NEW SMYRNA BEACH
EXPOSURE ANALYSIS FROM HURRICANE IAN

New Smyrna Beach | June 2023

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EXPOSURE ANALYSIS FROM HURRICANE IAN

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1 BACKGROUND

In September 2022, Hurricane Ian produced approximately 20 inches of rainfall over the City of New Smyrna Beach. The rainfall coincided with a very high surge in Turnbull Bay. As a result, the City experienced widespread flooding. Some citizens were concerned whether the City could have done more to prevent or reduce the flooding through its maintenance practices and Stormwater Code and Standards, which covers events up to the 100-year storm event – a practice common throughout the state.

To address those concerns and determine what recommendations may be considered to further improve the City's resilience, the City contracted with Jones Edmunds to perform an Exposure Analysis. The Exposure Analysis was conducted in a manner that it can serve as part of the City's upcoming Florida Department of Environmental Protection (FDEP)-funded Vulnerability Assessment, for which the City applied for and received an FDEP grant that covers the full cost of the study. The following summarizes the Scope of Services for the Exposure Analysis:

- Task 1 – Kickoff Meetings – Review the project scope, project goals, schedule, key milestones, deliverables, project communication, and points of contact. One public meeting and one with City staff.
- Task 2 – Acquire Background Data – Gather data necessary to develop and validate a Two-Dimensional Unsteady FLOW (TUFLOW) model of the City and its contributing area and to review the City's Stormwater Code and Standards.
- Task 3 – Review City Stormwater Code and Standards – Review the City's Stormwater Code and Standards and compare them to standards from similar communities in Florida. Provide an opinion of their appropriateness and where improvements may be feasible enough to consider.
- Task 4 – Exposure Analysis – Develop and validate a TUFLOW model of the City and its contributing area. Simulate Hurricane Ian and validate to recorded flooding from that event. Run the 100-year/24-hour event using the same model and compare to the results from the Hurricane Ian simulation to quantify the amount of flooding that was in excess of the 100-year/24-hour event.
- Task 5 – New Development Analysis – Starting with the model from Task 4, restore the hydrology of two large developments to predevelopment conditions. Compare pre-/post-flood stages to test the effectiveness of the City's Stormwater Code and Standards.
- Task 6 – Final Report – Summarize data collection, approach for analyses, findings, and recommendations.
- Task 7 – Special City Commission Presentation – Present findings and recommendations to the Commission.

2 DATA COLLECTION

2.1 STORMWATER DATA INVENTORY AND EVALUATION

The City provided Jones Edmunds with shapefiles of their stormwater system network, which consists of structure and pipe locations. The stormwater pipes polyline shapefile comprised 4,921 features with pipe size and material fields. The stormwater structures point shapefile consisted of 6,613 point features showing the locations of stormwater inlets.

Volusia County provided Jones Edmunds with shapefiles containing information about the County's stormwater pipes, open channels, retention ponds, and outfall structures. The stormwater pipes polyline shapefile comprised 12,622 features with fields containing pipe size, material, and shape. The County also provided a shapefile containing the locations of National Pollutant Discharge Elimination System (NPDES) outfall structures.

In reviewing these datasets, Jones Edmunds found that most pipe features from the City and County contain pipe size and material information but do not contain invert elevations. Jones Edmunds determined a best-fit assumption using the digital elevation model (DEM) at pipe endpoints for pipes with known invert elevations for filling in inverts with missing invert elevations for modeling purposes.We then updated the inverts where the pipe crown was calculated to be above the road or within 12 inches of the road elevation. For the analyses performed in this study, the model is relatively insensitive to these estimated invert elevations.

3 REVIEW OF CITY STORMWATER CODE AND STANDARDS

Jones Edmunds reviewed the City's Stormwater Code and Standards and compared them to standards from similar communities in Florida. The review provides an opinion of the Code and Standards' appropriateness and where improvements to them could be considered. Although we reviewed all aspects, our focus was on flood protection. This Section summarizes the review.

3.1 STORMWATER STANDARDS

Most of the City's Stormwater Standards are in *Article VI. Development Design and Improvement Standards* of *Part III – Land Development Regulations* of the *Code of Ordinances City of New Smyrna Beach, Florida (Code of Ordinances)*. The *Code of Ordinances* contains important amendments from Ordinance No. 109-20, which covered changes to Buildings and Building Regulations and Floodplain Management, among other items.

In general, the City's Stormwater Standards are among the most comprehensive and protective we have reviewed in the state. In this Section, we highlight important flood-protection aspects of the Standards and suggest minor improvements.

3.1.1 EXISTING STANDARDS

The following elements of the Standards are among those that are helpful for preventing adverse off-site flooding (i.e., protecting existing properties from increases in flooding due to development, redevelopment, capital improvement projects, or alterations to the stormwater management system):

- The Standards require conformance with Florida Administrative Code (FAC) Chapter 40C-42, *Stormwater Discharge Rule – St. Johns River Water Management District (SJRWMD)*. Local standards cannot be less stringent than State or Water Management District standards. Generally, the City's Stormwater Standards are more stringent (i.e., more protective) than those in Chapter 40C-42.
- Article VI, 604.01.A(2) reads as follows:

  All development that utilizes a central lake or series of lakes for water retention/ detention, must provide protection against flooding for the 100-year, three-day storm; and if the development is located within a FEMA flood hazard zone, the FEMA 100-year flood elevation cannot be increased.

  This standard is higher than the typical controlling requirement to a 25-year/24-hour storm event.
- All property owners must maintain stormwater management systems approved by the City Engineering Department.
- A permitting exemption exists for new building additions to existing single-family and duplex homes of up to 500 square feet. This type of exemption is common, and the threshold used by the City is relatively low. A lower area threshold may become impractical and not significantly helpful for mitigating adverse off-site flooding impacts.
- The existing requirement that a sufficiently wide drainage easement is provided to ensure that adequate maintenance can be provided in the future.
- Phased projects are required to provide an overall plan for the applicant's total land holdings.
- Article VI, 604.01.B(3)e reads as follows:

  No site alteration shall cause siltation of wetlands, pollution of downstream wetlands, or reduce the natural retention or filtering capabilities of wetlands, or lowering of the existing water table.

  This requirement helps to ensure that the flood-protection benefits provided by wetlands are maintained.
- Article VI, 604.01.B(7) reads as follows:

  > *Maintenance. The installed systems required by this section shall be maintained by the owner except that the city may accept certain systems for city maintenance. The selection of critical areas and/or structures to be maintained by the city engineer shall be determined after receipt of comments from the appropriate officials. All areas and or structures to be maintained by the city must be dedicated to the city by plat or separate instrument and accepted by the city commission. The systems to be maintained by the owner shall have adequate*

easements to permit the city to inspect and, if necessary, to take corrective action should the owner fail to properly maintain the systems. Should the owner fail to properly maintain the systems, the city engineer shall give such owner written notice of the nature of the corrective action. Should the owner fail, within 30 days from the date of the notice to take, or commence taking, corrective action to the satisfaction of the city engineer, the city may enter upon lands, take corrective action and place a lien on the property of the owner for costs thereof.

This provision ensures that critical drainage infrastructure can be maintained by the City at the owner's expense if not properly maintained by the owner.

- Ordinance No. 109-20 has multiple provisions to ensure that new buildings will not be built at elevations that place them at a high risk of flooding.

- Article VI, 26-684 reads as follows:

  (f) Compensating storage. Flood storage volume shall not be reduced by development unless compensating storage for all floodwater displaced by development below the base flood elevation is provided:

  a. No more than 50 percent of the total flood storage volume of a parcel may be filled or occupied by development.
  b. The volume of the development for which compensating storage is required is to be calculated between the base flood elevation and the seasonal high water table. The seasonal high water table shall be established by a registered professional engineer licensed in the State of Florida with expertise in geotechnical engineering based on recent soil borings on the subject site.
  c. For development on parcels of one acre or less, compensating storage volume shall be equal to the volume of the development.
  d. For development on parcels larger than one acre, compensating storage volume shall be 1.5 times the volume of the development.
  e. Compensating storage volume shall be provided onsite and within the same drainage sub-basin as the development, unless otherwise approved by the City Engineer.

  This level of required compensating storage is more than the typical 1:1 requirement and is protective of new and existing structures.

3.1.2 Potential Improvements to the Standards

The elements below are also helpful for preventing adverse off-site flooding but could be improved or further clarified:

- *Increased impervious area of 2,500 square feet or less to an existing commercial structure including related site improvements is exempted from permitting.*

  This threshold is significantly larger than the residential threshold of 500 square feet and may be large enough in some instances to cause or contribute to adverse off-site impacts. The City may consider reducing this threshold or reserving the right to waive or lower the exemption at the discretion of the City Engineer.

- Article VI, 604.01.B(3) reads as follows:

  … a hydrologic requirement necessitates compliance with the latest releases and revisions of the US Department of Agriculture, Soil Conservation Service's Technical Release No. 55, titled Urban Hydrology for Small Watersheds, except that the 100-year storm requirements shall not be required.

  The qualifier at the end about the 100-year storm may be inconsistent with other parts of the Standards that require covering the 100-year storm and may need clarification for consistency.

- Article VI, 604.01.B(3)b reads as follows:

  For a 25-year storm of 24 hours duration, the peak discharge rate and the total runoff volume leaving the developed or redeveloped site shall be limited to the 110 percent of the peak discharge rate and the total runoff volume prior to development or redevelopment.

  Apparently, the value of 110 is intended to be 90, which is consistent with past research showing that controlling peak flows to the 100-percent level is sometimes not fully protective of adverse off-site impacts. As with the previous comment, clarification is needed for when the 25-year or 100-year storm is required.

- Article VI, 604.01.B(3)d appears to reference critical duration storms. Although the use of critical duration storms is a sound practice, it is not consistent with 604.01.B(3)b, which specifies a 24-hour duration event. The City should consider revisions to the Standards that clarify event durations in the several locations where they are referenced for consistency.

- Article VI, 604.01.B(3)I reads as follows:

  In subdivisions and on parcels where stormwater retention meeting current standards is not provided, filling of low lots shall not be allowed within required yard areas except that a minimum amount of fill may be allowed for: (1) a driveway and up to five feet on either side of the driveway; and (2) no more than six inches of fill may be allowed within the required yard areas provided an adequate drainage scheme is constructed to not allow stormwater onto adjacent lots. Construction techniques allowed to elevate the first floor of a structure include use of stem wall and pier foundations.

  Whether the compensating storage requirement in Article VI, 26-684(f), *Compensating Storage,* applies to the allowed fill is not clear. Also, the City may consider adding the safe discharge of off-site flows coming onto properties where fill is allowed.

- Although a general requirement exists to safely convey off-site stormwater flows, a specific standard for how that is demonstrated to the City does not exist. The City may consider a standard for demonstrating that a new development or redevelopment area does not create adverse off-site impacts for flows that historically passed through the property.

- Ordinance No. 109-20 has multiple references to minimum first floor elevation requirements that are reasonable and, to an extent, protect against increasing flood risks due to climate change by adding freeboard. However, the City has been awarded an FDEP Resilient Florida Planning Grant to conduct a Vulnerability Assessment. The FDEP requirements for the Grant will include analyzing the existing, 2040, and 2070 conditions for coastal and inland flooding. The City can compare the difference in results from the existing to 2070 conditions to the current freeboard requirements in Ordinance No. 109-20 to determine whether they are adequate for protecting against future increases in flood risks.
- Given the number of properties in the City that are in a FEMA Special Flood Hazard Area (SFHA) and were developed before modern stormwater regulations and the City's current Stormwater Codes and standards, the City may consider regulating all new development and redevelopment to the 100-year storm event.

3.2 Comprehensive Plan

The Comprehensive Plan – and as reflected in the City's development standards – appears to be in compliance with the Peril of Flood Act.

4 EXPOSURE ANALYSIS

4.1 Citywide Inundation Model Extents

Jones Edmunds developed a two-dimensional (2D) inundation model for the City within TUFLOW HPC (Release 2020-10-AF). Figure 1 (at the end of this report) shows the extents of the citywide model. The model was broken into the Mainland and Beachside regions since these two regions could be modeled independently of each other.

4.2 Computational Mesh

Jones Edmunds developed the citywide model using a variable-grid resolution. The computational mesh was set up to enable sub-grid sampling of elevations every 2.5 feet. This enabled the model to sample elevations every 2.5 feet along the cell edges characterizing flow between the grid cells. Storage within each cell was also characterized at a resolution of 2.5 feet within each grid cell. This allowed the model to take advantage of the high-resolution light detection and ranging (LiDAR) obtained from the US Geological Survey (USGS). We used a grid resolution of 60 feet in areas outside the city limits and a resolution of 15 feet within the City limits.

4.3 Digital Elevation Model

Jones Edmunds downloaded a copy of the 2019 LiDAR data for Volusia County from USGS. The 2019 LiDAR data were collected between December 4, 2018, and March 22, 2019. The data coordinate reference system is as follows:

- The horizontal datum is the North American Datum of 1983 with the 2011 Adjustment (NAD83 [2011]).
- The vertical datum is the North American Vertical Datum of 1988 (NAVD88).
- The coordinate system is NAD83 (2011) State Plane Florida East (US Survey Feet).

- The geoid model is Geoid12B.

The vertical accuracy of the 2019 LiDAR was reported as having a root-mean-square-error relative to non-vegetated checkpoints of 0.32 foot at the 95-percent confidence interval. The LiDAR was provided as a 2.5-foot-by-2.5-foot DEM.

4.4 Green-Ampt Soil Parameters

Jones Edmunds used the US Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographic (SSURGO) database for classifying soils within each model. The spatial data from SSURGO was last updated by NRCS in September 2019 and tabular data were last updated in September 2022. Jones Edmunds used a combination of SSURGO soil data, the Characterization of Florida Soil (University of Florida/Institute of Food and Agricultural Sciences [UF/IFAS], 2006) database, and other standard soil characterization references to develop Green-Ampt infiltration parameters for the model. As part of model calibration, some adjustments were made to soil parameters. Table 1 shows the soil parameters used for the citywide model following calibration.

4.5 Landcover and Impervious Mapping

Jones Edmunds used the following sources to generate a landcover map over the model domain:

- 2014 SJRWMD landcover mapping.
- 2018 USGS National Hydrography Dataset (NHD).
- 2022 Microsoft state-wide building footprints.
- Jones Edmunds' impervious mapping.

The landcover map from SJRWMD was developed based on 2013 to 2016 digital orthoimagery. Jones Edmunds manually edited areas that have been developed or changed since 2014. The USGS NHDPlus dataset uses the 10-meter three-dimensional (3D) Elevation Program Digital Elevation Model (3DEP DEM) and the National Watershed Boundary Dataset (WBD) to map stream networks and waterbodies across the country. We supplemented our impervious mapping with 2022 Microsoft building footprints. Some residential areas are missing building footprints, potentially because they were built after the footprints were developed. Jones Edmunds mapped imperviousness across the City using a combination of LiDAR data and four-band aerial imagery obtained from the National Agriculture Imagery Program (NAIP). The impervious mapping generated by Jones Edmunds consists of over 430,000 unique polygons.

Table 1 Modeled Green-Ampt Soil Parameters

MUKEY	Soil Name	Ksat (in/hr)	Suction Head (inches)	Porosity	Initial Moisture
1544142	Astatula fine sand, 0 to 8 percent slopes	26.49	1.95	0.44	0.08
1544186	Basinger fine sand, frequently ponded, 0 to 1 percent slopes	6.24	2.06	0.40	0.19
1544112	Canaveral sand, 0 to 5 percent slopes	49.96	1.95	0.70	0.00
1544113	Cassia fine sand, 0 to 2 percent slopes	20.73	1.95	0.59	0.05
1544114	Chobee fine sandy loam	0.05	5.36	0.44	0.36
1544115	Cocoa sand, 0 to 5 percent slopes	45.72	1.95	0.52	0.05
1544117	Daytona sand, 0 to 5 percent slopes	18.39	1.95	0.50	0.13
1544121	EauGallie fine sand	1.39	3.74	0.38	0.24
1544123	Electra fine sand, 0 to 5 percent slopes	18.29	3.14	0.50	0.17
1544124	Farmton fine sand	5.41	3.11	0.54	0.18
1544125	Fluvaquents	1.50	1.97	0.80	0.50
1544126	Gator muck, 0 to 1 percent slopes, frequently flooded	1.41	6.94	0.54	0.30
1544127	Holopaw sand	5.24	2.25	0.54	0.16
1544128	Hontoon muck, frequently ponded, 0 to 1 percent slopes	5.23	1.95	0.97	0.00
1544130	Immokalee sand	13.67	1.95	0.55	0.16
1544133	Malabar fine sand	5.42	2.31	0.40	0.18
1544134	Myakka-Myakka, wet, fine sands, 0 to 2 percent slopes	3.57	2.03	0.65	0.16
1544139	Orsino fine sand, 0 to 5 percent slopes	23.21	1.95	0.53	0.08
1544141	Palm Beach sand, 0 to 8 percent slopes	40.70	1.95	0.64	0.00
1544143	Palm Beach-Urban land-Paola complex, 0 to 8 percent slopes	40.70	1.95	0.64	0.00
1544145	Paola fine sand, 0 to 8 percent slopes	33.86	1.95	0.43	0.05
1544148	Pineda-Pineda, wet, fine sand, 0 to 2 percent slopes	1.27	1.95	0.50	0.19
1544149	Pinellas fine sand	0.38	4.65	0.50	0.20
1544151	Placid fine sand, frequently ponded, 0 to 1 percent slopes	3.91	1.95	0.42	0.20
1544152	Pomona fine sand	10.43	2.70	0.63	0.13
1544156	Pompano fine sand	22.86	1.95	0.38	0.05
1544157	Pompano-Placid complex	21.37	1.95	0.62	0.09

MUKEY	Soil Name	Ksat (in/hr)	Suction Head (inches)	Porosity	Initial Moisture
1544159	Riviera fine sand	0.37	3.19	0.41	0.20
1544160	Samsula muck, frequently ponded, 0 to 1 percent slopes	0.43	1.95	0.79	0.10
1544161	Satellite sand, 0 to 2 percent slopes	44.00	1.95	0.68	0.03
1544163	Scoggin sand	0.02	4.71	0.37	0.30
1544165	Smyrna-Smyrna, wet, fine sand, 0 to 2 percent slopes	8.01	2.06	0.64	0.11
1544166	St. Johns fine sand	0.97	2.00	0.50	0.25
1544167	St. Lucie fine sand, 0 to 5 percent slopes	29.44	1.95	0.43	0.04
1544168	Tavares fine sand, 0 to 5 percent slopes	18.86	1.95	0.45	0.05
1544169	Tequesta muck, frequently ponded, 0 to 1 percent slopes	15.10	1.95	0.62	0.13
1544170	Terra Ceia muck, frequently ponded, 0 to 1 percent slopes	1.88	3.35	0.96	0.00
1544171	Tomoka muck, frequently ponded, 0 to 1 percent slopes	25.00	3.35	1.00	0.00
1544172	Turnbull muck	0.29	8.09	0.76	0.17
1544173	Turnbull variant sand	0.29	8.09	0.76	0.17
1544174	Tuscawilla fine sand, 0 to 2 percent slopes	0.43	2.84	0.60	0.15
1544177	Urban land, 0 to 2 percent slopes	10.43	2.70	0.63	0.13
1544178	Valkaria fine sand, 0 to 2 percent slopes	4.53	1.95	0.39	0.09
1544179	Wabasso-Wabasso, wet, fine sand, 0 to 2 percent slopes	0.79	4.23	0.61	0.17
1544181	Wauchula fine sand	1.56	4.04	0.49	0.23
1544183	Winder fine sand, 0 to 2 percent slopes	0.60	3.92	0.41	0.24

Note: in/hr = inches per hour; Ksat = saturated hydraulic conductivity.

Jones Edmunds aggregated the previous sources to create a 5-foot landcover raster categorized into eight classes. Table 2 lists the eight classes. Each class was assigned either a constant or depth-varying Manning's n value. Classes were also categorized as being impervious or pervious; impervious landcover classes do not allow infiltration to take place. In a traditional, lumped-parameter model, impervious areas are generally classified as being made of the directly connected or unconnected areas. The connectedness of the impervious areas is not defined in a high-resolution distributed model such as TUFLOW because the model simulates the infiltration downstream of the mapped impervious areas.

Table 2 Modeled Landcover Parameters

Landcover	Roughness				Pervious/ Impervious
	Depth 1		Depth 2		
	Depth (inch)	Manning n	Depth (inch)	Manning n	
Building	0.1	0.02	0.3	3	Impervious
Compacted Dirt	0.1	0.022	0.3	0.022	Impervious
Forest	0.1	0.192	0.3	0.192	Pervious
Grassed	0.1	0.1	0.3	0.04	Pervious
Paved	0.1	0.011	0.3	0.011	Impervious
Water	0.1	0.03	0.3	0.03	Impervious
Wetland	0.1	0.1	0.3	0.1	Pervious
Open Space	0.1	0.06	0.3	0.06	Pervious

Buildings were based on the 2022 Microsoft building footprints and are represented explicitly in the landcover mapping. Buildings were defined as having a low roughness at low-flow depths (0.1 inch) and a very high roughness at higher depths (0.3 inch). This representation allows the models to represent rainfall-induced runoff from building roofs with minimal attenuation, while also significantly reducing overland flow over areas defined as buildings within the landcover. Alternatives for modeling buildings included blocking buildings out of the 2D domain, which would prevent runoff being generated from roofs or raising the DEM elevations over buildings and create discontinuities in the DEM surface that can result in model instabilities.

4.6 One-Dimensional (1D) Hydraulic Features

The City provided Jones Edmunds with copies of their stormwater feature shapefiles. Jones Edmunds reviewed the pipe shapefiles and found that size and material fields were populated. Jones Edmunds compared the invert elevations to the LiDAR DEM and confirmed that most inverts reasonably assumed a minimum pipe cover. Where these inverts were missing or appeared to be unreasonable, we updated the elevations or assigned them based on surrounding structure inverts or estimated the pipe depth below the surface.

The County provided Jones Edmunds with a copy of their stormwater feature shapefiles. The database contained the locations of stormwater culverts, conduits, inlets, and control structures within the study area. The County's stormwater data were not as comprehensive as the City's data in terms of infrastructure locations and attributes. The County's data did not include invert elevations but did contain pipe sizes and material types. We used the County's data to help identify subsurface conveyance features in the unincorporated portions of the project area.

Jones Edmunds used a combination of the City data, County data, and a desktop review to identify stormwater culverts, pipes, and weirs to include in the citywide model. We selected structures based on our estimate of the structure's impact on the inundation mapping, especially for the extreme rainfall events being simulated. Jones Edmunds also considered the intended planning-level accuracy of the final mapping when selecting these features. Most subsurface stormwater systems within the City are designed for more frequently occurring storms and do not significantly impact inundation during extreme, infrequent storms. However, Jones Edmunds added an additional 462 culverts in critical locations to support the model. In some cases, we made assumptions on inverts or dimensions based on the LiDAR DEM, assumed pipe cover, and drainage area upstream of the structure. The structures that required these assumptions were generally private structures. Figure 1 shows the location of all the structures included in the citywide model.

Although not a part of this effort, Jones Edmunds recommends that future refinements and enhancements to the citywide model include adding more 1D structures to the citywide model to better reflect local subsurface conveyance, which would allow the model to simulate frequent storms more accurately in some localized areas.

4.7 Simulated Storms

One of the purposes of the study was to quantify the extents of the flooding beyond the 100-year storm event caused by Hurricane Ian. To that end, Jones Edmunds used the citywide model to simulate inundation for the 100-year/24-hour storm and Hurricane Ian. We used a 2-kilometer (km)-by-2-km grid that aligns with the SJRWMD radar rainfall grid to apply spatially varying rainfall to the model. This section summarizes the storms that we simulated.

4.7.1 Hurricane Ian

SJRWMD provided Jones Edmunds with hourly radar rainfall data for Hurricane Ian. These data showed rainfall totals of approximately of 20 inches, which aligned with gauges in the area.

4.7.2 100-Year/24-Hour Storm

Jones Edmunds used the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall depth to represent the 100-year/24-hour rainfall. The rainfall depths were varied across the citywide model using the maps provided by NOAA Atlas 14. We used the NRCS Florida Modified rainfall distribution to simulate the 100-year/24-hour storm. The 100-year/24-hour rainfall total was approximately 13 inches.

4.8 Boundary Stages

The primary downstream boundary stage for the citywide model was the Mosquito Lagoon, Turnbull Bay, and the Atlantic Ocean. Jones Edmunds represented the water level in these systems during Hurricane Ian using time-varying water levels. We developed this time series using recorded water levels from the Trident Pier gauge. We offset these water levels so that the peak water level was at an elevation of 7 feet NAVD88 based on the observations reported by the City. We assumed a constant water elevation of 1.1 feet NAVD88 for the 100-year/24-hour storm for the inland portion of the analysis and directly applied the Federal Emergency Management Agency (FEMA) data for the coastal portion. We based the constant water elevation on the NOAA-reported mean high high-water level.

4.9 MODEL VALIDATION

The City collected 1,348 points of reported flooding from Hurricane Ian. These include eye-witness reports of flooding from local residents and City staff. Considering the size of the City and the number of properties, this collection of points represents a very robust description of flooding throughout the City for Hurricane Ian.

Jones Edmunds compared the results from the simulation of Hurricane Ian to the areas of reported flooding to validate the model. Figure 2 shows the results of the comparison in and around the City. In general, the predicted and reported flooding are in very close agreement. The exceptions are in a few isolated areas on the beach side where the model possibly has more soil storage than existed before Hurricane Ian.

4.10 MODEL RESULTS

Jones Edmunds mapped inundation at a 2.5-foot resolution across the County using the high-resolution flood-mapping routine available within the modeling platform. Areas with flooding less than 0.2 foot deep or less than 1,600 square feet were excluded from the flood mapping. The depth threshold is necessary since every grid cell in a 2D model has some level of inundation due to rainfall that falls directly on each cell.

Figure 3 shows the flood depths and extents of the 100-year/24-hour storm event model results combined with the FEMA 100-year coastal surge results. Figure 4 shows the flood depths and extents of the model results from Hurricane Ian. Figure 5 shows the difference in flood extents and depths between Hurricane Ian and the combined inland and coastal 100-year flooding. In additional to the areal extent of flooding, Figure 5 shows that the flooding from Hurricane Ian was generally 1 to 2 feet higher than the projected 100-year flood stages throughout many of the portions of the City that experience flooding during extreme events.

4.11 EFFECT OF DITCH MAINTENANCE FOR HURRICANE IAN

The City is interested in understanding what effect ditch maintenance may have contributed to flooding during Hurricane Ian. Although that analysis is not in our original scope of services, we evaluated the 2D model results to determine if an analysis would be necessary to make that determination. We sampled results from 10 ditch locations throughout the watershed to assess how much flow was conveyed by the ditch and how much was conveyed by the floodplain surrounding the ditch (i.e., out-of-bank flow). In all 10 locations, the amount of flow in the floodplain was substantially more than what was being conveyed by the ditch during the peak runoff conditions. This finding suggests that the level of ditch maintenance would have had minimal impact on peak stages for Hurricane Ian. As a result, we did not recommend further analysis of ditch maintenance. For smaller events where all or most of the flow is contained within the ditch, the level of maintenance is likely to have more of an influence on peak stages.

5 NEW DEVELOPMENT ANALYSIS

Jones Edmunds used the citywide model to analyze the impact of significant new developments and their associated grading and stormwater management systems on flooding for Hurricane Ian. The City directed Jones Edmunds to focus this analysis on the Venetian Bay and Coastal Woods subdivisions. Figure 6 shows the locations analyzed in and around those subdivisions, which were influenced by the availability of suitable pre-development topographic data. Construction on the Venetian Bay subdivision started in 2004, and construction of the Coastal Woods subdivision began in 2018. We revised the current-conditions version of the citywide model to represent the landscape where these subdivisions are now situated as they were before development. To do that, we completed the following steps:

- Revised the landcover mapping based on the SJRWMD landcover mapping from 2004. This included removing all the modeled imperviousness and updating the landcover classifications to their predevelopment condition.
- Revised the model DEM to represent the topography of the sites to their predevelopment condition. We combined the 2007 FDEM LiDAR mapping and predevelopment topographic surveys that were submitted to SJRWMD as part of the ERP permitting process.
- Removed all modeled stormwater infrastructure that was constructed as part of the new development from the two sites.

Jones Edmunds then ran the model for Hurricane Ian and compared the modeled peak water surface elevation results from the predevelopment model to the current-conditions model results. We selected a threshold difference of 0.5 foot to assess for new development impacts based on the accuracy inherent in the input data for the predevelopment and current-conditions versions of the model. The peak water surface elevation differences outside of the two subdivisions were less than the threshold used for assessing potential impacts, i.e., the model results showned no significant off-site impacts caused by the two developments for Hurricane Ian.

6 RECOMMENDATIONS

This Section summarizes general recommendations for the City's consideration to improve its overall stormwater management program. Although each recommendation has benefits, they incur additional cost to the City that are in some cases recurring. The City will have to assess the benefits and costs of each recommendation to determine whether the recommendations should be implemented and the feasibility of scheduling such implementation. The recommendations are listed in order of potential benefit:

- **Stormwater Master Plan Update (SMPU)**: The City may consider an SMPU for several reasons:
  - Several years have elapsed since an update was completed; therefore, an update would be beneficial.
  - Using the latest LiDAR and other geographic information system (GIS) data means that a more detailed analysis can be performed.

  - Typically, a significant number of CRS points are available from performing SMPU-related activities.
  - Due to the extent and magnitude of the flooding issues, the associated Capital Improvement Plan generated by an SMPU will likely be extensive and take years to implement. An SMPU can help identify projects that are most likely to be grant-fundable and establish priorities for funding and implementation. If funding of a Citywide SMPU is not feasible as a single project, the results from this study can be used to prioritize the phasing of basins to be studied.
  - As a part of or in advance of the SMPU, results from this study can be used to screen for locations where feasible solutions may exist to improve flooding by evaluating the water surface profiles to look for large drops (i.e., bottlenecks) and steep hydraulic grade lines indicating conveyance may be limited. Improvements in these areas would need to be evaluated within a larger model to ensure that no adverse downstream impacts would result from the solutions.
  - The analysis from this study showed that roads owned by the Florida Department of Transportation (FDOT) were flooded by Hurricane Ian and the 100-year storm. The SMPU should include coordination with FDOT on flood-improvement alternatives.

- **Demonstrative criteria**: The City's Stormwater Standards should generally protect existing properties from adverse impacts of new development and redevelopment using the presumptive criteria in the City's Stormwater Standards. However, an alternative approach is to require demonstrative criteria when the development is above a certain threshold. Demonstrative criteria typically require using an existing watershed model maintained by the regulating entity (the City in this case), which the developer's engineer must use to build into the proposed development and demonstrate that no adverse off-site increases in flood stages occur. The model is normally accompanied by a manual or set of standards that demonstrate how the system can be acceptably modeled. This approach may be more feasible for the City if an SMPU is developed. This approach is generally considered to be preferable to presumptive criteria, but an initial investment in the model and associated documentation is required together with committing to the ongoing investment to maintain the model and using City or consultant staff to review the submittals using the models. Examples of communities using this approach are Sarasota County, St. Johns County, and Hillsborough County.

- **Evaluate the Effectiveness of Improving the City's Community Rating System (CRS) Class**: Communities that participate in the CRS earn a rating from 1 to 9, with 1 being the best possible rating. The City currently maintains a Class 5 rating, which provides a 25-percent discount for National Flood Insurance Policy (NFIP) in SFHAs and a 10-percent discount in non-SFHAs. A CRS rating of 5 or 6 is a typical value for coastal communities in Florida. Achieving the next best (i.e., lower) rating is often incrementally more difficult because fewer – and often more expensive – ways are available for achieving the greater number of points required to attain the next best rating. CRS documentation from 2013 showed 8,289 NFIPs are in the City with a total annual premium value of $3,420,219 and a total annual discount of $371,247. Achieving a CRS rating of 4 would equate to another 5 percent discount on NFIP policies in SFHAs. Although the additional discounts are important for determining whether the City should pursue a better CRS rating, the activities associated with an improved CRS rating can provide other resiliency benefits. Performing an audit of the current CRS activities and those needed to achieve an improved rating is a suggested action for the City.

- **Drainage easement mapping and acquisition**: We recommend that the City complete its GIS layer of existing drainage easements and evaluate its existing easements versus critical stormwater infrastructure that needs to be maintained. The evaluation should include a prioritization of drainage easements to acquire and a description of County ditches, their responsible maintenance entity, and the current level of maintenance provided.

- **City ditch maintenance**: The City currently inspects its ditches and canals and maintains them as needed annually. That frequency should generally be adequate and is more frequent than some industry recommendations. For example, the American Society of Civil Engineers (ASCE) published recommendations for stormwater inspection frequencies in its *Standard Guidelines for the Design, Installation, and Operation and Maintenance of Urban Stormwater Systems* (ASCE 45-16/46-16/47-16). Inspection frequencies vary by system component type, but the publication suggests a spot-check every 3 years and a full inspection every 6 years for ditches/waterways. The City may consider spot-checking critical ditches and those that may be prone to heavy debris loads following large storm events. A Computerized Maintenance Management System is recommended for scheduling the inspections and recording the maintenance work performed. Over time, the results can be used to refine maintenance schedules in different parts of the system.

  A challenge for ditch or canal maintenance in some locations is determining the original cross section, particularly in parts of the system that are over 100 years old. The Turnbull Creek Preservation Board and Southeast Volusia Historical Museum may have records showing the original design conditions in some locations.

These recommendations are in addition to potential improvements to the Stormwater Code and Standards in Section 3.1.2.

7 MORATORIUM CONCLUSIONS

Based on our analyses, Jones Edmunds did not find deficiencies with the City's Stormwater Code and Standards or how they are applied that are leading to increases in flooding due to development or redevelopment. In general, the City's Stormwater Code and Standards are more protective against increases in flooding than most communities in Florida. However, we have made recommendations regarding how the City's Stormwater Code and Standards may be better clarified in some instances to provide further protection against increases in flooding.

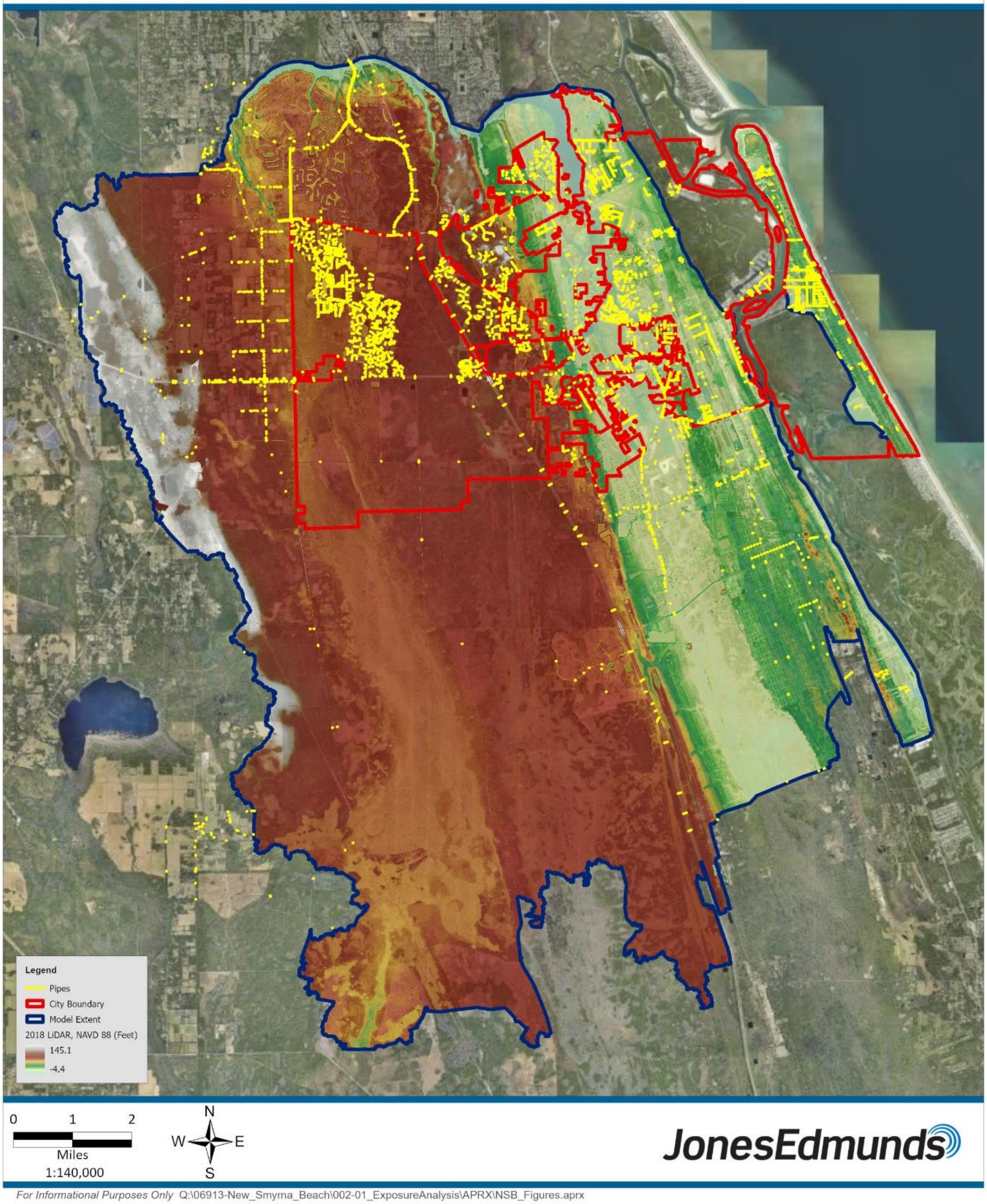
Many of the developed parcels in the City were constructed before modern or current stromwater regulations and are in FEMA SFHAs that are at or below the 100-year flood stages. Hurricane Ian significantly exceeded what is currently considered to be the 100-year rainfall volume by the most current reference for rare-event rainfall statistic (i.e., NOAA Atlas 14). A high coastal surge was coincident with the rainfall, impeding the ability to quickly discharge flows from the stormwater management system.

A substantial investment will be required by the City to determine feasible, permittable solutions that will significantly reduce 100-year flood stages in most parts of the City. Parts of the City will likely have no feasible solutions for removing properties from an SFHA. In those instances, raising the finished floor elevation of the structures will likely be the only solution to eliminate 100-year flood risks.

Figures

Figure 1

Modeled Stormwater Network



JonesEdmunds

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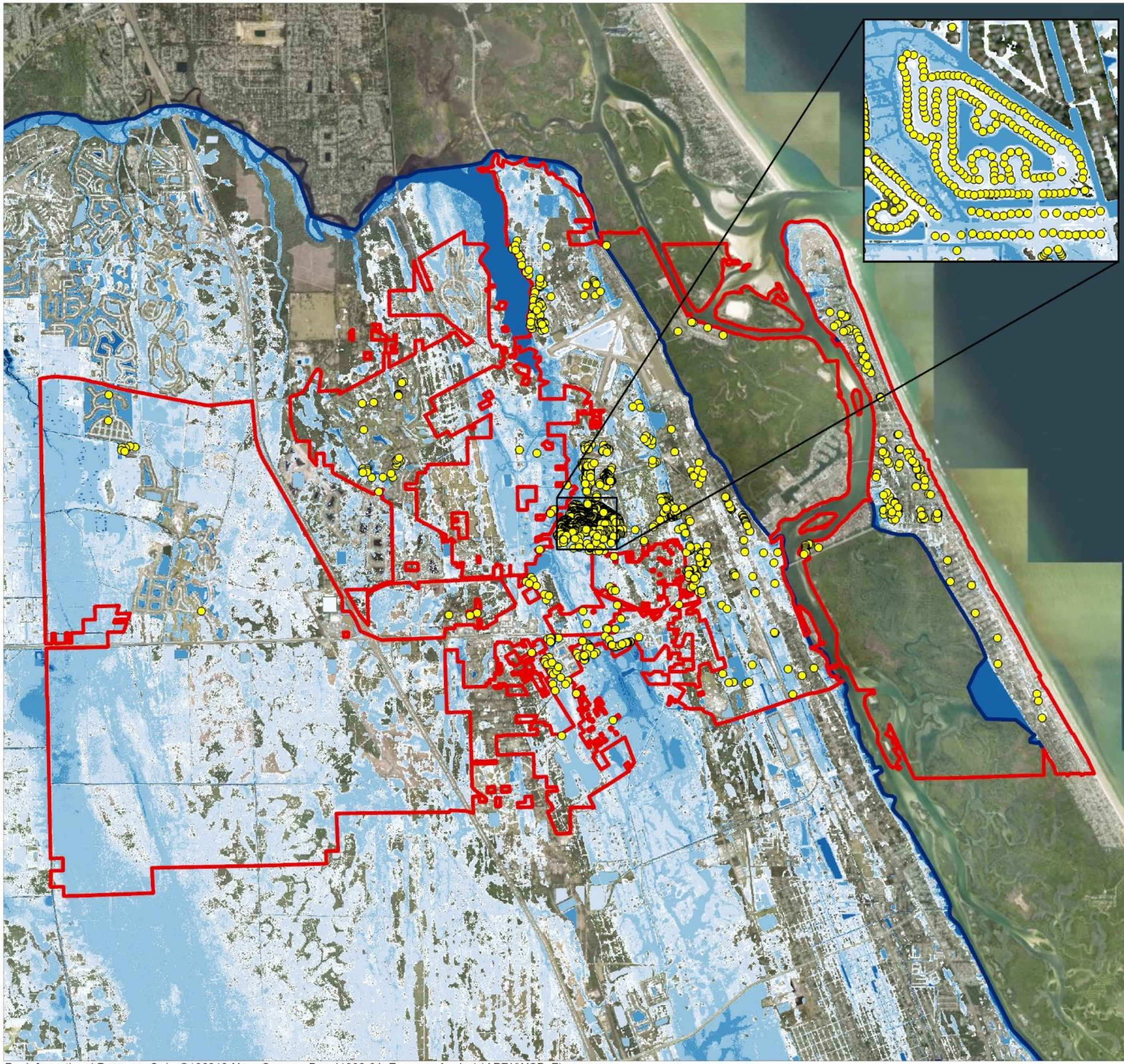

Figure 2
Hurricane Ian Depths and Extent

Legend

- Addresses Associated with Flooding Reports
- City Boundary
- Model Extent

Hurricane Ian Inundation Depth (Feet)

- 0.5 - 1
- 1 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- > 8

N W E S

0 3,750 7,500
Feet
1:90,000

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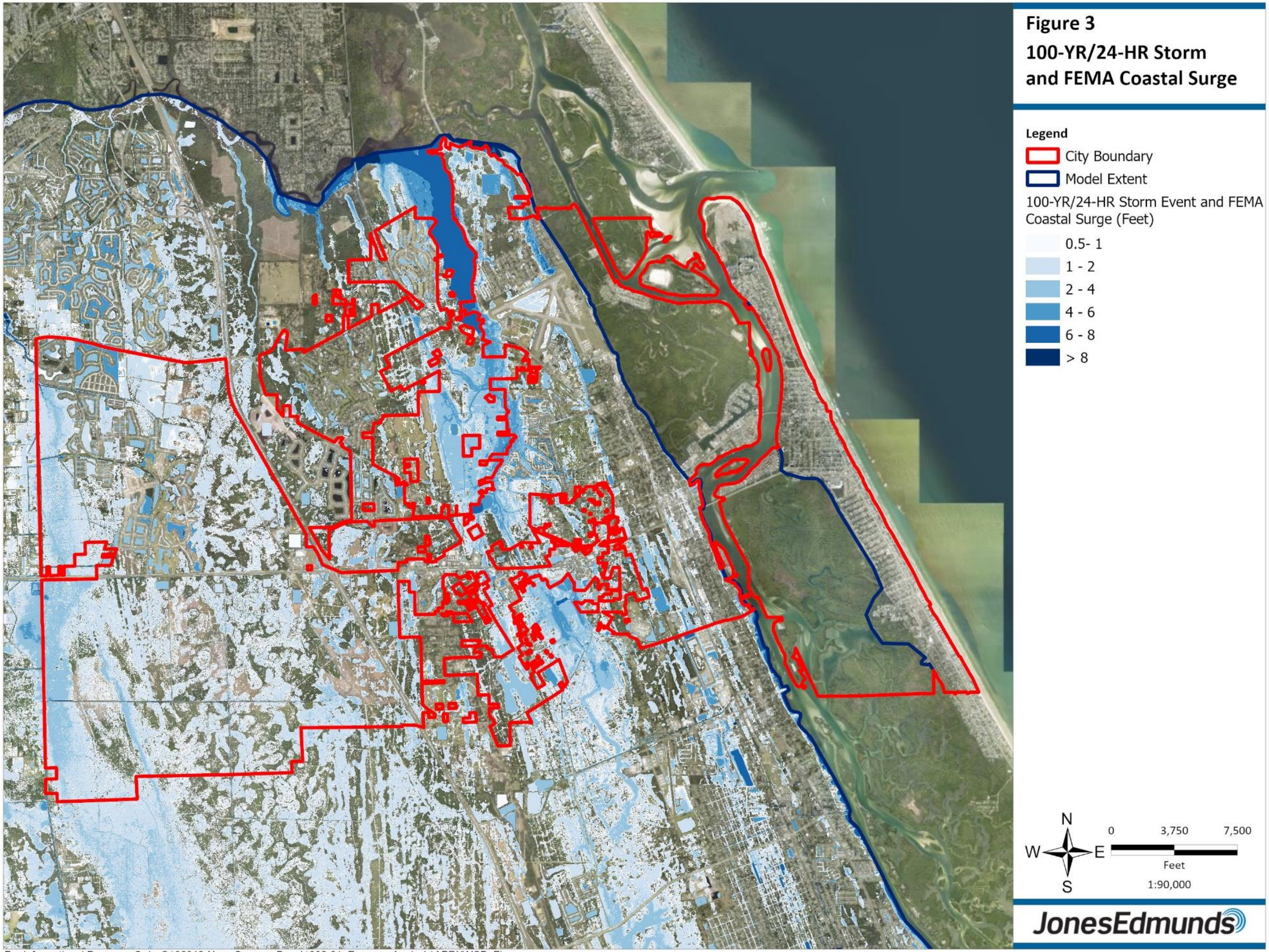

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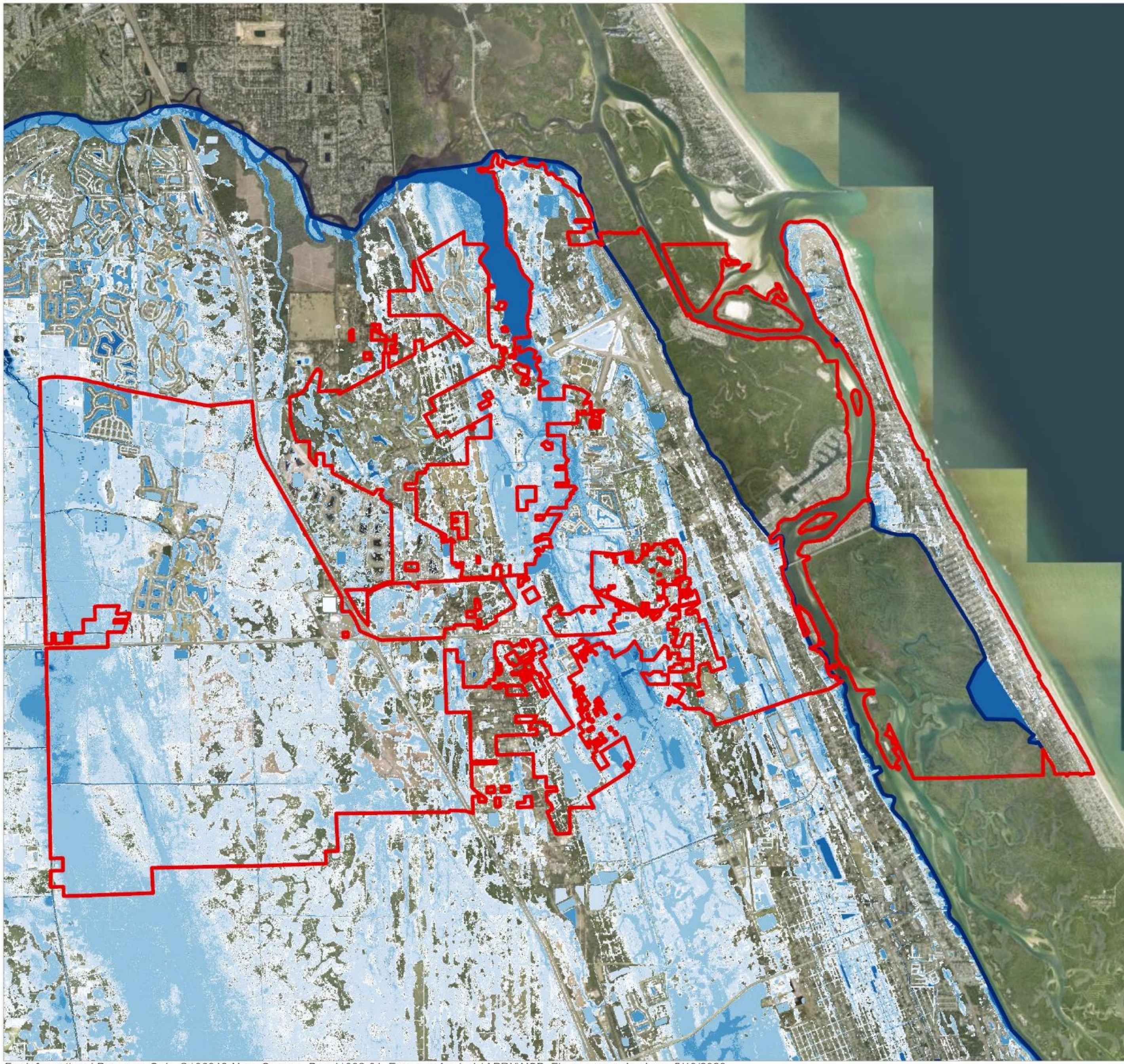

Figure 4
Hurricane Ian Flood Depths and Extent

Legend

- City Boundary
- Model Extent

Hurricane Ian Inundation Depth (Feet)

- 0.5 - 1
- 1 - 2
- 2 - 4
- 4 - 6
- 6 - 8
- > 8

N
W E
S

0 3,750 7,500
Feet
1:90,000

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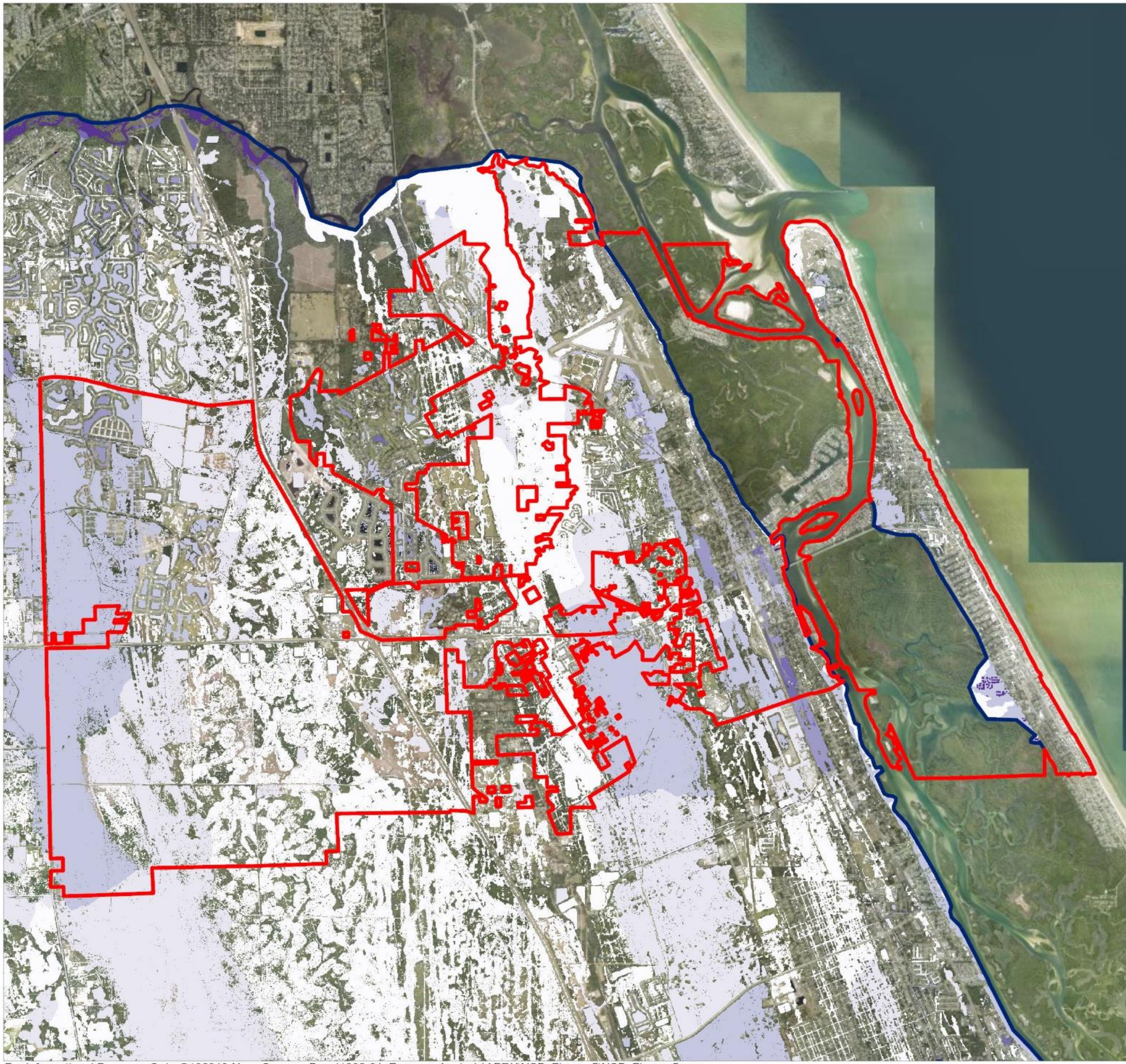

Figure 5

Hurricane Ian Height Above 100-YR/24-HR Storm Event

Legend

City Boundary

Model Extent

Hurricane Ian Height Above 100-YR/ 24-HR Storm and 100-YR FEMA Coastal Surge (Feet)

- < 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- > 5

N W E S

0 3,750 7,500

Feet

1:90,000

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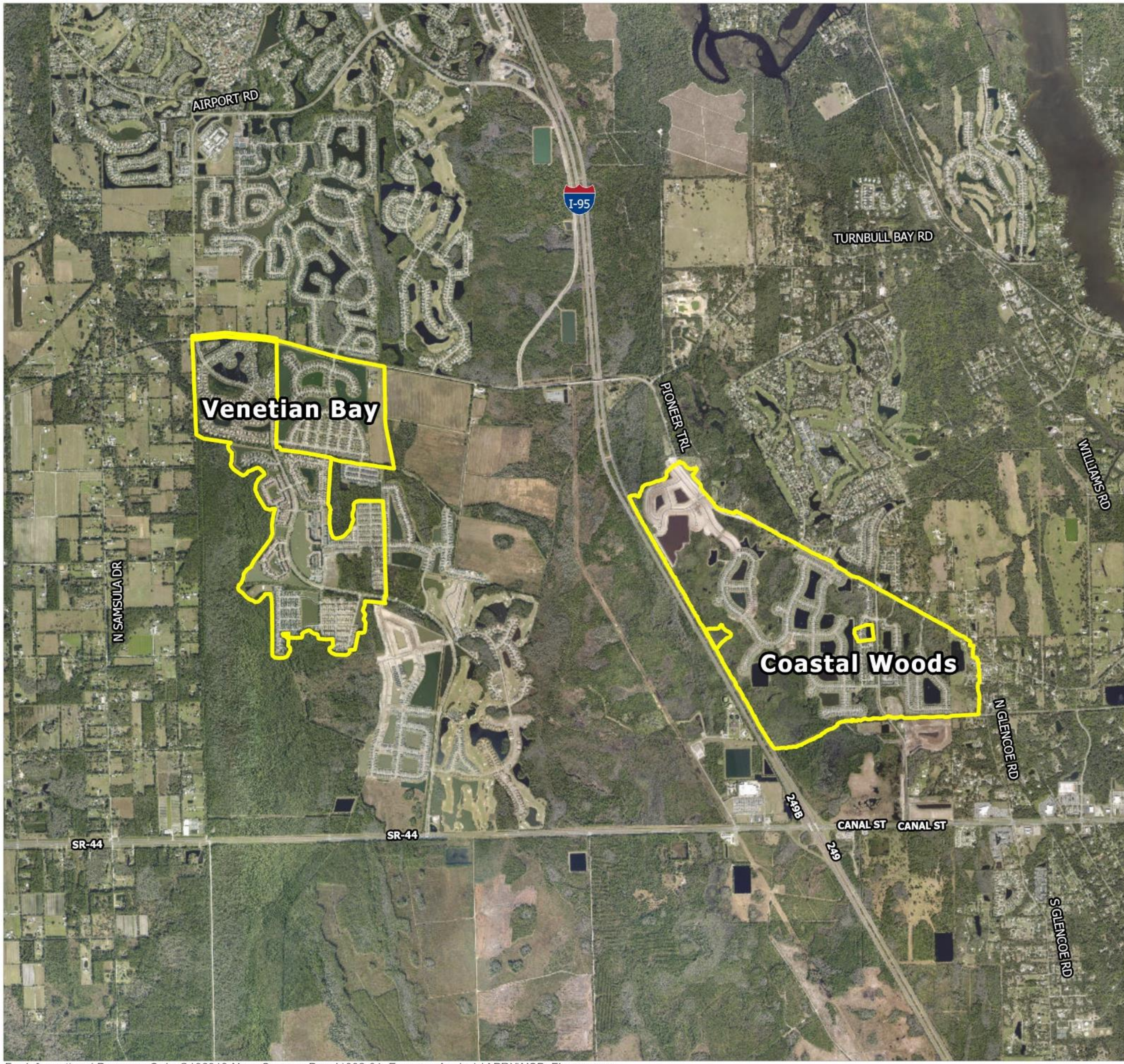
Figure 6
New Development Assessment



Legend

Development Boundary

N
W E
S

0 2,000 4,000

Feet

1:48,000

JonesEdmunds

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