green-Ampt Parameters assigned City of Sebastian USDA/NRCS Soil Types

Soil Type	Hydrologic Soil Group	Hydraulic conductivity, in/hr	Suction head, in	Initial deficit (fraction)
Chobee loamy fine sand, frequently ponded, 0 to 1 percent slopes	C/D	0.06	8.66	0.262
EauGallie fine sand	A/D	0.06	8.66	0.262
Immokalee fine sand	B/D	2.49	6.49	0.378
Myakka-Myakka, wet, fine sands, 0 to 2 percent slopes	A/D	2.49	6.49	0.378
Oldsmar fine sand	A/D	0.06	8.66	0.262
Pepper sand	D	0.43	4.33	0.368
Riviera fine sand, 0 to 2 percent slopes	A/D	2.49	6.49	0.378
St. Lucie sand, 0 to 8 percent slopes	A	4.74	1.93	0.413
Archbold sand, 0 to 5 percent slopes	A	4.74	1.93	0.413
Wabasso-Wabasso, wet, fine sand, 0 to 2 percent slopes	B/D	2.49	6.49	0.378
Pineda-Pineda, wet, fine sand, 0 to 2 percent slopes	A/D	2.49	6.49	0.378
Quartzipsamments, 0 to 5 percent slopes	A	4.74	1.93	0.413
Pomello sand, 0 to 5 percent slopes	A	4.74	1.93	0.413
Arents, 0 to 5 percent slopes	A	4.74	1.93	0.413
Floridana sand, frequently ponded, 0 to 2 percent slopes	C/D	0.06	8.66	0.262
Immokalee-Urban land complex	A/D	4.74	1.93	0.413
Astatula sand, 0 to 5 percent slopes	A	4.74	1.93	0.413
Satellite fine sand, 0 to 2 percent slopes	A	4.74	1.93	0.413
Malabar fine sand	A/D	0.43	4.33	0.368
Myakka fine sand, frequently ponded, 0 to 1 percent slopes	A/D	2.49	6.49	0.378
Holopaw fine sand, 0 to 2 percent slopes	A/D	2.49	6.49	0.378
Electra sand, 0 to 5 percent slopes	A	0.43	4.33	0.368
Pompano fine sand, 0 to 2 percent slopes	A/D	4.74	1.93	0.413
Riviera fine sand, frequently ponded, 0 to 1 percent slopes	A/D	0.43	4.33	0.368
Lokosee fine sand	A/D	0.06	8.66	0.262

West of the coastal divide the infiltration is affected by additional factors that limit the potential for infiltration. The high water table and hardpan layer are reflected in the hydrologic soil groups (HSG) assigned by NRCS, 78% of the soils within the drainage area are hydrologic soil group D or two HSG groups (i.e., A/D, C/D) which indicate that a confining layer or high water table when present affects the infiltration rate that a given soil group would normally exhibit and the soil acts like HSG D. Additionally, the East Central Florida Transient Expanded Model (ECFTX) groundwater model recharge rates are less than 0.005in/hr in the City of Sebastian which confirms the limited infiltration potential. Therefore, the PCSWMM stormwater model Green-Ampt parameters West of the coastal divide were set to the most restrictive soil type documented in the City, a Sandy Clay Loam, which are provided in Table 3-4. For reference the hydraulic conductivity assigned to the area west of the coastal divide is reflective of the infiltration rate that would be achieved using the Curve Number method in this area.

Table 3-5. Green-Ampt Parameters assigned to Subcatchments West of the Coastal Divide

Soil Type	Hydraulic Conductivity, in/hr	Suction Head, in	Initial Deficit (fraction)
Sandy Clay Loam	0.06	8.66	0.262

Once the variable parameters were generated for each subcatchment, general hydrology parameters for all subcatchments were applied and are listed in Table 3-5.

Table 3-6. Subcatchment Hydrology Parameters

Subcatchment Parameter	Value
Overland Roughness (Manning's N) - Impervious	0.03
Overland Roughness (Manning's N) - Pervious	0.25
Depression Storage - Impervious	0.075 in
Depression Storage - Pervious	0.75 in
Percent Impervious with Zero Depression Storage	25%
Subarea Routing	Pervious
Percent Routed	75%

3.4.5.2 Rainfall

The existing City of Sebastian stormwater network performance was evaluated for the 10yr-24hr, 25yr-24hr, and the 100yr-24hr design storm events. The NOAA Atlas 14 Precipitation Frequency Data[12] was used to develop design rainfall depths for these design events and is included in Appendix G. The design event rainfall depths are provided in Table 3-6. The design rainfall depths were distributed over the 24-hour duration using the NRCS Type II FL Modified Distribution with a 30-minute interval. The NRCS Type II FL Modified Distribution is one of the recommended design storm distributions in the St. Johns River Water Management District Permit Information Manual and was selected because it was derived to more accurately simulate hydrographs for the State of Florida compared to the standard NRCS Type II rainfall distribution.

Table 3-7. Design Storm Rainfall Depths and Distributions

Design Storm Event Time (hr)	NRCS Type II FL Modified Rainfall Ratio *(SJRWMD Table 35.1-1)*	Cumulative Rainfall Depth (in)		
		10yr-24hr Design Storm	25yr-24hr Design Storm	100yr-24hr Design Storm
0:00	0.000	0.000	0.000	0.000
0:30	0.006	0.043	0.055	0.074
1:00	0.012	0.087	0.110	0.149

12 Point Precipitation Frequency Estimates, National Oceanic and Atmospheric Administration Atlas 14, Volume 9, Version 2. Accessed 28 February 2022.

Table 3-7. Design Storm Rainfall Depths and Distributions

Design Storm Event Time (hr)	NRCS Type II FL Modified Rainfall Ratio *(SJRWMD Table 35.1-1)*	Cumulative Rainfall Depth (in)		
		10yr-24hr Design Storm	25yr-24hr Design Storm	100yr-24hr Design Storm
1:30	0.019	0.138	0.174	0.236
2:00	0.025	0.181	0.229	0.310
2:30	0.032	0.232	0.293	0.397
3:00	0.039	0.282	0.358	0.484
3:30	0.047	0.340	0.431	0.583
4:00	0.054	0.391	0.495	0.670
4:30	0.062	0.449	0.569	0.769
5:00	0.071	0.514	0.651	0.880
5:30	0.080	0.579	0.734	0.992
6:00	0.089	0.644	0.816	1.104
6:30	0.099	0.717	0.908	1.228
7:00	0.110	0.796	1.009	1.364
7:30	0.122	0.883	1.119	1.513
8:00	0.134	0.970	1.229	1.662
8:30	0.148	1.072	1.357	1.835
9:00	0.164	1.187	1.504	2.034
9:30	0.181	1.310	1.660	2.244
10:00	0.201	1.455	1.843	2.492
10:30	0.226	1.636	2.072	2.802
11:00	0.258	1.868	2.366	3.199
11:30	0.308	2.230	2.824	3.819
12:00	0.607	4.395	5.566	7.527
12:30	0.719	5.206	6.593	8.916
13:00	0.757	5.481	6.942	9.387
13:30	0.785	5.683	7.198	9.734
14:00	0.807	5.843	7.400	10.007
14:30	0.826	5.980	7.574	10.242
15:00	0.842	6.096	7.721	10.441
15:30	0.857	6.205	7.859	10.627
16:00	0.870	6.299	7.978	10.788
16:30	0.882	6.386	8.088	10.937
17:00	0.893	6.465	8.189	11.073
17:30	0.904	6.545	8.290	11.210
18:00	0.913	6.610	8.372	11.321
18:30	0.923	6.683	8.464	11.445

Table 3-7. Design Storm Rainfall Depths and Distributions

Design Storm Event Time (hr)	NRCS Type II FL Modified Rainfall Ratio *(SJRWMD Table 35.1-1)*	Cumulative Rainfall Depth (in)		
		10yr-24hr Design Storm	25yr-24hr Design Storm	100yr-24hr Design Storm
19:00	0.931	6.740	8.537	11.544
19:30	0.940	6.806	8.620	11.656
20:00	0.948	6.864	8.693	11.755
20:30	0.955	6.914	8.757	11.842
21:00	0.962	6.965	8.822	11.929
21:30	0.969	7.016	8.886	12.016
22:00	0.976	7.066	8.950	12.102
22:30	0.983	7.117	9.014	12.189
23:00	0.989	7.160	9.069	12.264
23:30	0.995	7.204	9.124	12.338
24:00	1.000	7.240	9.170	12.400

3.4.6 H&H Model Validation

The H&H model was validated to historical flooding locations documented by the City of Sebastian. Locations of historic flooding and the relative flooding depth were provided geospatially and were focused on roadway areas. Hydrologic and hydraulic parameters were adjusted in the model to match observed flooding. Additionally modeled peak flows throughout the stormwater network were compared to the flows provided in the 2004 Master Management Plan developed by CDM Smith. The PCSWMM model simulated higher flows on average compared to the 2004 ICPR model. This is likely due to the additional detail in the PCSWMM model and the fact the 2004 ICPR model was a skeleton model which only included the main conveyance network, approximately 80 culvert crossings and 204 subcatchments. The PCSWMM model is a planning level tool and provides a dynamic representation of the stormwater network performance based on the best available hydrologic and hydraulic input data. The model focuses on the main conveyance network and does not include all pipes and open channels within the model extents. A potential future improvement to the H&H model is the addition of stormwater overflow from the PUD areas into the City of Sebastian Stormwater network. The PUD areas are disconnected from the City of Sebastian stormwater network but can overflow into the network during extreme wet weather events. The addition of the PUD flows can improve the accuracy of the modeled system conditions.

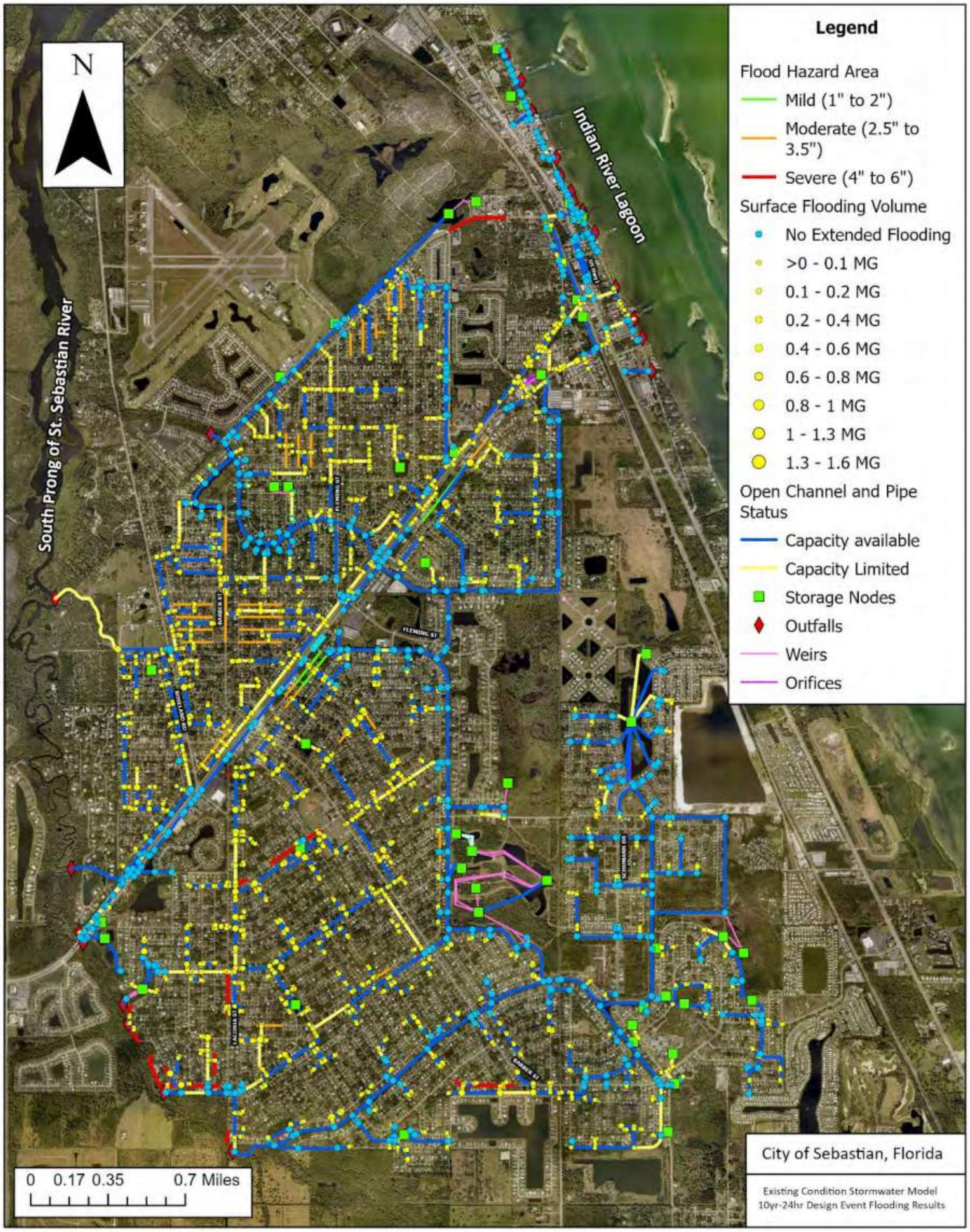
3.4.7 H&H Model Limitations

The model is a planning level representation of the City of Sebastian stormwater network and is based on the information available at the time of development. The model focuses on the main conveyance network and does not include all pipes and open channels within the model extents. The H&H model is a living model and as improvements are made to the system and additional information is collected, including new survey data and field investigations, the model will require updates to reflect the current conditions. Application of the model for future evaluations and design projects should include review of the project area to assess any model improvement needed to reflect the condition under analysis, comparison of modeled flows and/or heads with the most recent monitoring data available, and review of available survey data of the stormwater conveyance network.

3.5 Existing Conditions Design Storm Analysis Results

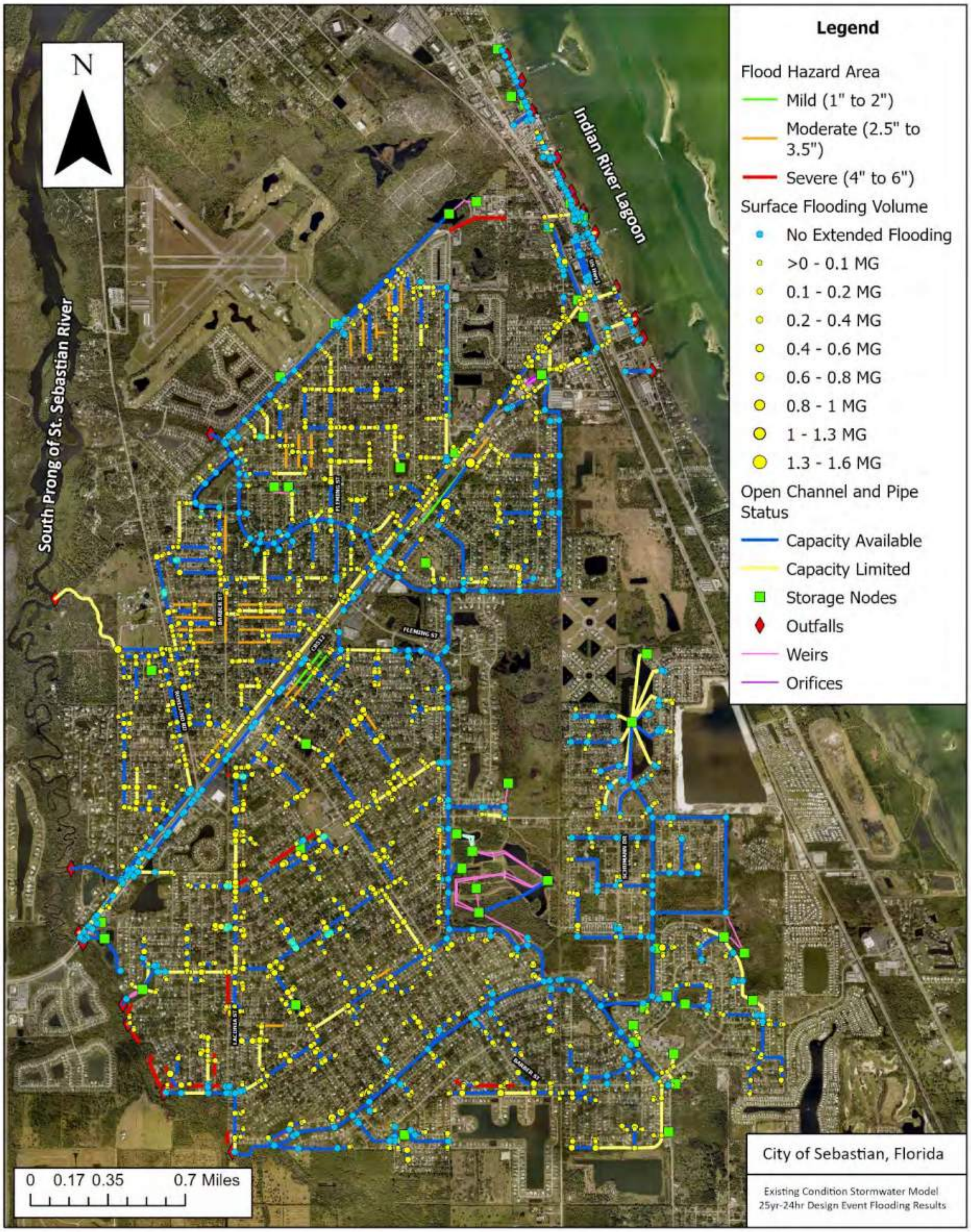
The validated 1D Hydrologic and Hydraulic stormwater model was used to identify locations and volumes of simulated surface flooding and review hydraulic gradelines for design wet weather events. According to the simulated existing conditions H&H model 1073, 1424, and 1738 locations experience flooding for more than two hours for the 10yr-24hr, 25yr-24hr, and 100yr-24hr design storm events respectively. The conveyance capacity of the existing stormwater infrastructure as calculated with Manning's Equation was used to identify pipes and open channel that are capacity limited for the design storms The surface flooding locations, relative flooding volumes, and capacity limited pipes/open channels simulated in the existing conditions model for the 10yr-24hr, 25yr-24hr, and 100yr-24hr design storm events are shown in Figures 3-4, 3-5, and 3-6. Modeled pipes and open channels identified as capacity limited for the design storm events in the plan view figures are provided in the Appendix K Stormwater Network Summary Tables. The current City of Sebastian Stormwater conveyance network experiences surface flooding during frequent wet-weather events which is represented in the model. The H&H model is a 1D model and the surface flooding is modeled with an assumed surface flooding area of 500 sf at each node; manhole, catch basin, culvert inlet/outlet, etc. The H&H stormwater modeling results identify areas with limited conveyance capacity and supported the development of capital improvement projects which reduce surface flooding within network. 2D modeling of the stormwater network including the surface topography in relation to the stormwater network will affect the simulated flooding locations and flooding extents compared to the 1D modeling results.

The existing conditions design storm results assume that drainage through Collier Creek is consistent with the conditions included in the 2012 FEMA Flood Insurance Study and that the Hardee Dam is able to discharge into the Collier Creek. The stormwater drainage through the Hardy Dam is a critical outfall in the City of Sebastian stormwater network. The loss of drainage and flood control capabilities through Collier Creek would have serious impacts on the flooding frequency and extent within the City of Sebastian.



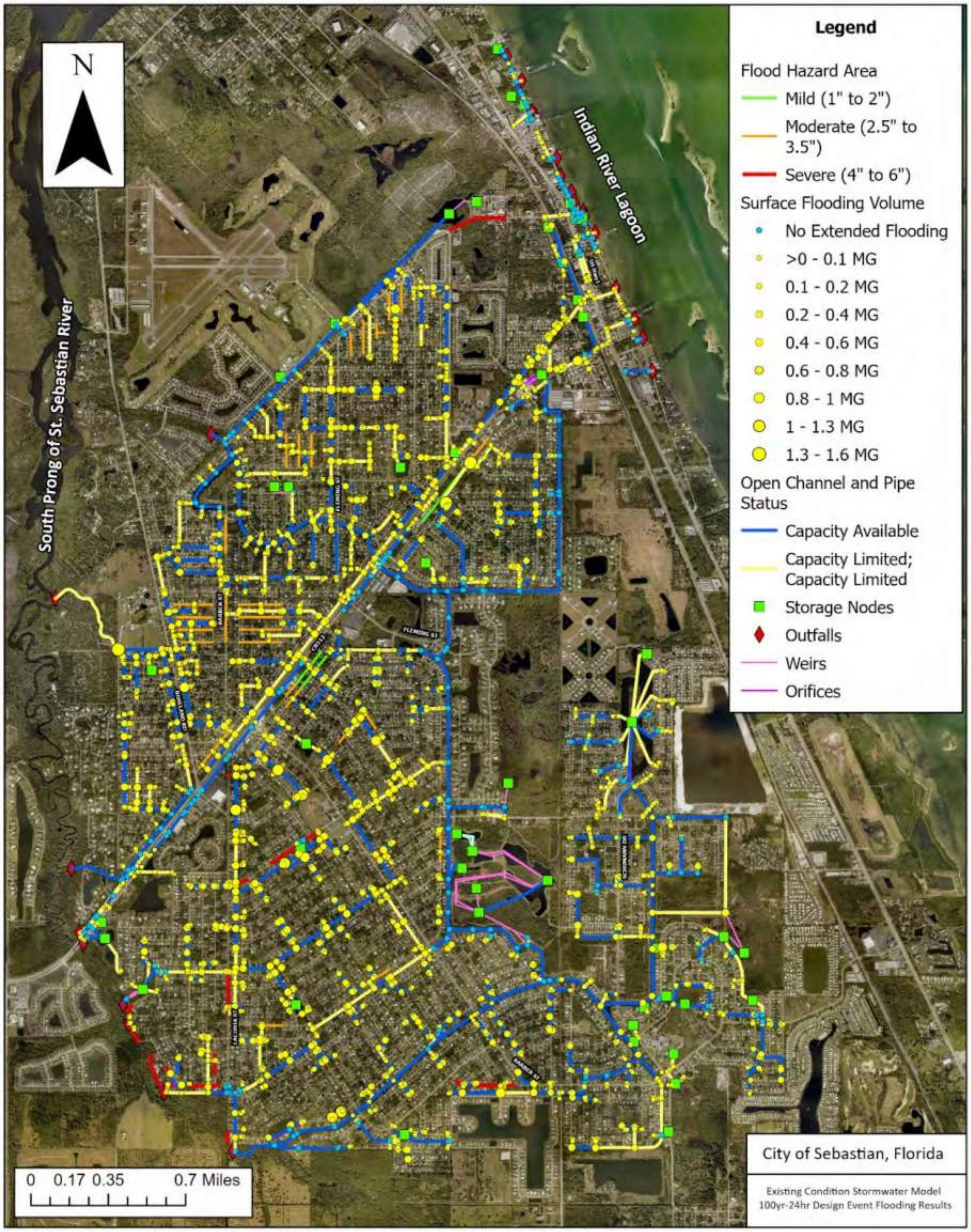
Note: Simulated flooding locations with a flooding duration less than two hours are not included in the presented results.

Figure 3-4. Surface Flooding Locations & Volumes, 10yr-24hr Design Storm



Note: Simulated flooding locations with a flooding duration less than two hours are not included in the presented results.

Figure 3-5. Surface Flooding Locations & Volumes, 25yr-24hr Design Storm



Note: Simulated flooding locations with a flooding duration less than two hours are not included in the presented results.

Figure 3-6. Surface Flooding Locations & Volumes, 100yr-24hr Design Storm