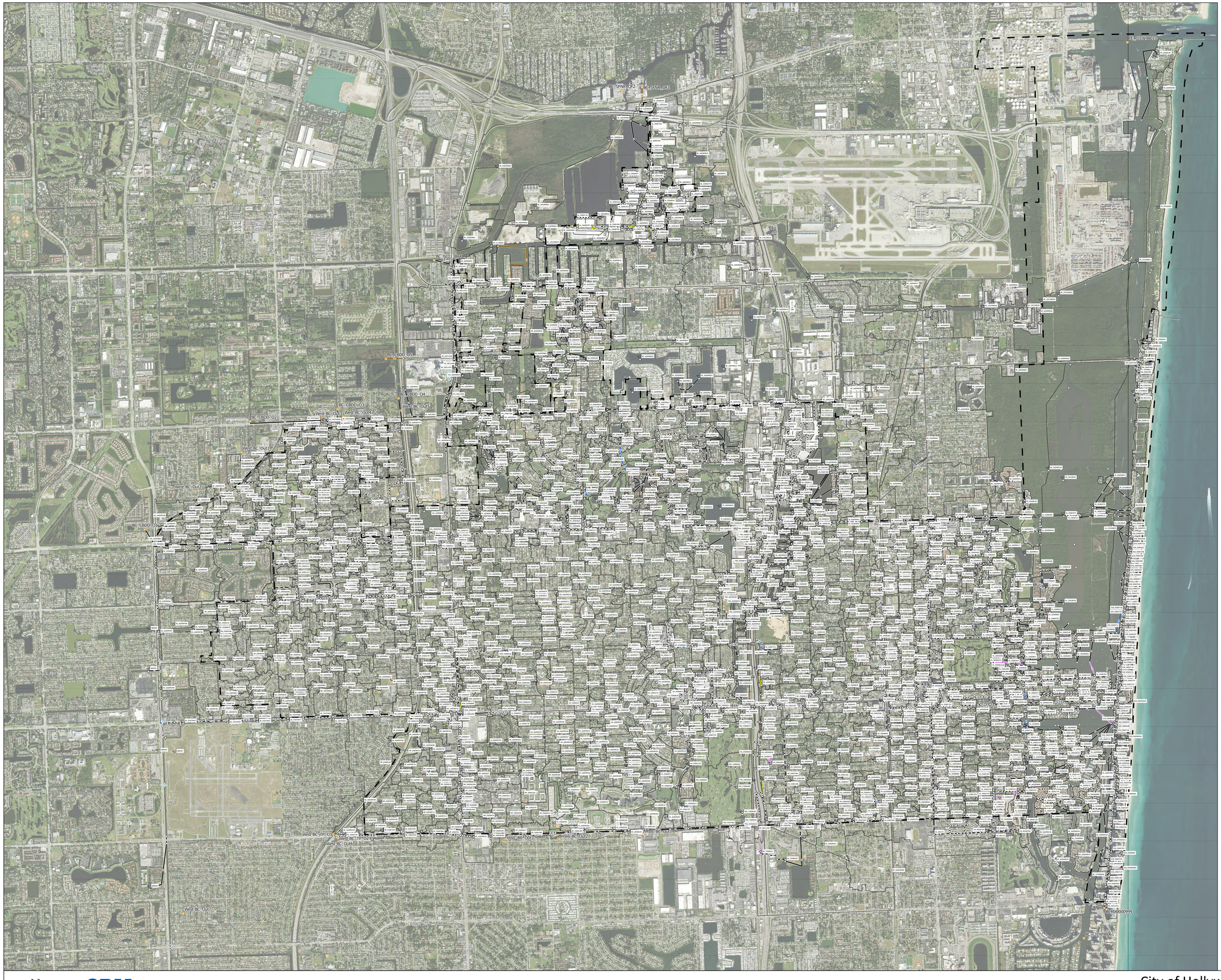


N

CDM Smith

CITY OF Hollywood FLORIDA

Stormwater Model Schematic

0 1,250 2,500 5,000 Feet

1:16,000 Map Scale

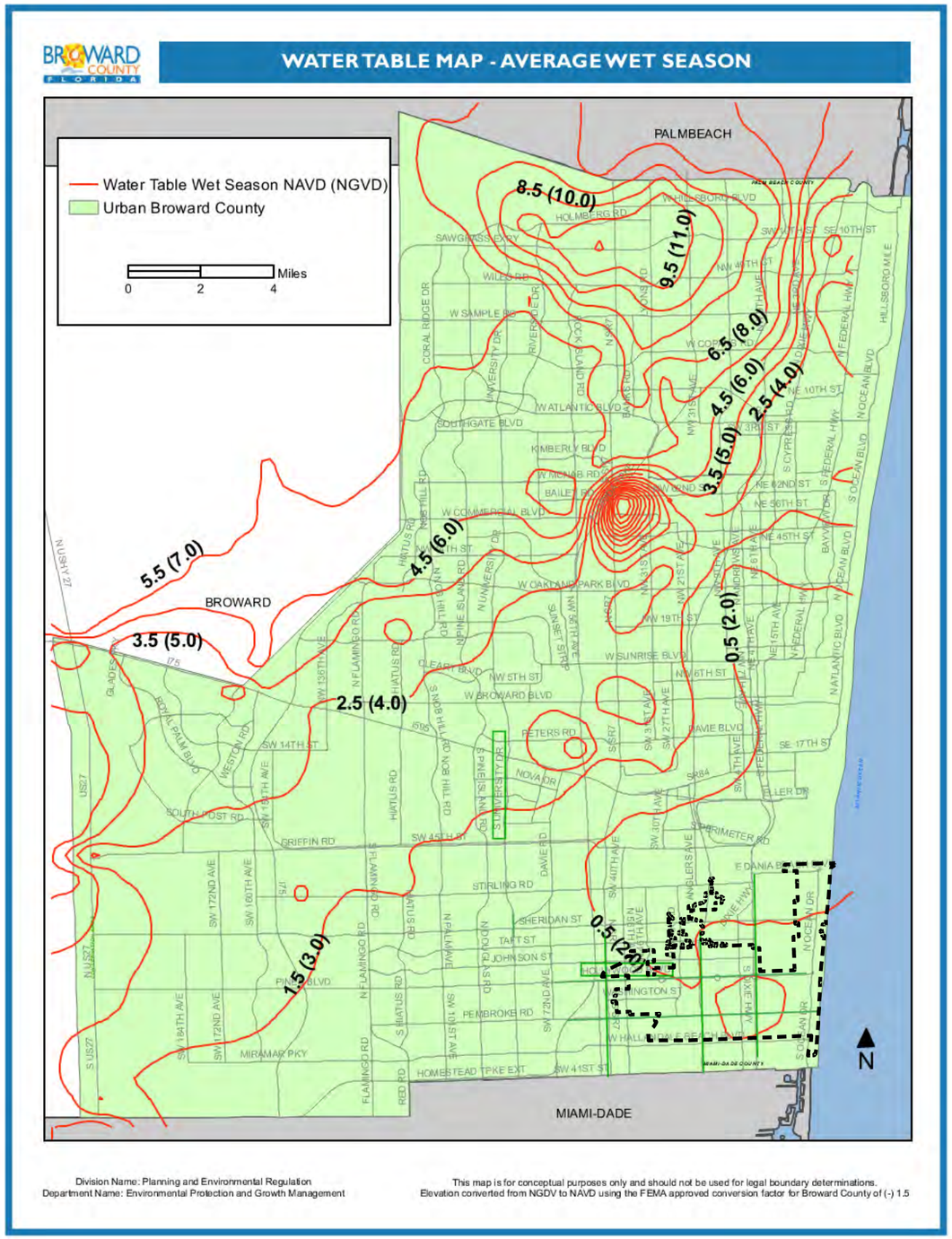
City of Hollywood Stormwater Master Plan

Figure B-1

4/6/2022

Appendix C

Broward County Published Groundwater Elevation 2000



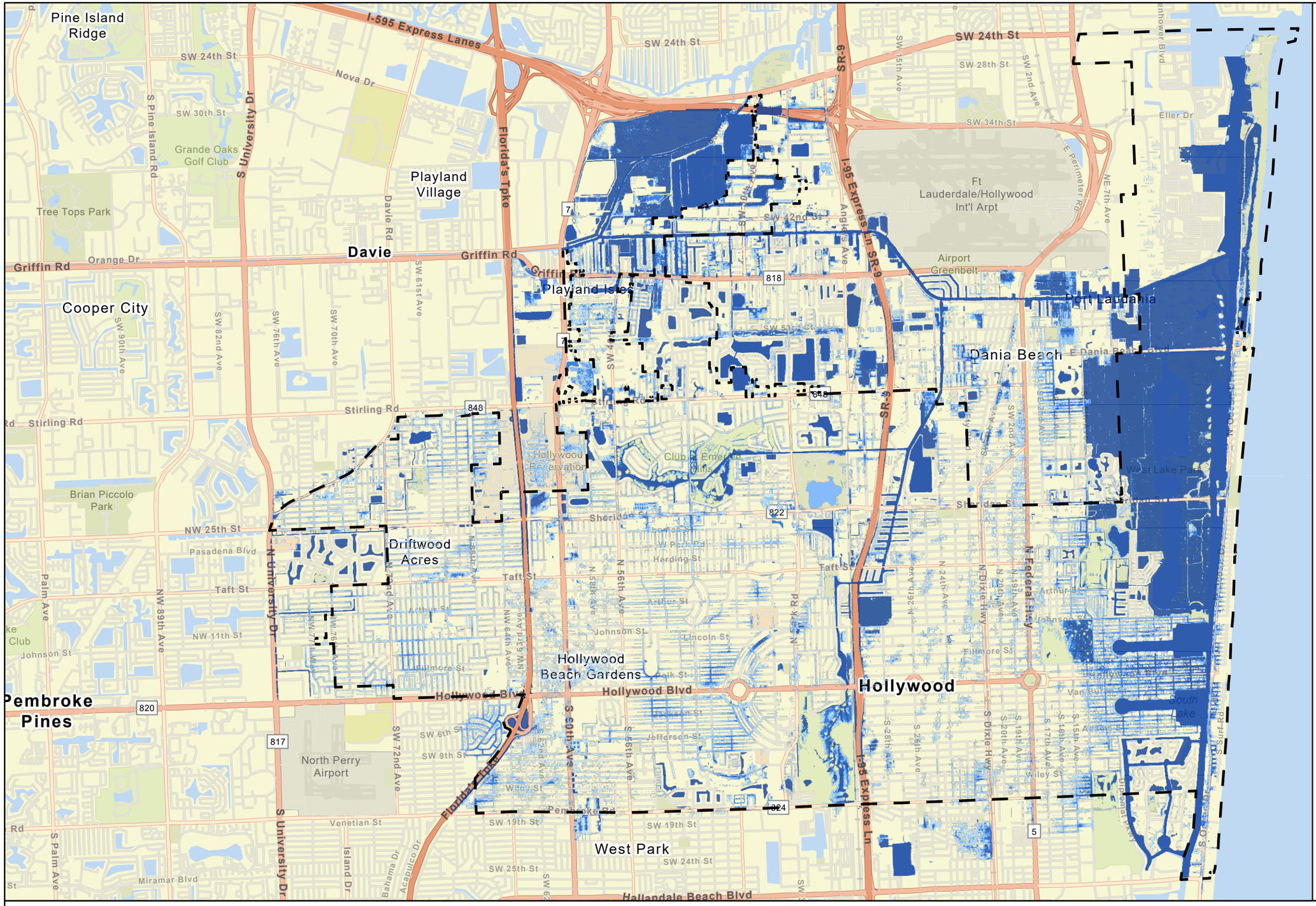
Hollywood City Limits

Broward County Published Groundwater Elevation 2000

City of Hollywood Stormwater Master Plan
Appendix C
4/12/2022

Appendix D

Inundation Maps Existing Conditions 5-yr 24-hr & 10-yr 24-hr Design Storms



5-Year 24-Hour Design Storm Flood

0 2,000 4,000 8,000 Feet

1:53,000

City of Hollywood Stormwater Master Plan
Figure D-1
4/6/2021

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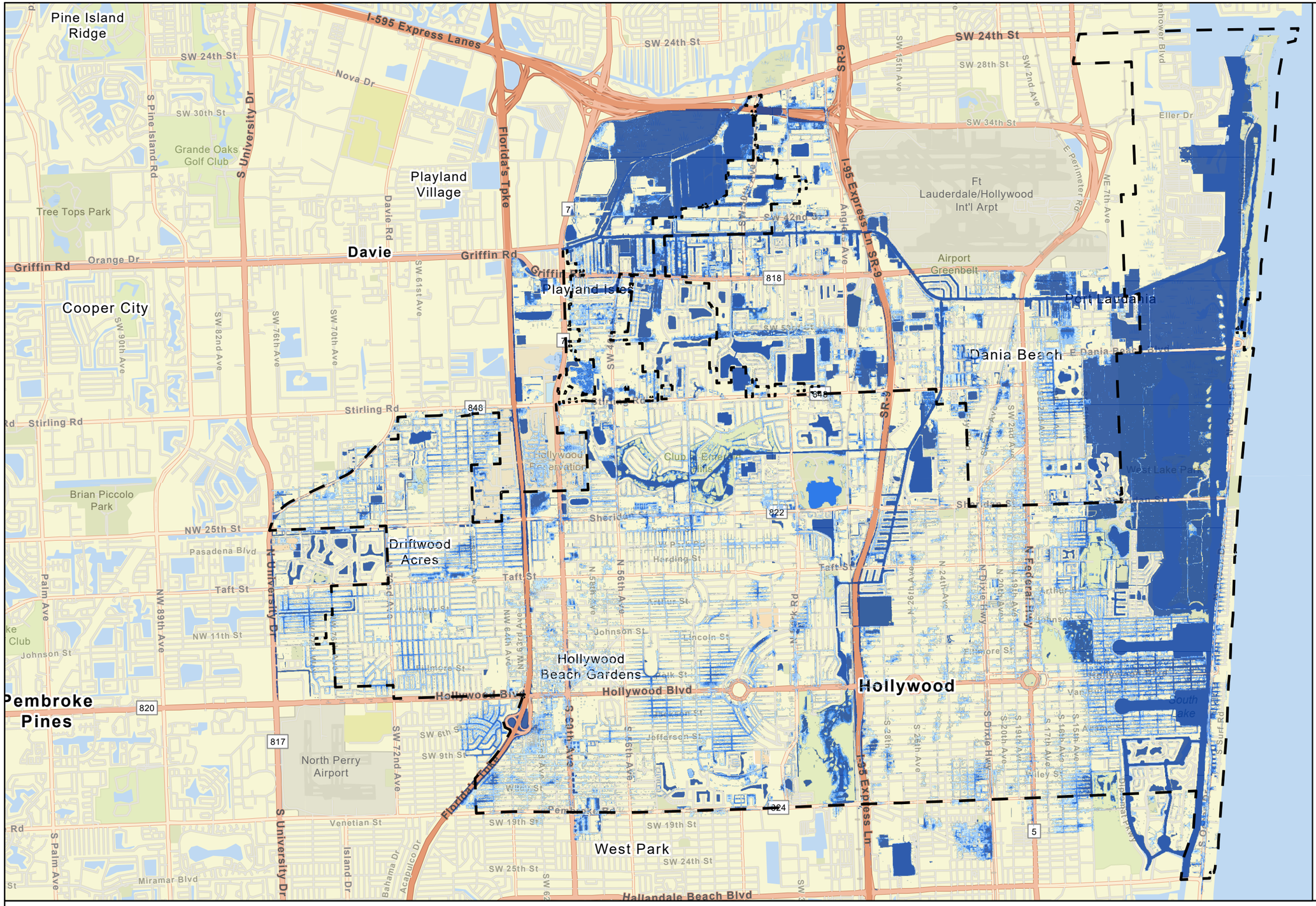

10-Year 24-Hour Design Storm Flood

City of Hollywood Stormwater Master Plan
Figure D-2
4/6/2021

0 2,000 4,000 8,000 Feet
1:53,000

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Section 2

Model Application Technical Memorandum

Technical Memorandum

Stormwater Model Application

City Project 20-11053
Comprehensive Citywide Stormwater Master Plan

November 2022

1.0 Introduction

This Technical Memorandum (TM) is provided as an interim deliverable for the Year 2 Services Scope item *Task 3* of City Project 20-11053, *Stormwater Master Plan Modeling and CIP Development Phase* and presents a summary of the application of the citywide stormwater models. This Model Application TM describes the specific techniques, parameters, and data processing used for the application of the stormwater models developed under Year 1 Services, implemented in the analysis phase of the work and presents the results of the flooding inundation simulations.

Project Work Phases

The full Stormwater Master Plan (SWMP) project is divided into four Tasks of major work phases:

1. *Data Collection and Evaluation Phase* – Development and production of the hydrologic and hydraulic data for surface and sub-surface conditions for the City and surrounding contributing area's Primary Stormwater Management System (PSMS). Creation of the interconnected storm systems and boundary conditions for the models and field survey of missing data required for the models. The deliverable for this task was the Data Gap Analysis TM providing a summary of what data was available and what was still needed, the data sources used, what was entered directly versus created, and the Updated City Stormwater Infrastructure Database (GIS). This effort was completed under Year 1 services.

2. *Stormwater Model Development Phase for Existing Conditions (EC)* – Development of the rainfall simulations and the detailed Storm Water Management Model (SWMM) to determine the EC Level of Service (LOS), validation of the models to actual rainfall events, and determination of the root causes of the flooding inundation extent and depth predicted. The deliverable for this task was the Model Development TM. This effort was completed under Year 1 services.

3. *Sea Level Rise Evaluation and Considerations Phase* (Year 2 Services) – Projection of climate change effects on the proposed Capital Improvements Program (CIP).

4. *Prioritized Capital Improvement Plan Phase with Benefit Cost Analysis Phase* (Year 2 Services) – Analysis of proposed CIP to meet two alternative LOSs desired by the City.

Other ongoing work includes a public information program and the final report, which will compile the results and summarize the recommendations of the prioritized CIP and costs.

1.1 Background Information

Stormwater Service Areas

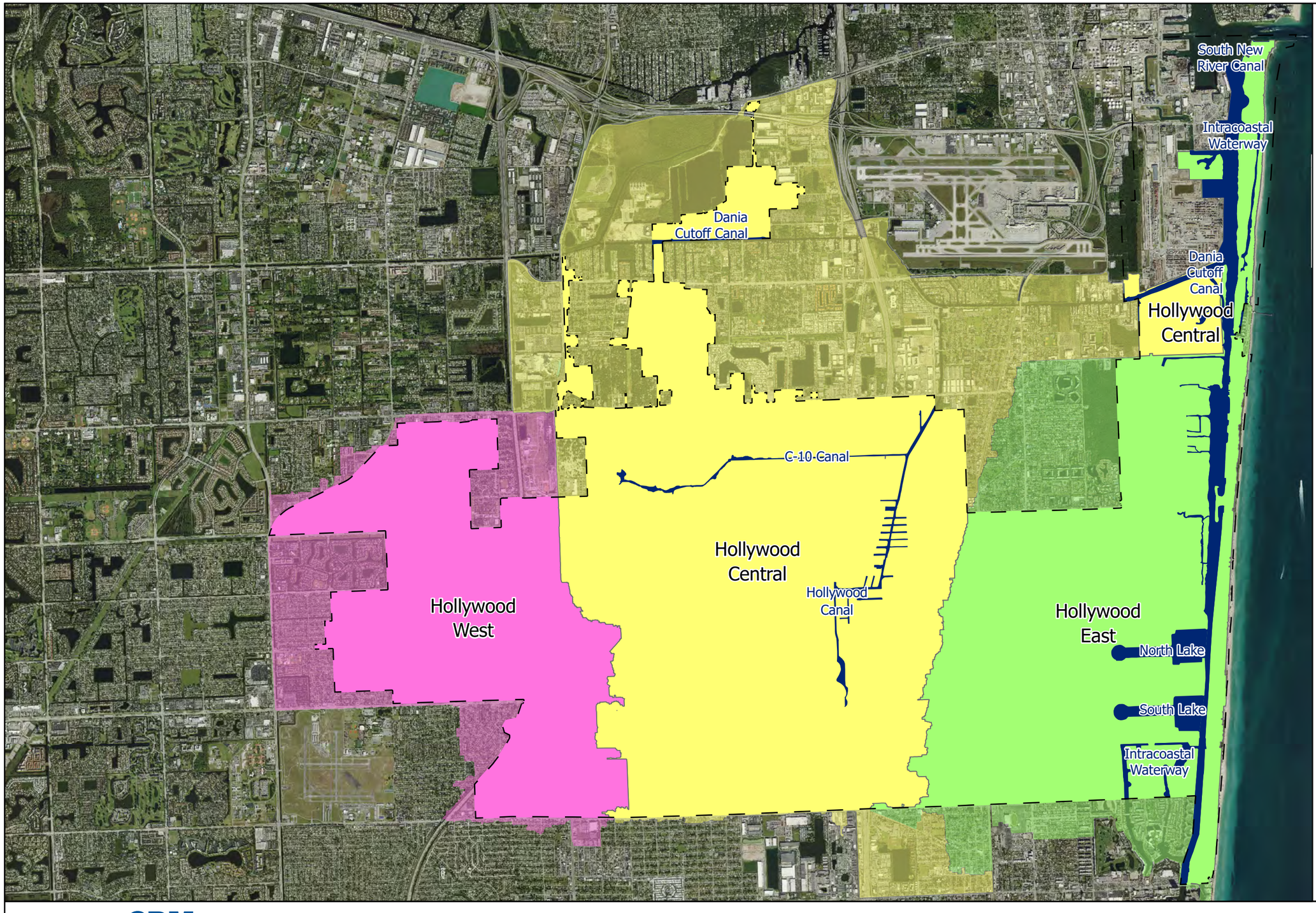
The City's mainland stormwater service area is divided by natural and man-made riverine/canal floodplains, topography, and major conveyance infrastructure into five major "Basins" as shown on **Figure 1-1**. The Hollywood Beach Basin is east of the Intracoastal Waterway (ICW) and is a separate, stand-alone basin primarily served by FDOT drainage systems along SR A1A.

There are areas of the City served by existing stormwater infrastructure that can be described as a "positive" drainage system infrastructure, such as catch basins, pipes, pumps, and outfalls that flow by gravity to the canals or ocean. Other areas are served by exfiltration systems where stormwater is captured and flows through underground perforated pipes that recharge the stormwater into the ground. However, many areas of the City have no stormwater infrastructure and floodwaters are solely conveyed by overland sheet flow, or they simply pond up as flooding and eventually infiltrate into the ground or evaporate.

As Hollywood is a coastal city with low ground elevations rising only to approximately 15 feet above sea level or lower (many areas are only 0.5–3 ft above sea level), there are many areas that are particularly susceptible to flooding as stormwater flows naturally into these low elevation depressional areas from the surrounding higher neighborhoods. With inadequate or non-existent stormwater infrastructure in place, the result is that flooding frequently occurs in the natural "bottoms of the bowls" whenever large amounts of rain fall. The flooding extent, depth, and duration increases when the ground is already saturated from previous storms, or when rainfall coincides with a high tide event, preventing the natural gravity flow off the land surfaces into the normally lower canals and other receiving waters.

Identification of Flooding Problems Areas Citywide

Flooding locations were identified by a combination of using existing reported flooding problems in the City database, FEMA repetitive losses and floodplains, Commission meetings for public input, and by use of the stormwater models and historic storms. Recorded rainfall intensity and volume, and the antecedent boundary conditions data for two past validation storms were simulated in the model under the previous analysis phase for the EC land use scenario and validated to actual reported flooding levels. Areas of major flooding inundation were identified along with an initial analysis of the root cause(s) of the flooding. Major flooding problem areas were identified and delineated within each Commission District. A description of each flood area and the probable causes of the flooding was presented in the Model Development TM and is shown graphically on **Figure 1-2**, which provides the citywide flooding inundation map as predicted for a 10-year recurrence interval storm. Flooding complaints identified by residents and at Commission-level workshops during the project as notable areas to be addressed in the SWMP are also shown on the figure.



Legend

- Hollywood City Limits
- Major Drainage Canals

Model Watershed

- Hollywood Central
- Hollywood East
- Hollywood West

CDM Smith

CITY OF Hollywood FLORIDA

City Limits, Major Drainage Canals, and Major Basins

0 2,000 4,000 8,000 Feet

1:53,000

City of Hollywood Stormwater Master Plan

Figure 1-1

08/08/2022

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Legend

Hollywood City Limits

10-Year Storm Flood Depth Feet

<= 0ft

0 - 0.5ft

0.5 - 1ft

1 - 1.5ft

> 1.5ft

Major Flooding Problem Areas

Major Flooding Problem Areas

Commissioner Meeting

Public Workshop Meeting

FEMA Reptitive Loss

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CDM Smith

CITY OF Hollywood FLORIDA

Major Flooding Areas

0 2,000 4,000 8,000 Feet

1:53,000

City of Hollywood Stormwater Master Plan

Figure 1-2

08/08/2022

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Stormwater Flood Control Level of Service

Stormwater LOS is defined as the benchmark used to determine how well the stormwater management system is operating for flood management compared to a goal or standard appropriate to the needs and desires of the City. Higher LOS will cost more to achieve, and in terms of most stormwater infrastructure, there is a point where it becomes exponentially more costly for only small additional improvements in flooding (i.e., "diminishing returns"). Based on competing needs for available budget and funding, system owners and operators need to choose a balance between the cost of fully achieving the desired LOS goal, versus allowing safe, short-duration ponding in known areas, for a known duration, for less frequent return interval storm events, or deem certain areas as known flooding areas and allow them to flood and return to being natural storage areas. The goal is to provide safe evacuation and emergency access for residents, police, fire, medical and emergency facilities, and to protect as many homes and buildings from flooding as possible.

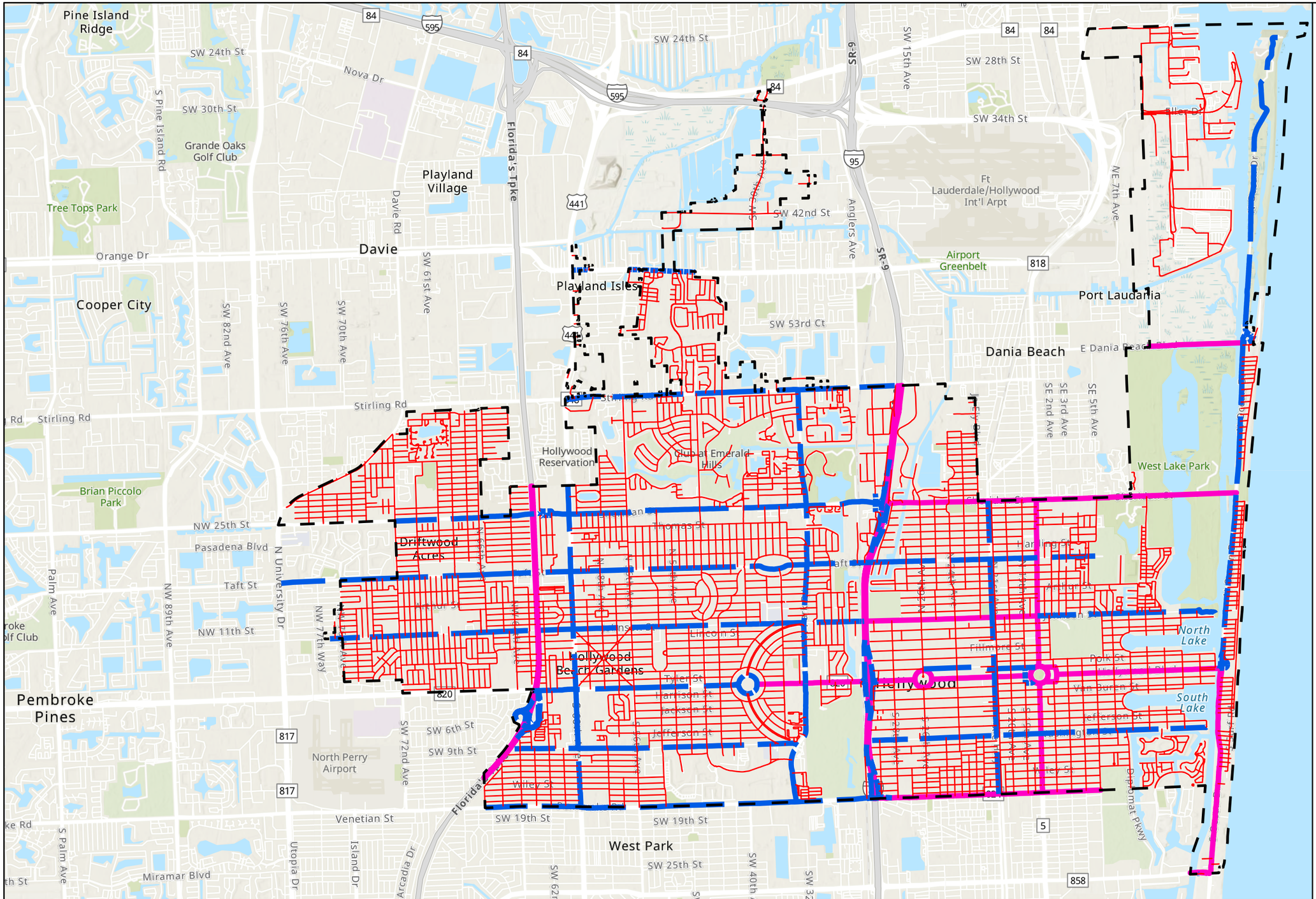
The analysis of two alternative LOS is performed for the SWMP so that the benefit-cost analysis (BCA) comparisons can be determined over a wider range of LOS, and to provide an alternate, potentially more practicable LOS goal. This is due to the anticipated high cost of implementing a CIP that fully meets the primary LOS goal in any existing area given the City's low topography, tidal and hydrologic characteristics, constraining permit requirements, and lack of dedicated land area for regional-scale stormwater management. The implemented LOS in any area will likely be a mix of LOS based on the area of the City and what the City can afford to fund to keep major roadways passable for emergency and evacuation traffic, and keep flooding below most homes and buildings to the maximum extent practicable within the available funding constraints.

The two Alternative LOSs chosen by the City during the discussions in Phase I are listed below:

- Alternative 1 – Primary LOS Goal – Up to 3 inches of flooding over the road crowns in the 10-year, 24-hour recurrence interval design storm for the major roadways and evacuation routes; and up to 3-inches above secondary and arterial residential streets for a 5-year, 24-hour storm; and flooding maintained below building finished-floor elevations in the 100-year recurrence interval design storm wherever practicable.
- Alternative 2 – Secondary LOS Goal – Potentially up to 6 inches of flooding allowable over the road crowns in the 10-year, 24-hour recurrence interval design storm for major evacuation routes; up to 6-inches of flooding above residential streets for a 5-year, 24-hour storm event; and flooding maintained below building finished-floor elevations in the 100-year recurrence interval design storm wherever practicable. This Secondary LOS goal may be re-evaluated with City staff once the draft of the Primary Goal has been developed.

Figure 1-3 provides a map of the major and minor roadways within the City being used for the LOS analysis with the above design flood criteria. The Broward County Evacuation Routes Map published by the Office of the Governor Florida Division of Emergency Management (FDEM) dated August 2021, has been adapted by the City for this use. The map shows the major cardinal evacuation roadways that lead to the major interstate highway I-95 for the east side and the Turnpike for the west side, including I-595 and the Sawgrass Expwy.

These evacuation routes are supplemented with other primary routes out of local roadways in the neighborhoods. The City Transportation Engineer 's review noted that Tyler, Polk, Hollywood Blvd, Johnson, and Taft Streets are additional evacuation routes that may carry some traffic under law enforcement guidance in an emergency.



Legend

- Hollywood City Limits
- Hollywood Evacuation Routes
- City Designated Major
- City Designated Minor/Residential

Major and Minor Roadways and Evacuation Routes Within Hollywood

0 2,000 4,000 8,000 Feet

1:53,000

City of Hollywood Stormwater Master Plan

Figure 1-3

08/08/2022

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2.0 Stormwater Model Application

The following sections describe how the USEPA Stormwater Management (SWMM) models were applied to obtain the baseline inundation results and establish the framework for documenting the current LOS. The models serve as the foundation for the water quantity analyses and stormwater infrastructure capital improvement planning. The figures presented in this TM section are subsets of the City-wide maps of topography, land-use, impervious cover, soils, geotechnical data, and groundwater, which were described in detail in the data development sections of the previously delivered Model Development TM.

The major basins created for the study area (that extend beyond the City limits to capture off-site contributions to flows and set boundary stages) were defined by both topography and interconnected stormwater infrastructure into the geographic boundaries shown previously on Figure 1-1. The major drainage basins identified for the study area were delineated as:

1. Hollywood Beach Basin
2. C-10 Spur Basin
3. C-10 (Hollywood Canal) Basin
4. C-11 Basin
5. Hollywood East Basin
6. Hollywood West Basin

Because of the interaction of the two "C-10 basins" (C-10 Canal Basin and C-10 Spur Basin) with the C-11 Canal basin, their inherent inter-connectivity, and for accuracy of results (as tested in the sensitivity analyses), these three basins were necessarily combined into one contiguous model, and renamed Hollywood Central Basin (HC), as their flows and stages will interact. Similarly, it was determined that the Hollywood Beach and Hollywood East models can interact under certain scenarios through the ICW and were also combined.

The three created SWMP models for the analysis are labeled:

1. Hollywood West (HW)
2. Hollywood Central (HC)
3. Hollywood East (HE)

As a result of the low-lying, relatively flat topography of the study area combined with the intensity of the largest design rainfall events and the associated depths of flooding, overland flow channels between major drainage basins were required to connect and capture the runoff between the individual models with the exception of the stand-alone model for the barrier island (HB) that is isolated by the Intracoastal Waterway (ICW) to the west and the Atlantic ocean to the east, and the

overland flows do not apply. Because of the high levels of detail in the stormwater model (average of 7 acre sub-basins), one single combined model is too cumbersome to be used efficiently for local neighborhood CIP iterative analyses for the SWMP, and the separate models are used for that purpose. Toward the end of the project, after the CIP Alternative analyses are completed for the two alternative LOS goals, the three separate models will be re-combined to a single City-wide model to check for boundary issues and for the overall analyses to determine boundary flow 5-10 acres conditions between the three area models where necessary.

Each of the three main basin models is described in further detail in the sub-sections below.

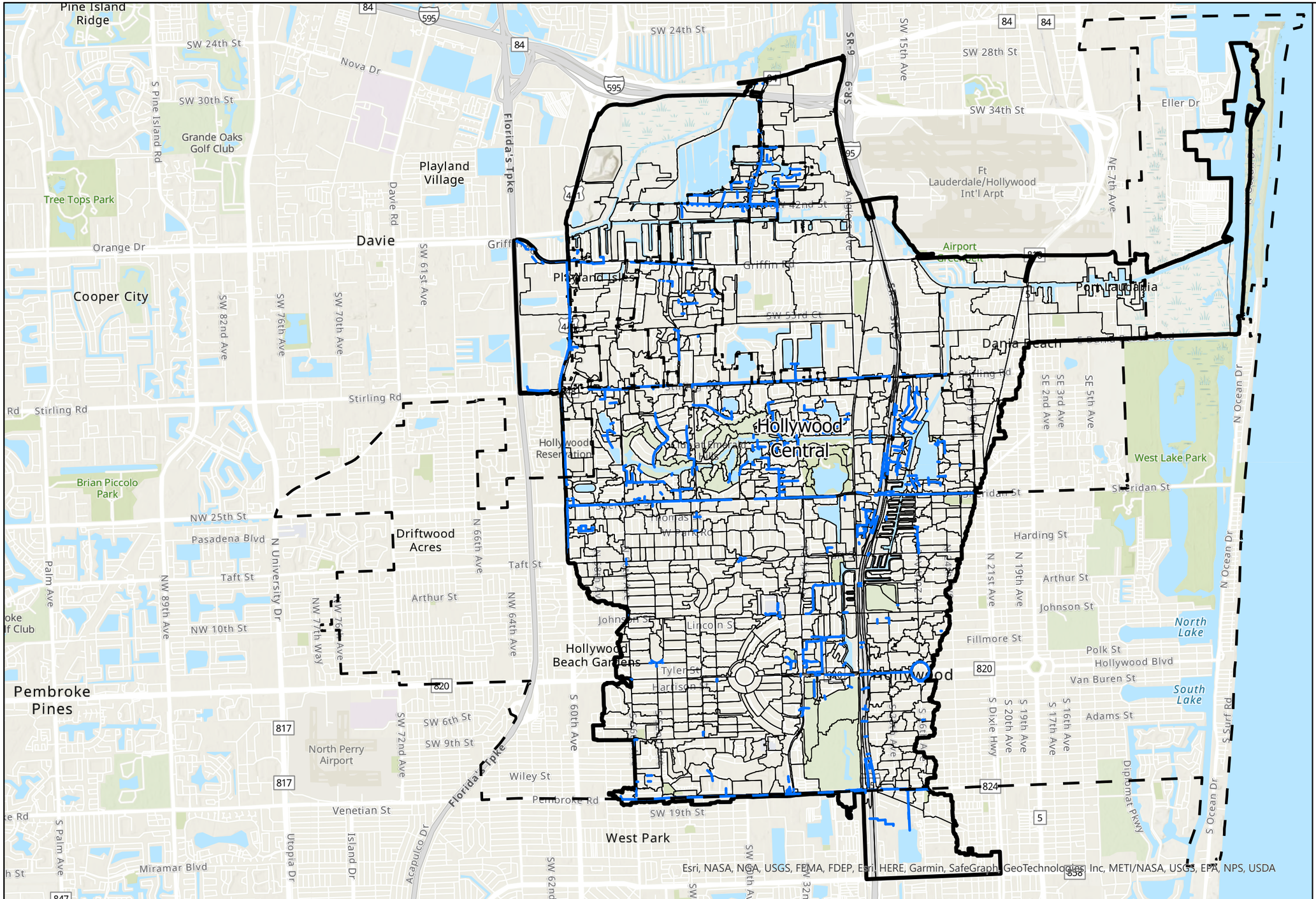
2.1 Hollywood Central Basin Model (HC)

2.1.1 HC Basin Description

In the Model Development TM and in the list above, the C-10 Basin was described as the watershed tributary to the "C-10 Spur" Canal, while the larger "C-10 Canal" from Orangebrook Golf and Country Club to the Dania Cutoff Canal was named the "Hollywood Canal." It is noted that there are some discrepancies between the SFWMD labels and the labeling on local maps between which section of the canal is truly designated the C-10 Spur, and what may be labeled as the Hollywood Canal. For modeling purposes, the C-10 Canal (or the Hollywood Canal) Basin is combined with the C-10 Spur Basin, so the entire combined basin is now labeled Hollywood Central (HC). As the City's subbasins tributary to the C-11 Canal represent a relatively small area, the C-11 Basin has been combined with the Central Basin as well.

The HC Basin spans 13,933 acres of low-lying land that primarily discharges east to the ICW through the Dania Cutoff Canal. The boundary condition in the ICW is a tidal stage time series, developed with the City-wide model for each design storm. However, since the ultimate boundary in the ICW at Port Everglades is fixed at 2.5 ft-NAVD for the base models (prior to sea level rise analysis), the stages in the ICW are very close to this elevation. A secondary outfall in this model is north of Interstate Highway I-595 through the South River Canal. Flows may occur both north (out of the modeled area), and south (into it) at this location, depending on stages in the New River and the Dania Cutoff Canal, respectively. A time series of canal stages have been implemented in the location, for each design storm, as discussed in the Model Development TM, Section 2.7.2.

Figure 2.1-1 includes a delineation of the HC Basin and a schematic representation of the PSMS within the basin. The northern boundary is delineated by W State Rd. 84, west of I-95 and Griffin Road east of I-95. The southern boundary is delineated near Pembroke Rd. west of I-95 and extending south to W Hallandale Beach Blvd east of I-95. The west boundary is determined by topography and PSMS, and roughly follows State Rd. 7 (a.k.a. US Route 441). The eastern boundary is delineated by a diagonal topographic ridgeline extending from NW 8th Ave at West Pembroke Rd to the intersection of Federal Hwy (US Route 1) and Dania Beach Blvd.



Legend

- Hollywood City Limits
- Subbasins
- PSMS >= 24in

CDM Smith

CITY OF Hollywood FLORIDA

Hollywood Central Basin and PSMS

0 2,000 4,000 8,000 Feet

1:53,000

City of Hollywood Stormwater Master Plan

Figure 2.1-1

11/28/2022

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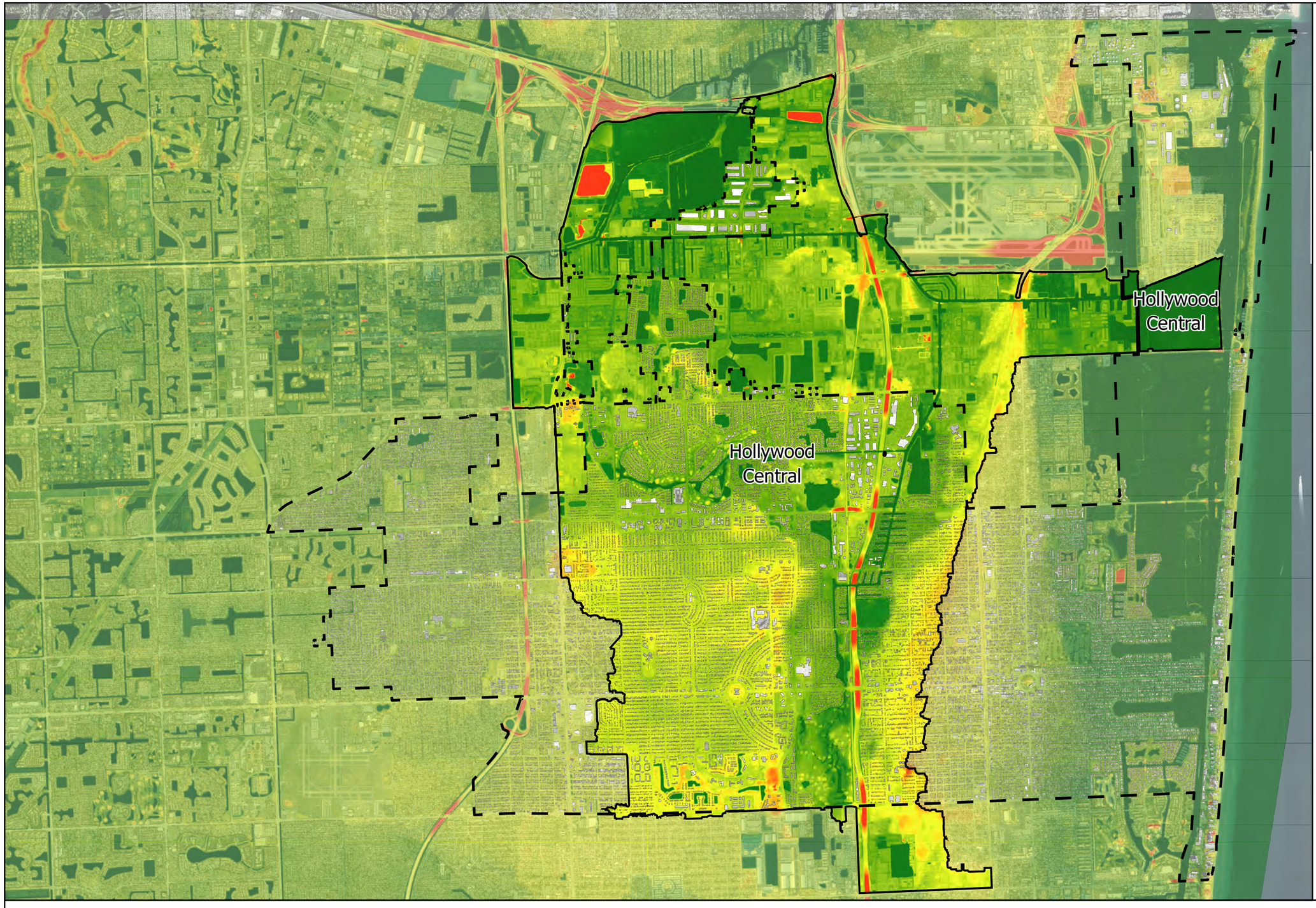
North of Dania Beach Blvd, the eastern boundary is the ICW. The HC Basin Model boundaries are adjacent to the Hollywood West Basin Model on the west and Hollywood East Basin Model on the East. This model also includes 8,321 acres within the City's limits and necessarily includes tributary areas beyond the City boundaries of 5,612 acres as shown on the figure.

Figure 2.1-2 shows the Digital Elevation Model (DEM) for the HC Basin in North American Vertical Datum (NAVD 88). Topographic elevations range from near 0 ft-NAVD in the wetlands near the ICW at the mouth of the Dania Cutoff Canal, to approximately 15 ft-NAVD along the ridge between the HC basin and HE basin, with one local neighborhood above 20 ft-NAVD. Approximately 95 percent (%) (1,670) of the HC Basin's stormwater inlets are between 2.5 ft-NAVD (the King Tide boundary condition) and 22.5 ft-NAVD; however, there are 88 of these (5% of the inlets) on the PSMS located where the LiDAR elevations are below 2.5 ft-NAVD. These lower elevations are all near the canal and are susceptible to storm surge and sea level rise. Further, the associated low street elevations preclude using gravity recharge wells or other exfiltration systems, since the driving heads are not sufficient for effective or efficient gravity discharge. Existing exfiltration systems currently installed in these areas and low-lying areas just above 2.5 ft-NAVD are not expected to work well, either as simulated in the model or in actual operation because of high water table effects.

Figure 2.1-3 presents a map of the impervious cover for the HC Basin based on the USGS NLCD coverage, and **Figure 2.1-4** presents a map of the SFWMD land-use for the HC Basin. As described in detail in the Model Development TM, impervious coverages were intersected with the sub-basin delineations to develop average impervious percentages for each sub-basin. The model also distinguishes between directly connect impervious areas (DCIAs), which are routed to the PSMS, and non-DCIA areas, which are routed to pervious areas within the sub-basin (such as a roof drain directed to a yard, rather than a driveway). In general, sub-basins with low total impervious area have large percentages of non-DCIA routed to pervious, while sub-basins with high imperviousness have low route-to-pervious percentages. The routing of runoff to pervious surfaces does not affect the volume infiltrated to soils but changes the timing of the runoff hydrograph. Other hydrologic parameters, such as pervious area roughness, were based on land-use type.

Figure 2.1-5 presents the total impervious percentage in the HC Basin, delineated by sub-basin. **Figure 2.1-6** presents a breakdown of the HC Basin land use by 10 standard consolidated categories, for use in the model. **Figure 2.1-7** presents a breakdown of the HC Basin impervious cover in the model. The area-weighted total impervious percent of the HC Basin is estimated to be 56.2%; therefore, approximately 7,836 acres of the 13,933 acres are expected to be impervious surface. Of this, approximately 1,067 acres are expected to be routed to pervious surfaces prior to entry into the HC Basin PSMS.

For design storm simulations, the SFWMD 24-hour and 72-hour unit hyetographs were used to simulate the rainfall distributions per storm. **Table 2.1-1** presents the volumes for the HC Basin for the 5-year, and 10-year 24-hour; and 25-year, and 100-year 72-hour design storms obtained from the NOAA Atlas 14.



Legend

- Hollywood City Limits
- Hollywood Central

2018 USGS DEM Elevation

20 ft

0 ft

Digital Elevation Model (DEM) for the Hollywood Central Basin

0 2,000 4,000 8,000 Feet

Scale: 1:53,000

City of Hollywood Stormwater Master Plan

Figure 2.1-2

08/09/2022

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