A SWMM ASSESSMENT OF GI/LID FOR FLOOD CONTROL IN HISTORIC DOWNTOWN ST. AUGUSTINE

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I. Introduction

Saint Augustine, FL

- Has direct access to the Atlantic Ocean through the Saint Augustine inlet.
- It is bounded by three tidal rivers:
  - Salt Run
  - San Sebastian River
  - Matanzas River

Figure 1. St. Augustine on a Map

Figure 2. Waterways and neighborhoods of St. Augustine, FL

Saint Augustine, FL

- Saint Augustine was founded in 1565 and is the oldest continuously inhabited European-established settlement in the continental United States.
- The Castillo de San Marcos is the oldest masonry fort in the continental United States.
- Historic district with old brick streets, coquina-shell walls, and Spanish Colonial architecture.
- A city of historical significance and a beacon for tourism and cultural exploration.

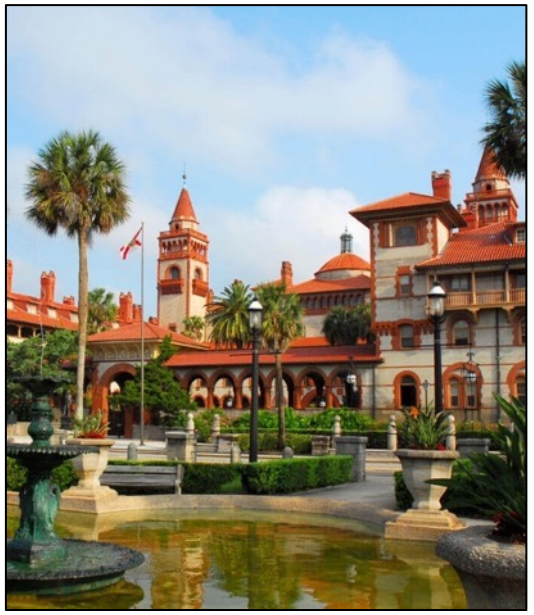


Figure 3. Flagler College

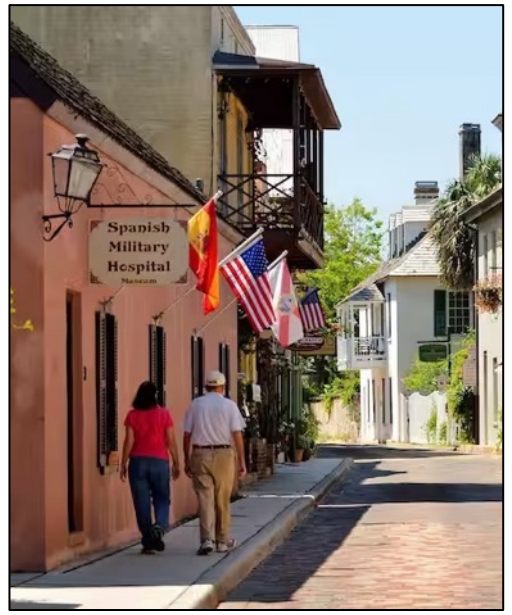


Figure 4. Historic brick streets

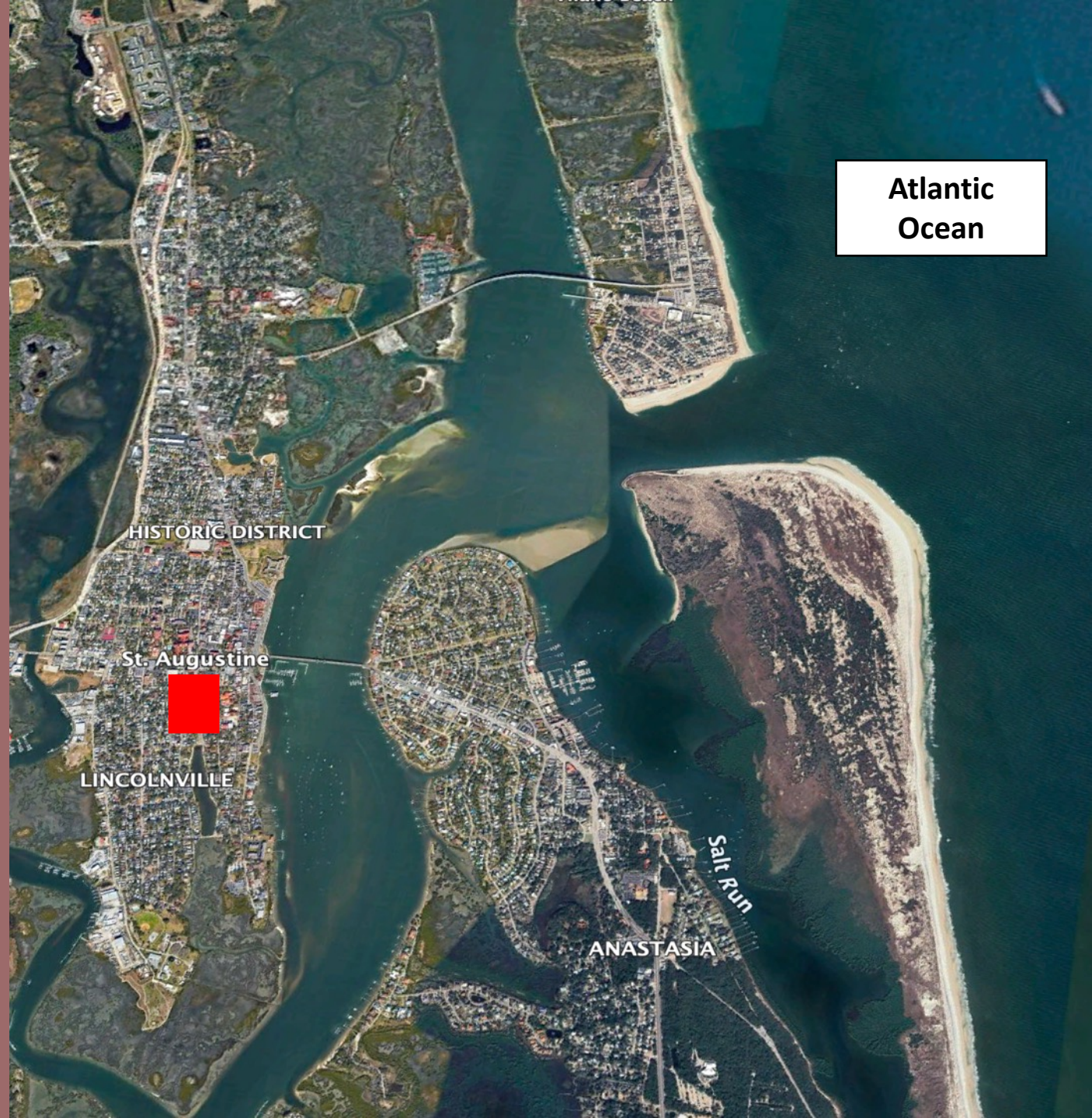
Figure 5. Castillo de San Marcos

The overall objective is to evaluate the impact of a Green Infrastructure (GI) approach and low impact development (LID) solutions for flood mitigation in downtown Saint Augustine, Florida.

- A key consideration for this study was that any LID solutions must **harmoniously align** with the city's architectural legacy and significance.

- The Storm Water Management Model, SWMM, was used for the methodology.

III. Site Description



Study Area

- 24.5 Acres
- City Hall, Lightner Museum, Flagler College, and historic residential homes.
- Most of the existing road infrastructure became “unsafe” for a 2-year storm event.

Figure 6. Flooding outside City Hall during Tropical Storm Nicole (USACE, 2023).

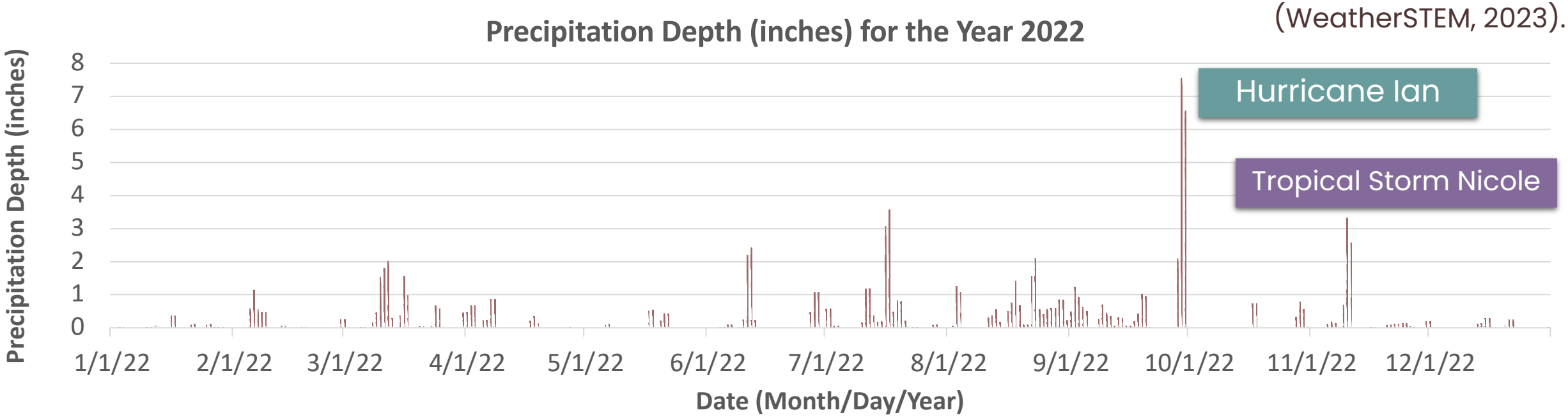
Figure 7. Map of the study site, streets, and historic buildings.

IV. Data Collection and GIS Analysis

Meteorological Data

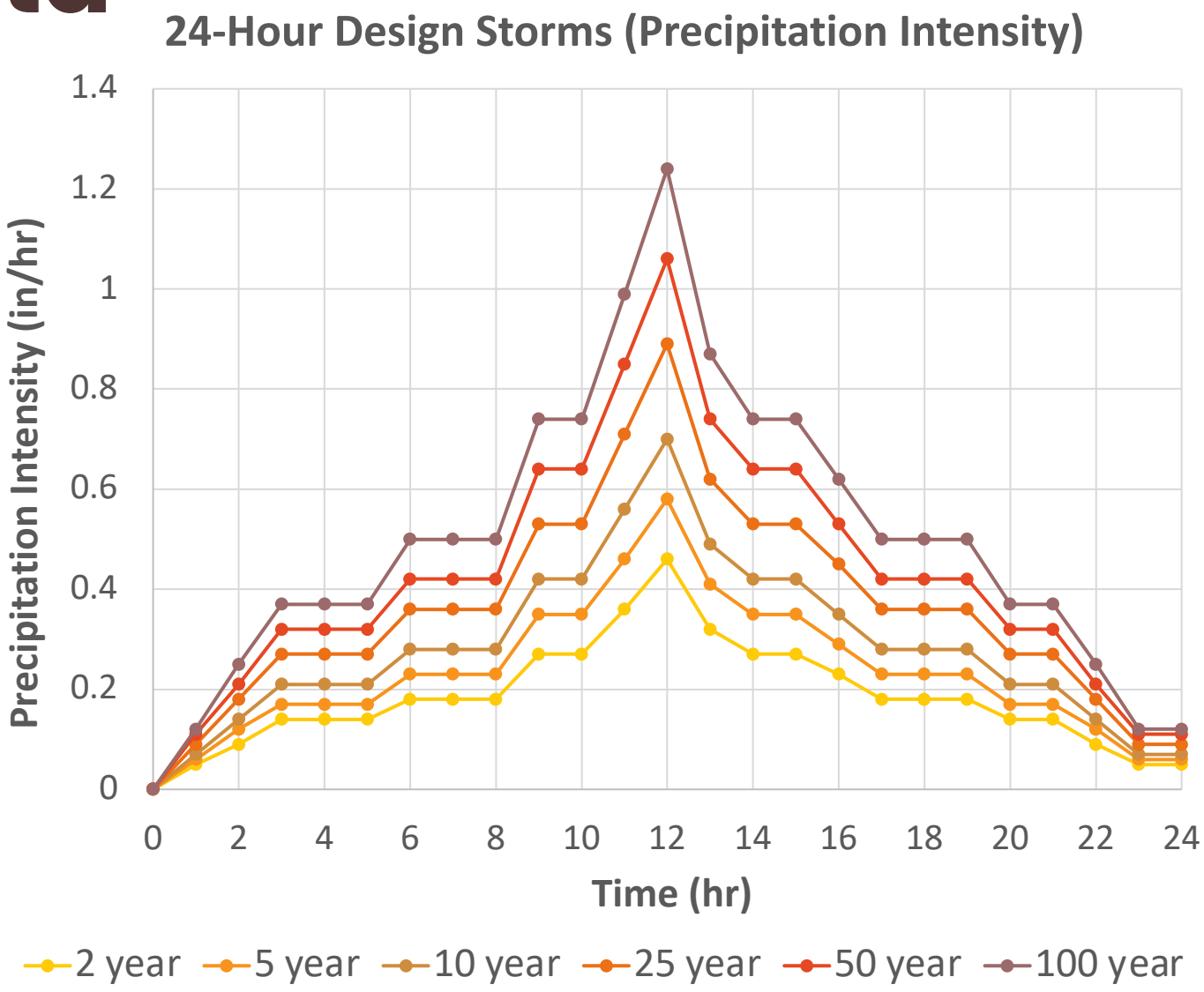
- January 1st , 2022 - December 31st, 2022.
- Hurricane Ian: September 28th through September 31st
  - 20 inches of rain over the three days
- Tropical Storm Nicole: November 10th and November 11th

Figure 8. St. Augustine WeatherSTEM unit (WeatherSTEM, 2023).



Meteorological Data

- Design Storms Depths
  - 2 year – 4.6 inches
  - 5 year – 5.8 inches
  - 10 year – 7.0 inches
  - 25 year – 9.0 inches
  - 50 year – 10.6 inches
  - 100 year – 12.4 inches
- The design storms were created using the NOAA ATLAS 14 and the Florida Department of Transportation (FDOT) Drainage Manual guidelines



Site Characteristics

- Soil Characteristics (Horton Method):
  - Maximum & Minimum infiltration rate = 5 in/hr & 0.5 in/hr
  - Maximum water volume = 4 inches
  - The water capacity of the soil is lower than a typical USDA soil group A due to a higher water table in the region.
- Pervious Areas:
  - Mixture of short, patchy grass and Bermuda grass (n = 0.3)
- Impervious Areas:
  - Mixture of parking lots, roads, and cobblestone (n = 0.015)

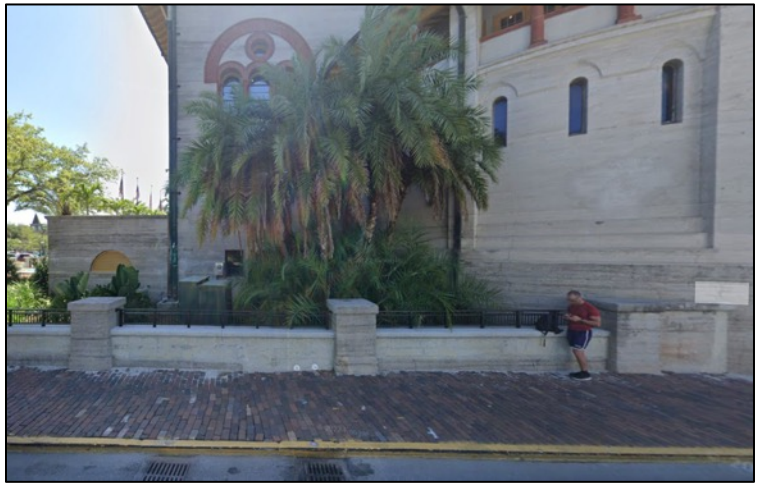


Figure 9. Cordova Street road and brick sidewalk (Google Earth, 2024).

Figure 10. City Hall parking lot (Google Earth, 2024).

GIS Analysis

- A watershed delineation was performed using the ArcHydro toolbox.
- Average slope of the subcatchments is between 2.5% – 4%.
- The subcatchments are between 80% - 100% impervious.

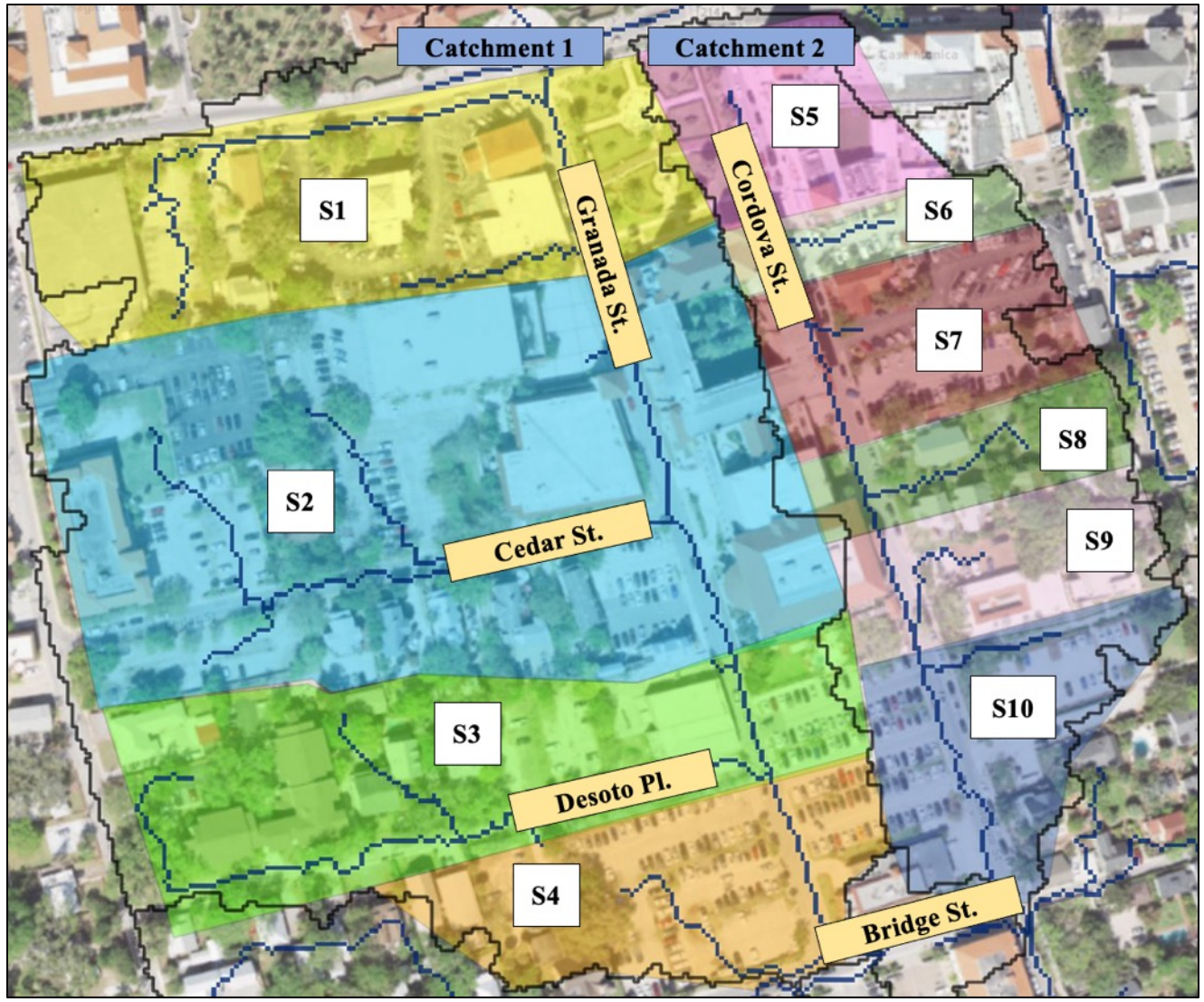


Figure 11. Two major catchments, 10 subcatchments (S1- S10), flow paths from the delineation (blue), and street names at the site (yellow).

V. Pre-LID Model

PRE-LID: Subcatchmets

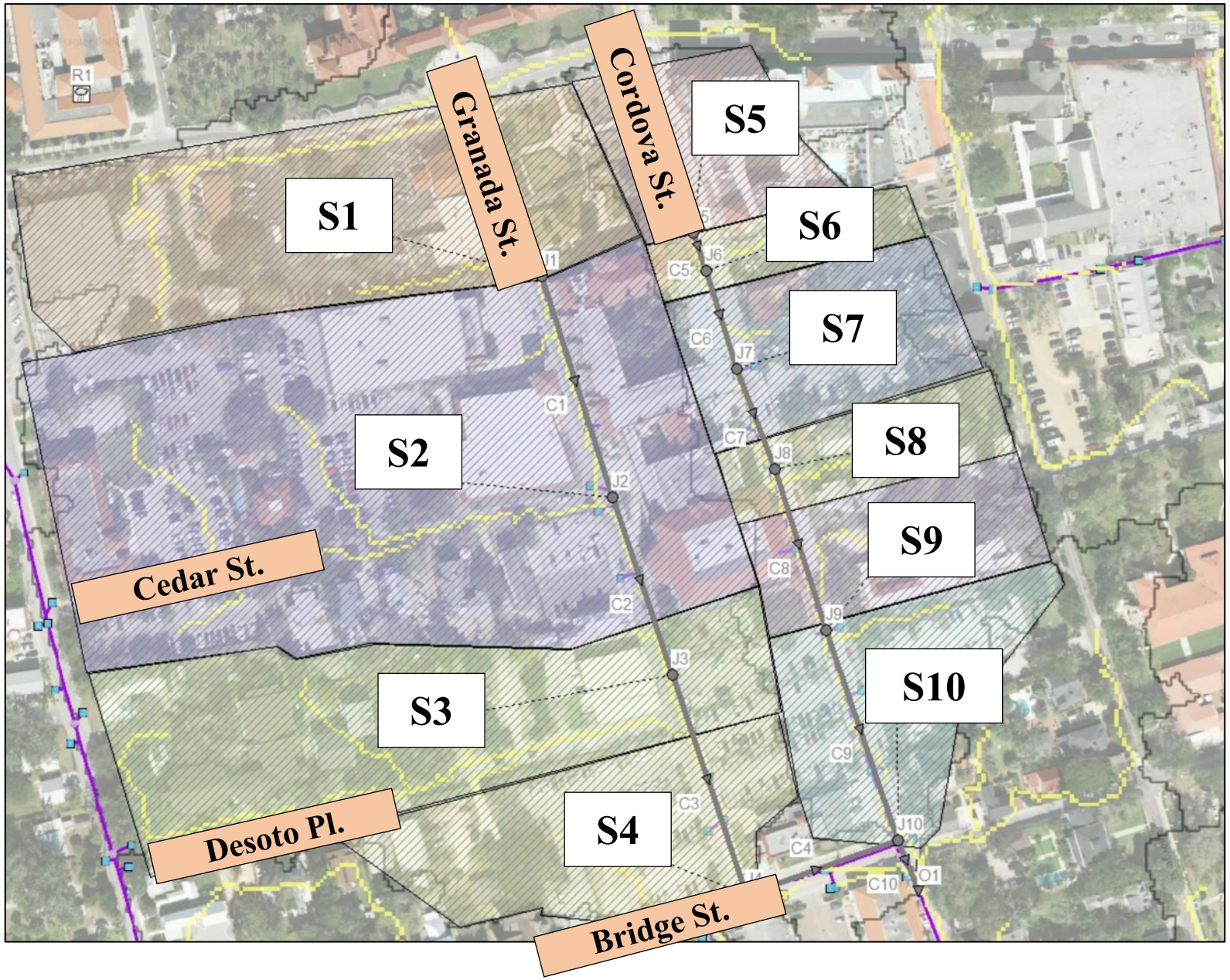


Figure 12. Subcatchments in the SWMM Pre-LID Model.

PRE-LID: Junctions

- Junctions placed at city manholes and flow convergent points.
- Estimated the manhole depth and invert elevation.
  - Shallow-Type Manhole depth = 4 ft
  - Drop between 180° manholes = 0.1 ft
  - Drop between 90° angle manholes = 0.24 ft

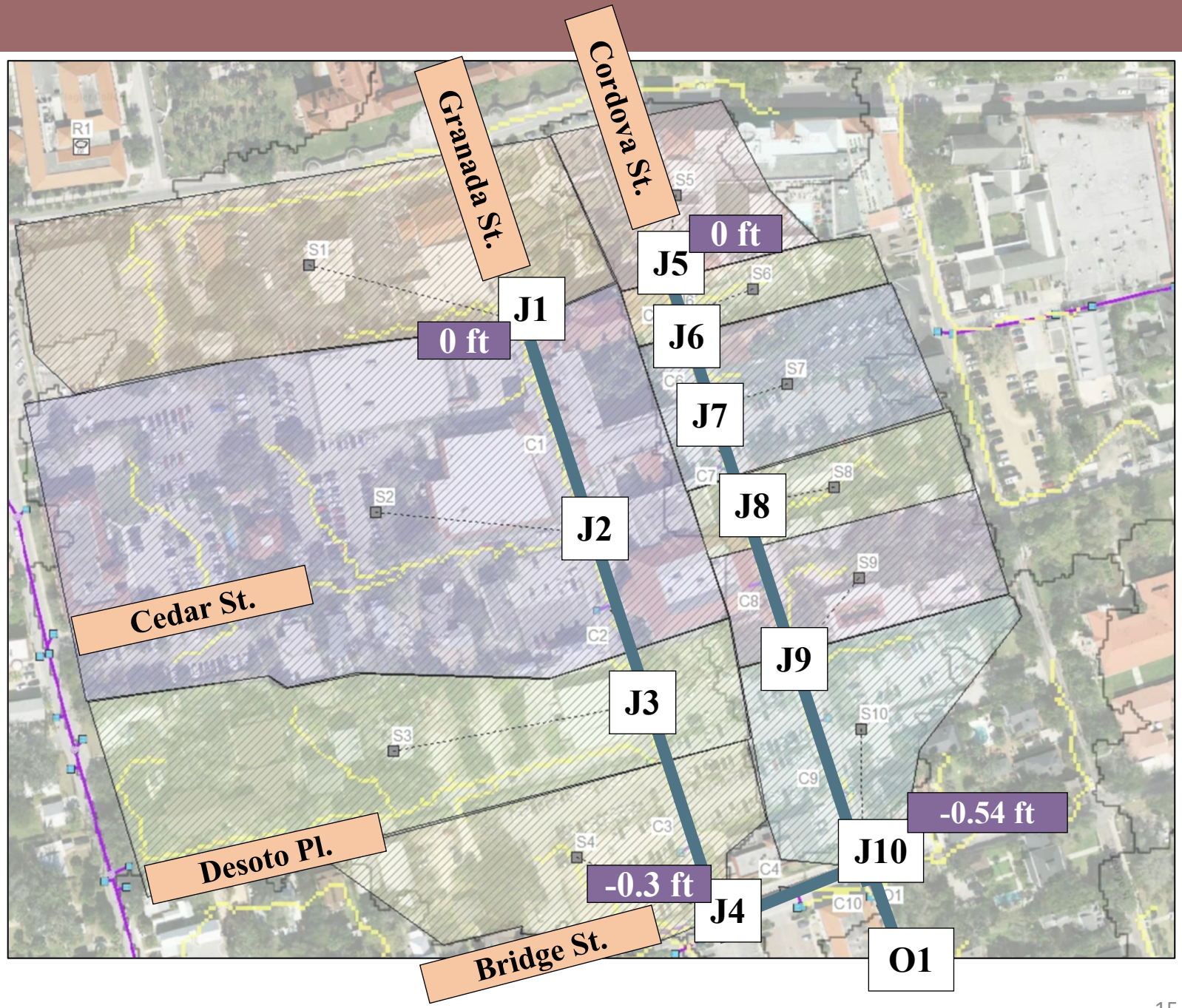


Figure 13. Junctions in the SWMM Pre-LID Model.

PRE-LID: Conduits

- Granada St. and Cordova St. have a circular gravity main (North to South).
- Bridge St. has an oblong gravity main (West to East).
- 12-inch diameter concrete pipes (n=0.013)

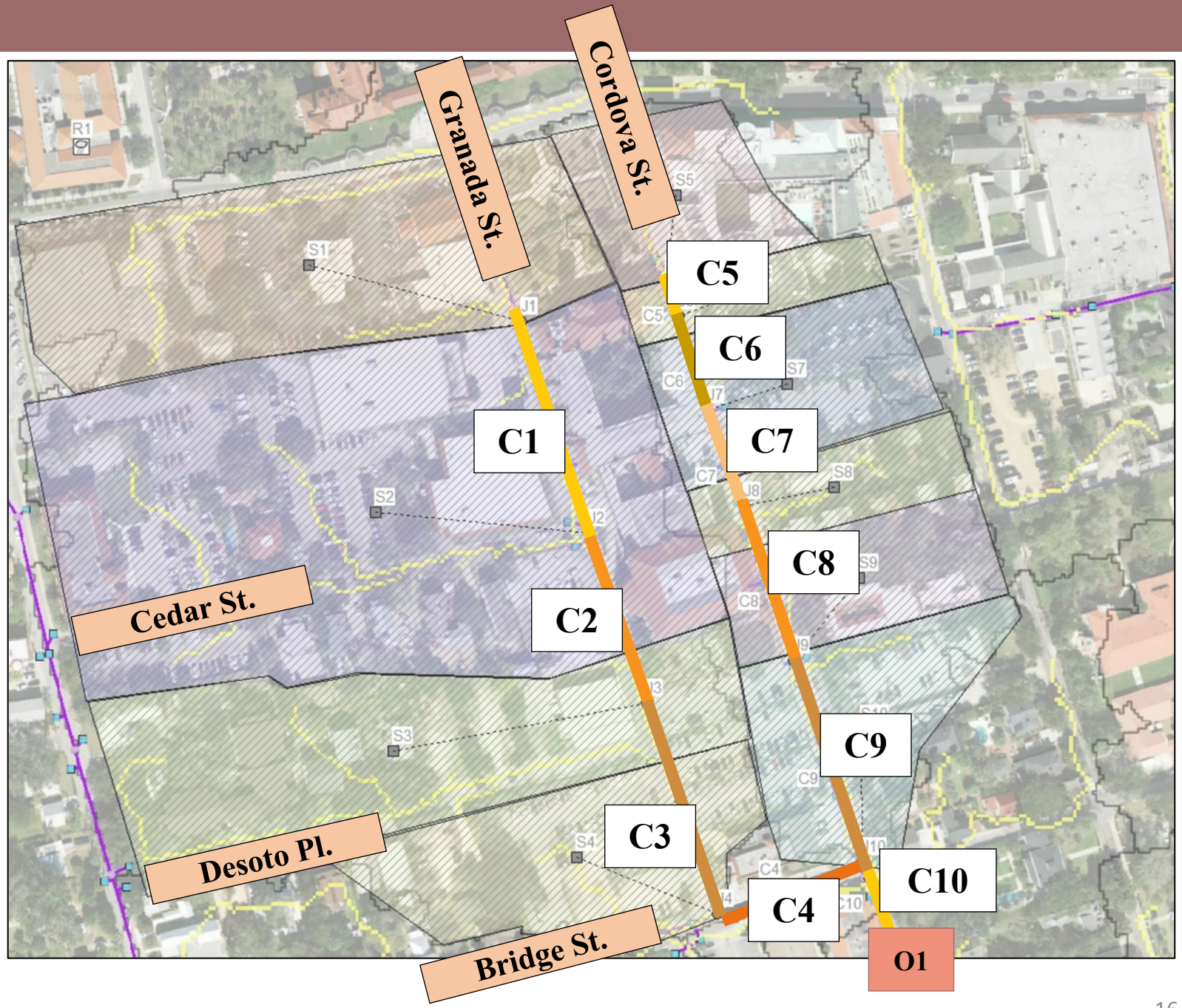


Figure 14. Conduits in the SWMM Pre-LID Model.

VI. LID Model

LID Model

- Rain Garden
  - S2.2 (Flagler College)
- Tree Trenches
  - S3 .1, S4.2, S10.1, & S10.2 (COSA)

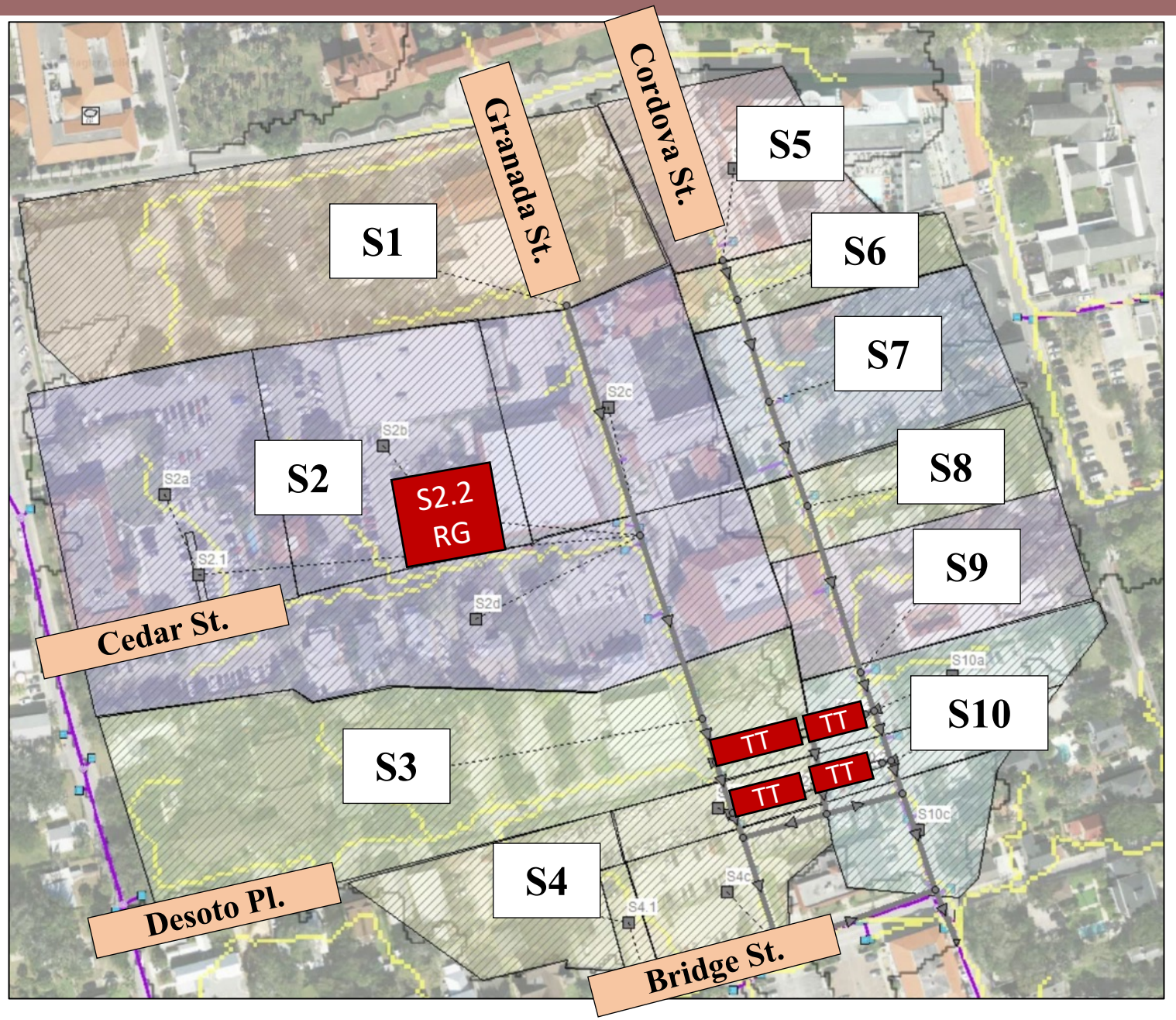


Figure 15. Subcatchments in the SWMM LID Model.

Rain Garden

- Goal is to increase infiltration, evaporation, transpiration, and reduce mosquito breeding.
- 100 feet long and 50 feet wide (0.115 acres).
- 7-inch berm height and 27-inch soil layer.

Figure 16. Ponded water present at the proposed rain garden site.

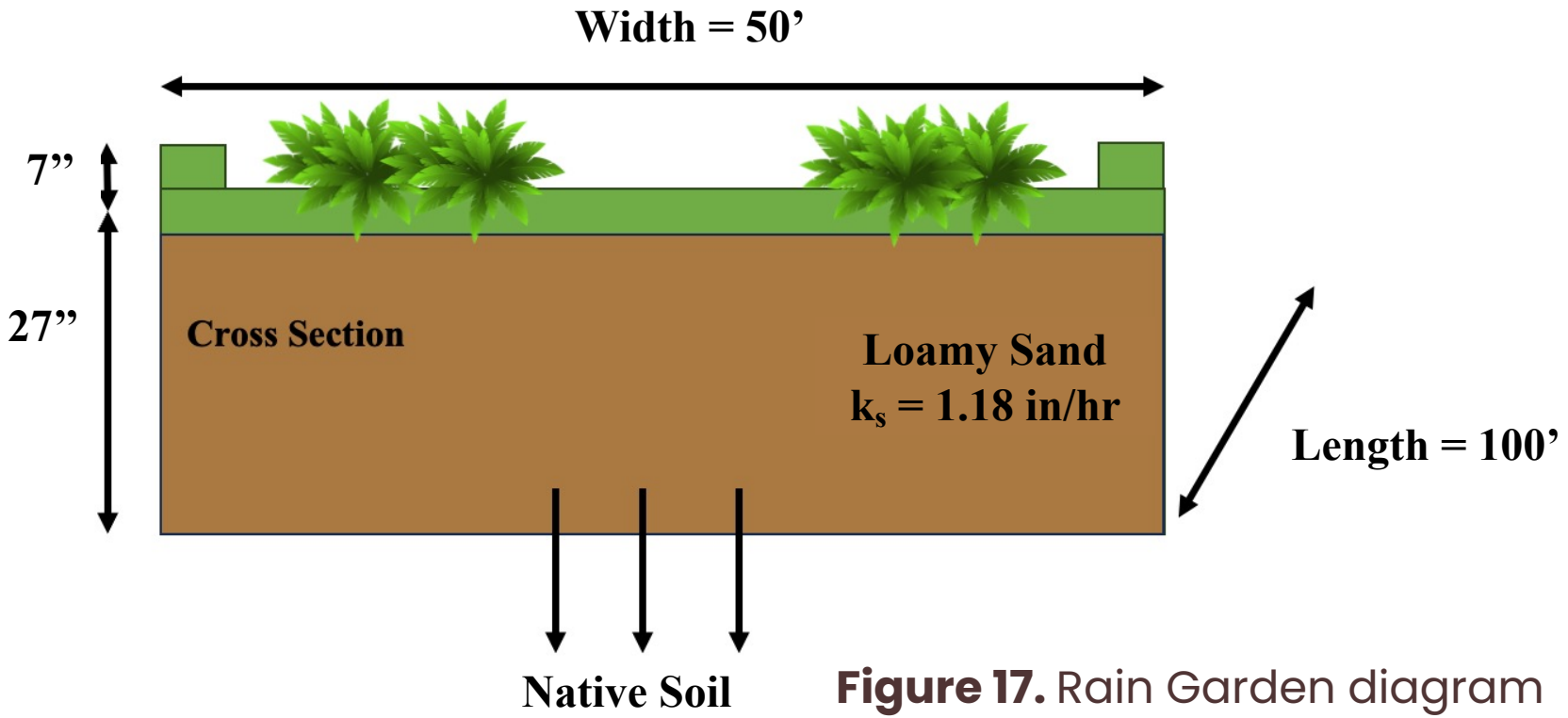


Figure 17. Rain Garden diagram

Tree Trench + Storage Vault

- Goal is to reduce the peak flow and volume of the stormwater in the system.
- 4 tree trenches receive water from the entire system.
- A perforated pipe is connected to the city stormwater system on Granada and Cordova Street.
- An underdrain located within the storage vault will release stormwater after 48 hours from the storm event.

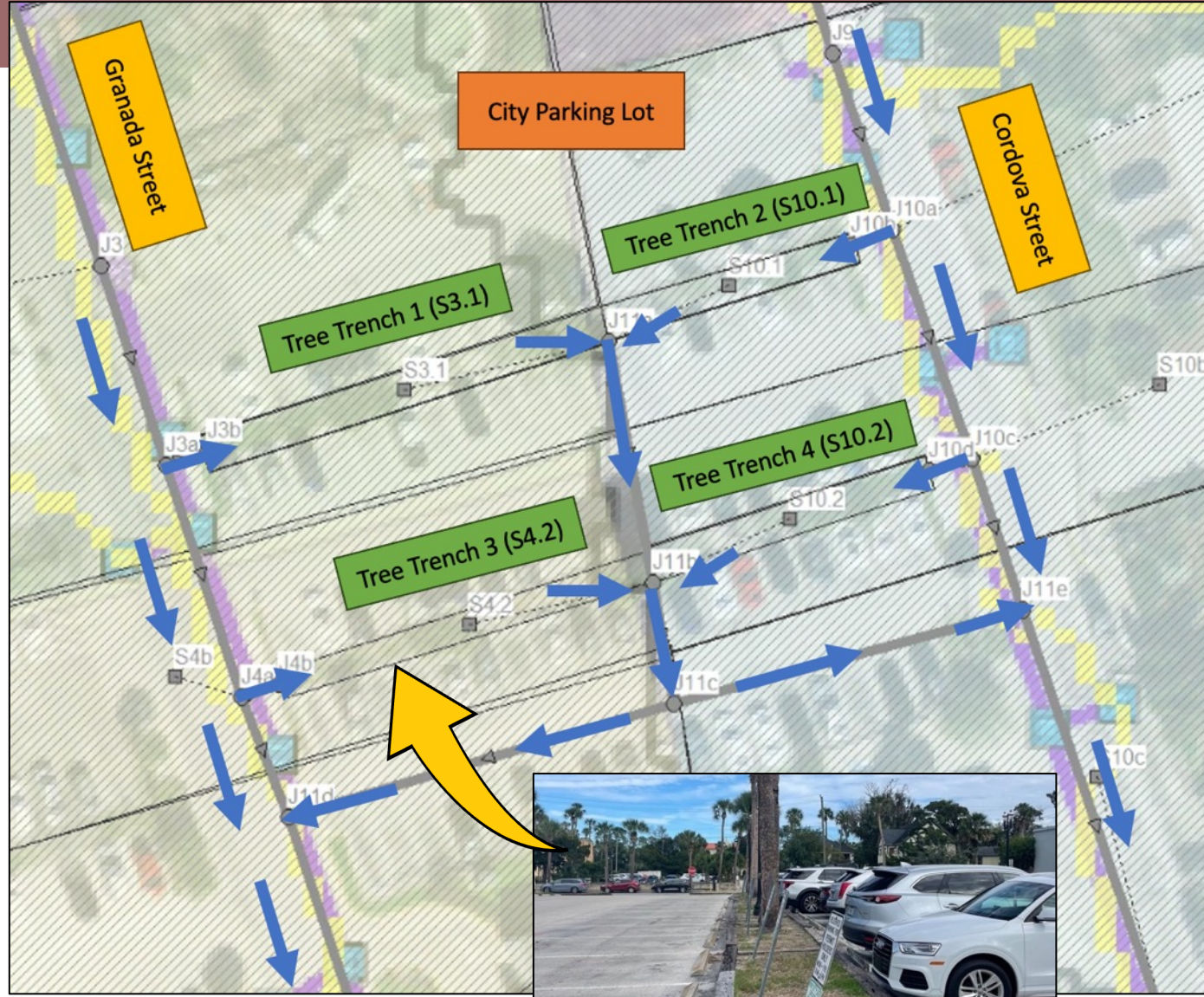


Figure 18. Proposed site of tree trench.

Tree Trench + Storage Vault

- 13,767 ft^3 storage vault under the tree trench soil.

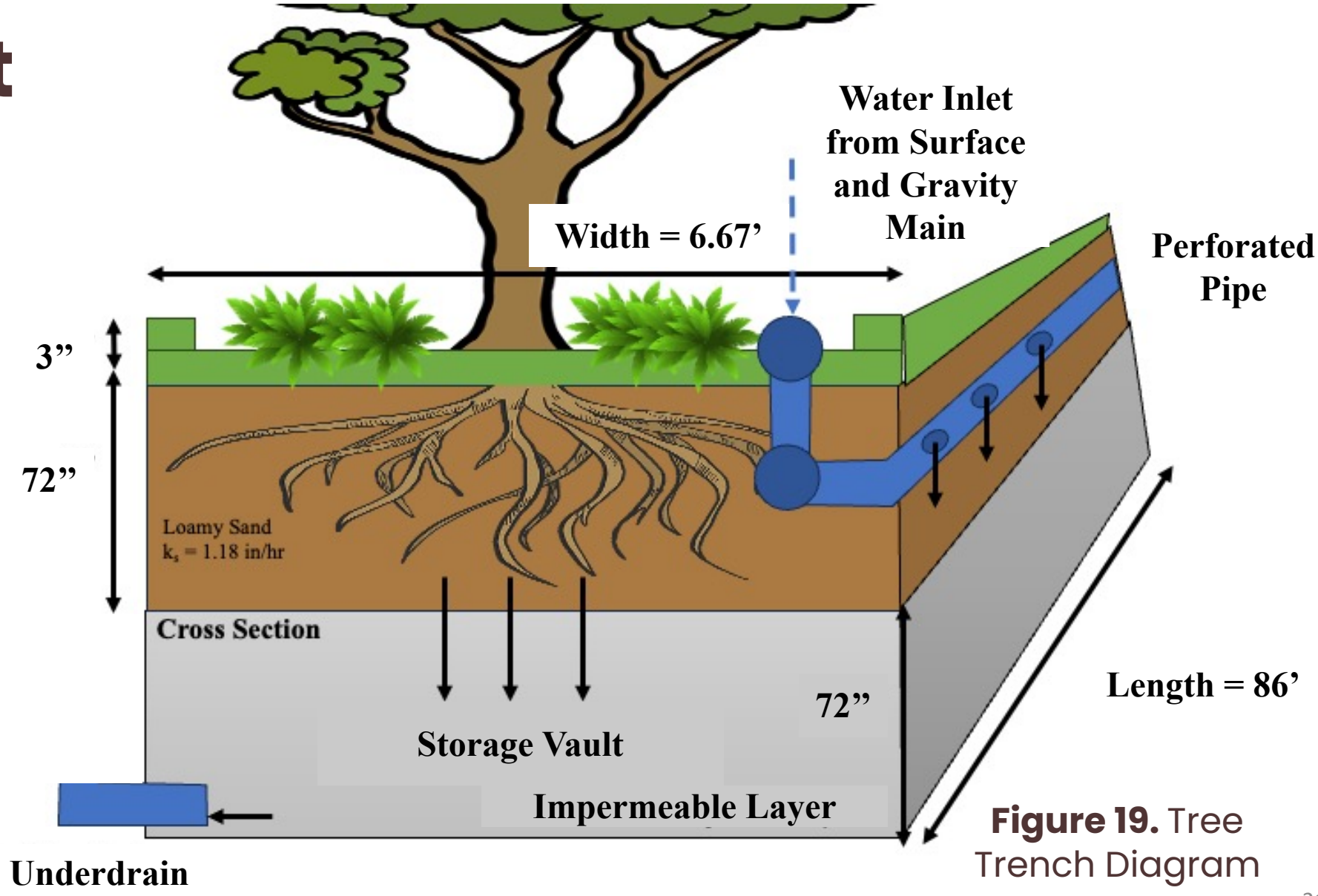


Figure 19. Tree Trench Diagram

VII. Results

System Outfall: 2022 Model

Before LID Solutions

Flow rate (cfs):

- Peak flow = 4.72 cfs
- Average flow = 1.32 cfs

Volume Runoff (gal):

- 15.5 million gallons of runoff

After LID Solutions

Flow rate (cfs):

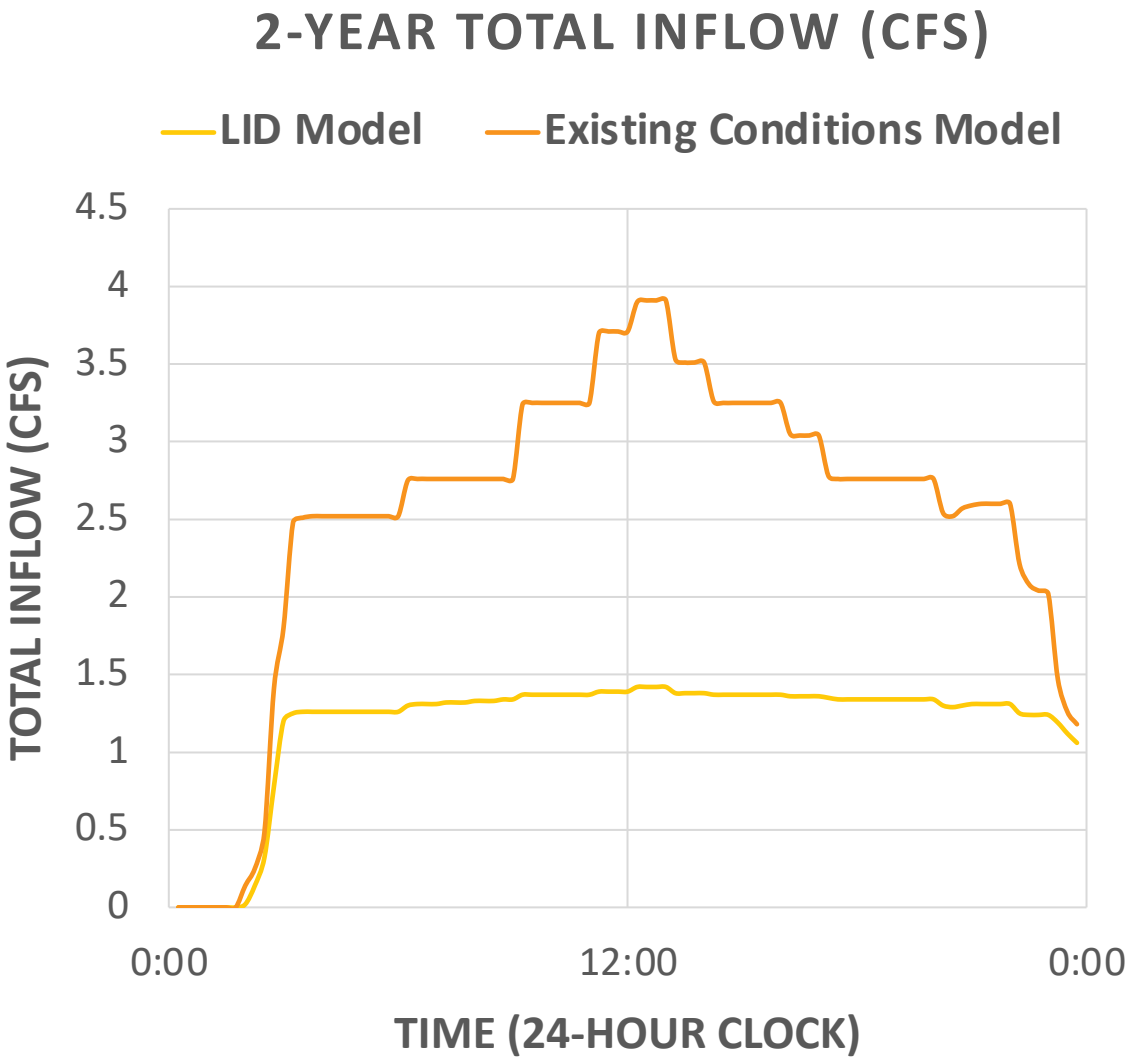
- Peak flow = 1.75 cfs
- Average flow = 0.27 cfs

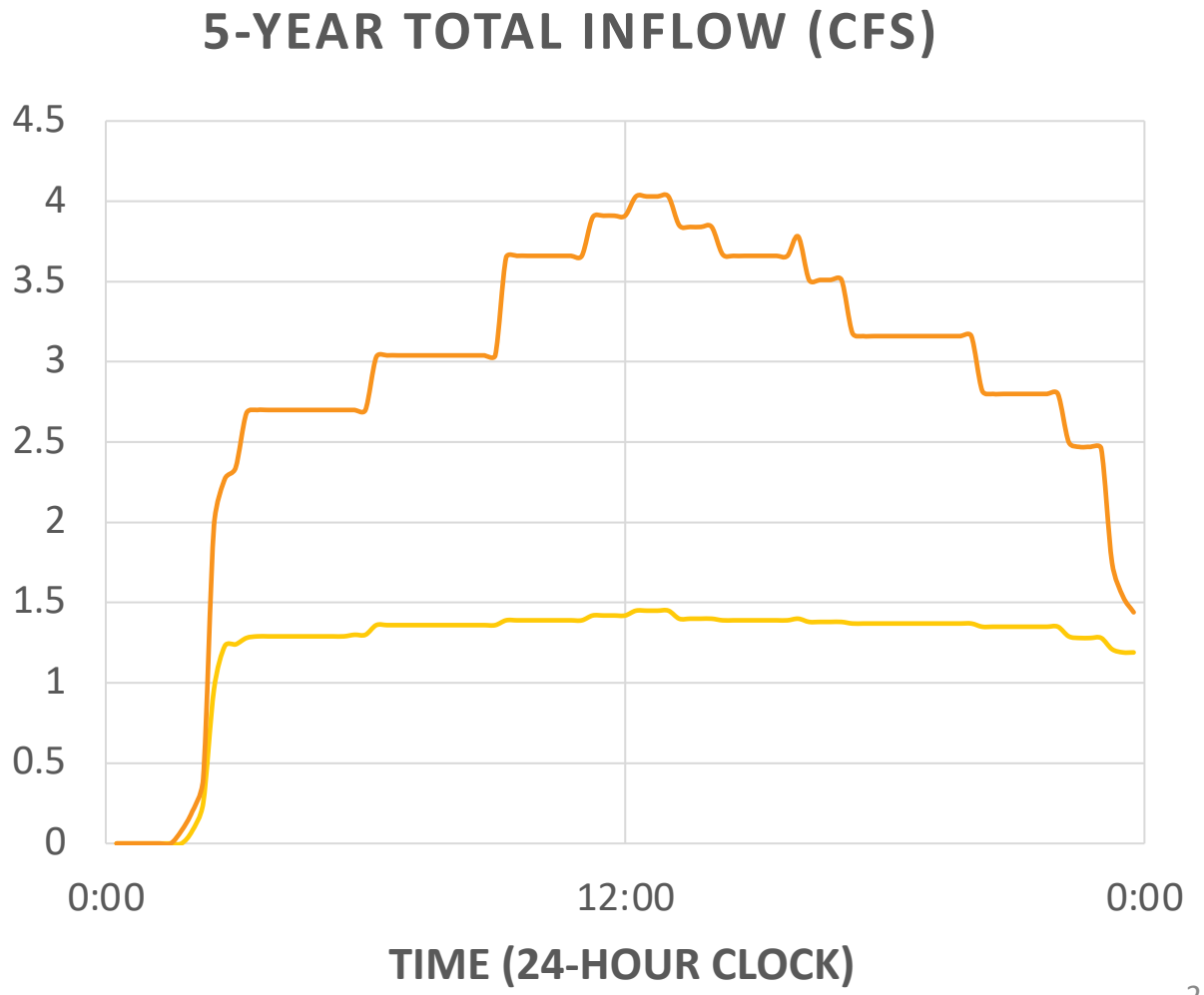
Volume Runoff (gal):

- 12.6 million gallons of runoff

- **63%** reduction the peak flow rate
- **80%** reduction in average flow rate
- **19%** reduction in total runoff volume

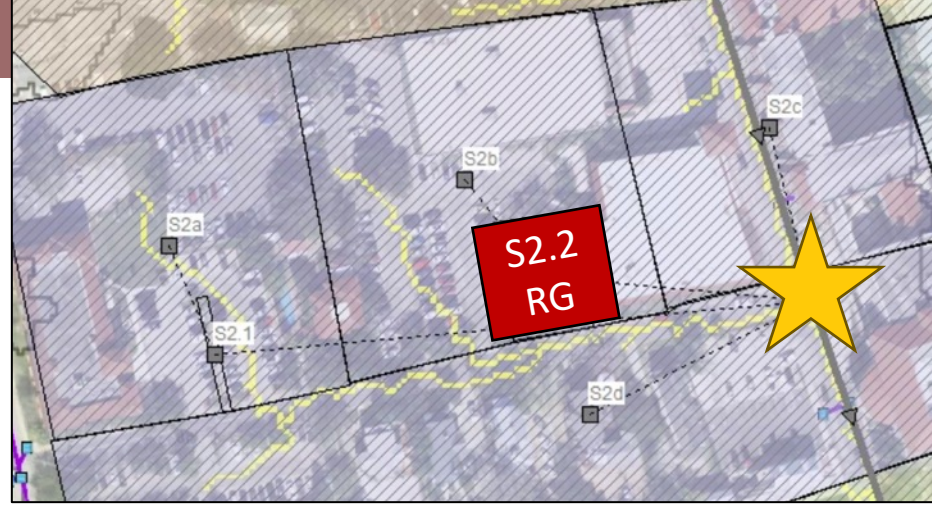
System Outfall: Event-Based





Subcatchments & LID : Flagler College

- Flooding of the stormwater system was reduced by 96% for a 2-year storm event.
- For 2022, there was a 61% reduction in manhole flooding events > 0.1 cfs (61 events to 24 events).



% Reduction in Flooding of the S2 Manhole (J2)

2-year	5-year	10-year	25-year	50-year	100-year
96%	91%	81%	67%	58%	49%

Figure 20. Flooding at S2 during Tropical Storm Nicole (USACE, 2023).

Rain Garden Results

	Parameter	Continuous (2022)	2-year	5-year	25-year
Rain Garden	Runoff Retained	65.69%	50.82%	40.28%	26.47%
	% Infiltrated of Retained	58.11%	26.61%	21.41%	14.30%
	% Evaporated of Inflow	7.24%	0.22%	0.17%	0.11%
	Storage (in)	4.53	17.41	17.55	17.75

Tree Trench + Storage Vault

- Tree Trench Junctions:
  - **J3b** – inflow into tree trench 1, **J10b** – inflow into tree trench 2, **J11b** – outflow from all tree trenches
- For all six design storms and 2022 the tree trenches and vault were never flooded.
- In 2022, there was a **52%** reduction in volume of stormwater within the tree.

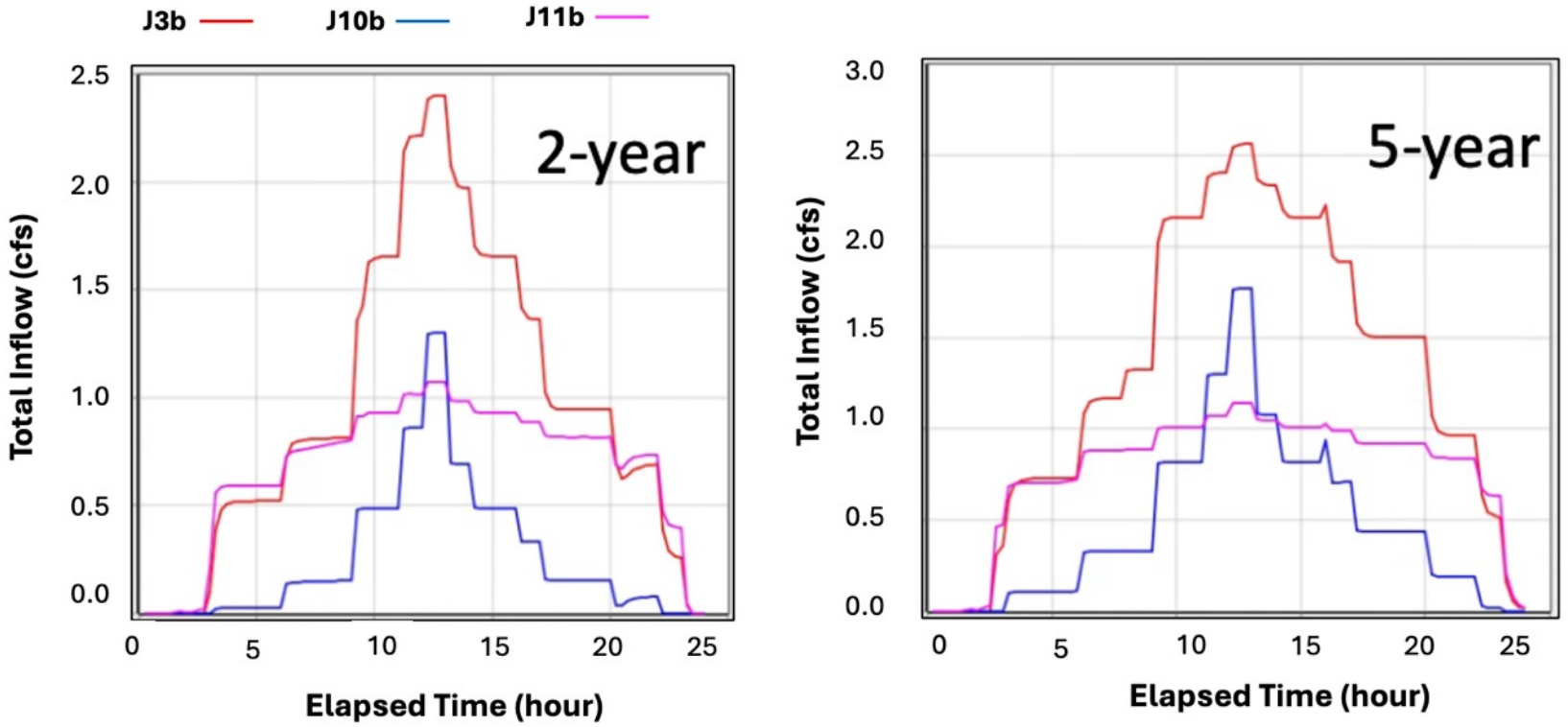
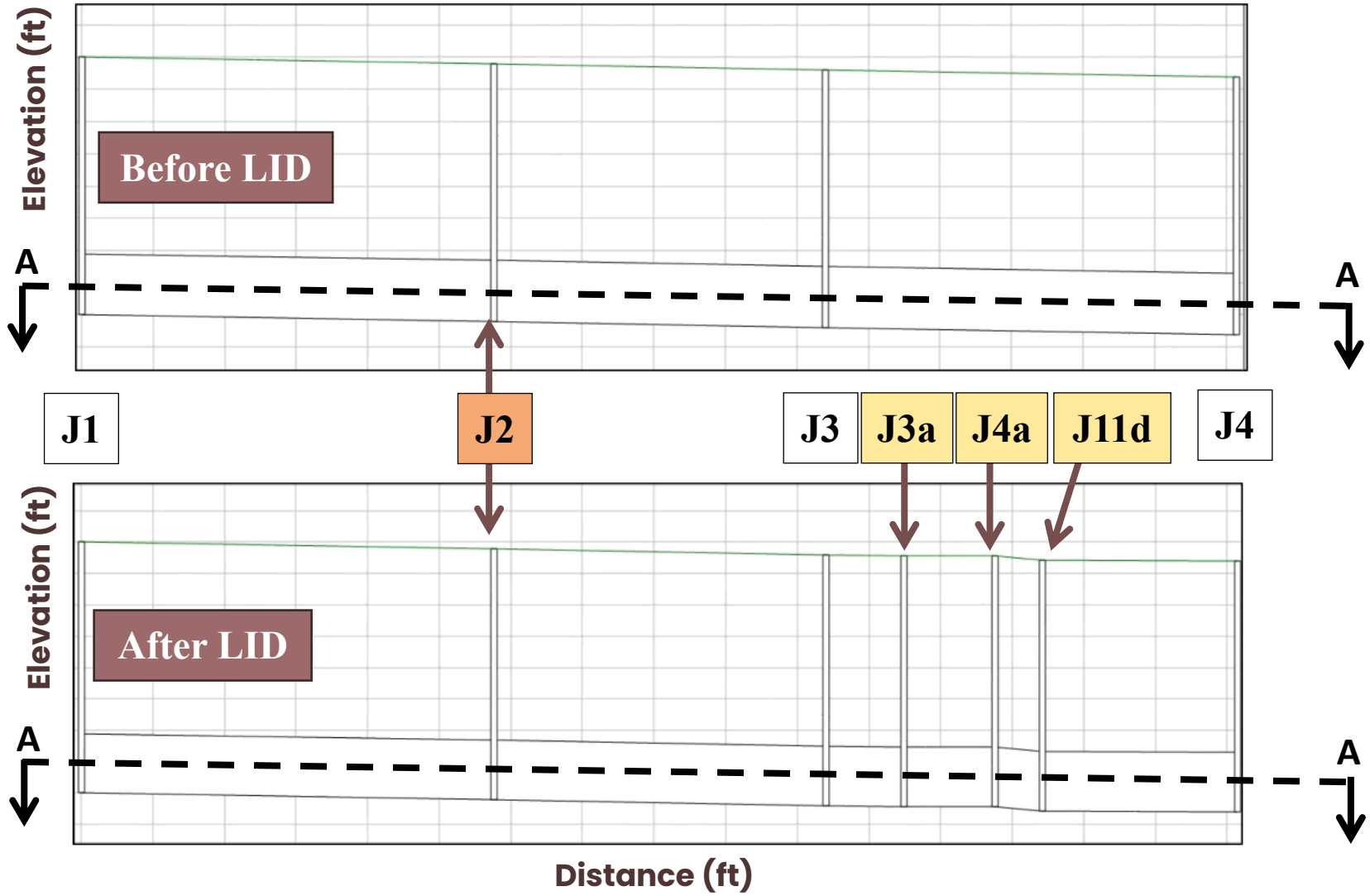
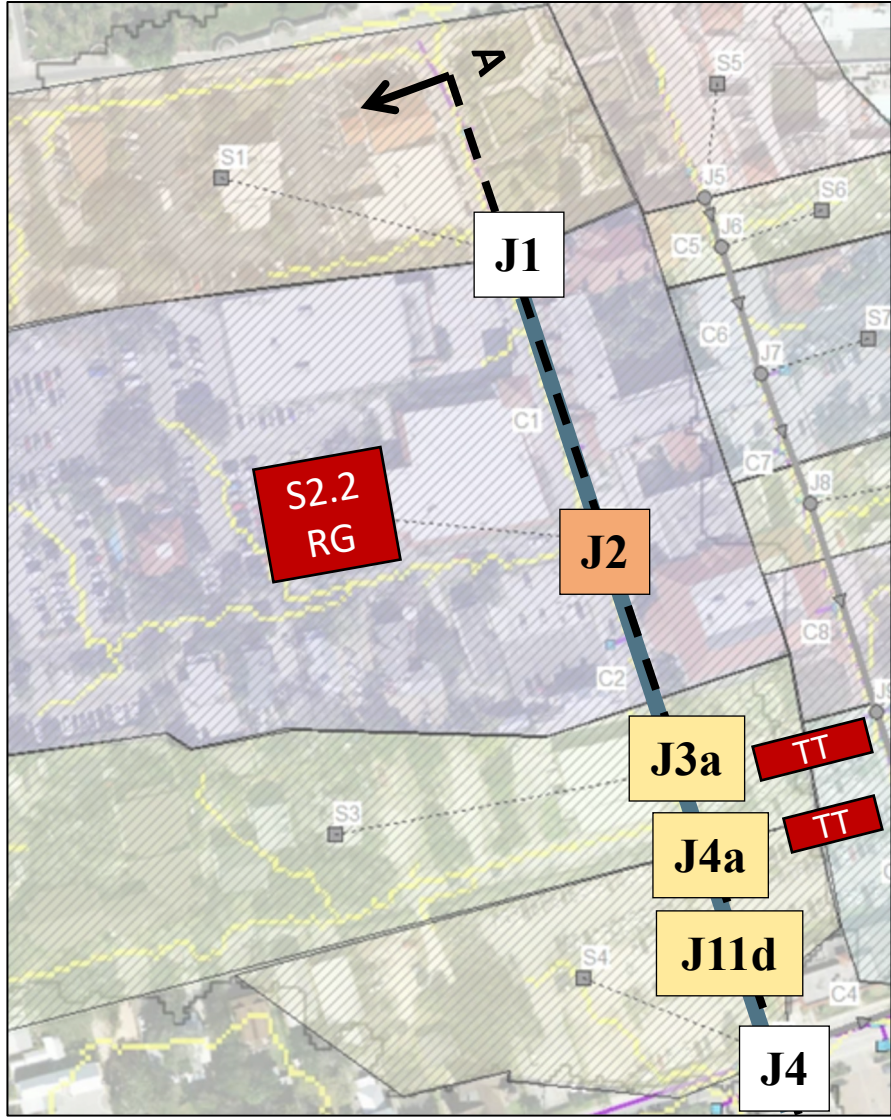


Figure 21. Total inflow (cfs) into the tree trenches (red & blue) and total outflow from the tree trenches (pink) for the storm events.

2-Year Event on Granada Street





J2 = Rain Garden Outlet

J3a & J4a = Tree Trench Inlet

J11d = Tree Trench Outlet

Figure 23. Visualization of water elevation along the Granada Street gravity main **before** LID (Top) **after** LID (Bottom).

VIII. Conclusion

LID solutions that align with the historic architecture can be implemented at the site to reduce peak flow and volume of stormwater.

- Limitations:
  - Lack of calibration and validation of the model.
  - Educated assumptions were made for the depths of manholes and the invert elevations, and further work should include fieldwork and observational data.
- Path forward:
  - Conduct a cost analysis.
  - Adjust the depth of the tree trench and vault design since the 100-year event simulation showed that 5.2 feet of the storage vault was needed and there was 6 feet available in the design.
  - The rain garden implemented in the model proved valuable for reducing stormwater, therefore similar rain gardens could be implemented in other areas of the site.

Acknowledgments

A Special thanks to the City of Saint Augustine for their invaluable contribution through their Open Data Hub initiative under the COSA Geographic Information Systems (GIS) Division. We would also like to acknowledge Reuben Franklin, P.E., Assistant City Manager for the City of Saint Augustine and Jessica Beach, P.E., Chief Resilience Officer, Deputy Director, Public Works & Utilities for the City of Saint Augustine for their assistance throughout the project.

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Thank you for listening.

Questions?