Watershed Master Planning Initiative Pilot Program

Example Inland Watershed Master Plan

Caloosahatchee East/Clewiston Subwatershed

(Ninemile Canal Subwatershed)

HUC 12 digit: 030902050102

FAU
CENTER FOR WATER RESILIENCY AND RISK REDUCTION
Florida Atlantic University

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Disclaimer
This document provides guidance for developing a specific watershed master plan. This document refers to regulatory provisions that contain legally binding requirements. However, this document does not impose legally binding requirements. Local government decision-makers retain the discretion to adopt or modify the approaches described in this document. Adoption of the suggestions or recommendations herein will not necessarily constitute approval during Community Rating System (CRS) cycle verification visits. Interested parties are free to raise their opinion about the appropriateness of the application of the guidance to a situation, and FDEM will consider whether the recommendations in this guidance are appropriate in that situation to make changes to this guidance document in the future.

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1.0 DEFINING THE WATERSHED PLANNING PROCESS

Watershed Master Plans (WMPs), as conceived by the National Flood Insurance Program (NFIP) Community Rating System (CRS), provide an outline for communities interested in reducing local flood risk. According to the CRS Coordinator's Manual (FEMA, 2017), "the objective of watershed master planning is to provide communities within a watershed with a tool they can use to make decisions that will reduce flooding from development on a watershed-wide basis." Successful watershed master plans consist of the following activities (Association of State Floodplain Managers, 2020):

1. Evaluation of the watershed's runoff response from specific design storms under current and predicted future conditions
2. Assessment of the impacts of sea level rise and climate change
3. Identification of wetlands and other natural areas throughout the watershed
4. Protection of natural channels
5. Implementation of regulatory standards for new development such that peak flows and volumes are sufficiently controlled
6. Specific mitigation recommendations to ensure that communities are resilient in the future
7. A dedicated funding source to implement the mitigation strategies recommended by the plan

The United States Environmental Protection Agency (USEPA) notes six basic steps to develop and implement a watershed master plan (2013). The first step is to build partnerships with surrounding communities. Few communities can go alone to resolve such issues, since water may enter a community watershed from upstream to cause major impacts, or water may leave to overwhelm another downstream community. The second step is to characterize the watershed in terms of topography, water levels, soils, land use/land cover, precipitation, open space, waterbodies, stormwater infrastructure, etc. Note that understanding build-out and the impacts build-out has on drainage are factors that must be considered in modeling. The third step involves identifying existing measures that are in place to reduce impacts at the various scales (regional→local). At the watershed level, the scale is far larger than individual neighborhoods, but development of the data for the entire watershed should include the ability to drill down from the regional to the local level. For example, this watershed master plan is a drilldown of the larger Everglades basin, and the study area in focus is the eastern portion of the Ninemile Canal subwatershed, which includes the Caloosahatchee East/Clewiston area shown in red in Figure 1.

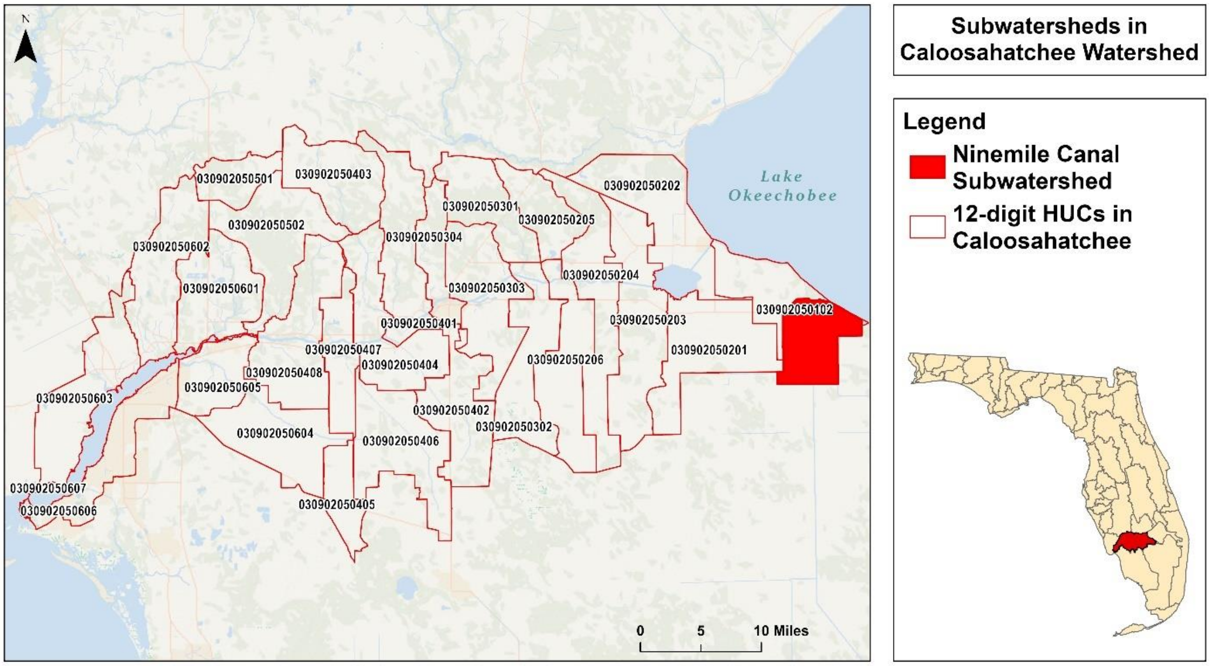

Figure 1. Location of the Caloosahatchee East/Clewiston (Ninemile Canal) HUC 030902050102 subwatershed in relation to the nearby subwatersheds, the greater Caloosahatchee watershed and the Everglades basin

An inventory of existing management efforts is completed via the following measures:

- Review and evaluation of existing watershed data
- Establishment of a GIS database for watershed resource inventory
- Development of preliminary watershed model

Floodplain analysis includes developing a watershed model and identifying associated inundation polygons so that planning and management decisions can be formulated. Floodplain analysis may include the following tasks:

- Completion of the watershed resource feature and parameter inventory GIS database for the watershed using the acquired information
- Assembly of GIS database information into a specific format for a selected modeling software that predicts the watershed's response to the hydrologic cycle
- Watershed model development, calibration, and verification
- Floodplain delineation

The fourth step involves implementation, which means local communities participate in defining projects and solutions as well as the timing and means to fund them.

An example process that USEPA (2013) suggests for capital plans is:

1. Inventory existing infrastructure in the watershed, taking into account local priorities and institutional drivers.
2. Identify critical areas in the watershed where additional efforts are needed.
3. Identify new infrastructure, policy or management opportunities.
4. Develop screening criteria to identify opportunities and constraints.
5. Rank alternatives and develop candidate options

The final step involves monitoring progress so that updates can be made. The processes involved in watershed assessment, planning, and management are iterative and targeted actions might not result in complete success during the first or second cycle. The recommendation is to include a continuous improvement plan that evaluates measurable goals and includes a 5-year window to reassess the plan to make needed adjustments in light of new data or resource availability as well as evolving regulations and CRS requirements.

1.1 Overview of the Watershed

The focus of this watershed master plan is the eastern portion of HUC 030902050102 Caloosahatchee East/Clewiston subwatershed, which is also known as the Ninemile Canal subwatershed (red boxes on Figure 2). These terms are used interchangeably in this document. The subwatershed is generally located in the north part of South Florida in the central portion of the state and includes the northeasternmost section of Hendry County that borders the western boundary of Lake of Okeechobee. As a result, the Caloosahatchee East/Clewiston subwatershed is intrinsically linked to the larger Everglades watershed.

In South Florida, water supply, water quality, and the health of the Everglades ecosystem are intrinsically linked. When attempting to evaluate the ecological health of South Florida, the entire southern portion of the peninsula of Florida must be analyzed. Historically there were no barriers or canals to direct or control the path of water except a minor connection created by native Americans between the Caloosahatchee and Lake Okeechobee for transportation purposes (Figure 2). However these shallow connections did not permit boat traffic. That changed when the first major anthropogenic modifications to the South Florida drainage landscape were constructed in the 1880s by Hamilton Disston with the dredging of the Caloosahatchee River and the creation of drainage canals in the Kissimmee Upper Chain of Lakes (C-38). The dredging was conducted in order to drain the land to facilitate agricultural production and urban development.

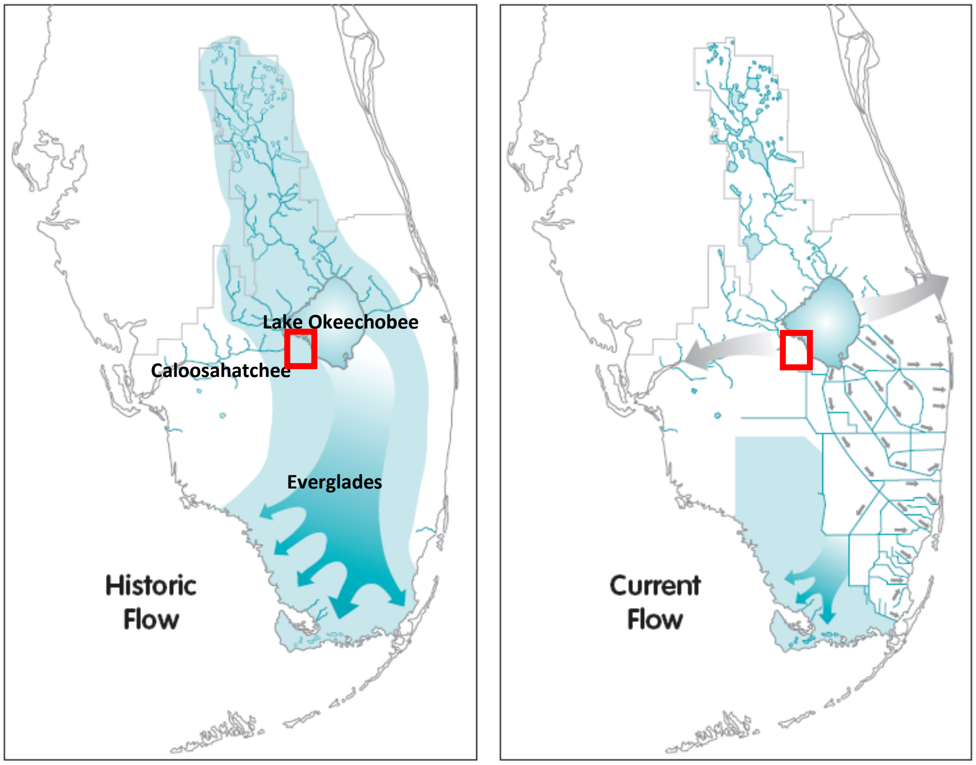

Figure 2. Change in natural flow paths in South Florida (SFWMD, 2020). The red box signifies the location of the study area in relation to the major hydrologic drivers of South Florida.

However Lake Okeechobee was not connected to either coast, and thus inland travel across the state was not possible, so the C-43 Canal and the associated locks and structures were constructed between 1916 and 1928 to connect Lake Okeechobee with the Caloosahatchee, and the C-44 Canals to connect Lake Okeechobee with the St. Lucie River, thereby providing a navigable connection between the east and west coasts of Florida by connecting Lake Okeechobee to the south fork of the St. Lucie River and creating the St. Lucie Estuary as one of the major outlets for water draining from the Upper Kissimmee and Lake Okeechobee basins (Figure 3).

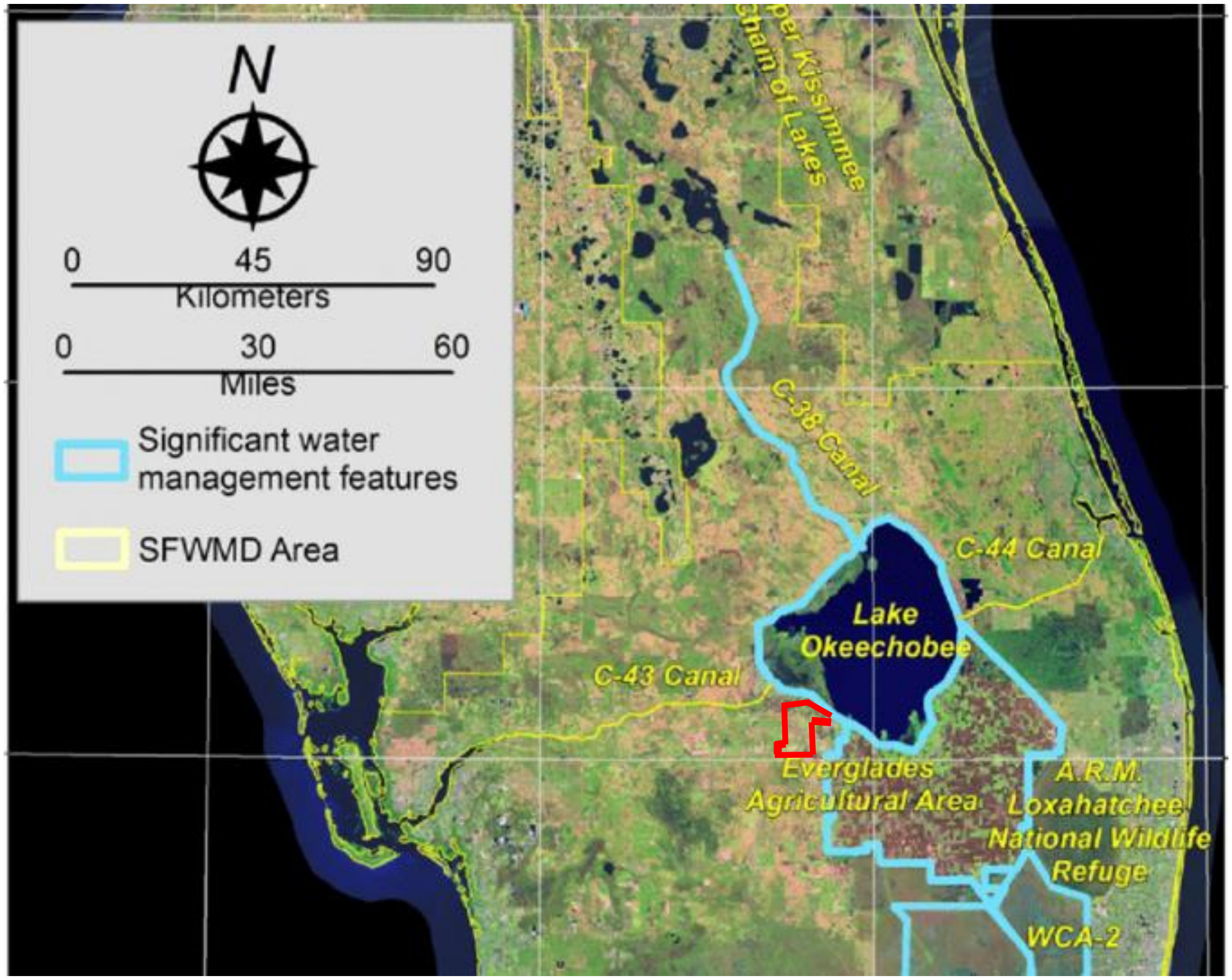

Figure 3. Location of key points of interest near the study area (approximate location denoted by the red box).

The first efforts to contain Lake Okeechobee overflows involved construction of a low levee and three drainage canals running south from Lake Okeechobee, the Miami, North New River (in Fort Lauderdale), and Hillsborough canals between 1913 and 1917. In 1930, during the aftermath of the Storm of 1928, which pushed water out of the shallow lake and drowned thousands of people, the federal government authorized the US Army Corps of Engineers (USACE) to build the Herbert Hoover Dike (Figure 4).

Figure 4. Herbert Hoover Dike surrounding Lake Okeechobee

Over the next several years, a series of levees, culverts, and locks were built to contain the lake overflows, including 67 miles of dikes along the southern shore, effectively halting natural water flows out of the lake to surrounding areas. In 1938, USACE began to regulate lake levels, and lake inflows and outflows were altered to include structures and channelization to move water more effectively in and out of the lake (Figure 5). Modifications to the outlets on the east and the west sides of the lake made the Caloosahatchee and St. Lucie rivers the primary outlets from the lake as well as travel corridors. Water could also be pumped into the lake.

Figure 5. Typical regional canal

However, due to a series of back-to-back hurricanes in 1946 and 1947 and resulting significant flooding in South Florida, the need for additional features to manage excess water became evident. In response to these conditions, the State of Florida requested assistance from the federal government resulting in the Central and Southern Florida Flood Control Project (C&SF Project) being authorized by the U.S. Congress in 1948. Subsequently, USACE produced a comprehensive water management plan for flood control to drain the land quickly to tide and allow for urban and agricultural development. It took approximately 20 years to implement the project features, canals, levees, pump stations, and other structures including the channelization of the Kissimmee River. By 1969, over 1800 miles of primary canals were constructed to reduce groundwater levels along the coast, which enabled the development of the southeast urban corridor that exists today. The canals serve as flood protection for low lying areas because they currently drain by gravity to the ocean. Figure 6 shows the canal networks in the South Florida Water Management District (SFWMD) service area. These areas would be flooded in the summer months without the canals. In addition, the need to control Lake Okeechobee levels requires discharges through the St. Lucie

River and Caloosahatchee watersheds. The timing of these discharges is historically different than the natural system, creating disruptions in water quality and supply.

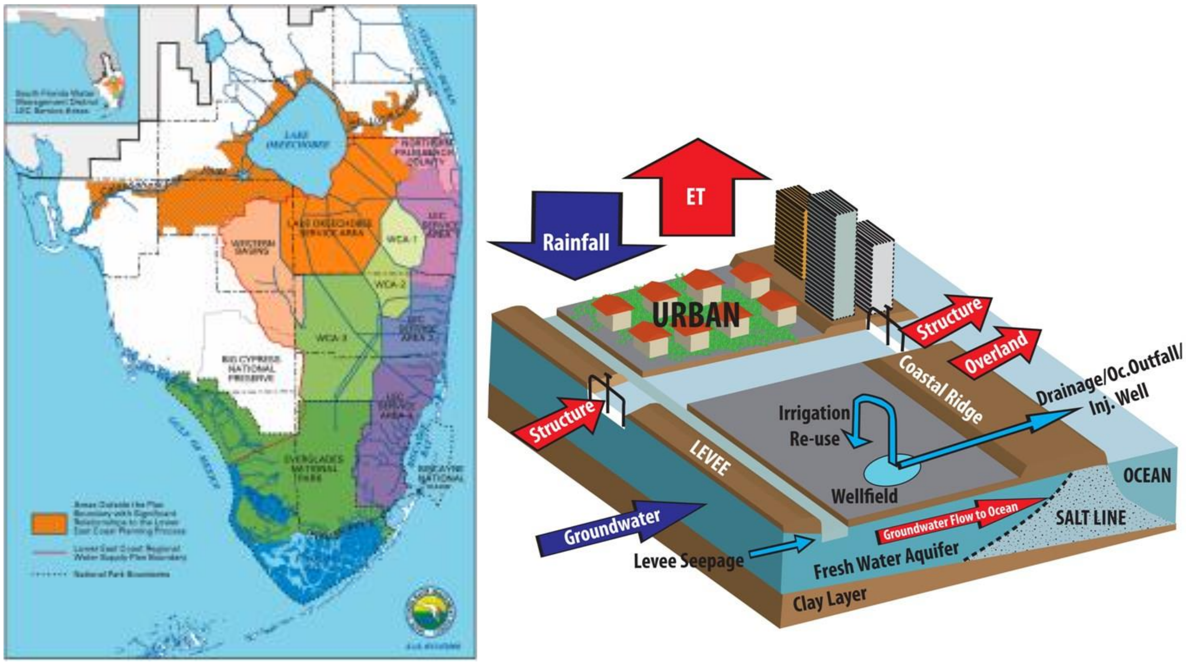

Figure 6. South Florida Water Management District Lower East Coast service area and drainage pattern after C&SF drainage improvements (SFWMD, 2020)

As a result, South Florida and the Caloosahatchee East/Clewiston subwatershed landscapes have been dramatically altered by construction of this elaborate system of canals, dikes, levees, flow control structures, pumps, and other water control facilities. These changes also allowed South Florida to be one of the largest metropolitan areas in the United States, and for the Fort Myers area of coastal Lee County to develop a population of nearly 1 million.

The watershed also affects local flood management. Highly engineered stormwater drainage systems and water control structures permit development in areas that were historically considered swamp lands on the southwest coast (parts of Fort Myers and Cape Coral). In these areas, the stormwater is collected locally in neighborhoods in swales (Figure 7), ponds (Figure 8), small lakes, ditches, small canals (Figure 9), and lagoons (Figure 10). In the agriculture areas east of the Franklin lock, most of the areas use the canals to move water from flooded fields to the larger regional system, or from the larger regional system to fields for irrigation. Even the agricultural portion of the canal system is heavily managed. The major waterways and structures on the Caloosahatchee are controlled by SFWMD and USACE.

Figure 7. Typical swale

Figure 8. Typical retention pond

Figure 9. Typical localized canal

Figure 10. Typical aerated lagoons

1.1.1 Geomorphological Considerations

The Caloosahatchee East/Clewiston subwatershed is located on the lower west coast of the upper part of South Florida and includes the northeasternmost portion of Hendry County (Barnes, 2005), as seen in Figure 11. This subwatershed is part of the larger Caloosahatchee TMDL basin that extends from Lake Okeechobee in the east to the western discharge of the Caloosahatchee into the Gulf of Mexico at Charlotte Harbor.

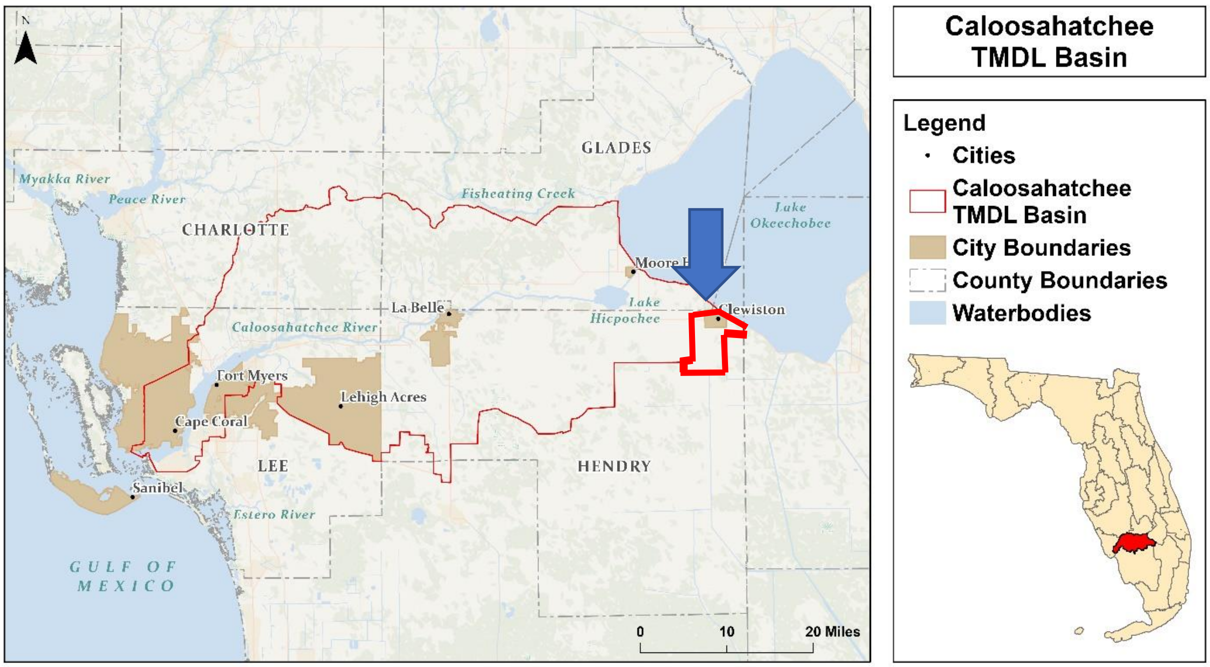

Figure 11. Map of the Caloosahatchee East/Clewiston subwatershed including the major population centers

Hendry County has a total area of 1,190 square miles, of which 1,153 square miles is land and 37 square miles (3.1%) is water. The Caloosahatchee East/Clewiston subwatershed encompasses 34.4 square miles. The only incorporated community in the Caloosahatchee East/Clewiston subwatershed is the City of Clewiston containing just over 4 square miles. For context, the FIRM panel index of the study area and surroundings is shown in Figure 12.

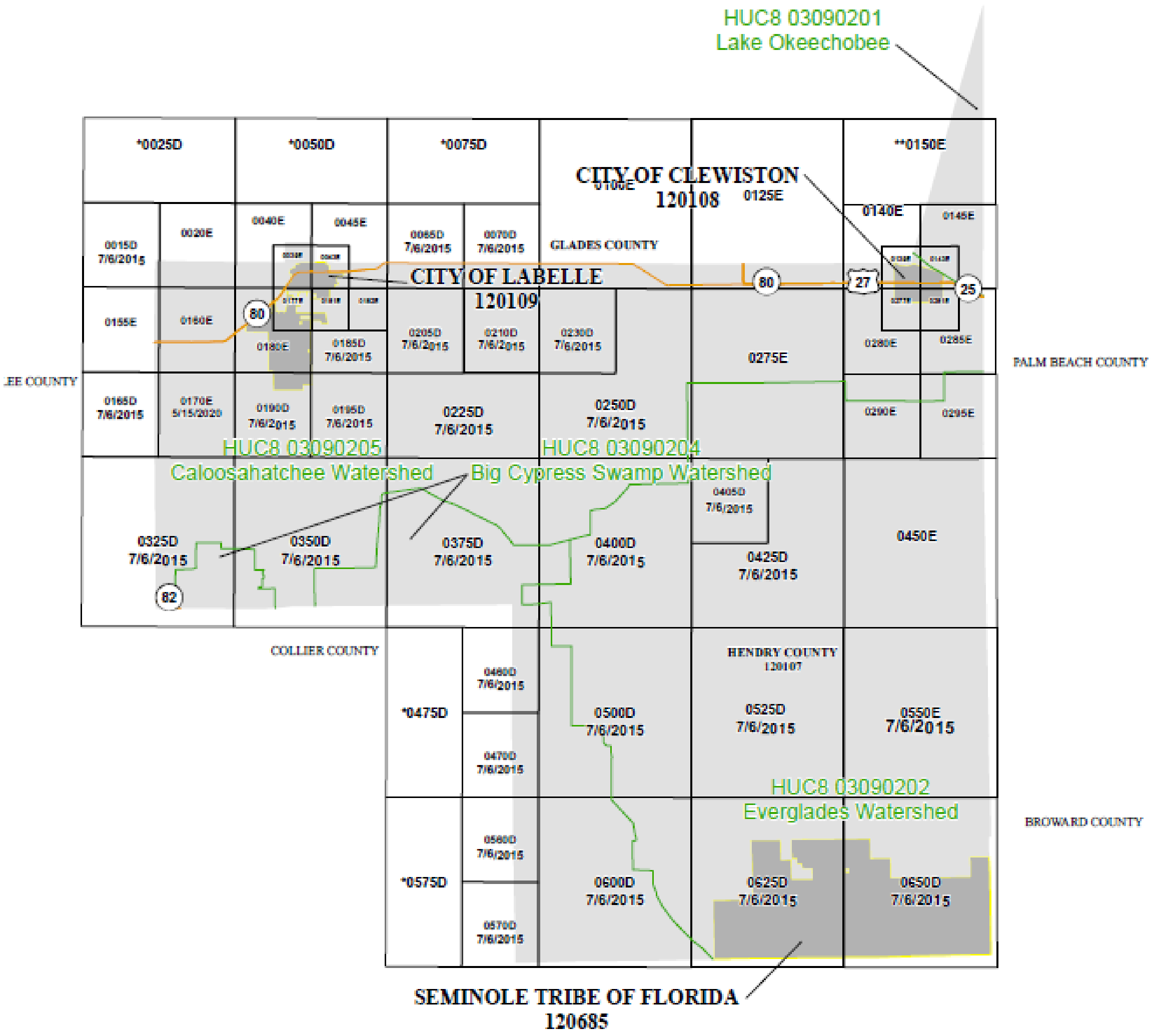

Figure 12. FIRM panel index (Hendry County FIS, 2019)

The Caloosahatchee River and Estuary system has been altered by human activities starting in the 1880s, when the river was straightened and deepened causing a loss of 76 river bends and 8.2 miles in length (Antonini et al., 2002) and further altered due to the management of water caused by the C&SF program described earlier. The Caloosahatchee River Watershed Protection Plan (CRWPP) study area includes the land that drains to the mouth of the Caloosahatchee and the associated offshore estuarine area, which comprises five subwatersheds (SFWMD et al., 2012b) (refer to Figure 1).

An important environmental disruption on the west end of the Caloosahatchee basin has been ill-timed discharges from Lake Okeechobee, which negatively impact the natural system water quality and quantity. Freshwater from Lake Okeechobee can create disruptions to the local ecology by flushing saltwater especially in the east side of Sanibel Island, which negatively impacts the aquatic nurseries. Added development on the west coastal areas increases impervious, thereby increasing runoff peaks, which can overwhelm existing stormwater systems. Numerous tributaries exist throughout both the freshwater and estuarine portions of the watershed and can influence overall hydrology of the river depending on rainfall and regional hydrological conditions. Closer to the study area, a network of secondary and tertiary canals (Figure 13) supports agriculture and urban development.

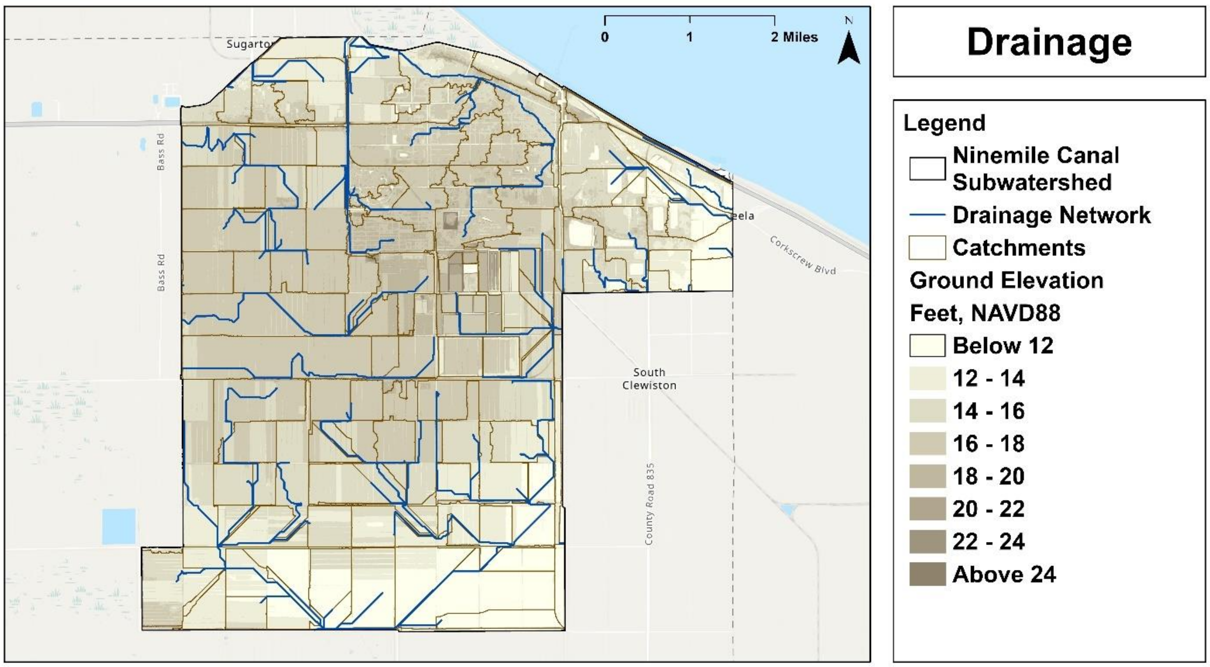

Figure 13. Flow paths for the Caloosahatchee East/Clewiston subwatershed, as processed by Florida Atlantic University (FAU)

Hendry County has a total area of approximately 1,190 square miles. The 12-digit HUC (030902050102) containing Clewiston is over 65 square miles with the Ninemile Canal running through the middle. So, the lower half that is south of the Ninemile Canal was used as the study area for modeling (~34.4 square miles). The City of Clewiston entered the CRS as a Class 9 community on May 1, 2017. Based on this CRS classification, Clewiston receives a 5% flood insurance policy premium discount for property located both inside and outside of Special Flood Hazard Areas (SFHA). The City has a total area 4.51 square miles, which is entirely within the HUC 030902050102 Caloosahatchee East/Clewiston subwatershed and makes up 13.1% of the study area. Clewiston contributes 1.55 square miles of SFHA to the study area, which is 4.5% of the total area of the study area.

Hendry County entered the Community Rating System on October 1, 2000, and is currently a Class 8 community. This community receives a 10% discount inside of Special Flood Hazard Areas and a 5% discount for areas outside of the SFHA. A summary of the existing CRS classifications and the areas associated with the special flood hazard area for the communities in the study area is listed in Table 1.

Table 1. Summary of key characteristics of the HUC 030902050102 Caloosahatchee East/Clewiston subwatershed

Community Name	CRS Entry Date	Current Class	% Discount for SFHA	% Discount for Non-SFHA	Area in the Study Area (mi^2)	% of the Total Area of the Study Area	Area in the SFHA (mi^2)	% of the Total Area of the Study Area
Clewiston, City of	05/01/2017	9	5%	5%	4.51	13.1%	1.55	4.5%
Unincorporated Hendry County	10/01/2000	8	10%	5%	29.90	86.9%	4.86	14.1%

1.1.2 Waterway Features

The study area ultimately drains to the Caloosahatchee/C-43 canal. Therefore a larger discussion of the greater basin dynamics is in order. The Caloosahatchee watersheds starts at Lake Okeechobee where the C-43 canal connects the lake to the Caloosahatchee. This permits flows from the lake into the estuaries that discharge to the Gulf of Mexico via San Carlos Bay in Fort Myers. As noted in Section 1.1.1, early descriptions of the Caloosahatchee River Estuary (CRE) characterize it as barely navigable due to extensive shoals, oyster bars near Shell Point (Sackett, 1888), and a shallow connection dug by native Americans pre-1880. In 1880, the river was channelized, locks were constructed, and canals were dug to drain the land. The navigation channel was dredged, and a causeway was built across the mouth of San Carlos Bay in the 1960s. Historic oyster bars upstream of Shell Point were mined and removed to be used in the construction of roads. Today the Franklin Lock represents the head of the CRE that extends 42 km downstream to Shell Point where it empties into San Carlos Bay. The surface area of the CRE is 22 square miles with an average depth of 8 ft (Buzzelli et al., 2013b). The flushing time ranges from 2 to 30 days (Buzzelli et al., 2013d).

Just east of the CRE is the W.P. Franklin Lock and Dam, operated by USACE, is located along the Caloosahatchee, approximately 33 miles upstream of the Gulf Intracoastal Waterway. The W.P. Franklin Lock and Dam were constructed in 1965 for flood control, water control, prevention of salt-water intrusion, and navigation purposes. The lock chamber is 56 feet wide × 400 feet long × 14 feet in a channel 90 feet wide × 8 feet deep (Figure 14). The elevation drop is only a few feet to sea level through a concrete structure with welded structural steel sector gates and concrete gate bays. The discharge is 28,900 cfs (https://www.saj.usace.army.mil/Missions/Civil-Works/Navigation/Navigation-Locks/WP-Franklin-Lock/). Approximately 13,300 tons of manufactured goods, equipment, crude materials, food, and petroleum products locked annually along with 15,000 recreational vessels.

Figure 14. W.P. Franklin Lock and Dam aerial (left) and structure (right) (Google Earth images)

Upstream (east) is the Ortona Lock and Dam (Figure 15) constructed in 1937 for navigation purposes. The structure is 27.9 miles east of the W.P. Franklin Lock and Dam, and 15.5 miles west of the Moore Haven structure at Lake Okeechobee. The lock chamber is 50 feet wide × 250 feet long × 12 feet deep in a channel that is 90 feet wide × 8 feet deep. Discharge capacity is 8600 cfs. Approximately 9,500 vessels lock through annually, 96% of which are recreational vessels. The drop is 7 to 8 ft (https://www.saj.usace.army.mil/OrtonaLock).

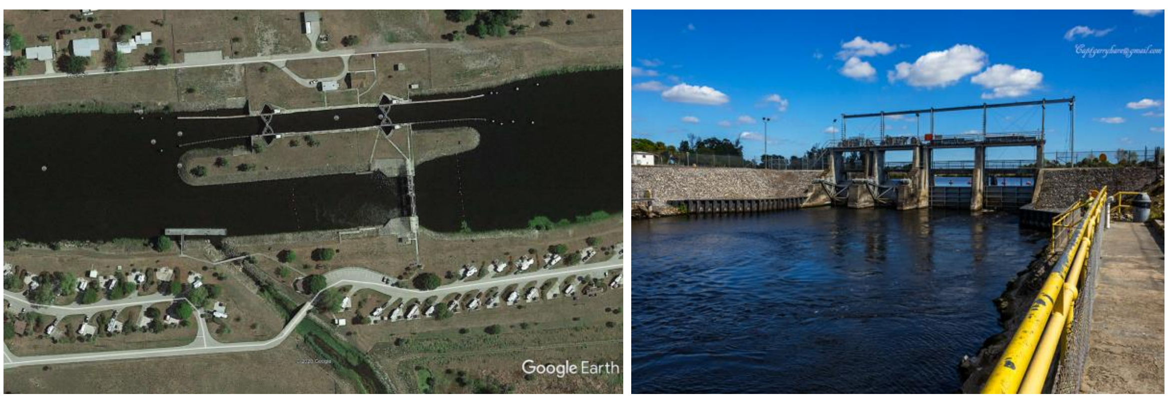

Figure 15. Ortona Lock and Dam aerial photo (left) and structure (right) (Google Earth images)

As noted, the river channel has been manipulated for management of flood waters for over 100 years. The channelization has significantly impacted the river ecosystem, particularly the oxbows (Delhomme, 2012), which have been surveyed in 2011 and compared to a SFWMD survey conducted in 1978. This work revealed that 21 of 37 oxbows are still open; however, 16 are partially filled. In both 1978 and 2011, oxbows in Lee County were significantly larger, wider and deeper than in Hendry County. Exterior limb cross-sections were significantly larger, wider and deeper than interior cross-sections in both 1978 and 2011 (Delhomme, 2012). Finally, an attempt to determine trends in the evolution of the morphology of the oxbows demonstrated that the overall maximum depth has significantly decreased but only in the interior of the oxbow and that the mean depth has significantly increased but only in the exterior cross-sections. This analysis also showed that the width has significantly increased throughout the oxbow. Factors responsible for such differences include natural geomorphic processes, pattern changes due to channelization, land use and anthropogenic activities. The conditions of the W.P. Franklin Lock and Dam (Figure 16) and the Ortona Lock and Dam (Figure 17) are monitored by USACE. Secondary drainage canals are monitored and maintained by SFWMD. Figure 18 shows the changes resulting from channelization and how the floodplain of the river has decreased with channelization (Delhomme, 2012).

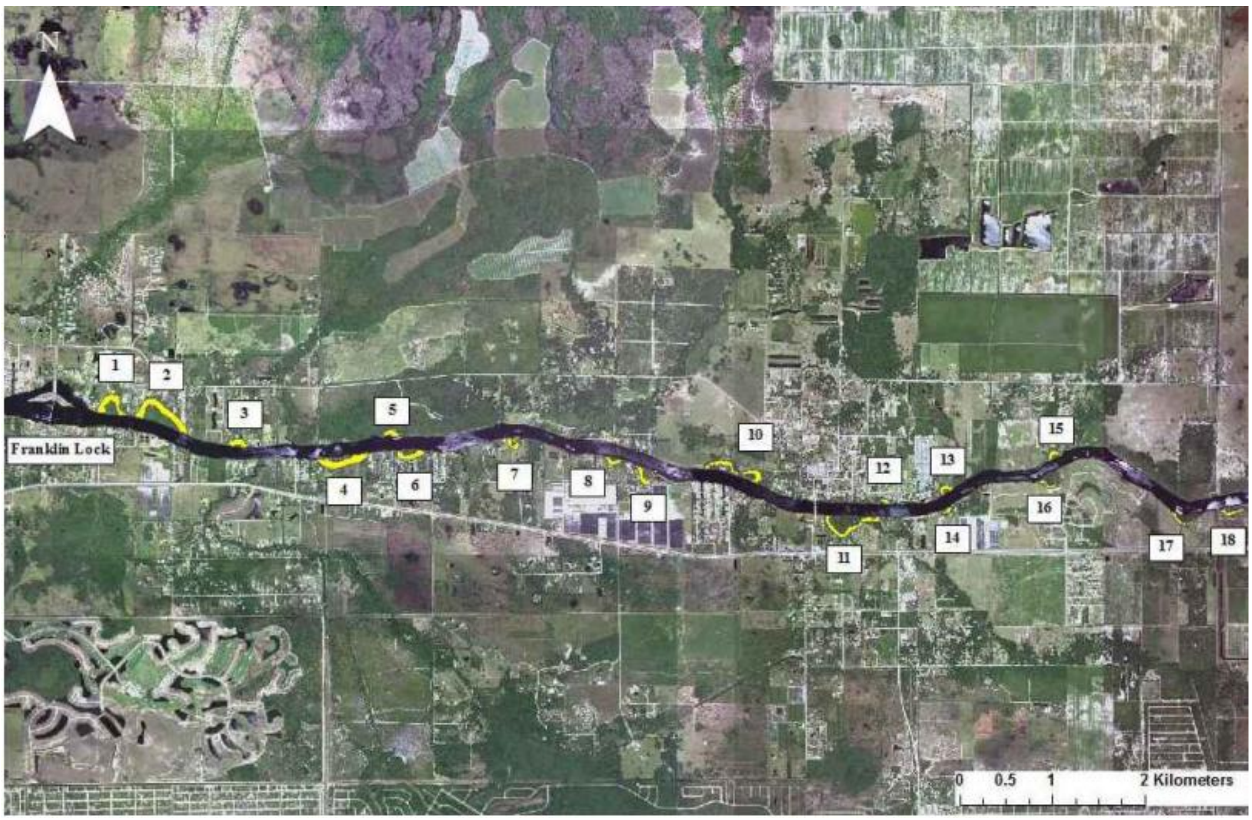

Figure 16. Oxbows (numbered) east of the W.P. Franklin Lock and Dam (Delhomme, 2012)

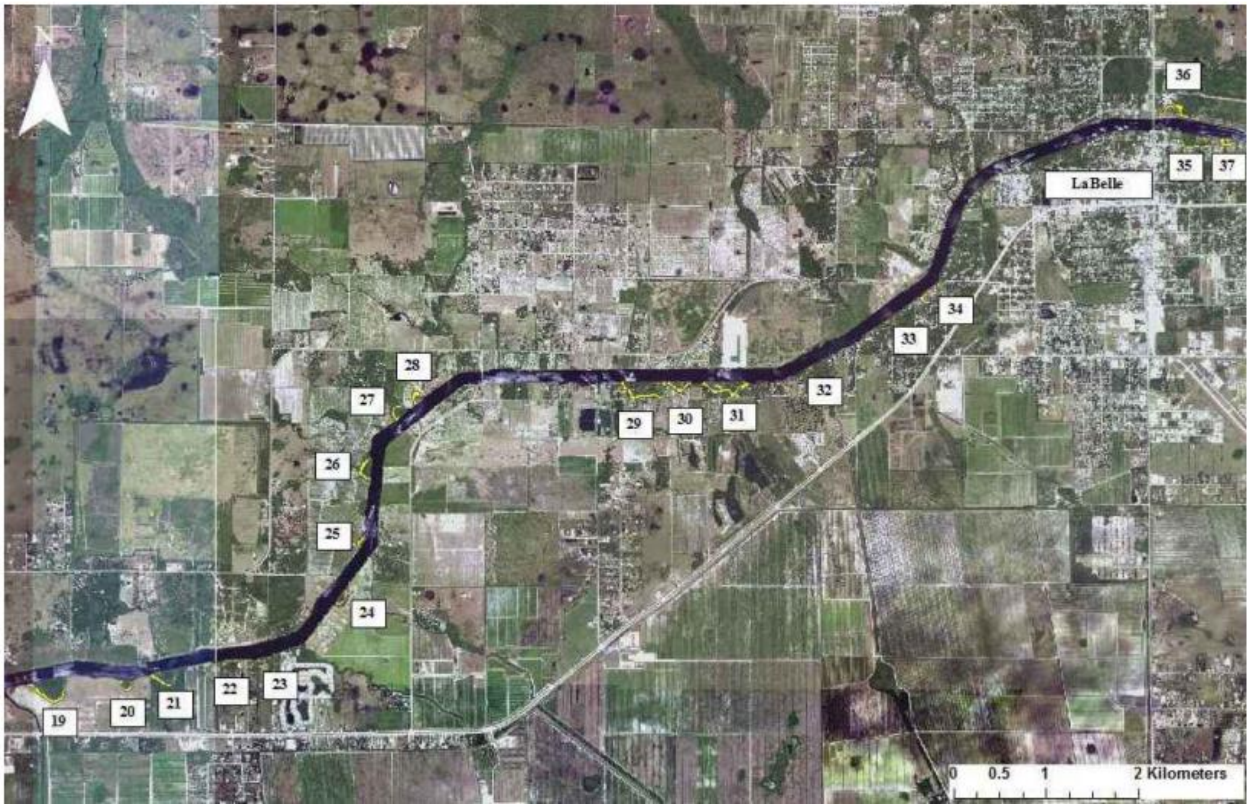

Figure 17. Oxbows (numbered) west of the Ortona Lock and Dam (Delhomme, 2012)

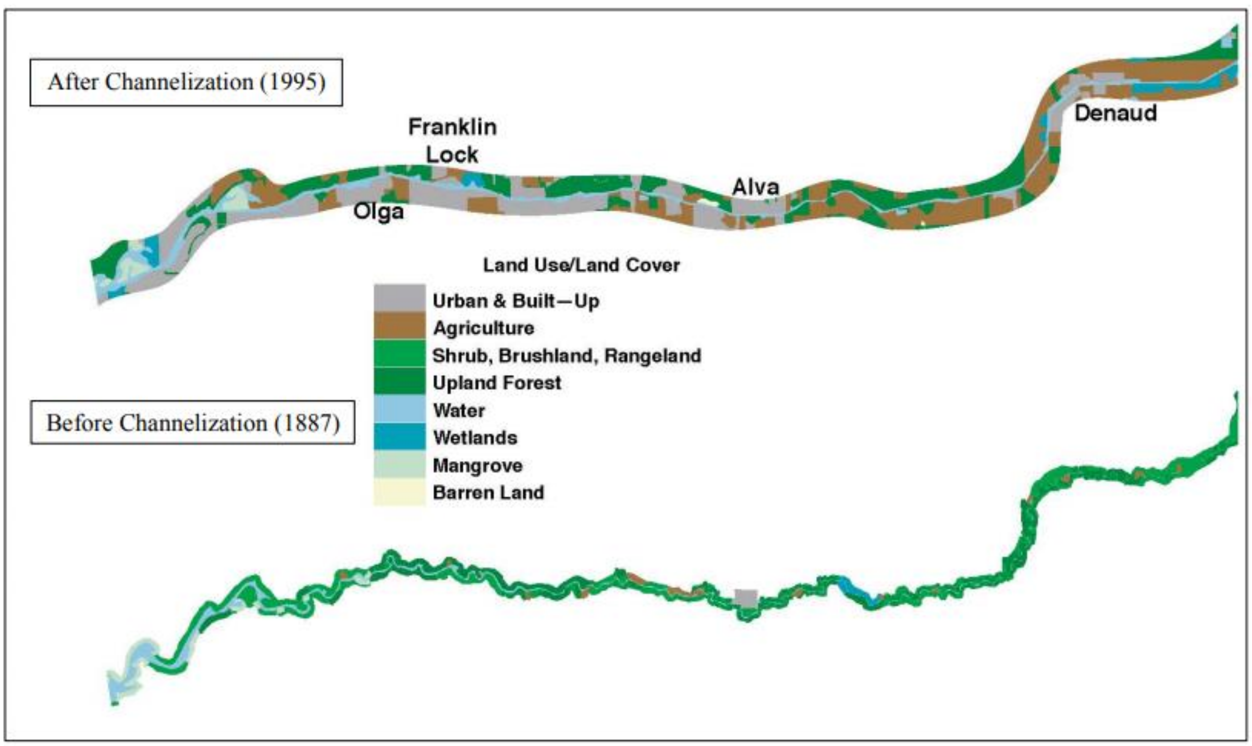

Figure 18. Comparison of historical and channelized Caloosahatchee riverbed (Delhomme, 2012)

Refer to Section 2.9 for more information on waterbodies in the study area.

1.1.3 Hydrologic Boundaries

USGS designates subwatersheds numbered with 12-digit hydrologic unit codes (HUCs). The study area boundaries for HUC 030902050102 Caloosahatchee East/Clewiston (Ninemile Canal) subwatershed were shown previously in context with the larger regional Caloosahatchee watershed in Figure 11. The major waterbodies are discussed later in Section 2.9. An aerial overview of the Caloosahatchee East/Clewiston subwatershed is shown in Figure 19.

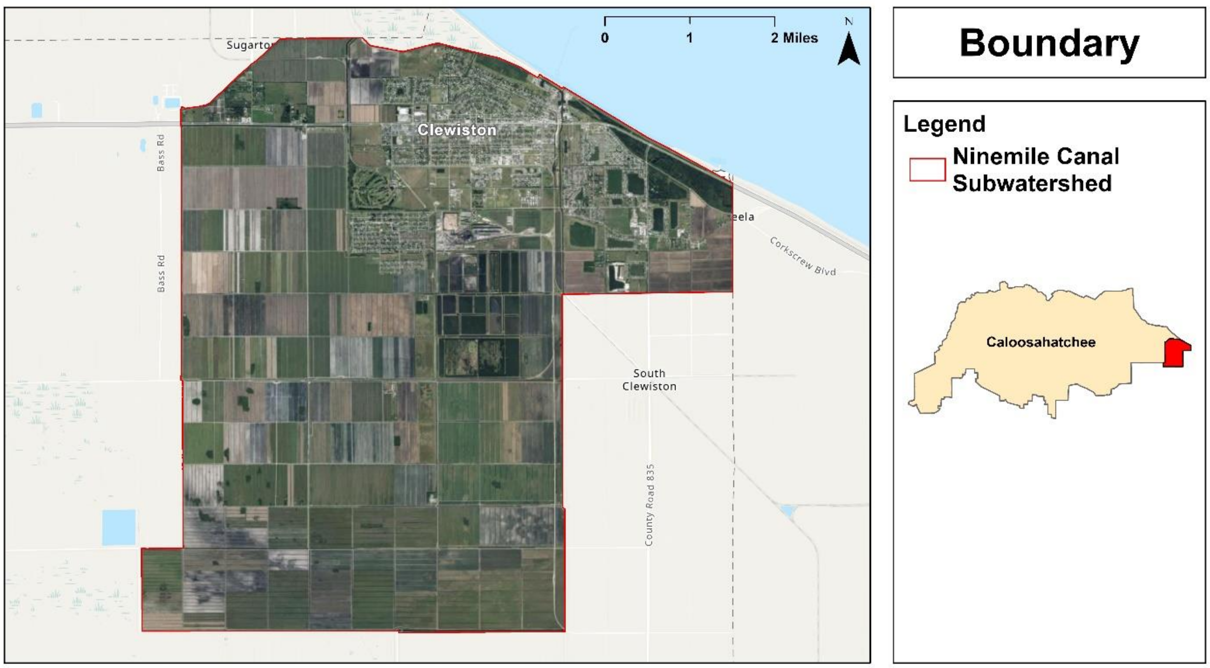

Figure 19. Caloosahatchee East/Clewiston subwatershed boundaries superimposed on an aerial photograph

Given that stream flow data are critical for estimating flooding, Figure 20 shows the relationship between historical rainfall and streamflow in the basin. Such data are useful in assessing relationships between precipitation and stream flow, potentially an important indicator of development.

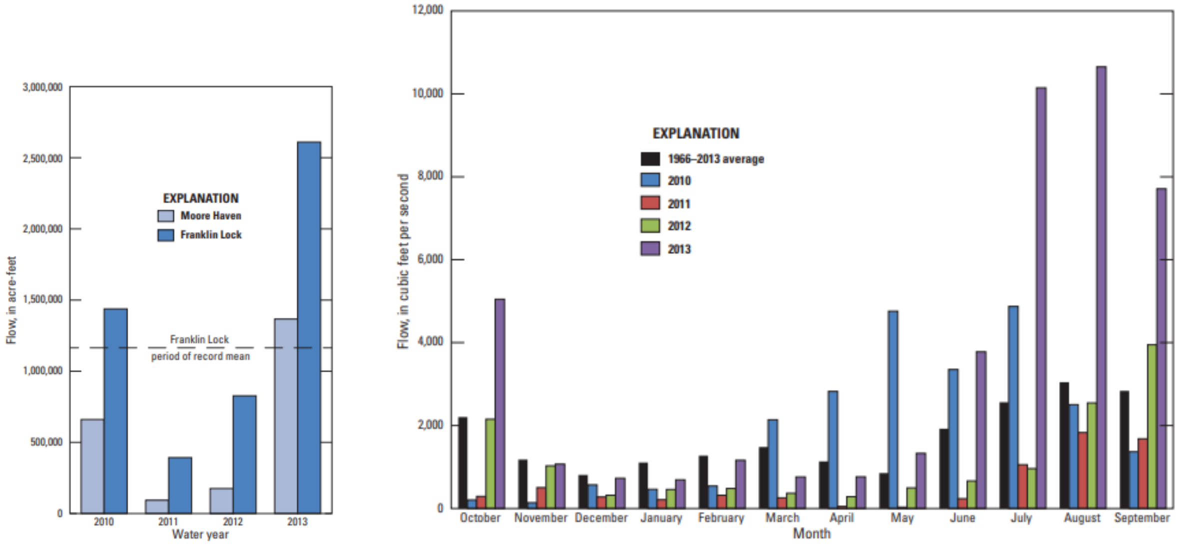

Figure 20. Average flows for the Caloosahatchee River – averaged by month over a 47-year period compared to 2010-2013 (SFWMD, 2020)

Figure 20 (right) shows that the flows are highest in August and September, while the flows are lowest during the winter months (November-February). Figure 20 (left) shows that the flows are not consistent from year to year.

1.1.4 Wetlands and Natural Areas

Wetlands serve many purposes, including acting as recharge areas, filters for contaminants and buffers that mitigate temperature changes in adjacent areas. In South Florida, as a result of hydrologic modifications over the past 100 years, the natural storage and buffering capacity of wetland areas in this study region have decreased such that water levels can rise substantially in short periods of time, and the water levels occur outside desirable ranges either too high or too low with rapid water level fluctuations. Wetland areas are shown in the map on Figure 21.

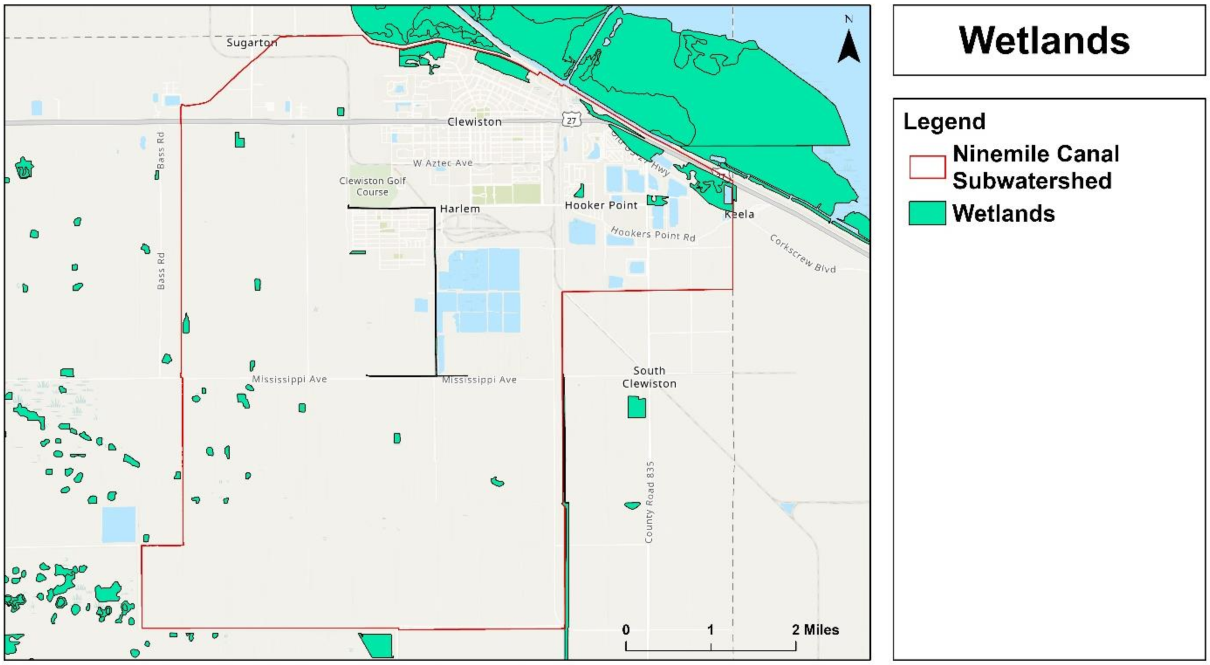

Figure 21. Wetlands in the Caloosahatchee East/Clewiston subwatershed

Upland areas, such as pines and palms, that provide habitat for certain species, are shown in Figure 22. Many of these areas are either protected or have limitations on development as discussed in Section 3.1.4.

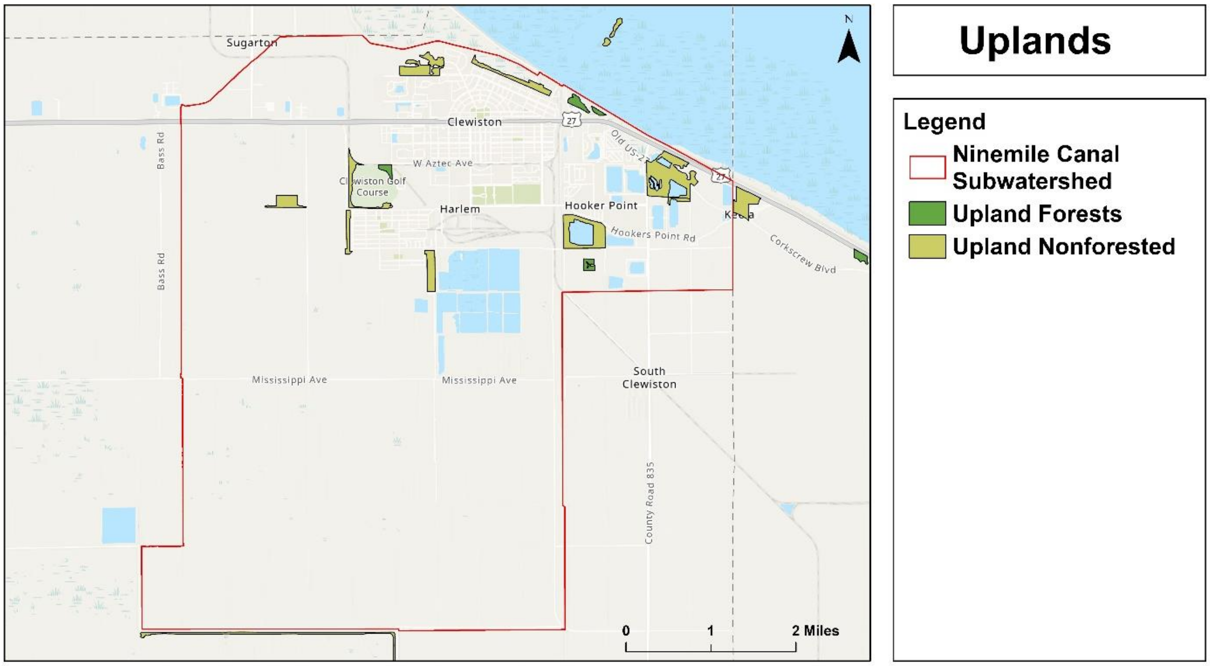

Figure 22. Uplands in the Caloosahatchee East/Clewiston subwatershed

The extent of Florida Panther habitat is shown in Figure 23, which covers most of the greater Caloosahatchee watershed.

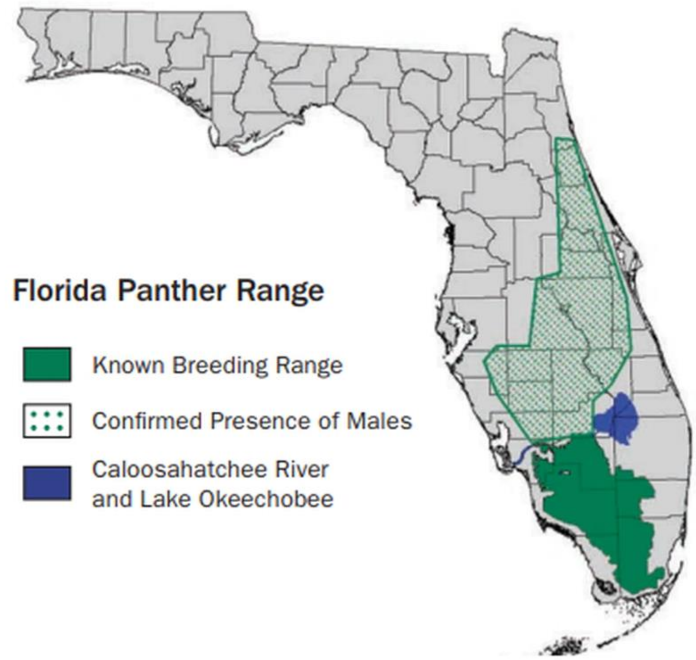

Figure 23. Florida panther habitat range (Florida Fish and Wildlife Conservation Commission, 2018)

Figure 24 shows the land use element from the Hendry County Comprehensive plan. The area is projected to remain roughly the same as today – mostly agriculture with some urban area in Clewiston. More details about the land use/land cover will be discussed in Section 2.5.

From the Henry County Comprehensive Plan:

> Policy 1.1.1b: Agriculture/Conservation Future Land Use Category
>
> Purpose The purpose of the Agriculture/Conservation Future Land Use Category is to designate those areas within Hendry County that will continue in a rural and/or agricultural state through the planning horizon of 2040 and may contain jurisdictional wetlands. Description/Uses All land uses shall be the same as for the Agriculture Future Land Use Category with the following exceptions:
>
> • No industrial or commercial development (including agriculture related or extraction related) shall be permitted within a wetland.
>
> • Residential development shall be limited to ensure that wetlands are preserved or that activities that impair the natural function of the wetland are prohibited

Also:

Policy 1.1.13: Leisure/Recreation Future Land Use Category

Purpose

The purpose of the Leisure/Recreation Future Land Use Category is to define those areas within Hendry County that are used or may become used for free standing/independent leisure/recreation activities through the planning horizon of 2040. This land use category includes various uses that, because of their nature, are intended to provide for the leisure and recreation activities of the residents and visitors of Hendry County and to encourage and promote recreation and or tourism in the County. Lands and uses in this category would not normally be part of a mixed-use community nor be accessory uses for other principal uses.

Description/Uses Leisure/Recreation areas are sites that are currently developed for leisure/recreation facilities or undeveloped sites that are designated for development as leisure/recreation facilities. This land use category includes various uses which, because of their nature, are intended to provide for the leisure and recreation activities of the residents of Hendry County and to encourage and promote recreation and/or tourism in the County. Uses allowed within this category shall be limited to sports facilities whether individually developed or in sports complexes, active and/or passive parks, recreation vehicle parks, campgrounds (whether primitive or improved), marinas, golf courses, equestrian centers and riding areas, sporting clay facilities, eco-tourism activities, and similar leisure and recreation facilities and ancillary uses.

Location Standards

Sites designated Leisure/Recreation may be within the urban/suburban area of the community or within the rural/agricultural areas of the county. The determination of adequacy/appropriateness of location will be by the Board of County Commissioners utilizing the following guidelines:

• The impact the proposed use will have on the transportation system of the County.

• Proximity to recreational attractions or environmental features that would support the proposed development to include but not be limited to water bodies, governmental recreational facilities, natural amenities, ecosystems, or other tourist attractions.

• Appropriateness of location versus availability to provide public services, including water, 1029 wastewater treatment, police service, fire service, and EMS service.

• Relationship of proposed site to adjacent land uses to determine compatibility based upon hours of operation, noise, light, dust, traffic impact, impact on residential areas, and impact on natural areas

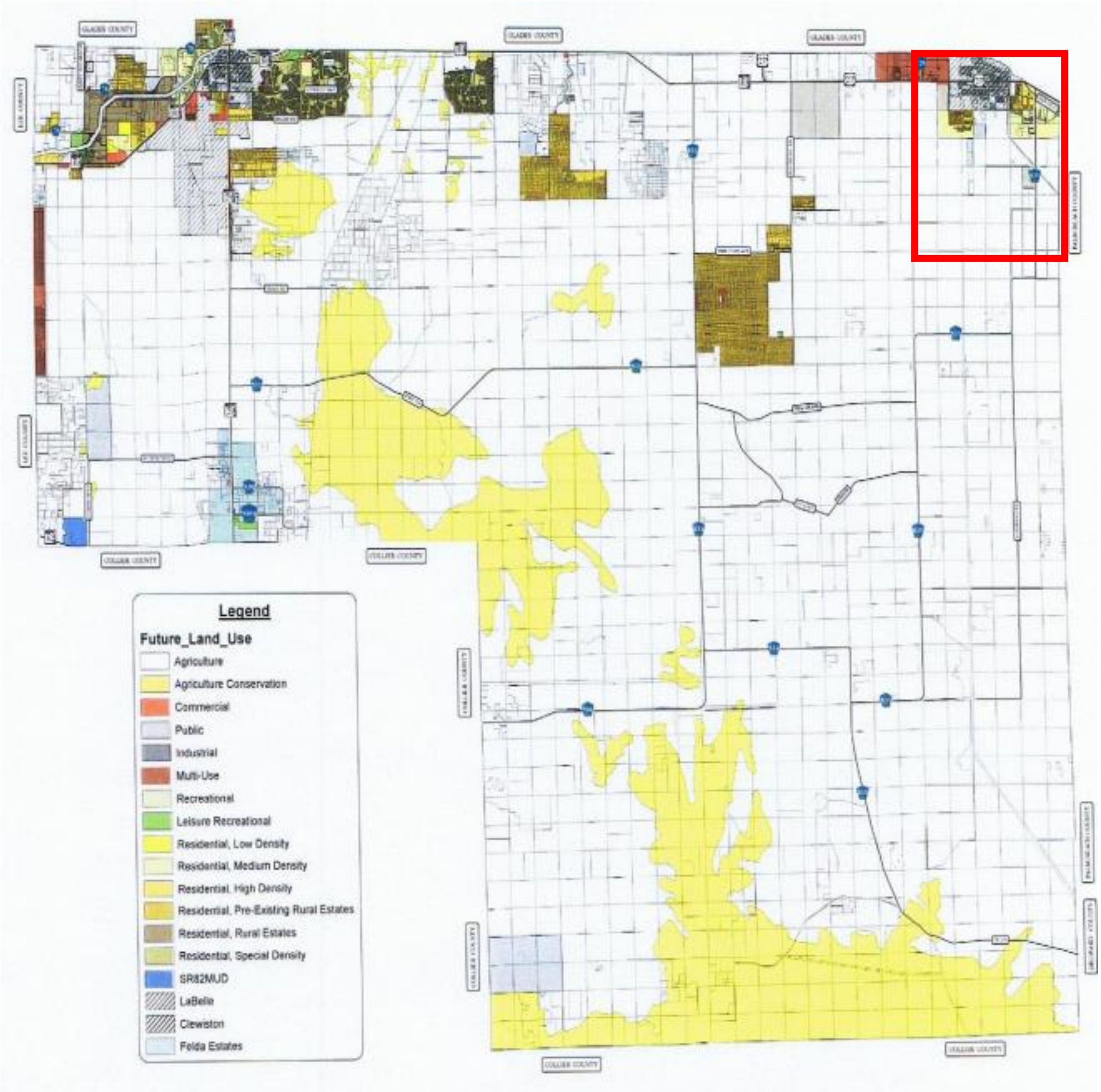

Figure 24. Conservation areas (gray) in Hendry County – the sub-watershed is roughly delineated in red (http://www.hendryfla.net/hendrycountynew/uploads/2013_Comp_Plan_Complete.pdf)

1.1.5 Floodplains

A meandering stream can contribute to a floodplain's aggradation, or build-up in land elevation, as well as its erosion. A typical aggradation environment is a wide, shallow, braided river. Braided rivers often include river deltas, where the main floodway is separated into discrete channels and tiny islands. As the stream meanders, it creates oxbows that change as time, flooding and storms alter the flow path of the stream. Oxbow lakes are formed when a meander, or bend, in the river is cut off from the river's mainstem. Features such as oxbow lakes and seasonal wetlands are often a part of floodplains created through erosion and deposition. Figure 18 in Section 1.1.2 shows the historical oxbows in the greater Caloosahatchee TMDL basin. The flood zones are marked in the flood insurance rate map for Hendry County (Figure 25) and the closer view for the City of Clewiston (Figure 26). For the most part, these flooded areas are outside the channels of the Caloosahatchee and its major tributaries because the land is low and flat and contains many wet swampy areas.

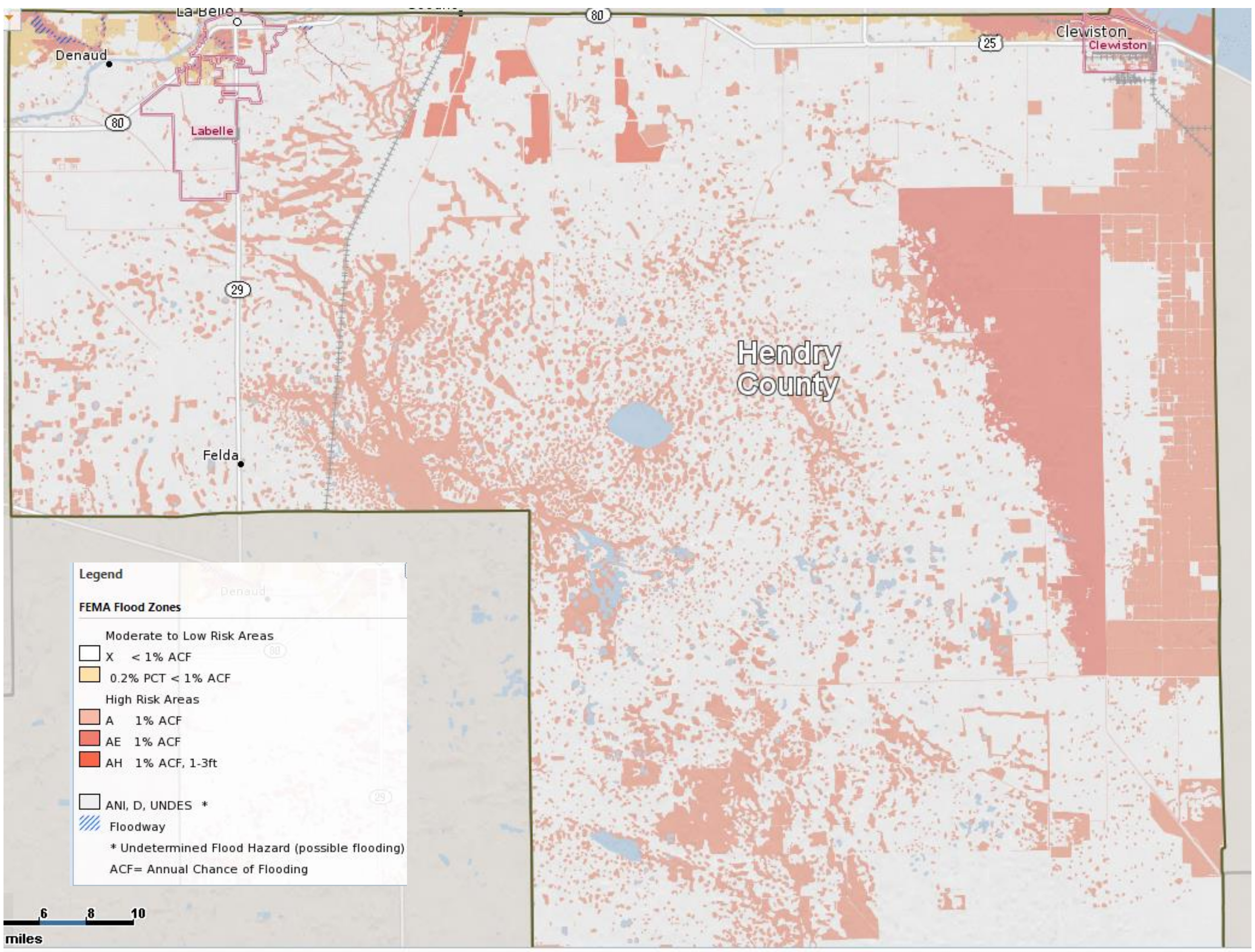

Figure 25. Hendry County flood insurance rate map with the Clewiston subwatershed shown in the top right corner.

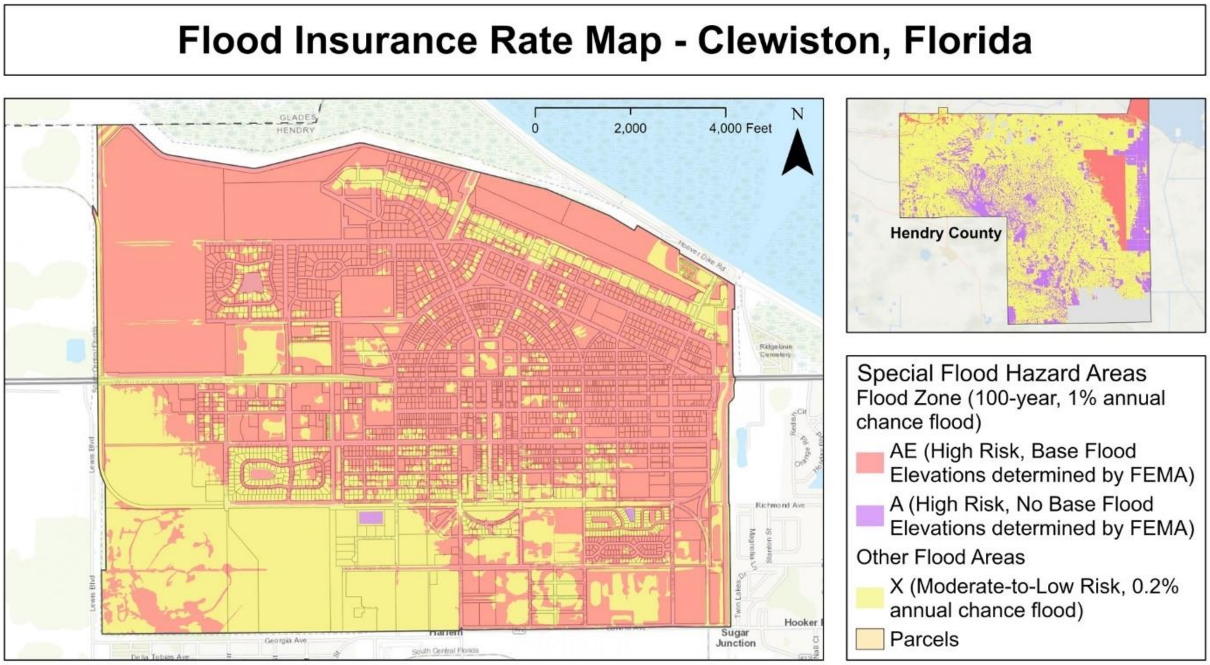

Figure 26. City of Clewiston flood insurance rate map

The 1% annual chance (100-year) flood has been adopted by FEMA as the base flood for floodplain management purposes. Flood risk is evaluated based on factors such as known flood hazards and projected impact on the built environment. In the 2019 FIS for Hendry County, engineering analyses were performed for each flooding source to calculate its 1% annual chance flood elevations. The engineering models and methods are described in detail in the 2019 FIS. The modeled elevations at cross sections were used to delineate the floodplain boundaries on the FIRM; between cross sections, the boundaries were interpolated using elevation data from various sources.

1.1.6 Flow Paths and Natural Channels

Figure 13 in Section 1.1.1 previously showed the flow channels for the Caloosahatchee East/Clewiston subwatershed based on modeling conducted by Florida Atlantic University (FAU).

1.2 Planning Goals and Scope

The primary purpose of a watershed master plan is to guide watershed coordinators, resource managers, policy makers, and community organizations to restore and protect the quality of lakes, rivers, streams, and wetlands in their jurisdiction. The specific goals for the WMP process for the study area are to identify:

- Existing physical and natural features of the subwatershed (Sections 2.1-2.11)
- Existing flood protection infrastructure, including that which is close to failure or inadequate (Section 2.12)
- Existing policy frameworks and local regulatory constraints (Chapter 3)
- Dedicated funding for projects (Section 3.5)
- Locations and value of flood prone areas (Chapter 4)
- Proposed flood protection projects (Chapter 5)

Table 2 shows the ultimate planning goals derived from the previous requirements. Note these goals mimic those established by the SFWMD and its stakeholders in the Caloosahatchee Water Management Plan (SFWMD, 2000).

Table 2. Goals related to flood protection at the watershed level

Goal	Quantitative Indicator	Management/Project
Increase intergovernmental communication	• Increasing number of attendees to periodic meetings • Increasing number of website viewers	• Coordination of projects
Reduce overbank flooding	• Decreasing number of incidents per year • Decreasing number of repetitive loss claims	• Improved management strategies for the river • Restoration of oxbows • Bypass flood waters to offsite reservoirs
Restore wetlands	• Increasing wetlands areas in the inventory map • Increasing wetland species	• Restore water flow • Increase regulatory protection • Acquire properties
Increase water supply	• Decreasing water use restrictions imposed by the SFWMD	• Construct upstream reservoirs and store water in wetland areas to increase natural recharge
Reduce flood frequency	• Decreasing number of incidents per year • Decreasing number of repetitive loss claims	• Improve management strategies for the river • Locally, install pump stations, piping, stormwater treatment areas, and develop additional green strategies • Changes to flood maps

1.3 Public Outreach

The key stakeholders in the study area include the county government, the municipal governments, the water management district, agriculture, recreation (fishing/hunting), tourism interests, and environmental interests that may have more concerns associated with timing of flood releases and water quality. Public works agencies and the Florida Department of Transportation (FDOT) should also be included as a part of the process because roadways, bridges, and culverts are major components of stormwater conveyance.

The goals of the public outreach program reflect the steps required to solicit public input and build awareness of the project throughout diverse communities. Public information must be straightforward, factual, and designed to be appreciated by non-technical audiences. The goals of this plan are as follows:

- Communicate effectively with the diverse communities and stakeholders
- Create public forums and collateral materials that provide clear, concise, and easy-to understand information to enable the public to provide input and make informed decisions about the project
- Publish and distribute materials for review and also notify the public, elected officials and other stakeholders of upcoming community meetings and public hearings
- Develop a comprehensive list of public and regional benefits that the project will generate
- Create and implement a meaningful public involvement process, and evaluate the public involvement process on a regular basis
- Create measurable objectives tied to the milestones that are required for the successful conclusion of the project.
- Respond to public and stakeholder feedback in an accurate, consistent, and timely manner

To facilitate community participation, there is a need to develop a database of specific stakeholders (community groups, residents, local and regional business owners, labor, environmental organizations, employers, employees, academia, cultural and entertainment attractions, emergency responders, media, surface transportation industry, policy leaders, other institutions, etc.) to make sure that each is represented in the WMP process. Then the outreach program should be applied to the stakeholders to:

- Develop corollary key messages that are consistent with the goals and objectives of the planning process
- Assess attitudes and perceptions among target audiences
- Identify barriers, opportunities, and levels of support

The meetings must be public, and all input recorded. Each meeting should be developed with an agenda that includes:

- Date/times
- Locations
- Attendance
- Meeting formats
- Speakers/presenters
- Content of presentation material

A website should be created to provide documentation for all meetings including:

- Agendas
- Notices/ads
- Meeting materials
- Meeting summaries
- Minutes
- Public comment logs
- Plan documents
- Action items

Because many stakeholders cannot attend daytime meetings in person, options to provide input should include:

- Comment tool on the webpage
- Virtual meetings
- Blogs/discussion boards
- Survey platforms
- Electronic news outlets

Such forums must be monitored to incorporate feedback into the plan. All outreach should incorporate a news media outlet. For this basin, the *Fort Myers News-Press* is the most widely circulated newspaper. In addition, the following government websites should be considered good hosting places as well:

- Hendry County (hendryfla.net)
- Clewiston (clewiston-fl.gov)

A suggested partial list of potential stakeholders for the Caloosahatchee East/Clewiston subwatershed includes the following:

- Community Coordination Officer
- Resilience team
- SFWMD
- USACE
- Hendry County
- City of Clewiston
- FDEP
- Southwest Florida Regional Planning Council
- University of Florida- IFAS
- Conservancy of Southwest Florida
- The Nature Conservancy

- Audubon Society of Southwest Florida
- Sierra Club
- Riverwatch
- Gulf Citrus Growers Association
- PURRE Water Coalition
- Southwest Florida Watershed Council

2.0 WATERSHED CHARACTERIZATION

Despite historical water management conflicts and periodic disruptions, South Florida will remain a desirable place to live, so the interconnectedness of waterbodies will require a more integrated solution to resolve water quantity and quality issues. Making thoughtful, long-term decisions will be important because infrastructure and development typically have an expected life cycle of at least 50 years or more. To characterize the physical and hydrologic aspects of the study area, historical and current data were collected from various key sources for the following:

- Topographic data (LiDAR)
- Groundwater levels
- Relevant waterway locations and levels
- Soils data
- Land uses including vacant land, wetlands, etc.
- Precipitation
- Open space and impervious areas
- Natural resources
- Demographics
- Stormwater infrastructure locations and conditions

In addition, the FEMA flood maps were obtained, and the storms of interest to eventually achieve class 4 in CRS were identified for screening purposes (1-day, 10-year; 3-day, 25-year; and 1-day, 100-year storm event). Table 3 is a summary of datasets available at cwr3.fau.edu that were used to construct this plan.

Table 3. List of datasets collected by FAU for the project (07/20/2020)

Data Category	Dataset Name	Original Source	Spatial Coverage/ Resolution	Temporal Coverage/ Resolution	Link to the Dataset on our Server (physical location)	Dataset size and Format	Native or FAU Processed dataset
Topography	USGS_NED	USGS	Part of Florida, raster image in 1 m	Created by USGS in 2016	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\LiDAR_DEM\DEM_1m	3.28 GB, raster images	Native
	USGS_NED	USGS	Part of Florida, raster image in 3 m	Created by USGS	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\LiDAR_DEM\DEM_3m	40.9 GB, raster images	Native
	USGS_DEM	USGS	Florida, Raster data in 10 m	Created by USGS	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\USGS_DEM	22.6 GB, raster images	Native
	DEM_3m_merged	USGS	3 m in tif		\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\LiDAR_DEM\DEM_3m_merged	186 GB, raster images	FAU Processed
	SRTM_30m	NASA	30 m Raster		\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\LiDAR_DEM\SRTM_30m_UCF_Chang	607 MB, raster images	Native
Groundwater	FL_GW	South Florida Water Management District	Florida, Excel	Daily, 1980-2020	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_GW\South Florida District	140 MB, excel	Native
	FL_GW	Southwest FL Water Management District	Florida, Geodatabase	Daily, 1980-2020	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_GW\SWFWMD_GeoDatabase	27.9 GB, Geodatabase	Native
Surface Water and Tides	FL_SW	Southwest Florida Water Management District	Southwest of Florida, site observations	Daily, since 2000	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_SW\	74.5 MB, in excel and dbf	Native

Data Category	Dataset Name	Original Source	Spatial Coverage/ Resolution	Temporal Coverage/ Resolution	Link to the Dataset on our Server (physical location)	Dataset size and Format	Native or FAU Processed dataset
Soil	FL_Soil	FY2019 USDA Soil SSURGO gSSURGO) Database https://sdmdataaccess.nrcs.usda.gov/	Florida, Raster data is in 10 m	Released by USDA in 2019	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_soil Processed data for water holding capacity ratio is at: \\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_soil\aws0_150_whc1.tif	107 GB, both vector and raster	FAU Processed
Land Cover	USGS_LC	USGS	Conterminous United States, raster format, 30 m derived from satellite	Created by USGS in 2016 (Most recent)	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\USGS_LC\NLCD_2016_Land_Cover_L48_20190424	20 GB, raster	Native
	Impervious Surface	USGS	Florida, 30 m derived from satellite	Created by USGS in 2016 (Most recent)	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\Impervious\NLCD_2016_Impervious_descriptor_L48_20190405\	24.6 GB, raster Image	FAU Processed
	Open Space	USGS	Florida, 30 m derived from satellite	Created by USGS in 2016 (Most recent)	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_LCLU\NLCD2016_OpenSpace\	21 GB, raster	FAU Processed
Precipitation Records	FL_NOAA14_Precipitation	NOAA Atlas 14 Database	Florida, raster in 800 m	Most recent release from NOAA	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_NOAA14_Precipitation\se25y3d_inch.tif	34 MB, raster images	FAU Processed

2.1 Surface Topography

Topography is a key parameter that influences many of the processes involved in flood risk assessment, and thus, up-to-date, high-resolution, high-accuracy elevation data is necessary. In order to meet the requirements for FEMA Risk Mapping, Assessment, and Planning (RiskMAP), 1-meter (2015 to present) and 1/9 arc-second (~ 3-meter) (2010 -2015) LiDAR digital elevation models (DEMs) were acquired. The 3 m × 3 m LiDAR tiles were kriged to create a topographic map of the study area (Figure 27). This accuracy meets the 3DEP Quality Level 2 vertical root mean square error accuracy threshold of ±10 cm for FEMA (Arundel et al., 2015). The LiDAR used for this study area was flown in 2016.

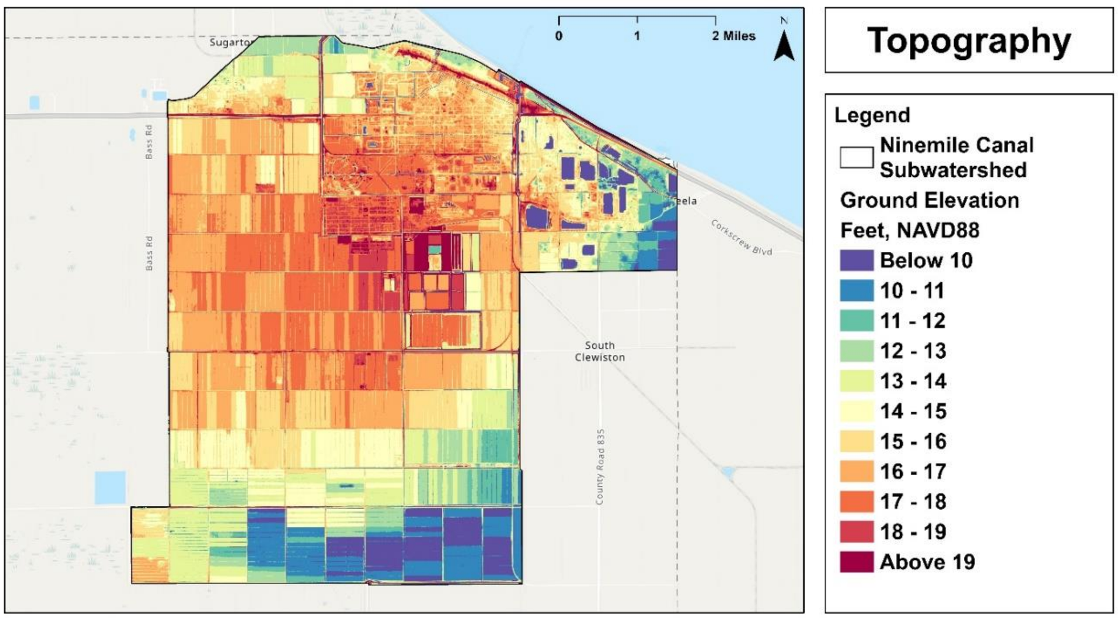

Figure 27. Topographic map of the Caloosahatchee East/Clewiston subwatershed processed by FAU (2016 flight).

2.2 Groundwater

The entire South Florida plain is underlain by beds of porous limestone that absorb water standing on the land surface during the wet season (mostly in the Everglades). These limestone formations contain large volumes of fresh water. A geologic profile of South Florida has been developed based on drilling data from USGS (Figure 28). The uppermost formation generally encountered along the southwest Florida coast is a series of Pleistocene Age deposits that occur throughout most of southern Florida and consists predominantly of fine to medium-grained quartz sand, with varying amounts of shell, detrital clays, and organic constituents (Meyer, 1989). These subsurface layers are termed the surficial aquifer system (SAS) and form the water supply for most potable and irrigation users. Thickness of sand layers are variable in the area, but average approximately 40 feet. Under the surficial sand lies a series of fossiliferous, sandy limestones, which are part of the Anastasia or Fort Thompson formations (Meyer, 1989). The SAS and its associated wetlands depend on rainfall for aquifer recharge. During dry conditions, recharge diminishes, drainage persists, and water demands increase, compounding stress on the SAS and wetland systems. The water table and Tamiami formations are the major sources of water supply in the basin, and throughout southwest Florida (SFWMD, 2009)

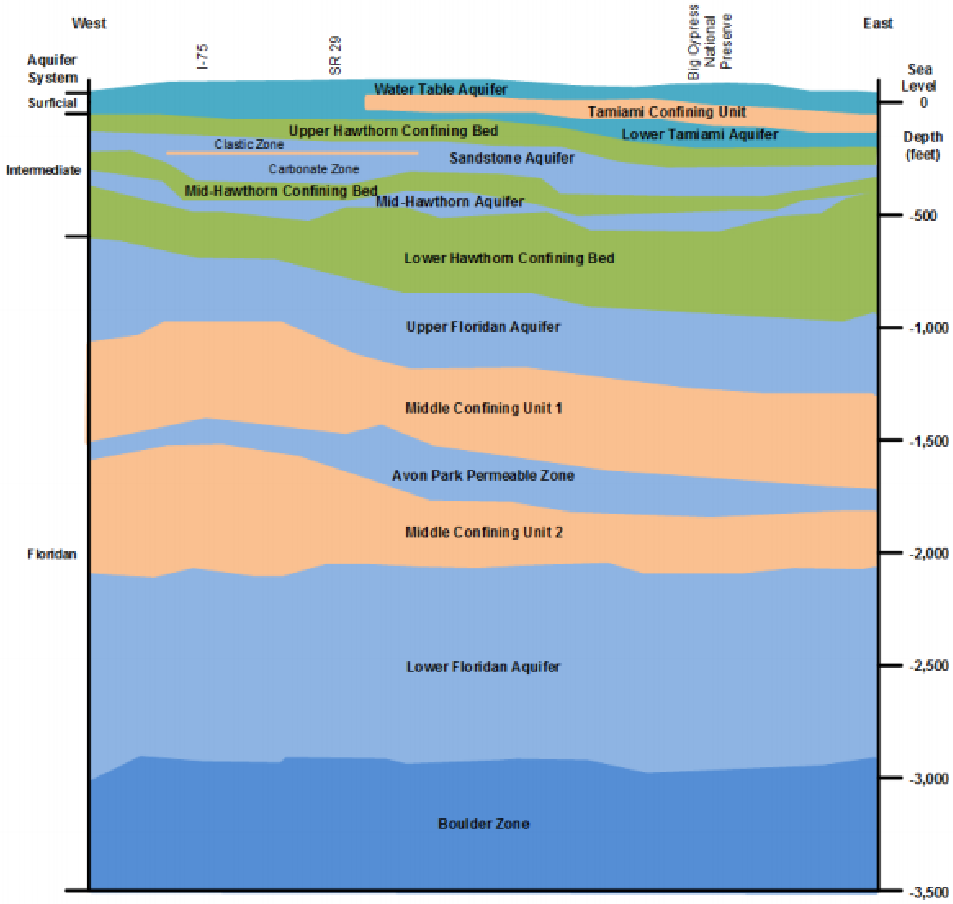

Figure 28. Hydrogeological profile across South Florida from the Big Cypress (west of Lake Okeechobee) to the Gulf of Mexico, from land surface down 3500 feet (Meyer, 1989).

Below the SAS is the intermediate aquifer system (IAS). Past and present analyses of the SAS and IAS indicate that they are a limited water resource in many areas. Typically, the IAS is recharged by seepage from above or laterally. The IAS is also limited, as it has become the major potable supply source for the region. The southern Florida coastal condition is characterized by direct interaction between groundwater and surface water. The land has relatively flat terrain (refer to Figure 27 in Section 2.1). The typical water table elevation ranges from 0 to 6 ft bls (discussed in Section 2.4, refer to Figure 36).

For situations in which groundwater is under the influence of surface water, it is necessary to collect groundwater table elevation data to calculate soil storage capacity. Since well density varies considerably, interpolation of data was required to create a groundwater surface developed using groundwater data from 2005 to 2018. To establish a common date for the 99th percentile modeling purposes, the recorded groundwater table elevations were sorted in ascending order to determine the 98th -100th percentile date of occurrence in Excel®, following the manual procedure detailed in

Romah (2011). In this study, the manual procedure was automated using a python code to process the groundwater data more efficiently. Outliers and anomalous groundwater levels in the database are initially identified (e.g. catastrophic storm events) and replaced by region-specific mean values based on observations available from the nearest wells. Missing date-specific data are estimated using simple temporal interpolation based on observations available in time. If a station (or monitoring well) data contains missing data, it was not used. As a result, surficial wells were noted across the area (refer to Figure 31), and in conjunction with the surface water stations, were used to develop a groundwater surface layer for the basin following the multiple linear regression (MLR) protocol described in Zhang et al. (2020) (Figure 29).

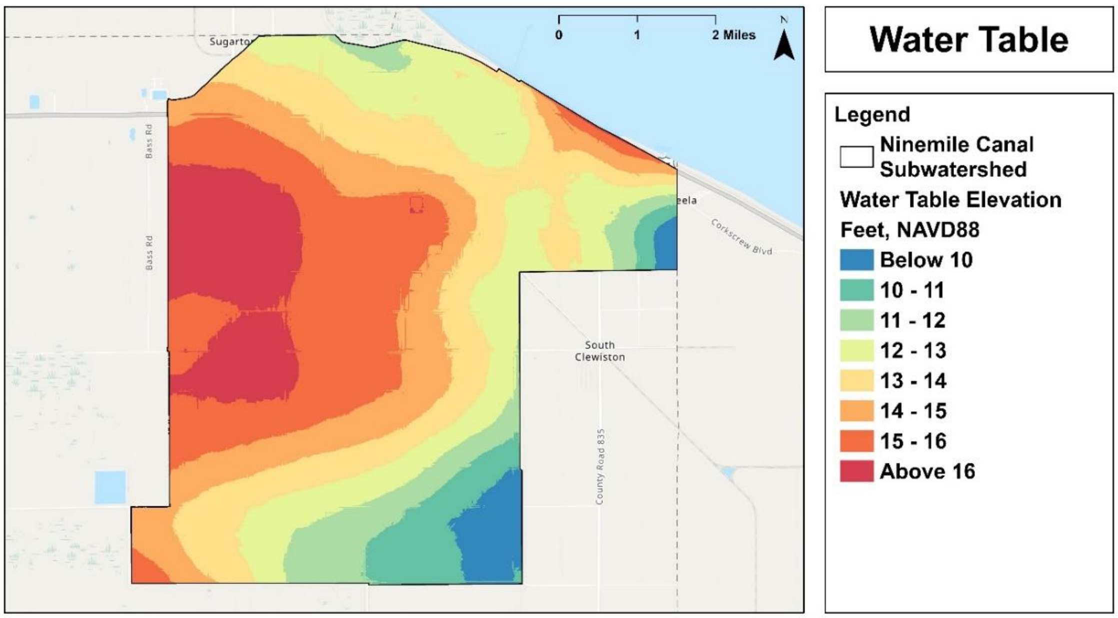

Figure 29. Elevation of the top of the surficial groundwater layer for the Caloosahatchee East/Clewiston subwatershed created by multiple linear regression analysis – elevation NAVD88, as processed by FAU

2.3 Surface Water/Tides

Historically, surface water and tides have been an important factor in determining how much freshwater is delivered, how fast this water enters wetlands and estuaries, and the quality of that water. Evapotranspiration and rainfall do not coincide (Figure 30), which makes water supply planning difficult (Bloetscher, 1995).

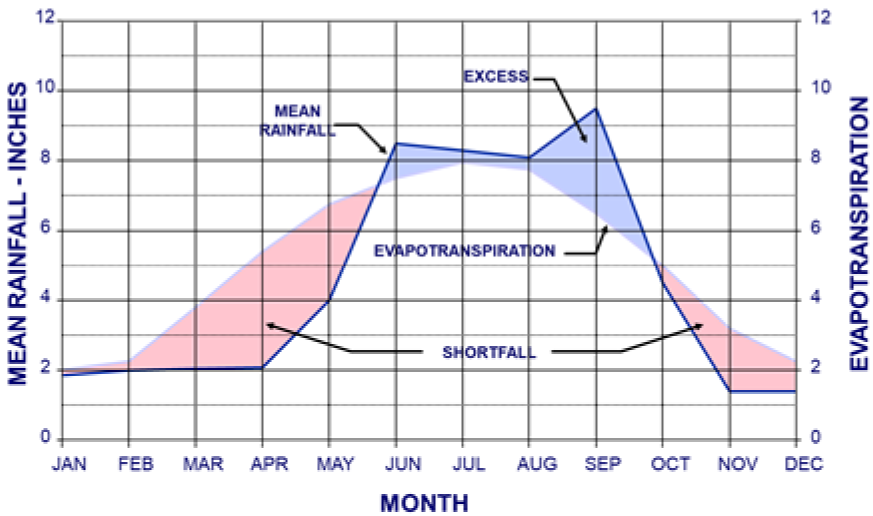

Figure 30. Comparison of rainfall and evapotranspiration for Southwest Florida (Bloetscher, 1995)

While the topography (Section 2.1) and native soil (discussed later in Section 2.4) create an environment that is highly permeable and capable of infiltrating significant percolation into the soil, changes in land use and land cover (refer to Section 2.5) have resulted in water falling on impervious areas, where the water collects in pools or runs off rapidly, in direct contrast to the natural condition. This runoff flowing over impermeable regions can lead to larger scale flooding.

In this region of Florida, there is a direct interaction between groundwater and surface water. In addition to low land elevations and topographic relief, the groundwater and surface water are controlled by the canals and rivers. Since there is a limited number of groundwater monitoring stations (Figure 31), the strong relationship between groundwater and surface water was leveraged to develop a 99th-percentile surface of the water table elevation for mapping purposes. To establish a common date for modeling, the recorded groundwater table elevations were sorted in ascending order to determine the 98th -100th percentile date of occurrence in Excel®, following the procedure detailed in Romah (2011), which was automated for this effort using a python code to process the groundwater data more efficiently as described in Zhang et al. (2020). Outliers and anomalous groundwater levels in the database are initially identified (e.g. catastrophic storm events) and replaced by region-specific mean values based on observations available from the nearest well. Missing date-specific data are estimated using simple temporal interpolation based on observations available in time. If a station (or monitoring well) data contains large amounts of missing data, it was not used in the generation of the groundwater surface. Many stations are located along canals and rivers, which assists in determining the water levels across open and connected surface waterbodies. As shown on the map in Figure 31, there are a total of 95 stations with observations available in the greater Caloosahatchee watershed. Sixteen were groundwater stations, mostly within and to the south of the watershed. This is because the watershed is primarily agricultural. Surface water stations are more extensive (n = 79) including nearly a dozen in Lake Okeechobee, which is a major driver of groundwater levels. All daily mean surface water level observations for the common date in this study (09/27/2013) were gathered from monitoring stations in the SFWMD DBHYDRO database.

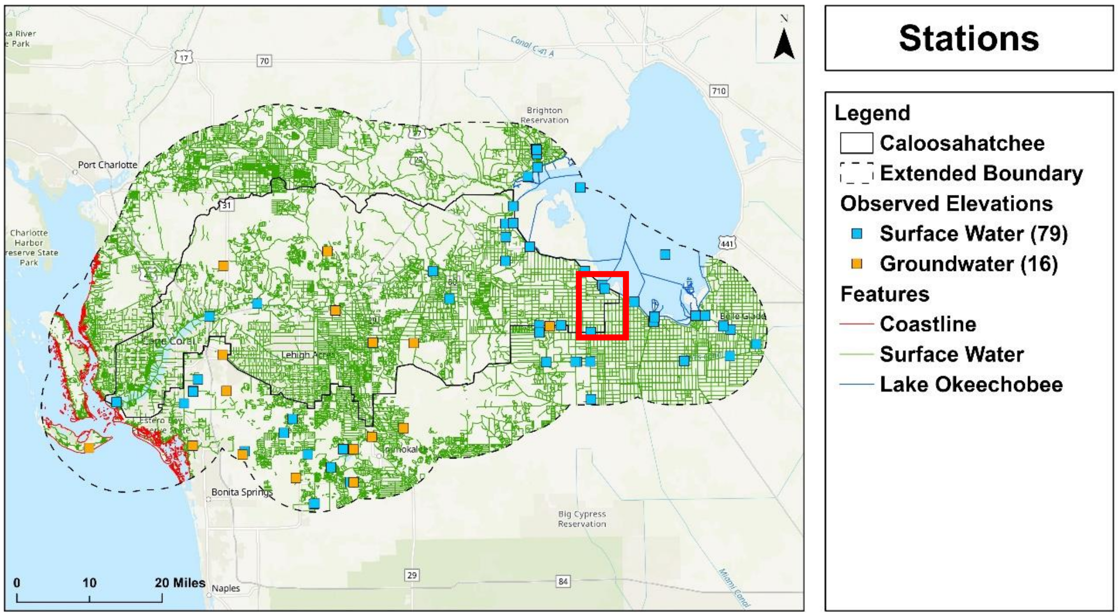

Figure 31. Control and surface water stations maintained in the greater Caloosahatchee watershed, as processed by FAU

2.4 Soils

Soil can store water if there is adequate distance between the topographic surface and the groundwater, and the soil types are capable of infiltrating the water. Soil storage capacity is the volume of soil pores in the unsaturated zone that is available to store stormwater (Gregory et al., 1998). Throughout Florida, it is common to have large volume storm events that fill the voids in the unsaturated zone as shown in Figure 32.

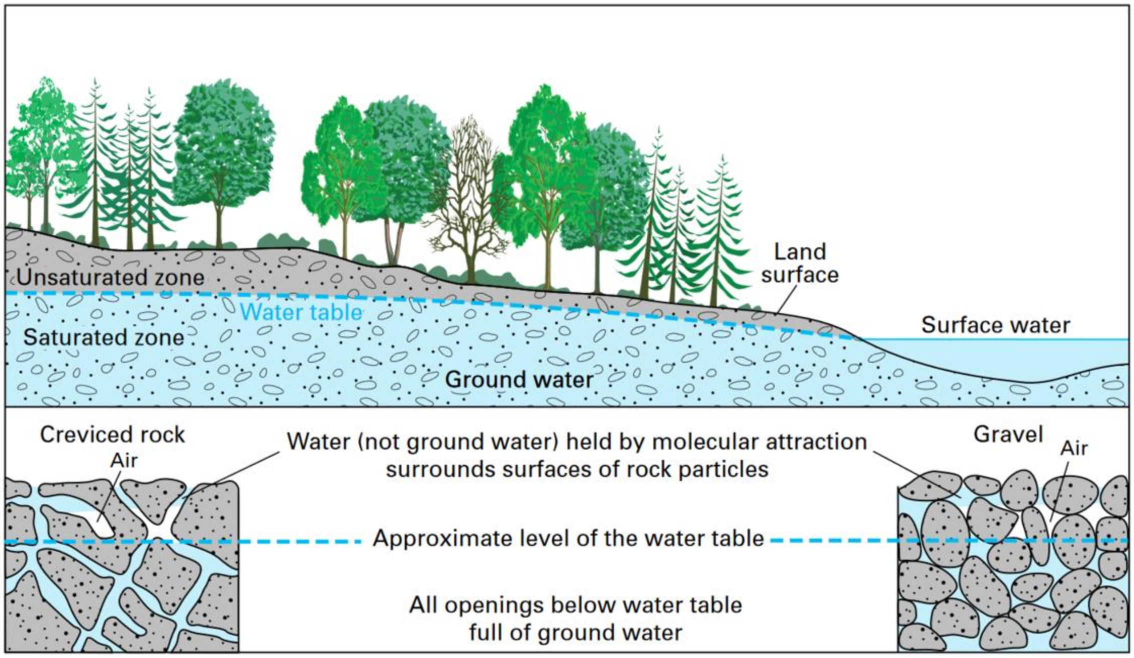

Figure 32. Description of zones where underground water exists (USGS, 2020)

The unsaturated zone is the portion of the subsurface above the water table that contains soil/rock and air and water in its pores as shown in Figure 33. This zone affects the rate at which the aquifer gets recharged by controlling water movement from the surface of the land downward towards the aquifer. During rain events, the soil voids fill up quickly resulting in the water table rising to the surface, and the surplus rainfall becomes runoff.

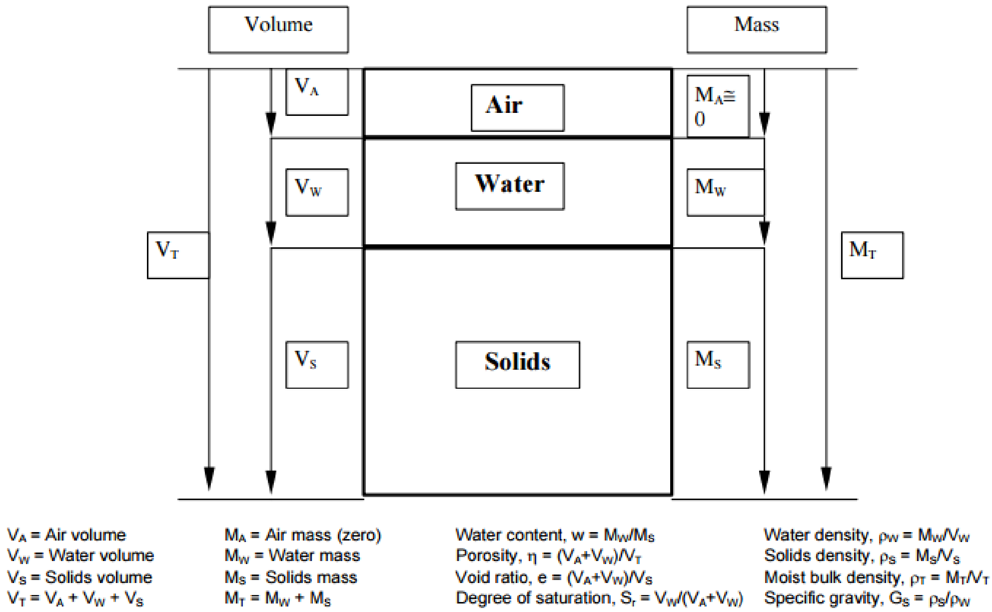

Figure 33. Saturated zone soil phase diagram and definitions (Gregory et al., 1998)

Soil data is available from the United States Department of Agriculture (USDA) or other agencies in the form of maps that can be incorporated as a GIS layer. The Gridded SSURGO (gSSURGO) dataset from USDA is chosen. This dataset is similar to the standard product from USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database, but is in the Environmental Systems Research Institute, Inc. (ESRI®) file geodatabase format. A file geodatabase allows for statewide or even Conterminous United States (CONUS) tiling of data. The gSSURGO dataset contains all of the original soil attribute tables in SSURGO. All spatial data are stored within the geodatabase instead of externally as separate shape files. Both SSURGO and gSSURGO are considered products of the National Cooperative Soil Survey (NCSS).

The statewide available water storage from USDA derived for the soil layer (0-150 cm or 0-6 ft) is shown in Figure 34, which covers most of Florida with a spatial resolution of 10 m. The unit is in cm.

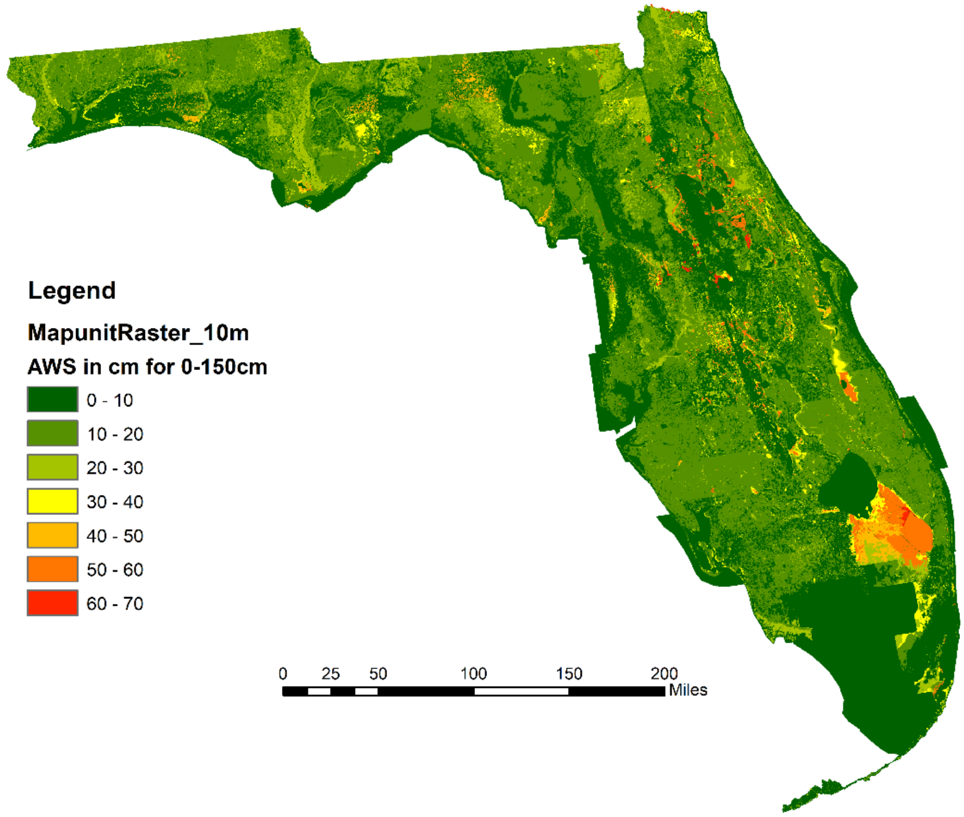

Figure 34. Available water storage derived from the gSSURGO soil database for all of Florida, as processed by FAU

Water holding capacity refers to the amount of water held between field capacity and the wilting point. Available water storage (AWS) is that portion of the water holding capacity that can be absorbed by a plant. As a rule, plant available water is considered to be 50% of the water holding capacity. The water holding capacity (ratio) is calculated using the following equation:

$$\textit{Water holding capacity} = 2 \times (\textit{AWS for a soil layer of 0-150 cm}) / 150 \textit{ cm}$$

To find the unsaturated zone, the groundwater layer as influenced by the surficial canals is subtracted from the topographic layer in GIS to create an apparent unsaturated zone depth layer. The unsaturated zone depth layer is then multiplied by the water holding capacity ratio layer (Figure 35) to create the soil storage capacity layer (refer to Figure 36 and also to Section 4.2.1), which gives the actual amount of water that can enter the soil before filling it. Much of the greater Caloosahatchee watershed including the study area has very limited soil storage capacity.

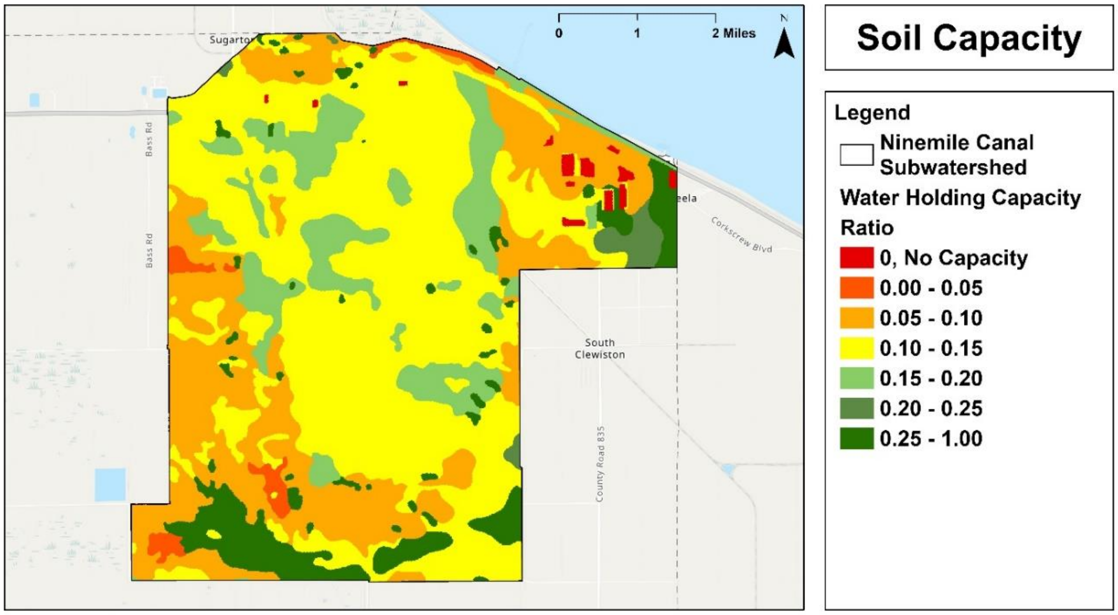

Figure 35. Water holding capacity ratio of soil for the Caloosahatchee East/Clewiston subwatershed, as processed by FAU

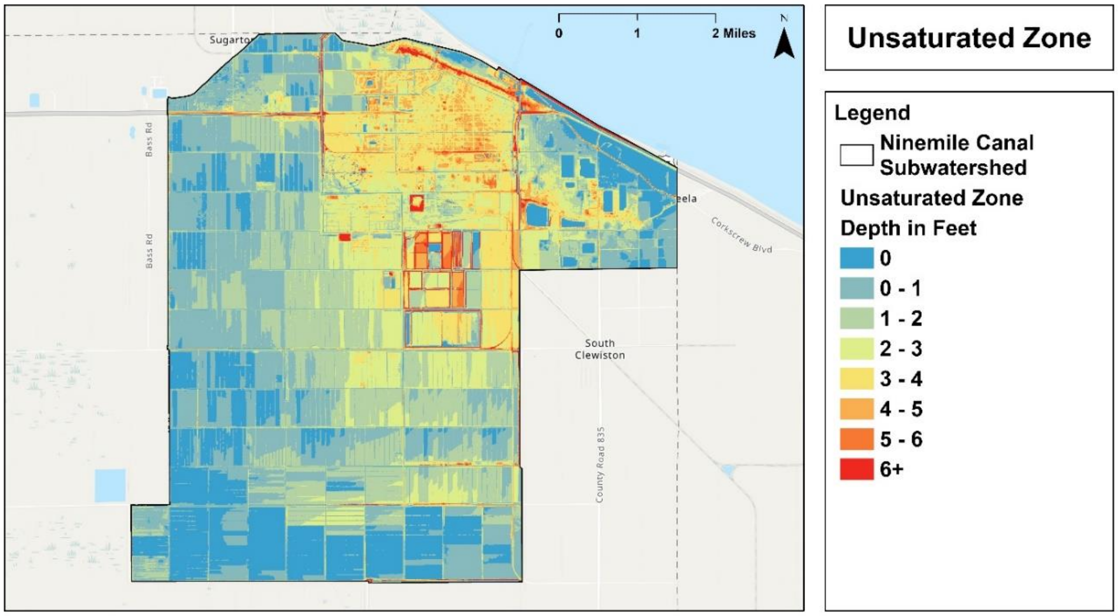

Figure 36. Unsaturated zone map for Caloosahatchee East/Clewiston subwatershed, as processed by FAU

2.5 Land Cover

The USGS produces the NLCD of nationwide data on land cover at a 30-m resolution with a 16-class legend based on a modified Anderson Level II classification system. NLCD is coordinated through the 10-member Multi-Resolution Land Characteristics Consortium (MRLC) to provide digital land cover information nationwide. For the conterminous United States, NLCD 2016 contains 28 different land cover products characterizing land cover and land cover change across 7 epochs from 2001-2016, urban imperviousness and urban imperviousness change across 4 epochs from 2001-2016, tree canopy and tree canopy change across 2 epochs from 2011-2016 and western U.S. shrub and grassland areas for 2016. Note that NLCD has a standardized color scheme convention:

https://www.mrlc.gov/data/legends/national-land-cover-database-2016-nlcd2016-legend

This color scheme was followed exactly for the NLCD2016 land cover maps presented in this document. Note that since there is no “12 Perennial Ice/Snow” in the area, such that there are only 15 classes shown on the legend. The NLCD2016 only has a 30-meter resolution derived from Landsat imagery.

A more accurate current land use dataset is derived from the Florida Land Use Cover Classification System (FLUCCS), which is digitized by photo-interpretation on county-based aerial photography with varying resolution in the range of 4 inches to 24 inches pixel (hence, the NLCD maps appear much coarser and pixelated in comparison). The land cover/land use map for the study area used the FLUCCS dataset. A close-up comparison of these current land use maps is provided in Figure 37. Based on the 2014-2016 Florida Land Use Cover Classification System (FLUCCS) Level 1 land use, the top ranked land uses are agriculture (72.1%) and urban and built up (19.8%) with all other land use categories representing less than 2.0%, as shown in and summarized in Figure 38. The FLUCCS mapping has higher resolution but is less aerially extensive.

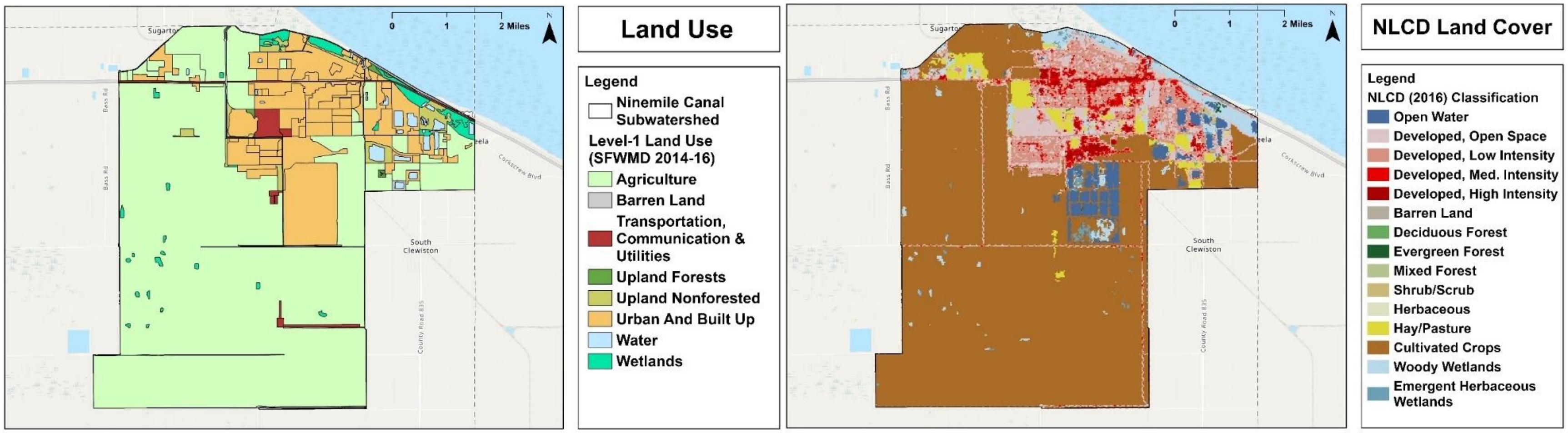

Figure 37. Current land cover maps derived by FLUCCS (left) and NLCD2016 (right).

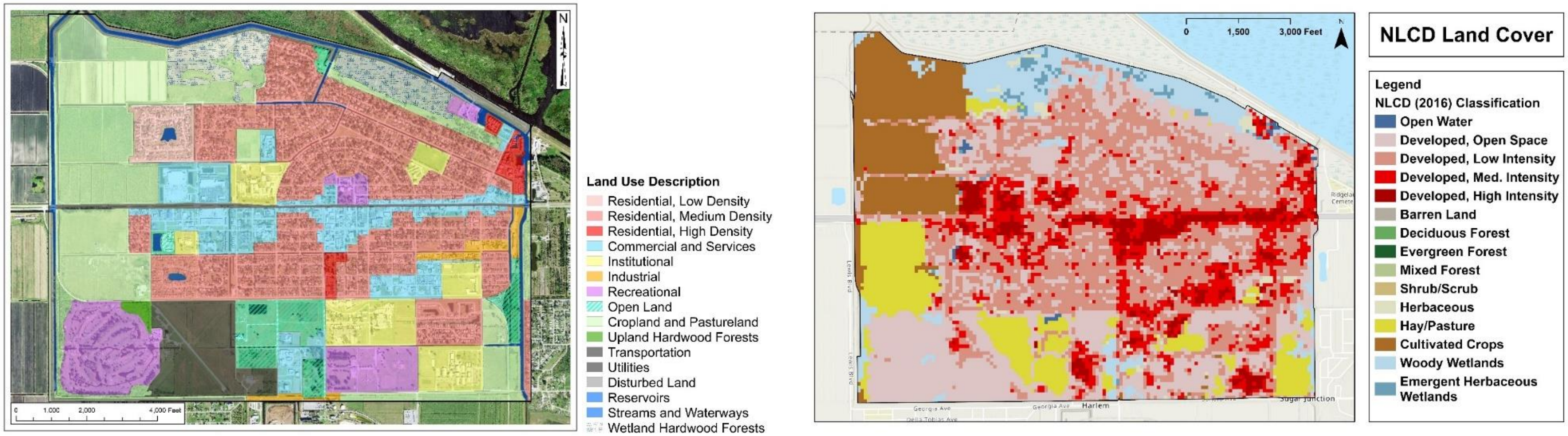

Figure 38. Closeup view of the Clewiston portion of the subwatershed current land cover/land use map developed from 2014-2016 FLUCCS (left) and NLCD2016 (right), as processed by FAU for use in addressing tiered risk

LaRue Planning Consultants prepared a future land use map for the City as shown in Figure 39 with a different set of color codes compared to the current maps.

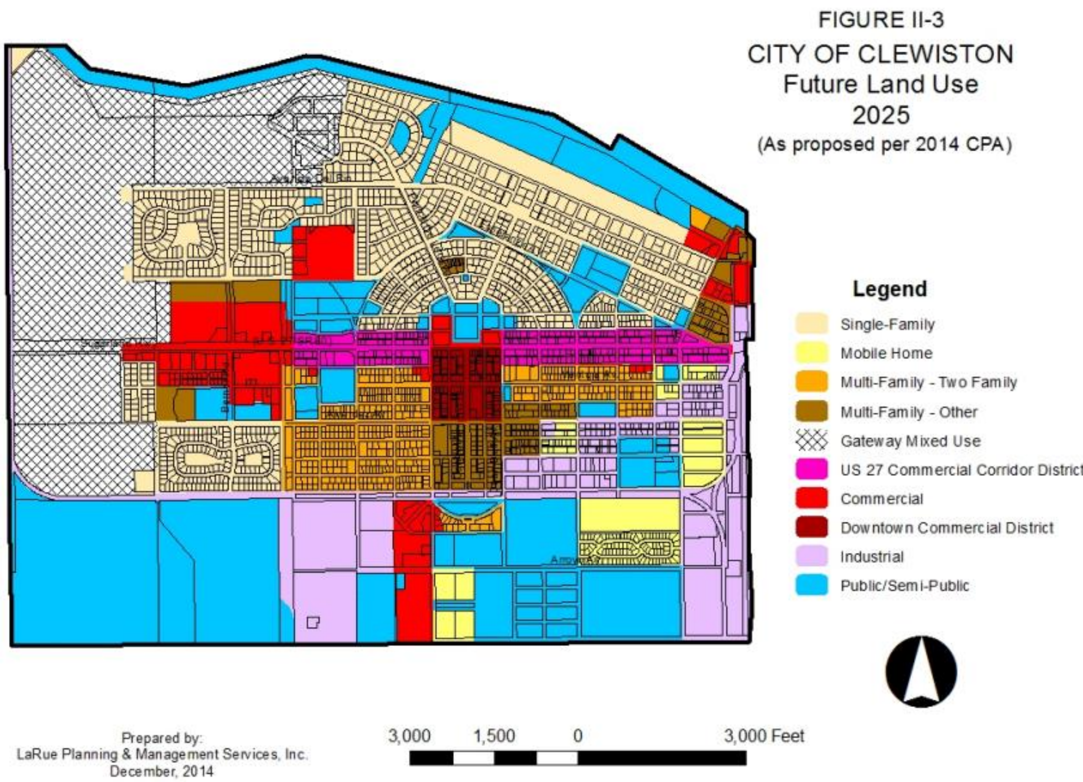

Figure 39. Future land use map for the City of Clewiston (LaRue Planning for the City of Clewiston)

The future land use map for the study area (Figure 40) was created by superimposing the City of Clewiston's future land use map on the Hendry County map (note that the different jurisdictions have different land use codes). Most of the County area remains agricultural in the future projected land use map. Note that development is anticipated to be renovations of existing structures (rather than new construction) in the currently developed areas, which will meet the County ordinance specifying the 1-day, 100-year flood elevation and water retainage, as opposed to older construction prior to 1980, which does not. All new development and renovated areas will have to meet the County ordinance specifying the 1-day, 100-year flood elevation (refer to Section 3.1.4). The result is that future development is likely to improve the current situation.

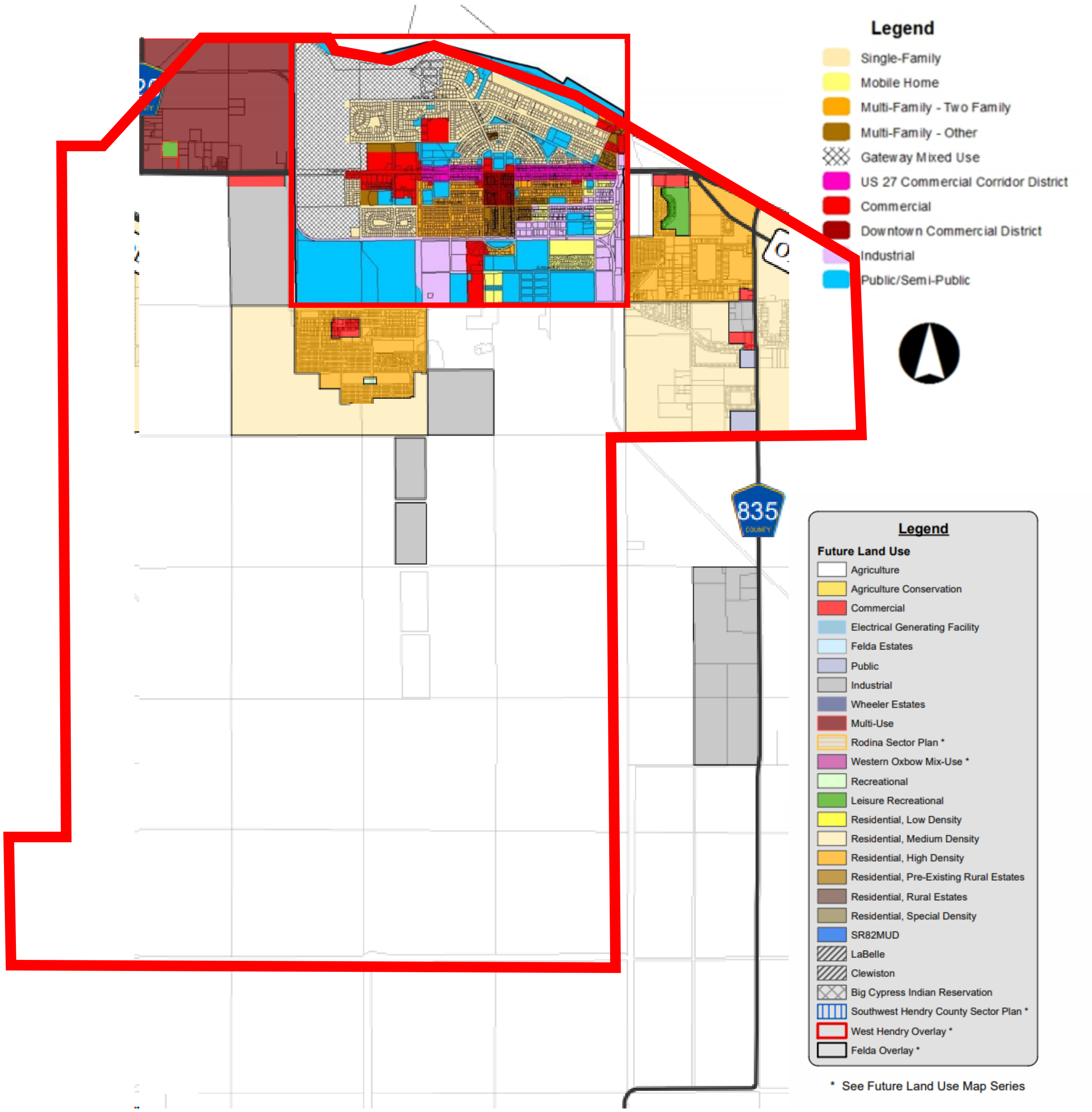

Figure 40. Future land use map – note City is superimposed on the County map. The City legend is on top of the County legend.

Table 4. Summary of current versus future land use/land cover in the study area using the modified level-1 FLUCCS dataset (left) and the NLCD2016 land cover dataset modified to match the FLUCCS categories (right)

Modified Level-1 FLUCCS	**Current Area (sq mi)**	**Percent**	**Modified NLCD2016 Land Cover**	**Current Area (sq mi)**	**Percent**	**Future Area**	**Percent**
Agriculture	24.81	72.10%	Cultivated Crops and Hay/Pasture	24.37	73.60%	19.87	57.70%
Barren Land	0.29	0.80%	Barren Land	0	0.00%	0	0.00%
Transportation, Communication and Utilities	0.54	1.60%	Transportation, Communication and Utilities	0.54	1.60%	0.54	1.60%
Upland Forests	0.06	0.20%	Upland Forests	0.02	0.10%	0.02	0.10%
Upland Non-forested	0.56	1.60%	Upland Non-forested	0.48	1.40%	0.48	1.40%
Urban and Built Up	6.81	19.80%	Developed (open space, low, medium, high density)	6.4	18.70%	10.9	31.70%
Water	0.68	2.00%	Open Water	1.1	3.10%	1.1	3.10%
Wetlands	0.67	1.90%	Wetlands	1.4	4.00%	1.4	4.00%
Total	**34.41**	**100.00%**	**Total**	**34.41**	**100.00%**	**34.41**	**100.00%**

2.6 Precipitation

Rainfall used in the screening tool is initially based on the SFWMD 3-day, 25-year storm, but was modified for other rainfall events using the accumulated rainfall table obtained from NOAA Atlas 14 Point Precipitation Frequency Estimates (https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html). In this study, all storm events described in Section 3.2 were analyzed. Figure 41 shows the 3-day, 25-year rainfall map based on the NOAA Atlas 14 dataset zoomed in to 883-m resolution.

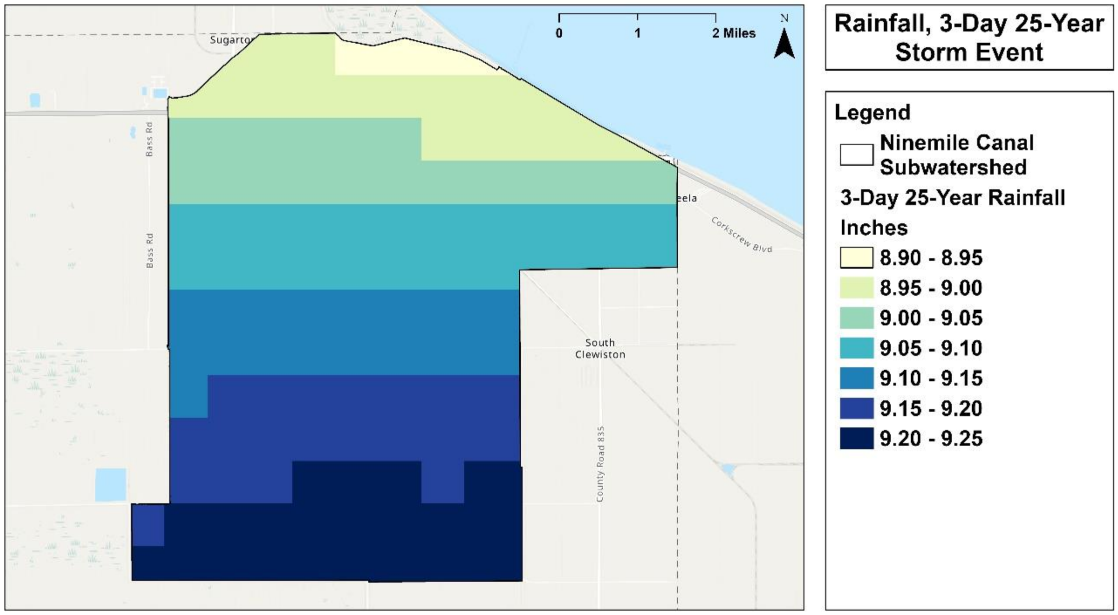

Figure 41. Rainfall distribution across the basin for 3-day, 25-year storm, as processed by FAU

Figure 42 shows the variation by month as measured in the community of Clewiston using the average monthly rainfall from 2010-2020 as reported in the SFWMD data clearinghouse DBHYDRO for the Clewiston station from 01/01/2010 to 03/21/2021. Rainfall is higher in the summer.

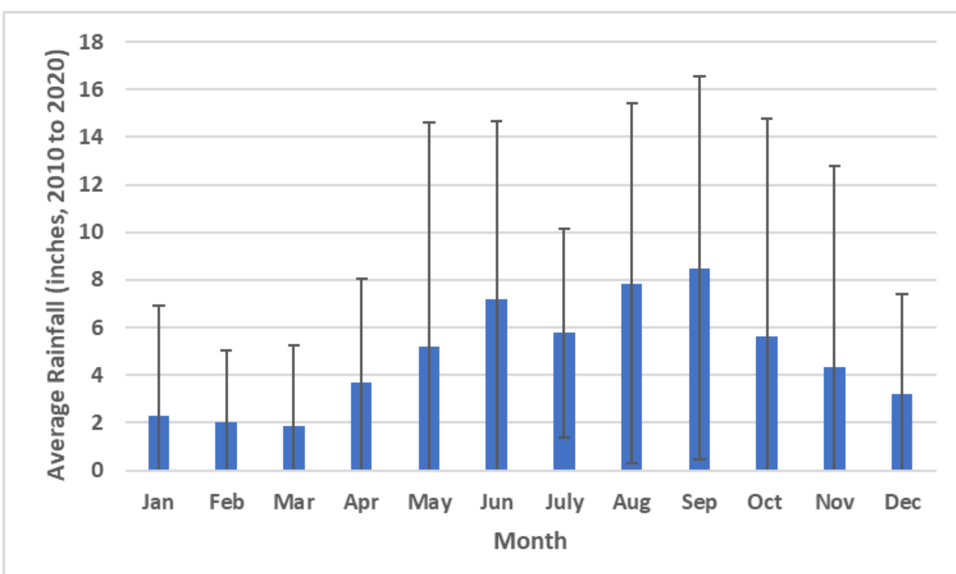

Figure 42. Historical variation (01/2010-03/2021) of monthly rainfall for Clewiston, FL as reported by SFWMD (DBHYDRO, 2021)

2.7 Open Space

Open space is defined as areas that are exempted from development. Generally this means one or more of the following qualifiers exist:

1. Land that is valuable for recreation, forestry, fishing, or conservation of wildlife or natural resources
2. Land that is a prime natural feature of the state's landscape, such as a shoreline or ridgeline
3. Land that is habitat for native plant or animal species listed as threatened, endangered, or of special concern
4. Land that is a relatively undisturbed example of an uncommon native ecological community
5. Land that is important for enhancing and conserving the water quality of lakes, rivers, and coastal water
6. Land that is valuable for preserving local agricultural heritage
7. Proximity to urban areas or areas with open space deficiencies and underserved populations
8. Vulnerability of land to development
9. Stewardship needs and management constraints
10. Preservation of forest land and waterbodies that naturally absorb significant amounts of carbon dioxide

Permanent protection of sensitive areas can provide critical areas to store excess water after storms, thereby serving the dual benefit of nutrient reduction and storage. There is land throughout the Caloosahatchee East/Clewiston subwatershed that has been protected via acquisition by federal, state, or local agencies already, and contains conservation easements and areas designated as wetlands or areas of critical concern. These are primarily shown on the conservation maps noted in Section 1.1.4. Agricultural land and other land cover are shown in the land cover maps in Section 2.5. As shown in Figure 43, toward the central eastern section of the study area south of the City, there are irrigation storage ponds affiliated with the sugar industry. Within the City of Clewiston, there are large open space areas, namely the Clewiston Golf Course in the southwest corner and Sugarland Park in the southeastern zone to the west of the Clewiston High School. Also along the northeast corner of the city, there are large tracts of agricultural and undeveloped property. Added to this are the waterbodies discussed in Section 1.1 and Section 2.9, which serve a related function to open space. Hendry County has regulations under Code of Ordinances Sec. 1-55-2. – Development review criteria for environmentally sensitive lands. This is discussed in Section 3.1.

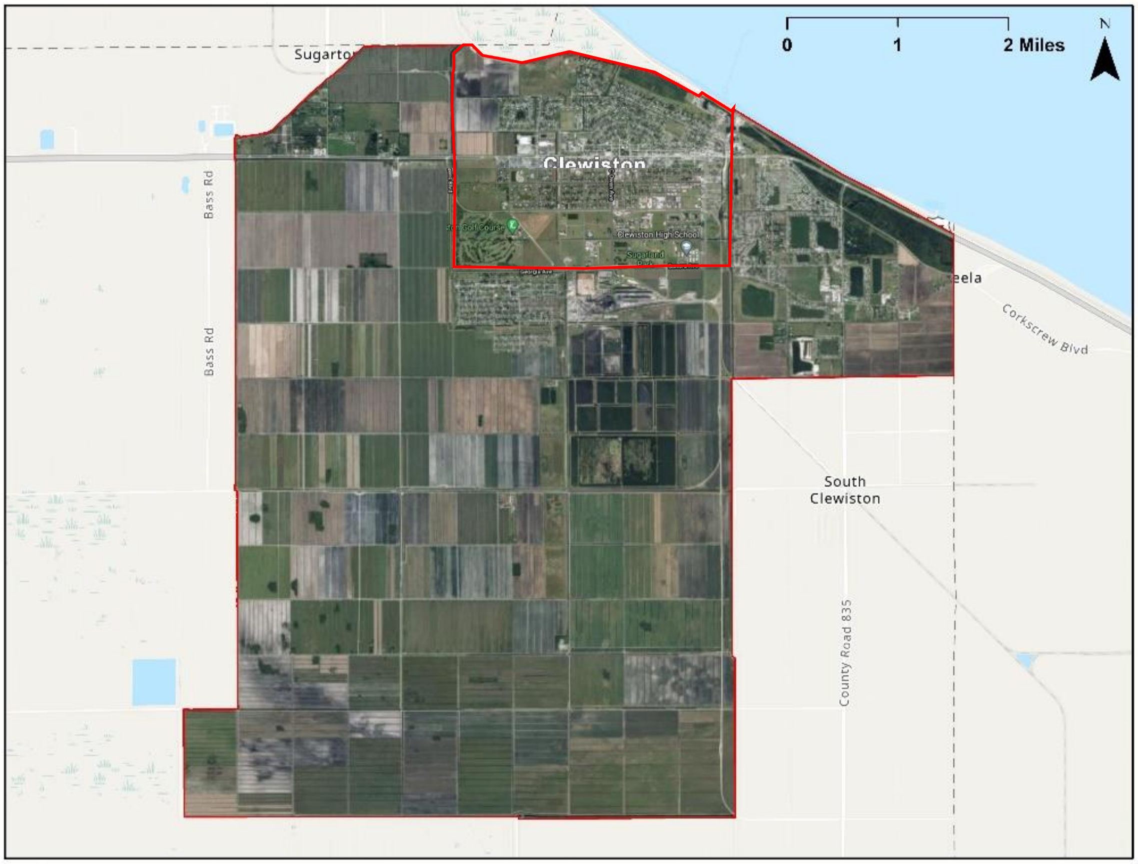

Figure 43. Location of areas of open space in the study area.

2.8 Impervious Areas

Impervious areas do not permit the infiltration of rainfall to groundwater, and because the water cannot infiltrate, it runs off faster. Faster runoff means that flows to waterbodies and storm sewers occur faster and with higher peaks. The result is a potential disruption of the natural and planned hydrology. Impervious areas include pavement, buildings, and other areas that reduce runoff capacity. In other words, developed areas have much higher imperviousness than open spaces that are natural or agricultural.

The NLCD2016 provides nationwide data on land cover and land cover change at a 30-m resolution to help understand both current and historical land cover and land cover change to enable assessment of trends. Using the NLCD2016 dataset, a layer was created by using only three categories (namely, primary roads in urban areas, secondary roads in urban areas, and tertiary roads in urban areas) out of the 13 to identify impervious areas. The new layer was then converted to match the 3-meter spatial resolution from the DEM and the standard State Plane Coordinate system. Figure 44 shows the impervious areas.

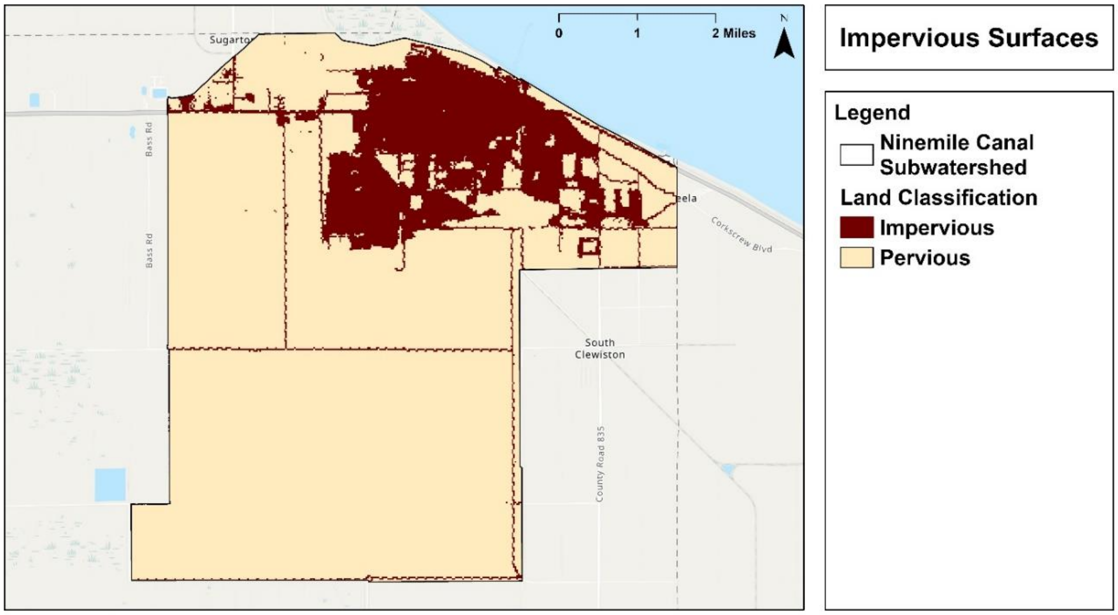

Figure 44. Impervious area map for the Caloosahatchee East/Clewiston subwatershed, as processed by FAU

2.9 Waterbodies

Since much of the property in the study area is agricultural land or wetlands, waterbodies were defined in the statewide land use land cover dataset to set soil water holding capacity to zero in model simulations (Figure 45). Note that tiny waterbodies may be missing from the maps. Lake Okeechobee and the Hoover Dike are adjacent to the subwatershed but are not actually part of it since Lake Okeechobee is technically in a separate watershed. Soils were discussed previously in Section 2.4.

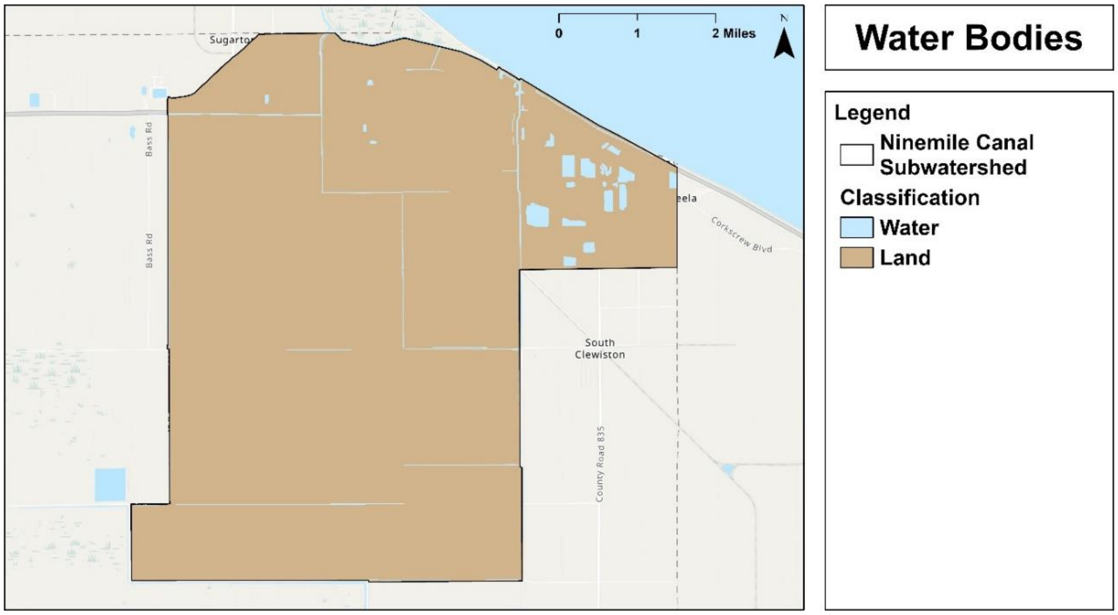

Figure 45. Waterbodies map for the Caloosahatchee East/Clewiston subwatershed, as processed by FAU

2.10. Natural Resources

Understanding the study area's natural resources is critical to identifying potential sources of water quality degradation and areas to designate for conservation, protection, and restoration. USGS maintains important sources of information on physical and geographical features as well as soil and mineral resources, surface and ground water resources, topographic maps, and water quality monitoring data. The USDA's Natural Resources Inventory (NRI) (www.nrcs.usda.gov/technical/NRI) is a survey of information on natural resources on non-federal land in the United States that captures data on land cover and land use, soil erosion, prime farmland soils, wetlands, habitat diversity, erosion, conservation practices, and related items. Since 2001, the NRI has been updated continually with annual releases of NRI data from all 50 states. The information provided can be used for addressing agricultural and environmental issues down to the county or cataloging unit level. Therefore, this data can be used to determine erosion and site-specific soil characteristics for certain land uses such as croplands, pasturelands, forestlands, etc., but the data is typically provided as inventories, not GIS layers. Much of this information is primarily covered in Section 1.1 and earlier parts of this chapter and is not repeated here.

2.11 Demographics

Demographics data is important for determining several key indicators for watershed master planning such as the ability to pay for improvements, social justice issues, land acquisition costs, property/land use, and communication strategies. The US Census has databases at the census tract level. Based on the census data for the study area, Table 5 outlines population and racial composition demographics.

Table 5. Demographics and housing characteristics of the study area (US Census 2010)

Demographic Parameter	**Study Area**
Area (square miles)	34.4
Population	14,499
Number of Households	4,605
Median Annual Household Income	$35,487
Median Age	33.9
Male	53.9%
Female	46.1%
White	68.4%
Black, African American	25.0%
Asian	1.8%
Other Race	3.6%
Two or More Races	1.2%
Hispanic or Latino (Regardless of Race)	46.0%

2.12 Stormwater Infrastructure Inventory

When most of the existing stormwater system was built, it was originally designed to handle the amount of water expected during a 1-day, 10-year storm, the FDOT standard. Larger storms can flood roadways, but that does not mean that buildings flood. As a result, these older man-made systems often do not have the capacity to keep roadways drained or handle heavy rains or intense storms. The key to modeling critical design storms in this WMP is to determine where property is at risk (See Section 4.4 for modeling results at different scenarios).

SFWMD and USACE infrastructure exerts the largest impact at the greater watershed level. Key stormwater assets that impact the Caloosahatchee East/Clewiston subwatershed are shown in Figure 46 and include the following:

- Franklin Locks and Dam (S79)
- Ortona Locks and Dam (S78)
- Moore Haven Lock and Dam (S77)
- S235
- S234
- S 47 B and D
- C1, 1A , 2 and 3
- G134, 136, 96, 150 and Montura stations
- S 130 and 169

The facilities control inflow of water from Lake Okeechobee and into the Caloosahatchee. Only one structure (G136 for control of water to the south and STA5) actually influences the study area – the rest (C2 for seepage control, S130, and S169) address water supply for crop irrigation. The City has no stormwater pumping stations and limited piping.

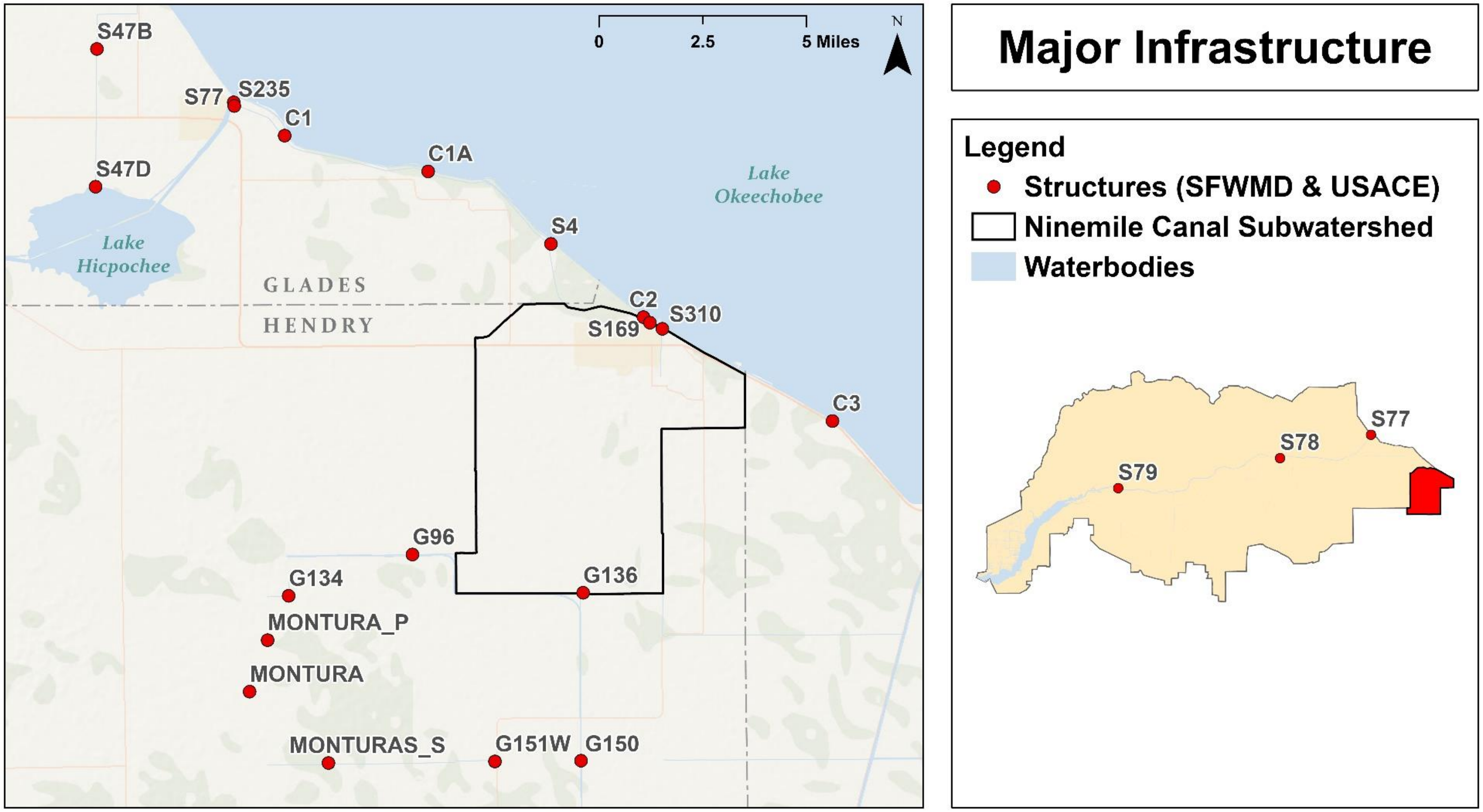

Figure 46. Location of major stormwater infrastructure within the study area and its surroundings (SFWMD, 2020)

In general, the local community stormwater systems consist of drainage ditches, storm sewers, retention ponds, and other facilities constructed to store runoff or carry it to a receiving canal, lake, or other waterbody. Other man-made features include swales that collect runoff and direct it to the sewers and ditches to protect roadways. When drilling down to the neighborhood level, there is minimal drainage infrastructure. In fact, shallow swales are really the only structures (Figure 47)

Figure 47. Examples of a typical street in Clewiston, FL with swales

There are very few street inlets, mostly along U.S.-27/Sugarland Highway, and no culverts under roadways in most of the City. Hence, there is no master stormwater system in Clewiston, only a series of small canals that traverse the City, as shown in Figure 48, which were used to model the city's stormwater system. The lines on the map with arrows are actually canals, and the rest are drainage basins. The canals include the Clewiston Drainage District Canals 1 through 7 and Lopez Canal, which connect to the major C-21 Canal (north) and Industrial Canal (east).

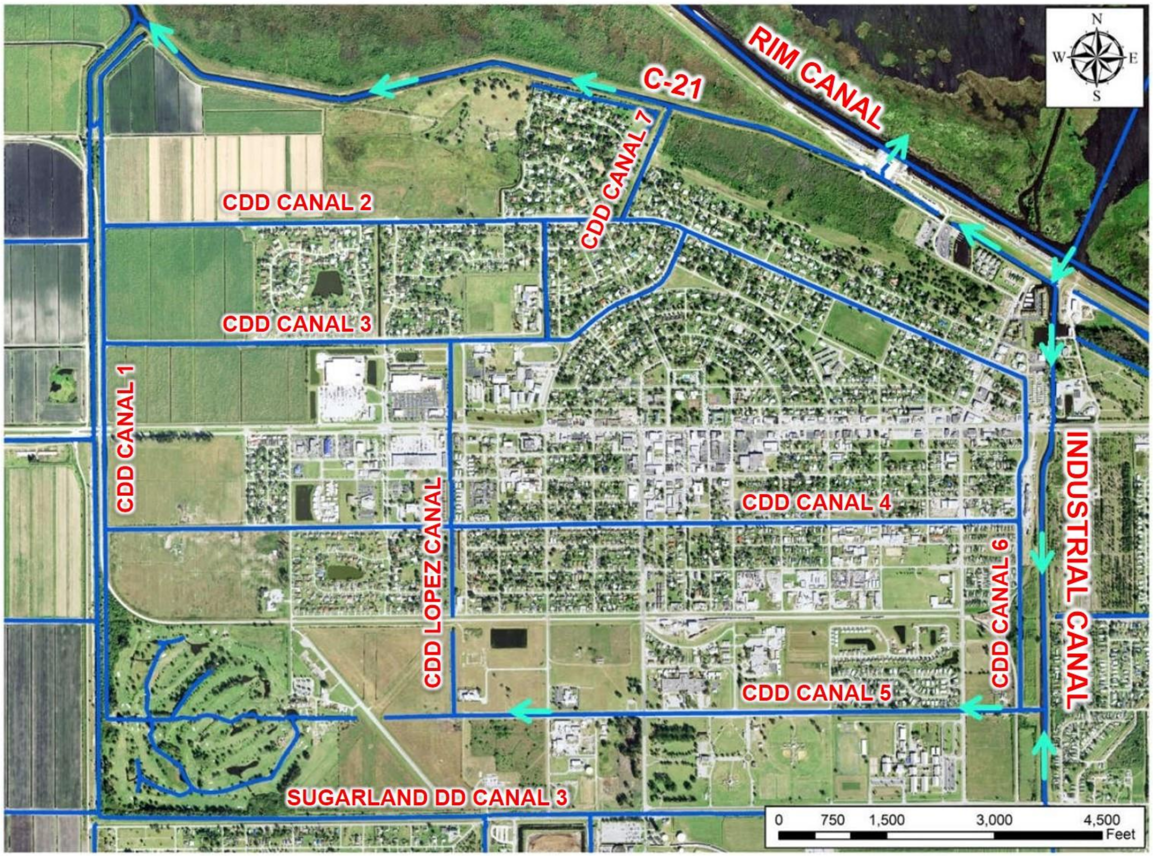

Figure 48. Local drainage canal system in the City of Clewiston (CCD=Clewiston Drainage District).

A recent program to seal the sewer system eliminated inflow of rainwater to the sanitary system, introducing "new" flooding to areas in the City. Historically, much of the stormwater ended up in the sanitary sewer system. Sealing of the sewer system in 2019 has exposed areas in Harlem (neighborhood that borders the southwest corner of Clewiston) that flood now as a result. To address this "new" flooding issue, the City proposes to conduct a stormwater master plan to add to prior work done by FAU.

2.13 Data Gaps

There is only one data gap for the watershed – existing stormwater infrastructure records are incomplete. This will be addressed in the upcoming stormwater master planning exercise.

3.0 POLICY FRAMEWORK

In this section, the available planning documents applicable to the study area are discussed as they relate to watershed master planning.

3.1 Existing Regulations

It is important that the WMP identify the control actions, management practices, and regulations as well as the agencies that have authority and jurisdiction, as applicable to the study area. The following section summarizes the universe of existing regulations, which includes federal, state, tribal, regional, and local rules.

3.1.1 Federal Regulations

The federal and state (of Florida) rules have been interconnected since the 1980s with delegation of enforcement and administration of the major environmental protection rules to the states. In response to increased flood damage, the escalating costs of disaster relief for taxpayers, and the lack of affordable flood insurance, Congress enacted the National Flood Insurance Act (NFIA) in 1968 (Public Law Number 90-448, 82 Stat. 572 (August 1, 1968). Codified, as amended, at 42 U.S.C. §4001), which established the National Flood Insurance Program (NFIP). Property located in a flood area where the community participates in the NFIP is subject to the NFIA's requirements.

Flood insurance compliance requirements for federally regulated financial institutions began in 1973, when Congress enacted the Flood Disaster Protection Act of 1973 (FDPA - Public Law Number 93-234, 87 Stat. 975.). Section 102(b) of the FDPA amended the NFIA to require the Board of Governors of the Federal Reserve System (Board), the Federal Deposit Insurance Corporation (FDIC), the Office of the Comptroller of the Currency (OCC), and the National Credit Union Administration (NCUA) to issue regulations directing lending institutions under their supervision not to make, increase, extend, or renew any loan secured by improved real estate or mobile homes located, or to be located, in a Special Flood Hazard Area (SFHA) where flood insurance is available under the NFIP unless the building or mobile home and any personal property securing the loan are covered by flood insurance for the term of the loan.

Congress subsequently enacted the National Flood Insurance Reform Act of 1994 (Reform Act - Title V of the Riegle Community Development and Regulatory Improvement Act of 1994, Public Law Number 103-325 (September 23, 1994), which made comprehensive changes to the NFIA and FDPA. The changes include obligating lenders to escrow all premiums and fees for flood insurance required under the NFIA. In part because the NFIP incurred large deficits from paying claims for major floods, Congress enacted the Biggert-Waters Flood Insurance Reform Act of 2012 (BWA) to ensure the NFIP's fiscal stability and for other purposes. To make the program self-sustaining, the BWA phased out both subsidized rates, which apply to approximately 20% of policyholders (Pub. L. No. 112-141, 126 Stat. 916 (2012). The BWA also directed FEMA to implement full-risk pricing for all policies.

USACE has rules associated with federal works that apply to dredging, and other activities on navigable waters, which also includes wetlands. Discharging into surface waters is one of the oldest methods of disposing of waste from the point of generation. Downstream, reduction of the waste occurs due to dilution and natural degradation processes. Given sufficient treatment prior to discharge, these mutual processes work to reduce the waste to relatively minimal levels. Failure to treat adequately will overload the natural attenuation ability of the waterbody, resulting in noticeable pollution. As a result of major issues with pollution in the 1960s, Congress passed the Clean Water Act (CWA). The preamble for the CWA is as follows:

> *"The objective of this act is to restore and maintain the chemical physical and biological integrity of the Nation's waters…"*

Congress further stated that the discharge of pollutants in toxic amounts must be prohibited. As a result, the Clean Water Act regulates surface discharges to fresh waters, ocean discharges by wastewater plants, disposal of concentrated process waters from water plants (such as concentrate from membrane facilities), and disposal of residuals (sludge). Implicit is that stormwater and agricultural runoff issues may affect potable water supplies and are potentially subject to regulation.

Legislation was first directed to wastewater because discharging to a stream or surface waterbody made it the source water for downstream communities. Hence, if wastewater could be treated before it was discharged into the rivers, this might reduce the amount of treatment necessary for drinking water. Thus, the focus was primarily on wastewater treatment plants. At the same time, there were a variety of other issues that were addressed such as the attempt to reuse wastewater for beneficial uses like irrigation, to deal with industrial pretreatment so that metals and other contaminants that would disrupt the wastewater treatment process would not be discharged to the sewer system as well as the idea that stormwater might contribute to overflows. Since 1990, the focus has shifted from wastewater (mostly addressed) to agricultural and urban nonpoint source stormwater runoff (nutrients). USEPA developed MS4 and other permitting systems to address area runoff. A municipal separate storm sewer system (MS4) is a publicly owned conveyance or system of conveyances (i.e., ditches, curbs, catch basins, underground pipes, etc.) designed or used for collecting or conveying stormwater and that discharges to surface waters of the state. Examples of MS4 operators include, but are not limited to, municipalities, counties, community development districts, universities, military bases, or federal prisons. Operators of large, medium, and regulated small MS4s are required to obtain NPDES permit coverage to discharge to waters of the state.

Runoff continues to be a regulatory challenge at the federal level, so much of the enforcement has been delegated to the states and regional/local governments. In Florida, the state has delegated much of this effort to FDEP and the water management districts. As implemented by Chapter 62-624, F.A.C., Phase I addresses discharges of stormwater runoff from "medium" and "large" MS4s (i.e., those MS4s located in areas with populations of 100,000 or greater). Under Phase II, the program regulates discharges from certain MS4s not regulated under Phase I, and that meet designation criteria set forth in Chapter 62-624, F.A.C.

Changes to any water channel or canal requires a USACE general permit. Processing such permits involves evaluation of individual, project-specific applications in what can be considered three steps: 1) pre-application consultation (for major projects), 2) project review, and 3) decision-making. Per the USACE website (https://www.lrl.usace.army.mil/Portals/64/docs/regulatory/Permitting/PermittingProcessInformation.pdf), the process for the general permit is as follows:

1. A pre-application consultation is recommended
2. The applicant submits ENG Form 4345 and plans electronically or to the appropriate USACE regulatory office
3. USACE notifies the applicant if additional information is required to complete the application
4. A public notice is issued within 15 days of receipt of a complete application to solicit comments from the public, adjacent property owners, interested groups and individuals, local agencies, state agencies, and Federal agencies
5. The public notice comment period is 15-30 days, depending upon nature of activity
6. USACE provides the applicant an opportunity to respond to comments received in response to the public notice
7. USACE considers all comments and the applicant's responses to those comments, including any proposed modifications of the project
8. A public hearing is held, if necessary
9. USACE conducts a public interest review evaluation and, if necessary, a section 404(b)(1) guidelines evaluation
10. USACE decides on the permit application and explains its decision in a decision document. This decision document may include an environmental assessment or

environmental impact statement, a statement of findings or record of decision, a Section 404(b)(1) guidelines evaluation (if necessary), and a public interest review evaluation

11. If USACE issues the permit, a copy is sent to the applicant for signature, otherwise an explanation of permit denial is sent
12. If the applicant refuses to sign the permit because he or she does not agree with the conditions in the permit, or if the permit is denied, the applicant can request an administrative appeal of the permit decision

Pre-application consultation is suggested to provide for informal discussions about a proposed activity. This invaluable feedback gives the applicant insight into the viability of alternatives available to accomplish the project goal and provides opportunities to discuss measures for reducing impacts and to inform the applicant of the factors USACE must consider in its decision-making process.

The following general criteria are considered in evaluating all applications (https://www.lrl.usace.army.mil/Portals/64/docs/regulatory/Permitting/PermittingProcessInformation.pdf):

1. Relevant extent of public and private need for the proposed work
2. Where unresolved conflicts of resource use exist, the practicability of using reasonable alternative locations and methods to accomplish the objective of the proposed structure or work
3. The extent and permanence of the beneficial and/or detrimental effects the proposed structure or work is likely to have on public and private uses to which the area is suited

The decision to issue or deny a permit is based on the public interest review and, where applicable, a Section 404(b)(1) guidelines analysis or an analysis of the ocean dumping criteria. The public interest review involves an analysis of the foreseeable impacts the proposed work would have on public interest factors, such as navigation, general environmental concerns, wetlands, economics, fish and wildlife values, land use, floodplain values, and the needs and welfare of the people. The permit decision document includes a discussion of the environmental impacts of the project, the findings of the public interest review process, and any special evaluation required by the type of activity, such as determining compliance with the Section 404(b)(1) guidelines. Because every project is subject to regulations and permitting requirements, preparing a comprehensive up-to-date list may be problematic. Therefore, it is recommended to conduct pre-application meetings with the pertinent regulatory agencies (USACE, FDEP, WMDs, and the counties) to identify the appropriate permits and guidelines for regulatory compliance.

To address floodplains, the 1972 Coastal Zone Management Act and the 1982 Coastal Barriers Resources Act protect coastal wetlands. The Coastal Zone Management Act encourages States (35 States and territories are eligible, including the Great Lakes States) to establish voluntary coastal zone management plans under NOAA's Coastal Zone Management Program and provides funds for developing and implementing the plans. The NOAA also provides technical assistance to States for developing and implementing these programs. For Federal approval, the plans must demonstrate enforceable standards that provide for the conservation and environmentally sound development of coastal resources. The program provides States with some control over wetland resources by requiring that Federal activities be consistent with State coastal zone management plans, which can be more stringent than Federal standards (World Wildlife Fund, 1992). A State also can require that design changes or mitigation requirements be added to Section 404 permits to be consistent with the State coastal zone management plan. The Coastal Zone Management Act has provided as much as 80% of the matching-funds grants to States to develop plans for coastal management that emphasize wetland protection (Mitsch and Gosselink, 1993). Some States pass part of the grants on to local governments. The Act's authorities are limited to wetlands within a State's coastal zone boundary, the definition of which differs among States. As of 1990, 23 States had federally approved plans.

The Federal Government regulates, through Section 404 of the Clean Water Act, some of the activities that occur in wetlands. The Section 404 program originated in 1972, when Congress substantially amended the Federal Water Pollution Control Act and created a Federal regulatory plan to control the discharge of dredged or fill materials into wetlands and other waters of the United States. Discharges are commonly associated with projects such as channel construction and maintenance, port development, fills to create dry land for development sites near the water, and water-control projects such as dams and levees. Other kinds of activities, such as the straightening of river channels to speed the flow of water downstream and clearing land, are regulated as Section 404 discharges if they involve discharges of more than incidental amounts of soil or other materials into wetlands or other waters. USACE and USEPA share the responsibility for implementing the permitting program under Section 404 of the Clean Water Act. However, Section 404(c) of the Clean Water Act gives the EPA authority to veto the permit if discharge materials at the selected sites would adversely affect such things as municipal water supplies, shellfish beds and fishery areas, wildlife, or recreational resources. By 1991, the EPA had vetoed 11 of several hundred thousand permits since the Act was passed (Schley and Winter, 1992).

Section 10 of the Rivers and Harbors Act of 1899 33 U.S.C. 403 That the creation of any obstruction not affirmatively authorized by Congress, to the navigable capacity of any of the waters of the United States is hereby prohibited; and it shall not be lawful to build or commence the building of any wharf, pier, dolphin, boom, weir, breakwater, bulkhead, jetty, or other structures in any port, roadstead, haven, harbor, canal, navigable river, or other water of the United States, outside established harbor lines, or where no harbor lines have been established, except on plans recommended by the Chief of Engineers and authorized by the Secretary of War; and it shall not be lawful to excavate or fill, or in any manner to alter or modify the course, location, condition, or capacity of, any port, roadstead, haven, harbor, canal, lake, harbor of refuge, or enclosure within the limits of any breakwater, or of the channel of any navigable water of the United States, unless the work has been recommended by the Chief of Engineers and authorized by the Secretary of War prior to beginning the same.

This part and the parts that follow (33 CFR parts 321 through 330) prescribe the statutory authorities, and general and special policies and procedures applicable to the review of applications for Department of the Army (DA) permits for controlling certain activities in waters of the United States or the oceans. This part identifies the various federal statutes which require that DA permits be issued before these activities can be lawfully undertaken; and related Federal laws and the general policies applicable to the review of those activities. Parts 321 through 324 and 330 address special policies and procedures applicable to the following specific classes of activities: (1) Dams or dikes in navigable waters of the United States (part 321); (2) Other structures or work including excavation, dredging, and/or disposal activities, in navigable waters of the United States (part 322); (3) Activities that alter or modify the course, condition, location, or capacity of a navigable water of the United States (part 322); (4) Construction of artificial islands, installations, and other devices on the outer continental shelf (part 322); (5) Discharges of dredged or fill material into waters of the United States (part 323); (6) Activities involving the transportation of dredged material for the purpose of disposal in ocean waters (part 324); and (7) Nationwide general permits for certain categories of activities (part 330).

Executive Orders 11988, *Floodplain Management*, and 11990, *Protection of Wetlands*, were signed by President Carter in 1977. The purpose of these Executive Orders was to ensure protection and proper management of flood plains and wetlands by Federal agencies. The Executive Orders require Federal agencies to consider the direct and indirect adverse effects of their activities on flood plains and wetlands. This requirement extends to any Federal action within a flood plain or a wetland except for routine maintenance of existing Federal facilities and structures. The Clinton administration has proposed revising Executive Order 11990 to direct Federal agencies to consider wetland protection and restoration planning in the larger scale watershed/ecosystem context.

USACE published, in 1987, the *Corps of Engineers Wetland Delineation Manual*, a technical manual that provides guidance to Federal agencies about how to use wetland field indicators to identify and delineate wetland boundaries (USACE, 1987). In January of 1989, USEPA, USACE, SCS, and FWS adopted a single manual for delineating wetlands under the Section 404 and Swampbuster programs-*The Federal Manual for Identifying and Delineating Jurisdictional Wetlands* (commonly referred to as the “1989 Manual”). The “1989 Manual” establishes a national standard for identifying and delineating wetlands by specifying the technical criteria used to determine the presence of the three wetland characteristics: wetland hydrology, water-dependent vegetation, and soils that have developed under anaerobic conditions (USEPA, 1991).

In 1991, the President’s Council on Competitiveness proposed revisions to the 1989 Manual because of some concern that non-wetland areas were regularly being classified as wetlands (Environmental Law Reporter, 1992a). The proposed 1991 Manual was characterized by many wetland scientists as politically based rather than scientifically based. In September of 1992, Congress authorized the National Academy of Science to conduct a $400,000 study of the methods used to identify and delineate wetlands (Environmental Law Reporter, 1992b). On August 25, 1993, the Clinton administration’s wetland policy, proclaimed that, “Federal wetlands policy should be based upon the best science available” (White House Office of Environmental Policy, 1993) and the 1987 Corps Manual is the sole delineation manual for the Federal Government until the National Academy of Sciences completes its study (White House Office of Environmental Policy, 1993).

On August 25, 1993, President Clinton unveiled his new policy for managing America’s wetland resources. The program was developed by the Interagency Working Group on Federal Wetlands Policy, a group chaired by the White House Office on Environmental Policy with participants from the USEPA, USACE, the Office of Management and Budget, and the Departments of Agriculture, Commerce, Energy, Interior, Justice, and Transportation. The Administration’s proposals mix measures that tighten restrictions on activities affecting wetlands in some cases and relax restrictions in other areas. The Clinton policy endorses the goal of “no net loss” of wetlands; however, it clearly refers to “no net loss” of wetland acreage rather than “no net loss” of wetland functions.

The President’s wetland proposal would expand Federal authority under the Section 404 program to regulate the draining of wetlands in addition to regulating dredging and filling of wetlands. Other proposed changes to the Federal permitting program include the requirement that most Section 404 permit applications be approved or disapproved within 90 days, and the addition of an appeal process for applicants whose permits are denied. The USEPA and USACE are directed to relax regulatory restrictions that cause only minor adverse effects to wetlands such as activities affecting very small areas.

The Clinton policy calls for avoiding future wetland losses by incorporating wetland protection into State and local government watershed-management planning. This policy also significantly expands the use of mitigation banks to compensate for federally approved wetland development or loss. This policy relaxed some of the current restrictions on agricultural effects on wetlands and increased funding for incentives to preserve and restore wetlands on agricultural lands. The administration excluded 53 million acres of "prior converted croplands" from regulation as wetlands. Also, authority over wetland programs affecting agriculture was shifted from the FWS to the NRCS and proposed increased funding for the Wetlands Reserve Program, which pays farmers to preserve and restore wetlands on their property.

3.1.2 State Regulations

The Florida Legislature enacted the Florida Watershed Restoration Act (FWRA) in 1999 to protect Florida's water resources from excessive pollution loading. It focuses on the Total Maximum Daily Load (TMDL) program that is required by the federal Clean Water Act and discusses specifics of how this program should be implemented in Florida. It does not address water quantity directly. A TMDL is the total amount of pollution discharge from all sources that a waterbody can assimilate and still meet water quality standards. This value is typically represented in lb/year allocations. For more information on water quality standards, consult Surface Water Quality Standards - Chapter 62-302. The TMDL program protects state waters by coordinating the control of pollution from point and nonpoint sources.

Waterbodies that do not meet water quality standards are identified as "impaired," and implementation plans must be developed describing how the point and nonpoint sources of pollution will meet their discharge allocations. This implementation plan is referred to as Basin Management Action Plan (BMAP). FDEP identified the following basic steps for the TMDL program (the bulleted list below is a direct quotation from the website at http://www.dep.state.fl.us/water/tmdl/):

- Assess the quality of surface waters—Are water quality standards being met?
- Determine which waters are impaired or are not meeting water quality standards for particular pollutants?
- Establish and adopt, by rule, a TMDL for each impaired water for the pollutants of concern
- Develop, with extensive local stakeholder input, Basin Management Action Plans (BMAPs)
- Implement the strategies and actions of BMAPs

- Measure the effectiveness of BMAPs, both continuously at the local level and through a formal re-evaluation every five years
- Adapt BMAPs to local conditions by changing the plan and changing the actions if things are not working
- Reassess the quality of surface waters continuously

FDEP is the lead agency in establishing TMDLs and for enforcing the FWRA when addressing point source and nonagricultural nonpoint source pollution, while the Florida Department of Agriculture and Consumer Affairs (FDACS) is the lead agency for enforcing the FWRA when it comes to agricultural nonpoint source pollution. FDEP is required to coordinate with the water management districts, FDACS, soil and water conservation districts, environmental groups, regulated parties, and local stakeholders during all phases of the TMDL process, which includes:

- Development of a TMDL assessment. The methodology includes determination of what information is required for the TMDL assessment, the acceptable methods of data collection, and analysis and quality control requirements.
- Development of an approved list of waterbodies or segments for which TMDLs will be applied, including a priority ranking and schedule for analyzing such waters.
- Calculation and implementation of TMDLs, accounting for seasonal variations and including a margin of safety to reflect uncertainties about pollution loading effects on water quality. A TMDL should be allocated among pollution sources in a reasonable and equitable manner (accounting for the availability of treatment technologies, existing treatment levels, and the costs/benefits of achieving allocation).

FDEP in coordination with the water management districts may develop a BMAP to achieve the TMDL. BMAPs can include such strategies as construction of regional treatment systems or voluntary trading of water quality credits. BMAPs should include water quality improvement milestones, and the progress with achieving these milestones should be evaluated every five years. FDEP can implement TMDLs under existing water quality protection programs, such as:

- Permitting and other existing regulatory programs, such as water-quality-based effluent limitations
- Non-regulatory and incentive-based programs, such as cost-share, best management practices, and public education
- Trading of water quality credits or other agreements
- Public works, including capital facilities
- Land acquisition

Section 303(d) of the Clean Water Act allows USEPA to assist states, territories, and authorized tribes in listing out any and all impaired waters and developing their respective TMDLs. A TMDL is the restoration goal of a specific watershed. FDEP checks the quality of watersheds across the State of Florida and determines if they are within an acceptable TMDL of pollutants (Figure 49).

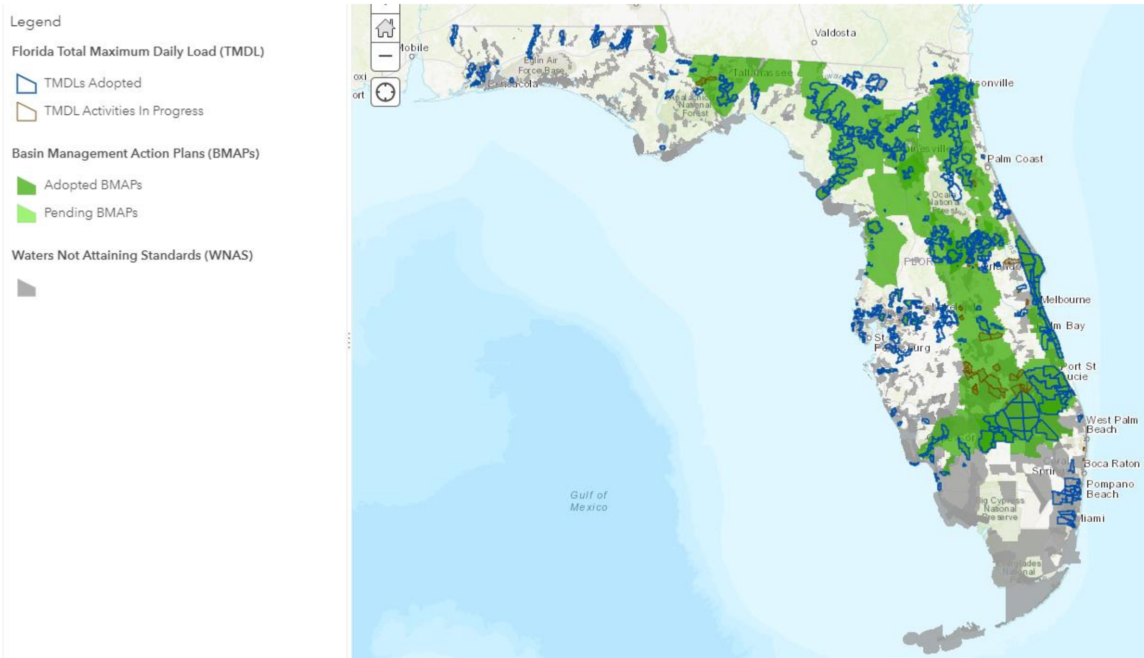

Figure 49. TMDL and BMAPs across the state of Florida (https://floridadep.gov/dear/water-quality-restoration/content/impaired-waters-tmdls-and-basin-management-action-plans)

A closer view is shown in Figure 50.

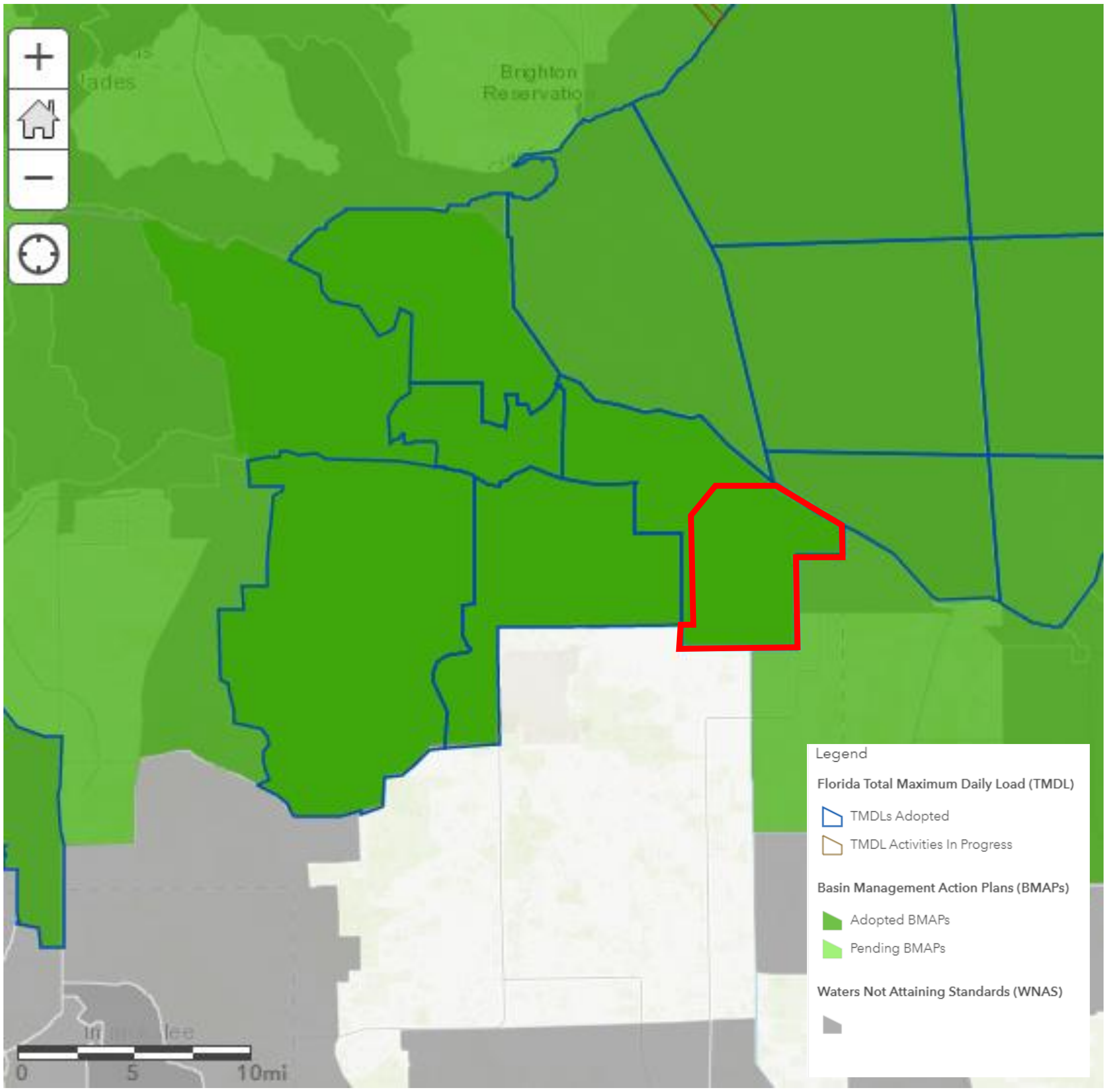

Figure 50. Close-up view of the BMAP in the study area (https://floridadep.gov/dear/water-quality-restoration/content/impaired-waters-tmdls-and-basin-management-action-plans)

In Florida, the authority for regulating wastewater, drinking water and injection wells has remained with the State, which has delegated watershed management regulatory authority to the water management districts under FS 373. Thus, the authority in this subwatershed is the SFWMD. TMDLs have been adopted for the full Caloosahatchee East/Clewiston subwatershed and its immediate surroundings to the east, the north, and the west. The TMDL focuses on nutrients and fecal coliforms via adopted BMAPs (https://floridadep.gov/DEAR/Water-Quality-Restoration/content/20777-caloosahatchee-basin-management-action-plan-bmap-meeting). The study area is completely within one of the adopted BMAPs, as shown in Figure 50. The major finding is the need to create an off-line water storage area for flood protection and water supply purposes.

3.1.3 Regional Regulations

Stormwater management systems in the study area are regulated by SFWMD. These regulations apply to the design of stormwater management systems that require a permit as described in Chapter 62-330, F.A.C., or Section 403.814(12) F.S. SFWMD published the Environmental Resource Permitting Manual (ERP) that contains SFWMD-specific appendices for regionally-specific criteria such as basin maps for cumulative impact assessments (see Applicant's Handbook Volume I, Section 10.2.8), mitigation bank service area determination (refer to Chapter 62-342, F.A.C), and above ground impoundments. Projects that qualify for a general permit in Section 403.814(12), F.S., are not regulated under Chapter 62-330, F.A.C. Volume II contains design and performance standards that are relevant to the design of projects that qualify for that general permit. The ERP provides specific, detailed water quality and quantity design and performance criteria for stormwater management systems regulated by SFWMD through the ERP program authorized under Part IV of Chapter 373, F.S, which is found at:

www.sfwmd.gov/sites/default/files/documents/swerp_applicants_handbook_vol_ii.pdf.

Unless otherwise specified by previous permits or criteria, a 3-day, 25-year storm is used in computing off-site discharge rates by the SFWMD (Figure 51). Applicants are advised that local drainage districts or local governments may require more stringent design storm criteria. An applicant who demonstrates unusual site-specific conditions may, as a part of the permit application process, request an alternate discharge rate. Hendry County uses a 1-day, 100-year storm event. All new development must retain this amount of water, which reduces the amount of added runoff to the existing drainage system. For this study, the 3-day, 25-year (Figure 51), 1-day, 100-year (Figure 52), and the 1-day, 10-year (Figure 53) storm events were analyzed.

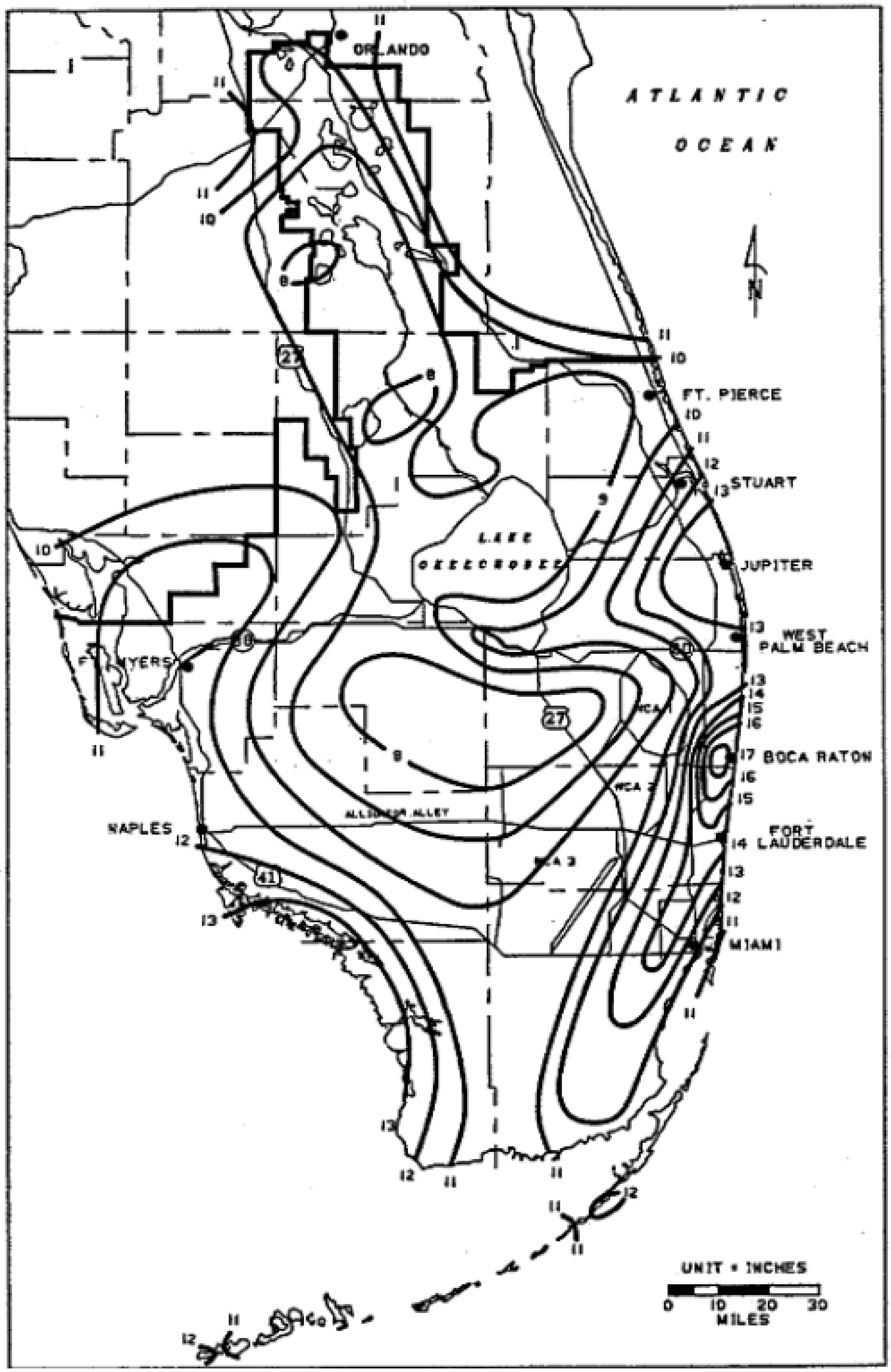

Figure 51. 3-day, 25-year rainfall map (SFWMD, 2014)
https://www.sfwmd.gov/sites/default/files/documents/swerp_applicants_handbook_vol_ii
.pdf

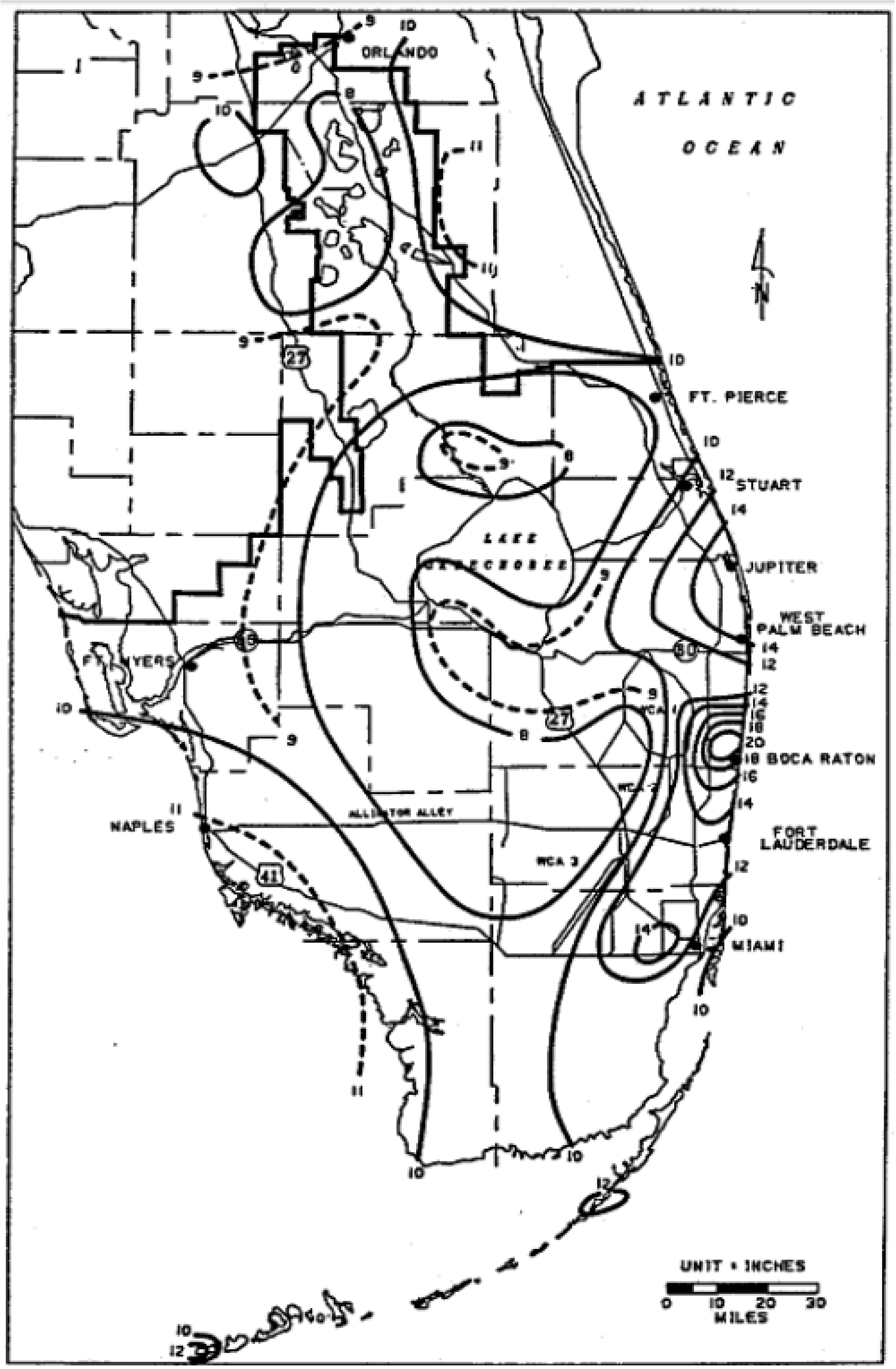

Figure 52. 1-day, 100-year rainfall map (SFWMD, 2014)
https://www.sfwmd.gov/sites/default/files/documents/swerp_applicants_handbook_vol_ii.pdf

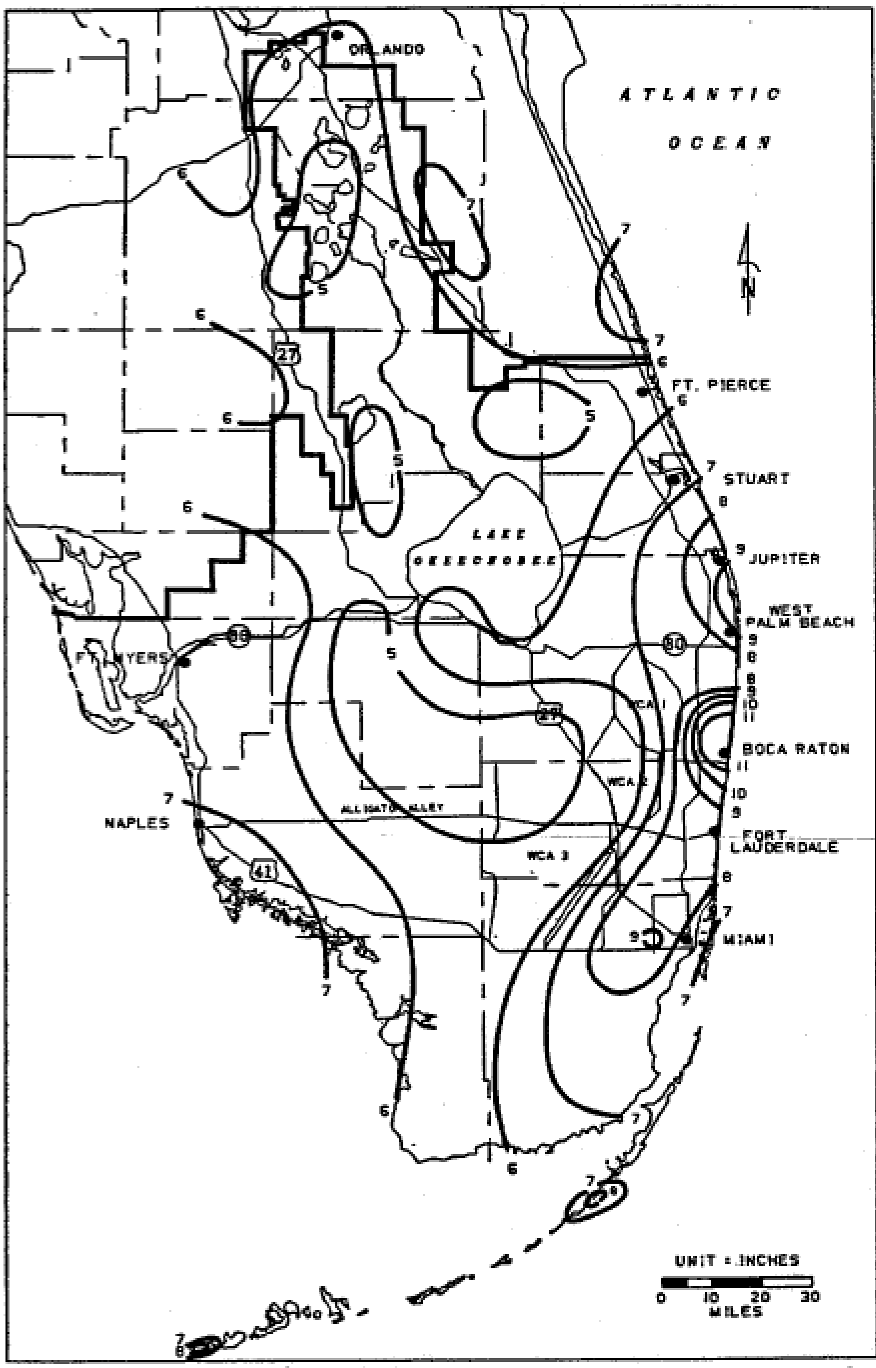

Figure 53. 1-day, 10-year rainfall map (SFWMD, 2014) (https://www.sfwmd.gov/sites/default/files/documents/swerp_applicants_handbook_vol_ii.pdf)

As the guidelines are promulgated throughout the SFWMD, they are applicable to all basins within their jurisdiction. For example, the ERP indicates that off-site discharge rates are limited to not causing adverse impacts to existing off-site properties, and: a) historic discharge rates; b) rates determined in previous permit actions; or c) rates specified in SFWMD criteria. An acceptable peak discharge analysis typically consists of generating pre-development and post-development runoff hydrographs, routing the post-development hydrograph through a detention basin, and sizing an overflow structure to control post-development discharges at or below pre-development rates. Acceptable design techniques also include the use of grassed waterways, and any other storage capability that the particular system may have. SFWMD normally uses the 3-day, 25-year storm for permitting purposes (see Figure 51), but the Florida Building Code and certain peak event permits use the 1-day, 100-year event (see Figure 52) or the 1-hour, 100-year storm (for roof drains). For CRS credit, the 1-day, 10-year storm event is also of interest (Figure 53). All new development must be constructed so as to retain water that meets these requirements, thereby minimizing the impact of development on flood protection.

The regulations note that peak discharge computations shall consider the duration, frequency, and intensity of rainfall, the antecedent moisture conditions, upper soil zone and surface storage, time of concentration, tailwater conditions, changes in land use or land cover, and any other changes in topographic and hydrologic characteristics. Large systems should be subdivided according to artificial or natural drainage boundaries to allow for more accurate hydrologic simulations. Peak discharge calculations must make proper use of the Soil Conservation Service (SCS) Peak Rate Factor or K’ Factor, which reflects the effect of watershed storage on the hydrograph shape and directly impacts the peak discharge value. As such, K’ must be based on the true watershed storage of runoff, and not on the slope of the landscape, which is more accurately accounted for in the time of concentration. More details can be found in the permitting guidelines (SFWMD, 2014).

Surface storage, including that available in wetlands and low-lying areas, must be considered as depression storage, which shall be analyzed for its effect on peak discharge and the time of concentration. Depression storage can also be considered in post-development storage routing, which requires development of stage-storage relationships. If depression storage is considered, then both pre-development and post-development storage routing must be considered.

The rules require that building floors must be at or above the 100-year flood elevation level, as determined from the most appropriate information, including Federal Flood Insurance Rate Maps (FIRMs). Both tidal flooding and the 1-day, 100-year storm event are considered in determining elevations. In cases where criteria are not specified by the local government with jurisdiction, the design criteria for drainage and flood protection, the 1-day, 5-year return frequency is used for roadways.

With respect to floodplains, no net encroachment into the floodplain, between the average wet season water table and that encompassed by the 100-year event, which will adversely affect the existing rights of others, is permitted. Treatment is required for offsite discharge to many categories of waters. Treatment that is part of retention/detention must provide for: 1) the first inch of runoff from the developed project, or the total runoff of 2.5 inches times the percentage of imperviousness, whichever is greater; or 2) dry detention volume must be provided equal to 75% of the above amounts computed for wet detention; or 3) retention volume shall be provided equal to 50% of the above amounts computed for wet detention. Projects having greater than 40% impervious area, and which discharge directly into receiving waters, are required to provide at least one-half inch of dry detention or retention pretreatment as part of the required retention/detention. The major point is that added volumetric loadings are not permitted in most circumstances.

3.1.4 Local Regulations/Comprehensive Plans

In 1985, the Florida legislature approved the Growth Management Act, which guided community development in the state until 2010. However, many communities still conduct planning activities as if the Growth Management Act were still in place. As a result, comprehensive plans are still available in most communities (some may be dated, but the information is still useful).

Comprehensive plans are official public documents that have been adopted by a local government as a policy to guide decisions regarding development in the community. These plans are generally how local leaders communicate how they view community growth over the next 20-30 years. Many communities still update these plans. Both Hendry County (2020) and the City of Clewiston (2015) have produced comprehensive plans. While the modeling of future floodway conditions will largely depend on the analytical approaches used (see Section 4.0), projected future land use and land cover will have a direct relationship to future runoff. All plans have a stormwater element.

Local governments in the study area have local land development regulations. Stormwater issues are addressed via reference to SFWMD standards. The 2016 stormwater utility report indicates the status for local stormwater utilities created for funding local improvements. That report (2016 FSA Stormwater Utility Report) goes over the utility fee, utility rate, and population served. Nearby communities that utilize stormwater utilities or utility assessments include Cape Coral, Fort Myers, and Charlotte County.

The following Caloosahatchee East/Clewiston subwatershed communities have stormwater plans:

- Hendry County - Stormwater Management section of Comprehensive Plan

As of July 2020, the following communities have no local watershed or stormwater plans that are publicly available:

- Clewiston

The following communities in the Caloosahatchee East/Clewiston subwatershed have a comprehensive plan with associated land development regulations:

- Hendry County (http://www.hendryfla.net/hendrycountynew/uploads/2013_Comp_Plan_Complete.pdf)
- Clewiston (https://www.clewiston-fl.gov/department/division.php?structureid=26)

As a general statement, the local plans for Hendry County and Clewiston contain the policy framework necessary for environmental resource regulation. All local plans, defer to state and federal regulatory agencies for the technical expertise for environmental permitting. The plans are summarized as follows:

3.1.4.1 Hendry County

Hendry County's plan notes that it will "ensure the control of current and future impacts to natural drainage patterns, and to protect water quality and water supply, as well as the quality and function of existing wetlands. The County will continue to implement the level of service standards for stormwater management consistent with the SFWMD." The most current floodplain management ordinance notes:

> **ARTICLE II. - FLOOD DAMAGE PREVENTION AND CONTROL**
> **Sec. 1-55-3. - Definitions.**
>
> *Base flood* means a flood having a one-percent chance of being equaled or exceeded in any given year. (Also defined in FBC, B, section 1612.2.1.) The base flood is commonly referred to as the "100-year flood" or the "one-percent-annual chance flood."
>
> *Base flood elevation* means the elevation of the base flood, including wave height, relative to the National Geodetic Vertical Datum (NGVD), North American Vertical Datum (NAVD) or other datum specified on the Flood Insurance Rate Map (FIRM). (Also defined in FBC, B, section 1612.2.)

Basement means the portion of a building having its floor subgrade (below ground level) on all sides. (Also defined in FBC, B, section 1612.2.)

Design flood means the flood associated with the greater of the following two areas: (Also defined in FBC, B, section 1612.2.)

(1) Area with a floodplain subject to a one-percent or greater chance of flooding in any year; or

(2) Area designated as a flood hazard area on the community's flood hazard map, or otherwise legally designated.

Design flood elevation means the elevation of the "design flood," including wave height, relative to the datum specified on the community's legally designated flood hazard map. In areas designated as zone AO, the design flood elevation shall be the elevation of the highest existing grade of the building's perimeter plus the depth number (in feet) specified on the flood hazard map. In areas designated as zone AO where the depth number is not specified on the map, the depth number shall be taken as being equal to two feet. (Also defined in FBC, B, section 1612.2.1.)

Sec. 1-55-34. - Information in flood hazard areas without base flood elevations (approximate zone A).

Where flood hazard areas are delineated on the FIRM and base flood elevation data have not been provided, the floodplain administrator shall:

(1) Require the applicant to include base flood elevation data prepared in accordance with currently accepted engineering practices.

(2) Obtain, review, and provide to applicants base flood elevation and floodway data available from a federal or state agency or other source or require the applicant to obtain and use base flood elevation and floodway data available from a federal or state agency or other source.

(3) Where base flood elevation and floodway data are not available from another source, where the available data are deemed by the floodplain administrator to not reasonably reflect flooding conditions, or where the available data are known to be scientifically or technically incorrect or otherwise inadequate:

a. Require the applicant to include base flood elevation data prepared in accordance with currently accepted engineering practices; or
b. Specify that the base flood elevation is three feet above the highest adjacent grade at the location of the development, provided there is no evidence indicating flood depths have been or may be greater than three feet.

(4) Where the base flood elevation data are to be used to support a letter of map change from FEMA, advise the applicant that the analyses shall be prepared by a Florida

licensed engineer in a format required by FEMA, and that it shall be the responsibility of the applicant to satisfy the submittal requirements and pay the processing fees. (Ord. No. 2015-01, § 2, 3-10-2015)

Stormwater management systems are also required to meet the design and performance standards established in Chapter 62, FAC with on-site treatment of the first inch of runoff to meet water quality standards without degrading the receiving waterbody below the minimum conditions necessary to assure the suitability of water for the designated use of its classification as established in Chapter 62, F.A.C. Individual single family and duplex lots that are not part of a subdivision, or exist as isolated vacant lots within developed subdivisions (and would therefore constitute infill), must utilize standardized swales or other detention/retention facilities consistent with area drainage requirements, based on professionally accepted and applied engineering principals and standards, which ensure that the adopted water quality and quantity standards are met.

They note that "the natural drainage patterns of Hendry County have been considerably disrupted over the years, so that certain areas of residential development do experience some problem with retained water after storms. The desire is to reduce this deficiency by continued coordinating of activities with the SFWMD." Furthermore, "the County will coordinate with the SFWMD in correction of problems created by the major state and federal drainage projects in the past." The design of new roads or major road improvements shall eliminate flooding conditions that specifically result from past road construction, or that can be relieved by new construction. Namely:

Sec. 1-55-2. - Development review criteria for environmentally sensitive lands.
1-55-2.01. *Procedure for review.*

(a) No building permit, except for a single-family or two-family residential unit, or land use or development permit will be issued by any agency of the county until the applicant provides evidence that the requirements of state and federal law as set forth in policies 1.1, 1.8, 2.1, and 2.2 of the county comprehensive plan have been or will be complied with by the applicant and that the natural functions of the designated or otherwise known environmentally sensitive lands will not be adversely affected by the use for which the application is sought.

(b) Proposed developments of 100 units or more and not falling within the development regional impact thresholds shall designate on a map or plan of the proposed development site the locations of any areas of five acres or more dominated by 50 percent or more with native vegetation. Such areas shall be incorporated into open space areas through planned unit development and/or cluster provisions, provided that if over 50 percent of the site involves such areas, no more than one-half of the total site shall be required to be preserved. The regulations shall also provide that when such areas are found in nonresidential

> projects or in residential projects of less than 100 units, such areas shall be preserved in open space uses up to 25 percent of the total site. Agricultural uses are exempted from the above requirements for designating native vegetation but shall be subject to all applicable state and federal laws and regulations.
>
> 1-55-2.02. *Management standards.*
>
> No building permit, except for a single-family or two-family residential unit, or land use or development permit will be issued by any agency of the county until the applicant provides evidence that the requirements of the (Florida) Endangered and Threatened Species Act and the (federal) Endangered and Threatened Species Act and (federal) Endangered Species Act of 1973, as amended, have been or will be complied with by the applicant.

Other policies involve utilizing the County-wide surface water master plan for decision-making, coordinating with the different drainage basins and "coordinating the activities and standards of the local water control districts that may exist in the County and continue a maintenance schedule for County operated stormwater management facilities as a preventative measure to maximize functionality of the existing facilities. The County also requires buffers between development sites and environmentally sensitive areas, including wetlands and other surface waters. The types of buffers may be a landscaped natural barrier, a natural barrier, or a landscaped or natural barrier supplemented with fencing or other man-made barriers.

Finally, the County requires staff to carry out a field visit and evaluation program for stormwater management facilities in the County for drainage problems not being addressed by the SFWMD and its facilities. The field visits are supposed to be coordinated with the cities of Clewiston and LaBelle, the SFWMD, and the local water management control districts for use as input to the master drainage and water management plan.

3.1.4.2 Clewiston

The link to the City's comprehensive plan (2015) is not currently active (https://www.clewiston-fl.gov/egov/docs/1457365150_864837.pdf). The City has been notified of this issue. Discussions with the City do not indicate anything different between the City's requirements and those of the SFWMD and the Southwest Regional Planning Council. However, the City defers to the County for permitting as noted above to comply with WMP2 in the CRS manual.

3.2 Design Storm Events (1 day, 10 year; 3-day, 25-year; 1-day, 100-yr)

As discussed in Section 3.1.3, Figure 51 showed the 3-day, 25-year storm event, and Figure 52 showed the 1-day, 100-year events to comply with. Figure 53 shows the 1-day, 10-year storm. Other events are not part of SFWMD guidance. However, FAU can provide screening model runs for alternate storms if needed. Note that FAU has compared the 3-day, 25-year event and the 1-day, 100-year events, and found that in general the difference was within the vertical accuracy of the LiDAR (see Section 4.2.2 for more detail). The County requires compliance with the 1-day, 100-year storm, and in some cases with 2 feet of freeboard.

3.3 Peak Flows and Volumes

Figure 20 in Section 1.1.3 showed the flow volumes for the Caloosahatchee, averaged by month over a 47-year period compared to 2010-2013. A summary discussion of how peaks are regulated in the study area by SFWMD was included in Section 3.1.3.

3.4 Minimum Flows and Levels (MFLs)

Minimum flows and levels (MFLs) are established to identify where further withdrawals would cause significant harm to the water resources or to the ecology of the area. Significant harm is defined in Subsection 40E-8.021(31), F.A.C., as the temporary loss of water resource functions, which results from a change in surface water or groundwater hydrology, that takes more than 2 years to recover, but is considered less severe than serious harm. Per Subsection 40E-8.021(17), F.A.C., an MFL exceedance means "to fall below a minimum flow or level, which is established in Parts II and III of Chapter 40E-8, F.A.C., for a duration greater than specified for the MFL water body."

In 2001, the SFWMD adopted an MFL for the Caloosahatchee River to prevent undesirable downstream salinity conditions in the Caloosahatchee Estuary [Subsection 40E-8.221(2), F.A.C.]. The current MFL criterion for the Caloosahatchee River is a minimum mean monthly flow of 300 cubic feet per second (cfs) at the S-79 structure, which at the time of MFL adoption in 2001 was determined necessary to maintain a balanced and healthy salinity regime to prevent an MFL exceedance (when the MFL is not met) and sustain submerged aquatic vegetation in the Caloosahatchee River Estuary (CRE).

The rule was reviewed, and a technical update document (SFWMD, 2003a) was produced. A combination of salinity models developed for the estuary, along with watershed modeling efforts, were used to define the optimum distribution of average monthly flows from S-79 (EST05). The defined optimum distribution provides the desirable salinity range in the geographic locations of key estuarine biota and achieves the minimum flows and levels salinity criteria. The document reported that 300 cfs at S-79 was insufficient to achieve the 10 ppt minimum flows and levels salinity criteria during periods of below average rainfall, when tributaries downstream of S-79 were contributing below average inflow. Subsequent analysis and documentation (including SFWMD, 2003b; Chamberlain & Doering, 2004) estimated that about 450 cfs is required from S-79 to ensure the minimum flows and levels salinity criteria is achieved under most downstream tidal flow conditions.

On the other extreme, average monthly flows below 450 cfs can produce high salinity conditions for tape grass upstream of Fort Myers and increase the probability of Minimum Flows and Levels Rule exceedance and violations. Mean monthly flows that fall well below 450 cfs for consecutive months that extend into late spring and early summer also result in increased oyster mortality. Hence the 450 cfs is the MFL for the study area.

3.5 Available Policy Documents

Note that WMPs are distinctly different than a variety of other plans developed for different purposes including water quality and TMDL plans, local mitigation strategy plans, flood insurance studies, floodplain management plans, stormwater master plans, local ordinances, and CRS plans. For example, a County's Local Mitigation Strategy (LMS) details all of the possible hazards that the incorporated and unincorporated areas need to be concerned about. These possible hazards are identified and rated on the potential for damage based on previous hazards of similar type. LMS plans follow the FEMA hazard mitigation definitions in an attempt to address issues that will reduce or eliminate exposure to hazard impacts, including flooding.

While the flood hazard event section of the Hendry County LMS relates directly to CRS activity 510, there are still more aspects of the LMS that can be used for WMPs. These reports are only produced at the County level but are adopted through resolutions into a municipal ordinance. Section 322 of the Disaster Mitigation Act of 2000 specifically addresses mitigation planning and requires state and local governments to prepare multi-hazard mitigation plans (and their resubmission every five years to stay eligible) as a precondition for receiving FEMA mitigation project grants and non-emergency assistance.

3.5.1 Water Quality Management Reports (TMDL/BMAP/SWIM Plans)

Section 303(d) of the Clean Water Act allows USEPA to assist states, territories, and authorized tribes in listing out any and all impaired waters and developing their respective TMDLs. FDEP checks the quality of watersheds across the State of Florida and determines if they are with an acceptable TMDL of pollutants. There are TMDLs in the eastern part of the watershed and a BMAP (Figure 50 in Section 3.1.2) created by the SFWMD. The impaired waters are shown in Figure 54. Caloosahatchee East/Clewiston subwatershed has TMDL limitations. Primarily the water quality issues involve fecal coliforms and nutrients.

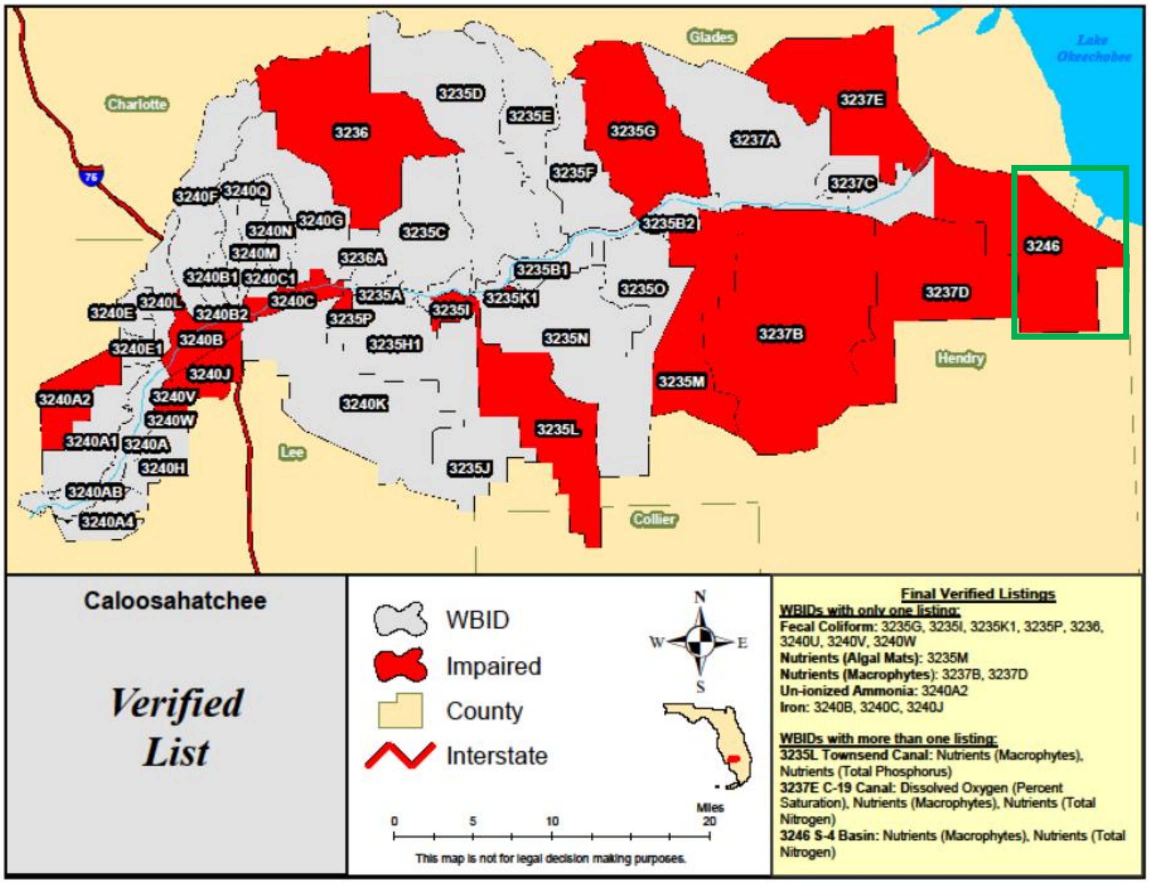

Figure 54. Impaired water bodies identified in the BMAP for the greater Caloosahatchee watershed (FDEP, 2009). The study area location is highlighted roughly in the green box.

Under the provisions of the Surface Water Improvement and Management (SWIM) Act, the SFWMD was required to develop and implement a SWIM plan to preserve, protect, and restore Lake Okeechobee. *The Lake Okeechobee SWIM Plan* was enacted in 1989 and was updated in August 1997. The environmental element recognized that adverse impacts to the Caloosahatchee Estuary occur when regulatory releases are made through C-43 Canal for lake flood protection purposes. Large, unnatural freshwater releases from the lake through the C-43 to the Caloosahatchee Estuary alter the estuarine salinity gradient and transport significant quantities of sediment to the estuary. Biota within the Caloosahatchee Estuary, and near-shore seagrass beds can be negatively affected by these high-volume discharges.

3.5.2 Flood Insurance Study

"A Flood Insurance Study (FIS) is a compilation and presentation of flood risk data for specific watercourses, lakes, and coastal flood hazard areas within a community. The FIS report contains detailed flood elevation data in flood profiles and data tables" (FEMA, 2020). FIS are encouraged by FEMA and commonly used to present flood risk data for specific waterbodies, lakes, and coastal flood hazard areas within a community.

Hendry County's FIS is within the same scope and provides details that can directly inform a WMP for Clewiston. Specifically, stipulations on the physical conditions of the floodway, water elevation, and the impact of waves from Lake Okeechobee as well as other water inputs help describe the natural conditions of the area (refer to Sections 2, 4, and 5 in the Hendry County FIS). Using only the descriptions found in the Hendry County FIS, Clewiston could develop a set of guidelines for stormwater regulations, low impact development (LID), erosion control, etc. that would be in-step with the FEMA directed standards. The maps were previously posted at:

www.hendryfla.net/HendryFloodMap.pdf

3.5.3 Floodplain Management Plan

There is no surface water management plan in the subwatershed study area.

3.5.4 Florida "Peril of Flood" Guidance

The 1000 Friends of Florida has a website for coastal resiliency (https://1000fof.org/) mainly focused on Tampa Bay. The study area is not included in the effort.

3.5.5 Comprehensive Plans

Refer to Section 3.1.4.

3.5.6 Unified Land Development Regulations (ULDRs)

Land development codes/comprehensive planning was discussed in Section 3.1.4, which is tied directly to the land development codes.

3.5.7 Stormwater Management Policies

The following Caloosahatchee East/Clewiston subwatershed communities have stormwater management plans:

- Hendry County - Stormwater Management section of Comprehensive Plan

3.5.8 Local Mitigation Strategies (LMS)

A county's LMS identifies potential hazards (including floods) and ranks them on a scale of potential for damage based on previous hazards of similar type. There is also a plan of action for responding to each potential event. FEMA requires these LMS reports and their resubmission every five years to stay eligible for funding (Section 322 of the Disaster Mitigation Act of 2000), which means that they are widely available. LMS follows FEMA hazard mitigation definitions in an attempt to address issues that will reduce or eliminate exposure to hazard impacts. While the flood hazard event section of LMS relate directly to CRS activity 510, there are still more aspects of LMS that can be used for WMPs. These reports are only produced at the county level but are adopted through resolutions into a municipal ordinance. Links for these are as follows:

- Hendry County –
    - https://www.hendryfla.net/2016%20LMS%20Binder.pdf
    - https://floridajobs.org/fdcp/dcp/hazardmitigation/MapsProfiles/Hendry/Hendry_profile_final.pdf

3.5.9 Intergovernmental Cooperative Agreements

There are no intergovernmental cooperative agreements in the basin. Both the City of Clewiston and Hendry County rely on the SFWMD for assistance with stormwater regulatory issues, as noted in their comprehensive plans.

3.4.10 Special Watershed Restoration Plans

One special regional plan directed from the federal government is the Comprehensive Everglades Restoration Plan (CERP), whose mission is to revert the altered south Florida watershed complex into a more natural state, thereby facilitating ecological restoration at a regional level while also maintaining drinking water resources. More information is available at https://evergladesrestoration.gov and https://www.sfwmd.gov/our-work/cerp-project-planning. This effort directly ties to any WMP effort within CERP's geography and mandates certain management criteria to various regulatory agencies accordingly.

The method by which the plan is enacted is succinctly detailed in the National Parks Service description of CERPs working order:

> "In recognition of the magnitude of the restoration effort and the critical importance of partnerships with state, tribal, and local governments, the intergovernmental South Florida Ecosystem Restoration Task Force (Task Force) was established by Congress in 1996. The Task Force uses a restoration framework to organize and assess this complex intergovernmental effort. It includes three strategic goals that address water (Goal 1), habitats and species (Goal 2), and the built environment (Goal 3). Efforts to achieve these goals include the Comprehensive Everglades Restoration Plan (CERP), a consensus plan approved by Congress specifically to reverse unintended consequences of the C&SF Project, and a host of additional projects to further restore the ecosystem's hydrology, improve water quality, restore natural habitats, and protect native species."

All three of these over-arching goals directly impact the execution of WMPs in the greater Caloosahatchee watershed. Clewiston, located proximally to both Lake Okeechobee and the Everglades Agricultural Area, is impacted by all three of CERP's mandates.

The Caloosahatchee Estuary BMAP was adopted in November 2012 (FDEP et al., 2013), following completion of a stakeholder driven process that identified projects constructed since 2000 or are planned to be built within the first five years after BMAP adoption (November 2012 - November 2017). Overall, the first five-year iteration is expected to reach approximately 40% of the required reductions for TN by 2017 based on projects submitted by stakeholders (17 entities). A copy of the BMAP (https://floridadep.gov/sites/default/files/caloosa-estuary-bmap-final-nov12.pdf) and its updates are available at http://www.dep.state.fl.us/water/watersheds/bmap.htm. Only Lee County has a BMAP at: https://www.leegov.com/naturalresources/WaterQuality/tmdls-bmaps at the County level that addresses Hendry Creek and Imperial River. None of these directly impact the Ninemile Canal subwatershed study area.

3.5.11 Stormwater Pollution Prevention Plans (SWPPPs)

Stormwater Pollution Prevention Plans (SWPPPs) identify primary sources of stormwater pollution at construction sites, best practices to reduce stormwater discharge from construction sites, and procedures to comply with construction permits. As part of the Clean Water Act, it is required that nearly all construction site operators engaged in clearing, grading, and excavating activities that disturb one acre or more, including smaller sites in a larger common plan of development or sale, must obtain a National Pollutant Discharge Elimination System (NPDES) permit for their stormwater discharges. Understanding the requirements of the SWPPP and the NPDES are helpful in addressing parts of a WMP with regards to stormwater and runoff management. No specific plan exists in the subwatershed. However, the County and FDEP have a TMDL BMAP that is enforced in the basin (see Section 3.1.2). The MS4 permitting process discussed in Section 3.5.9 replaces the NPDES permits for most of the communities in the study area.

3.5.12 Post-Disaster Redevelopment Plan

Some communities may decide to formalize a Post-Disaster Redevelopment Plan to facilitate long-term recovery following a disaster. A community's Post-Disaster Redevelopment Plan can address issues relating to the identification of key roles, personnel, and agencies for future land use and zoning of areas damaged by disasters. Key sections of Post-Disaster Redevelopment Plans that should be considered when developing a WMP are as follows:

- Mapping Hazard Risks. Aligns the need for geospatial hazard analysis and mapping efforts, which leads to more informed policy recommendations post-disaster.
- Protecting or Restoring Natural Areas. Focuses on the redevelopment process taking place in areas that are less sensitive to development, leaving areas more prone to disaster and allowing them to serve as a buffer or other mitigating effect.
- Funding through Capital Improvement Programs. The identification of funding can assist a community to implement well-managed growth and redevelopment.

Hendry County acts as the Emergency Manager for the County and has the emergency plan which is publicly available on the County's website:

- https://www.hendryfla.net/CEMP%20Base%20Plan%202019%20Final.pdf

3.5.13 Climate Adaptation Action Plan (CAAP)

The adaptation chapter of Florida's Climate Adaptation Action Plan (CAAP) is one that contains a series of 28 varying goals with strategies that work towards addressing the impacts of climate change as they relate to infrastructure, biodiversity, coastal areas, and oceans (Georgetown Climate Center, 2018). While all sections of the CAAP are significant, the topics of particular interest to the development of WMP are as follows:

- Coasts and Oceans. Recommends actions to improve overall coastal resilience to bolster both impact communities and ecosystems.

- Water. Identifies the impacts of climate change and how they relate to the water resources of the state. Recommends actions that would improve conservation measure and efforts to understand, quantify, and plan for uncertainties affecting water resources.
- Infrastructure. Identifies development strategies and engineering solutions that can reduce risks from tidal flooding, storm surge, stormwater-driven flooding, and related impacts of sea-level rise when updating coastal management elements of their comprehensive plans.
- Public Health and Emergency Preparedness. Recommends actions that would reduce public health threats from climate change and resilience against the impacts of climate change.

There is no climate action plan in the study area. The Southwest Florida Regional Planning Council created a climate change vulnerability action plan (https://www.swfrpc.org/wp-content/uploads/Projects/Ecosystem_Services/Vulnerability_Assessment_Final.pdf) that has information on the impacts of storms and storm related flooding in the study area.

3.5 Dedicated Funding Sources

Funding for stormwater improvement projects can come from various sources. Some can come from accumulating funds from stormwater fees. Borrowing of funds for implementation projects can be accomplished at low interest rates from the State Revolving Fund (SRF) loan program that finances the cost of construction of publicly owned water, wastewater, and stormwater facilities. Authority for the program is found in Chapters 62-622, 62-503 and 62-504 of the Florida Administrative Code. FDEP is charged with implementing the program. Generally, any local government entity is eligible to apply for SRF loans.

The concepts of Municipal Services Benefit Units (MSBUs), Municipal Services Taxing Units (MSTUs), a stormwater utility, or other funding option are available in the greater watershed. In Hendry County and Clewiston, use of stormwater utility fees or assessments as a dedicated funding source is available, but neither has taken advantage of this option. Clewiston should consider establishing some form of stormwater utility assessment to help fund their specific flood control needs.

USACE relies on ongoing federal funding from Congress to meets its obligations. The SFWMD has the ability to enact property taxes to meet its mission. As a result, there appears to be funding to meet some of the obligations for the regional watershed that will benefit Clewiston.

4.0 ASSESSMENT OF VULNERABLE AREAS

Defining flood risk due to compounding hydrographic influences is the central concern of this WMP. Modeling and assessment of vulnerability focused on the combination of a high water table elevation, heavy rains, and impervious conditions that can lead to localized nuisance flooding events. Through previous survey with local officials, the number of days of continuous nuisance flooding that the public will tolerate before that flooding is considered destructive is about 4 days (E Science, 2014).

For a large study area, small portions may actually be at risk. The point is to identify where further study might be needed. A screening tool accomplishes this goal applied to the subwatershed scale to designate areas that are susceptible to periodic flooding events during key design storms. Utilizing the information collected and analyzed in Chapters 1 and 2, and comparing to data in Chapter 3, vulnerability can be identified using this process.

4.1 Historical and Existing Challenges

There has been a total of 4 flood events officially reported in Hendry County between September 15, 1994 and February 28, 2009 (National Climactic Data Center of NOAA). These events resulted in no deaths or injuries. Based on previous occurrences, for future flood events, Hendry County could expect to see total flood insurance claims paid out around $500,000. On August 19, 2008, rainfall resulting from Tropical Storm Fay ranged between 7 to 10 inches over northern Collier, Hendry, and Glades counties near the path of the center of the storm. Isolated areas in northeastern Hendry and southeastern Glades counties received well in excess of 10 inches. Extensive flooding was observed over the areas with the highest totals, especially over Hendry and Glades counties. Hardest hit areas were the Felda and Montura areas in Hendry County where maximum rainfall amounts ranged from around 10 inches in Felda to as much as 12 to 15 inches in the Montura area. Property damages were estimated at $300,000. There have been no flooding events in the subwatershed or its surroundings in Hendry County since February 28, 2009. According to the 2020 Hendry County LMS, the City of Clewiston has 206 critical structures located in a storm wind zone, but 33 structures are located in the 100-year floodplain for a total of $24.9 million in value, which face an estimated $2.5 million in losses (building damage, contents loss, etc.) from flooding. Another issue is that 98.5% (n = 203) of the critical structures located in Clewiston are in the 18-ft reach dam break model area (Figure 55). As the dam system ages, the potential future risk to critical facilities located in its vicinity increases. Also, risk to critical facilities will increase as new critical facility structures are located or existing structures are designated as critical facilities in either the 18 foot reach or 21 foot reach area.

Figure 55. Hendry County critical facilities with evacuation zones map (Hendry County, 2020)

There are a series of historical challenges in the Caloosahatchee TMDL basin that impact the study area including the following:

1. Control of discharges to the Gulf of Mexico from Lake Okeechobee, which cause ecosystem damage, harmful algal blooms, and other water quality issues for the coastal ocean
2. Flooding near Lake Okeechobee and the coastal ocean
3. Development adjacent to the floodplain
4. C-43 storage as proposed in the Caloosahatchee Water Management Plan (SFWMD, 2000) is a useful solution to prevent a major flushing event
5. Water supply and flood protection are intertwined yet opposing issues throughout the greater watershed
6. Reconciling local and regional planning efforts
7. Water quality concerns with nutrient laden Lake Okeechobee water and runoff from agriculture

Pressure for development in the eastern portion of the greater watershed exacerbates effort to protect open space for land percolation of water. While regulations are in place to reduce the influx of stormwater, the challenges will continue with increasing population and development. In the eastern portion of the watershed, the major issues are associated with nutrient runoff and discharges from Lake Okeechobee that are regulated by USACE and SFWMD.

4.1.1 Existing Management Efforts in the Watershed

The entire basin is controlled by the SFMWD and USACE with the intent of reducing flooding within the water management district boundaries. Local governments have local stormwater utility infrastructure and planning/policy tools to reduce future flood potential as discussed in Chapter 3. Most of the major projects to date have been driven by the SFWMD. Table 6 shows the projects noted in the 2009 plan. Much of that plan focus, however, was on addressing water quality issues.

Table 6. Summary of the Caloosahatchee East/Clewiston subwatershed objectives/targets for the 2009 water quality improvement plan

Problem	Objective	Performance Measure/Indicator	Target
Excess freshwater discharges from Lake Okeechobee regulatory discharge events and local watershed runoff leading to an undesirable low salinity condition	Manage the frequency and duration of excess freshwater discharges to the CSE from the watershed	Number of times discharge from the watershed exceeds the High Discharge Criteria: 1. Mean monthly flow > 2800 cfs (14-day moving average) 2. Mean monthly flow > 4500 cfs	1. Limit mean monthly flow > 2800 cfs to 3 months or less over a 432-month period 2. Limit mean monthly flow > 4500 cfs to zero months over a 432-month period
Excess nutrient loads from surface water discharges leading to algae blooms and fish kills	Maximize N and P load reductions to meet anticipated TMDLs	Maximize load reductions and compare against TMDLs as appropriate	Meet TMDLs as established by FDEP
Increases in undesirable high salinity conditions due to insufficient surface water flows from the watershed leading to unfavorable conditions for estuarine organisms in the CRE	Manage watershed discharges to maintain a salinity range conducive to the ecological health of the CRE that includes maintaining salinity < 35 ppt for oysters at Shell Point and upstream and salinity < 10 ppt at Fort Myers location (Minimum Flows and Levels Rule)	Number of months that salinity envelope in the CSE is not met, due to little or no flow from watershed based on the low flow target of 450 cfs Use the Target Flow Index (TFI) based on EST05 flow time series (TFI assesses the level of divergence of each alternative from the desired flow distribution defined by EST05	Limit average monthly flows < 450 cfs from October – July TFI value of zero signifies perfect match to EST05 Progressively more negative index values are associated with flow deviations
Lake Okeechobee water levels falling below ecologically desirable levels	Maintain Lake Okeechobee water levels with a desirable range for ecological needs	Number of occurrences that the Lake Okeechobee minimum water level condition was not met during the 432-month period of record	Limit to no more than one occurrence every 6 years when Lake Okeechobee water levels fall below 11 ft NGVD for more than 80 days
Water supply cutbacks that affect the ability to meet existing and future municipal, industrial, and agricultural water supply needs in the region	Ensure plan does not adversely affect the Lake Okeechobee Service Area water supply demands	Evaluate the LOSA demand cutback volumes during 7 drought events and annual percentage of water supply demands not met during the period of record	Maintain or reduce the percent of LOSA cutbacks and the annual water supply demands not met

4.1.2 Critical Target Areas Identification

By modeling the subwatershed flood response to a 3-day, 25-year, 1-day, 10-year, and 1-day, 100-year storm events and further classifying flood risk as the probability of inundation, it is possible to identify critical target areas. These areas are particularly vulnerable to flooding and are subject to further study through a scaled-down modeling approach. The screening tool is first applied at the greater watershed level to provide an initial risk assessment focused on the hydrologic response to a rainfall event given the unique characteristics and features of the subwatershed or study area. At the greater watershed scale, flooding generally occurs around large waterbodies, namely the Gulf of Mexico (downstream), Caloosahatchee (downstream), and Lake Okeechobee (upstream). However, to prioritize funding for future mitigation and planning efforts at the local level, it is necessary to identify areas of concern within the subwatershed that are highly susceptible to flooding. The process is discussed later in Section 4.2, with results presented in Section 4.4.

4.1.3 Potential Preservation Areas

There are no potential preservation areas beyond what is currently protected in the study area.

4.2 Vulnerability Maps

4.2.1 Screening Tool

The screening tool utilizes topographic data from various sources (Section 2.1), water table elevations (Section 2.2) and surface water gauges (Section 2.3) downloaded from the SFWMD DBHYDRO website, tidal information for coastal areas obtained from the NOAA Current & Tides website (Section 2.3), soil maps obtained from the USDA (Section 2.4), and other key datasets, as described previously in Chapter 2. The design storms are discussed in Section 3.2. The reason this is critical is that to do any modeling (as required by the CRS program), a screening tool should be used to identify regions with a high risk of inundation based on multiple collected datasets and hydrological models. Figure 56 shows how the GIS layers interface in the tool and how they are combined for spatial analysis.

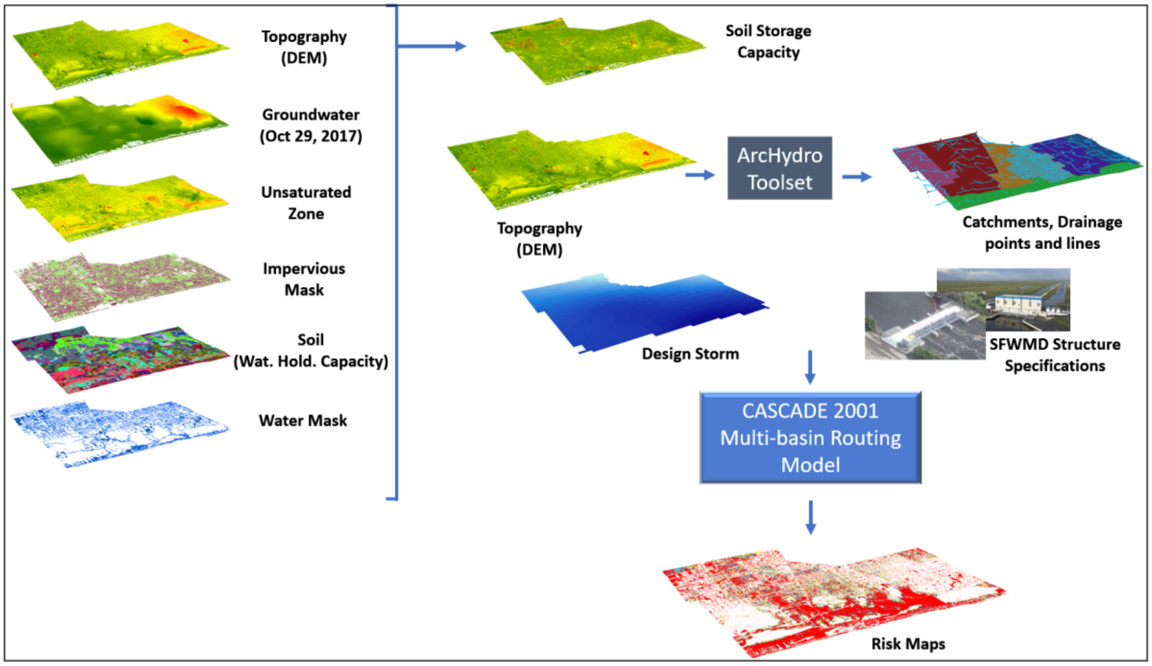

Figure 56. Screening tool methodology for creating flood risk maps

The model chosen for this screening tool is Cascade 2001, which is a multi-basin hydrologic/hydraulic routing model developed by the SFWMD to determine flooding scenarios for different storm events. The software creates a glass box where water rises to a certain level and then decreases. Running the simulation requires defining the basin (HUC or sub-HUC) and input of the following data:

- Area
- Portion of area above a given elevation
- Initial ground water stage
- Longest travel time for the runoff to reach the most distance point of discharge
- Ground storage as estimated from the USDA gridded National Soil Survey Geographic Database (gNATSGO)

  Ground storage ≈ (Water holding capacity) × (Surface elevation – GW elevation)
  = 2 × (AWS for a soil layer of 0-150 cm) / 150cm × (Surface elevation – GW elevation)

- Available water storage (AWS) for a soil layer of 0-150 cm
- Average amount of precipitation that can be stored in the soil layer

The output from the model is an elevation surface that can be used to develop a flood map for the study area. An example that depicts the spatial distribution of probabilities of flooding for the 3-day, 25-year storm event is shown in Figure 57.

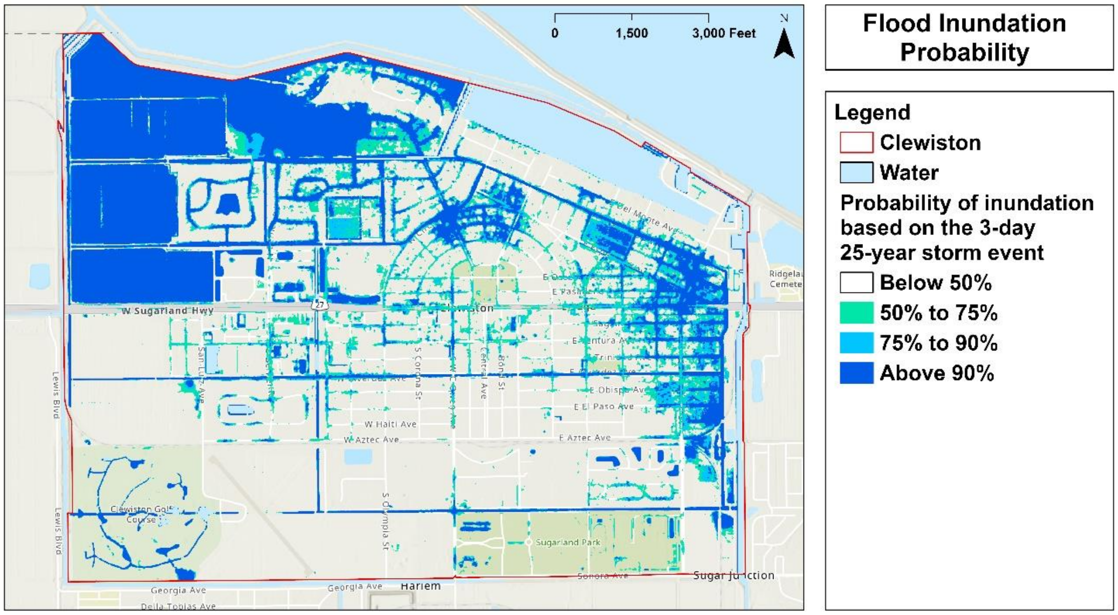

Figure 57. Flood risk map based on the 3-day, 25-year storm event for the City of Clewiston, FL, as processed by FAU using the current land use, as processed by FAU. Note this scenario assumes the drainage system is full, and therefore the ability to discharge water is limited.

4.2.2 Identification of Vulnerable Areas

Given the model assumptions and the Cascade 2001 outputs, the goal of this methodology is to produce a spatially-temporally quantified understanding of nuisance-destructive flood potential in the study area given observed values. Risk is a function of compounding geo-hydrological features, namely, surface water, groundwater, topography, build-out, and time of year. A GIS-based algorithm and spatial interpolation generated layers of the greatest observable hydrographic surfaces. These outputs were then compared with high resolution topographic LiDAR data to develop digital elevation models that reflect the observed risk landscape.

Figure 58 shows an example of the predicted flooding after the 3-day, 25-year storm event compared to the repetitive loss property maps superimposed to the GIS platform as a separate layer with the repetitive loss map. They compare favorably. The lighter blue areas represent land that floods, while the dark blue areas are classified as wetlands, lakes, rivers, streams, and other waterbodies.

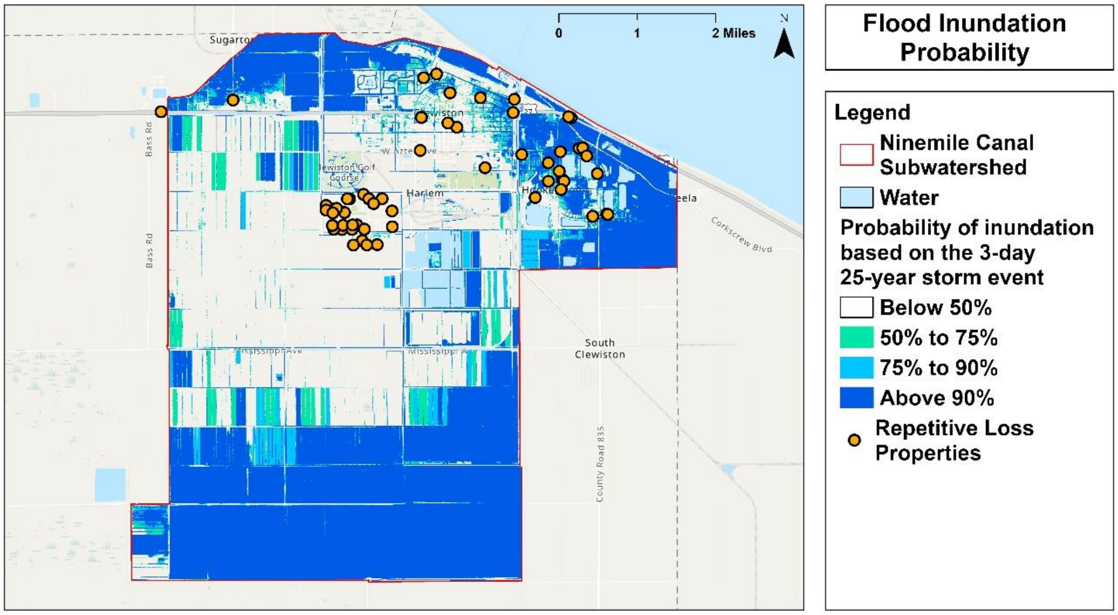

Figure 58. Flooded areas during a 3-day, 25-year storm in the study area, as processed by FAU. The gold dots indicate repetitive loss properties from 2004 to 2014, from FEMA files.

The spatial distribution of probabilities of flooding during the 1-day, 100-year storm event are shown in Figure 59. Just because a property is predicted to flood does not mean it always floods.

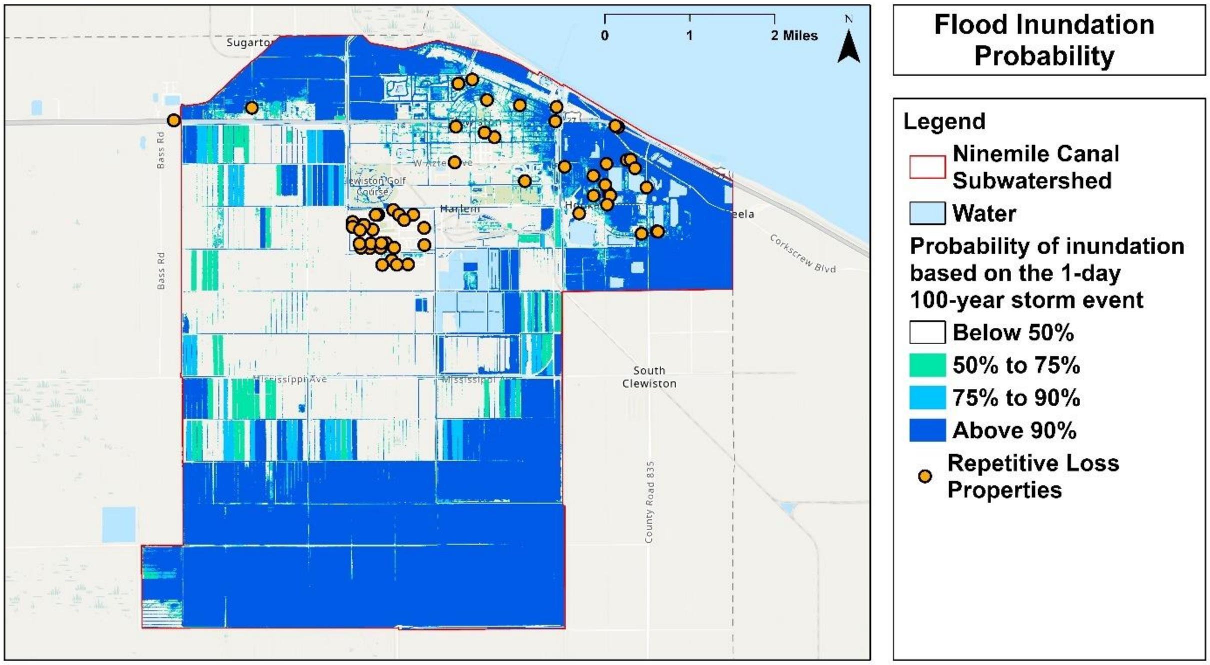

Figure 59. Probability of flood risk map for the study area for the 1-day, 100-year flood event, as processed by FAU. Note this scenario assumes the drainage system is full, and therefore the ability to discharge water is limited.

To evaluate flood vulnerability at this scale, the analysis starts with a binary flooding surface (0 = below 50% chance of flooding; 1 = above 50% flooding) based on output from the screening tool for a specified design storm. Next, attributes of that raster based on "VALUE = 1" query are extracted using *Extract by Attributes* tool. Then the *Batch Project* tool was used to map critical facilities data to the common coordinate system (NAD83 UTM Zone 17N), unit = meters. Then a field was added using *Add Field* for [PriorityTier] = assigned Tier #1-4 value from the DOR codes and [Area_sqmeter]. The critical facilities layers were then merged into a single layer to calculate the polygon geometry for [Area_sqmeter] using the *Merge* tool. Next, *Zonal Statistics as Table* is used to calculate the SUM of flooded values ("VALUE = 1") within each critical parcel. Output table has fields for SUM (i.e., total # of flooded pixels per critical parcel) and AREA in map units of square meters (since each pixel in the flooding surface has a cell size of 3-meters by 3-meters, each area is equal to the SUM value multiplied by 9 m^2). Using the *Join Field* tool, the SUM and AREA fields are joined to the merged critical facilities layer based on a key attribute, first renaming these fields for clarity (e.g., AREA_FLOODED_3d25y). Once all field data is included, the next step involves using *Export Table* to export the dataset as a CSV file. Note that non-flooded parcels have zero flooded area, so they receive a <Null> value from the zonal statistics tool. To replace null values with zeros, we use *Calculate Field* in the attribute table along with the following Python expression (replacing the respective field name): "0 if !AREA_FLOODED_3d25y! is None else !AREA_FLOODED_3d25y!". Next, the CSV file is saved as an Excel Workbook (.xlsx). The Range is converted to an Excel Table, and the columns are rearranged in the desired order. Finally, the "percent-flooded" columns are calculated as follows:

- PCT_FLOODED_3d25y = ([@[AREA_FLOODED_3d25y]]/[@[TotalArea_sqmeter]])*100
- PCT_FLOODED_1d100y = ([@[AREA_FLOODED_1d100y]]/[@[TotalArea_sqmeter]])*100

After this calculation, the table is sorted to show the higher priority tiers and higher percent-flooded values first. To reduce the number of critical facilities shown in the final table, a filter was created to show only critical facilities with 10% or more flooded area in the parcel during both storm events. Records with duplicate parcel ID numbers were removed from the table. The results of this procedure are discussed in Section 5.2 of this document.

With respect to dams and levees, for purposes of the NFIP, FEMA only recognizes systems that meet, and continue to meet, minimum design, operation, and maintenance standards that are consistent with comprehensive floodplain management criteria. The Code of Federal Regulations, Title 44, Section 65.10 (44 CFR 65.10) describes the information needed for FEMA to determine if a levee system reduces the risk from the 1% annual chance flood. FEMA has accredited levees and Provisionally Accredited Levees (that have a specified timeframe to obtain the necessary data to confirm the levee's certification status). If a levee system no longer meets Section 65.10, FEMA will de-accredit the levee system and issue an effective FIRM showing the levee-impacted area as a SFHA. FEMA coordinates its programs with USACE, who may inspect, maintain, and repair levee systems. USACE has authority under Public Law 84-99 to supplement local efforts to repair flood control projects that are damaged by floods. Like FEMA, USACE provides a program to allow public sponsors or operators to address levee system maintenance deficiencies. Failure to do so within the required timeframe results in the levee system being placed in an inactive status in the USACE Rehabilitation and Inspection Program. Levee systems in an inactive status are not eligible for rehabilitation assistance under Public Law 84-99. FEMA coordinated with USACE, the local communities, and other organizations to compile a list of levees that exist within Hendry County for the FIS. Clewiston has portions of the left bank of the Lake Okeechobee levee owned by USACE covered under Public Law 84-99 in FIRM panel 12051C0143E.

4.3 Future Challenges of Sea Level Rise and Climate Change

Global observations from satellites and long-term data collection have made it possible to document and analyze patterns of change in the Earth's climate. Scientific analysis of the impact of these changes has helped to improve the understanding of future flood hazard driving forces and long-term impacts on human activities and watershed master planning (http://www.research.noaa.gov/climate/t_observing.html). Examples of impacts are rising global average air and ocean temperatures, increased and earlier snow and ice melt, shorter subtropical rainy seasons, shifted seasons, sea level rise, and greater variations in temperature and precipitation (IPCC, 2013; Freas et al., 2008; Marshall et al., 2004; Bloetscher et al., 2010). Marshall et al. (2004) specifically focused on the Florida peninsula to predict changes in rainfall and warmer temperatures but interspersed lower low temperatures due to the potential loss of wetlands.

Figure 60 shows the average accumulated precipitation prior to 1973 versus 1994. Marshall et al. (2004) state that "because sea breezes are driven primarily by contrasting thermal properties between the land and adjacent ocean, it is possible that alterations in the nature of land cover of the peninsula have had impacts on the physical characteristics of these circulations." Their modeling suggests that land use changes have reduced total rainfall by 12% since 1900, attributed mainly to the loss of wetlands. This confirms the finding of Pielke (1999) who reported that "development has exacerbated their severity since landscape changes over south Florida have already appeared to have reduced average summer rainfall by as much as 11%" (Pielke, 1999). Future changes in climate will add to the existing impacts, at a time when the population of the state is expected to nearly double by 2030. Additional research and high-resolution climate modeling for the Florida peninsula and local jurisdictions is needed to help guide long-term plans like WMPs.

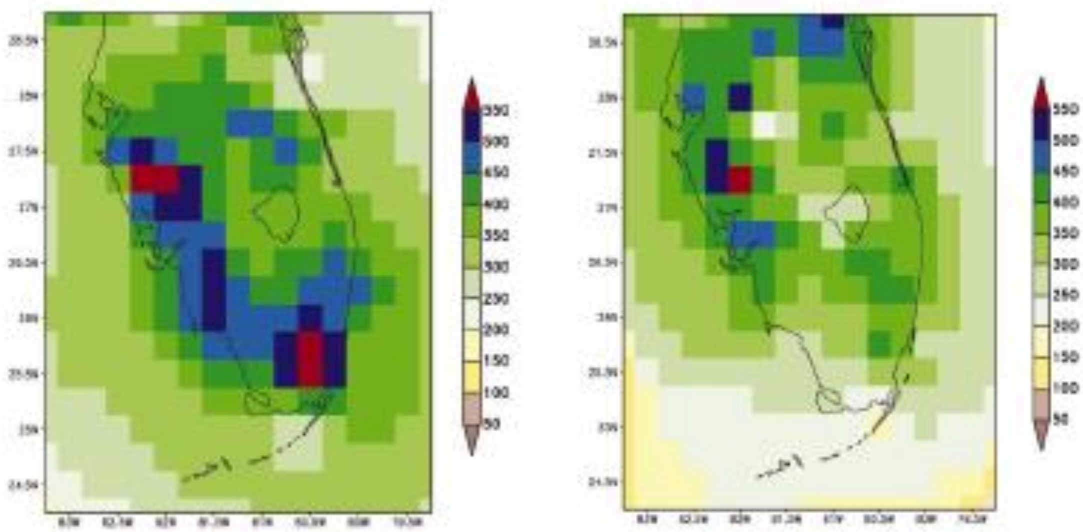

Figure 60. Accumulated precipitation 1973 (left) and 1994 (right) (Marshall et al., 2004)

Marshall et al. (2004) report that "while there is a great deal of spatial variability in these values, the results show that daytime maxima generally increased with the use of the 1993 land cover." When converted to heat flux, Marshall et al. (2004) noted that "the latent heat flux difference exhibits a consistent decrease of nearly 10% of the grid-average pre-1900 value." Figure 61 shows the change in average rainfall and the change in average temperature from 1924 to 2000. Note the reversed trend (higher temperatures and lower rainfall), which means groundwater inputs are reduced (Marshall et al., 2004) leading to the conclusion that land use changes (loss of wetlands) contribute to the higher variability of temperature.

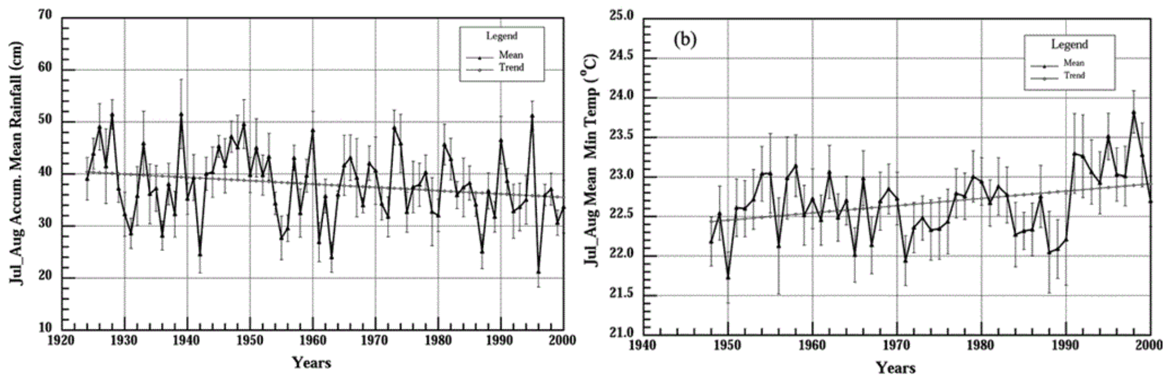

Figure 61. Change in average rainfall and change in average temp 1924 to 2000. Note the reversed trend, which means groundwater input variability is lessened (Marshall et al., 2004)

NOAA and IPCC (2013) predictions suggest that by 2100, global temperatures will be on the order of 2-3°C (3-5°F) higher than current values. The results of these climate changes are likely to: 1) threaten the integrity and availability of fresh water supplies and 2) increase the risk of flooding, not only in the low-lying coastal areas, but also in the interior.

4.3.1 NOAA Intermediate High Scenario for the Study Area

The NFIP proposes the use of the NOAA intermediate high projection for sea level rise scenario analyses. However there is limited tidal data for the greater Caloosahatchee basin. Instead the City of Fort Myers, which is most directly affected by sea level rise, uses the projection that NOAA (2017) created for Pensacola, FL (Figure 62), which indicates a 6 ft rise by 2100. Nevertheless, this study area is not coastal and is therefore not directly impacted directly by sea level rise.

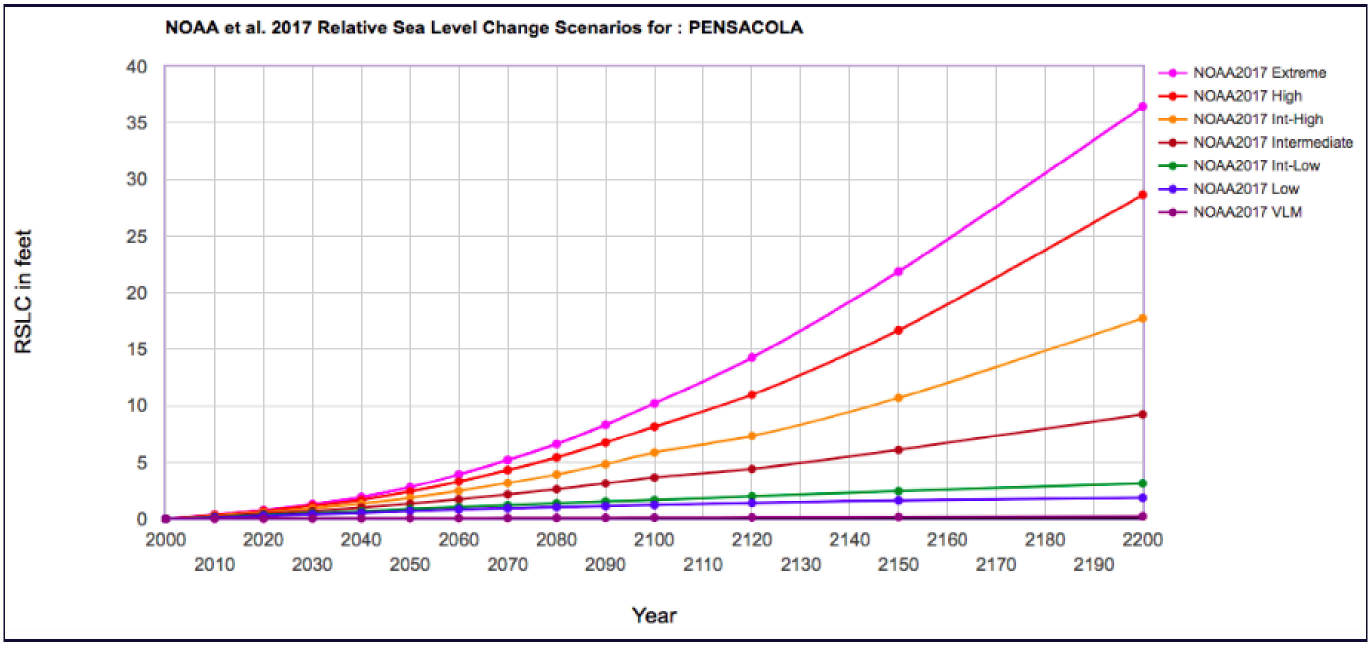

Figure 62. NOAA projection of sea level rise used by the City of Fort Myers (from Pensacola, FL) (Downloaded from https://www.u-surge.net/fort-myers.html)

4.3.2 Potential Sea Level Rise Impacts

The study area is inland and is not expected to experience sea level rise impacts.

4.4 Modeling Results

A series of maps that depict risk of flooding in the study area based on the following scenarios using the current land use with the system at full capacity:

1. 3-day, 25-year storm event (Figure 63)
2. 1-day, 100-year storm event (Figure 64)
3. 1-day, 10-year storm event (Figure 65)

The design storm simulation using the 3-day, 25-year event determined that floodwaters would rise to a maximum headwater height of 15.82 feet NAVD88. Under the current land use scenario, approximately 35% of Clewiston's total area, or 1.58 mi^2, has ground surface elevations below the maximum headwater height, and would therefore be expected to be inundated during a 3-day, 25-year design storm. The flooded areas include agricultural lands in the south and northwest as well as wetlands in the north. Flooding in the eastern portion of the city is of more concern as it poses a threat to residential housing, commercial businesses, and existing critical infrastructure. The risk associated with study area's flooded zones was classified as the probability of inundation, as shown on the map in Figure 63.

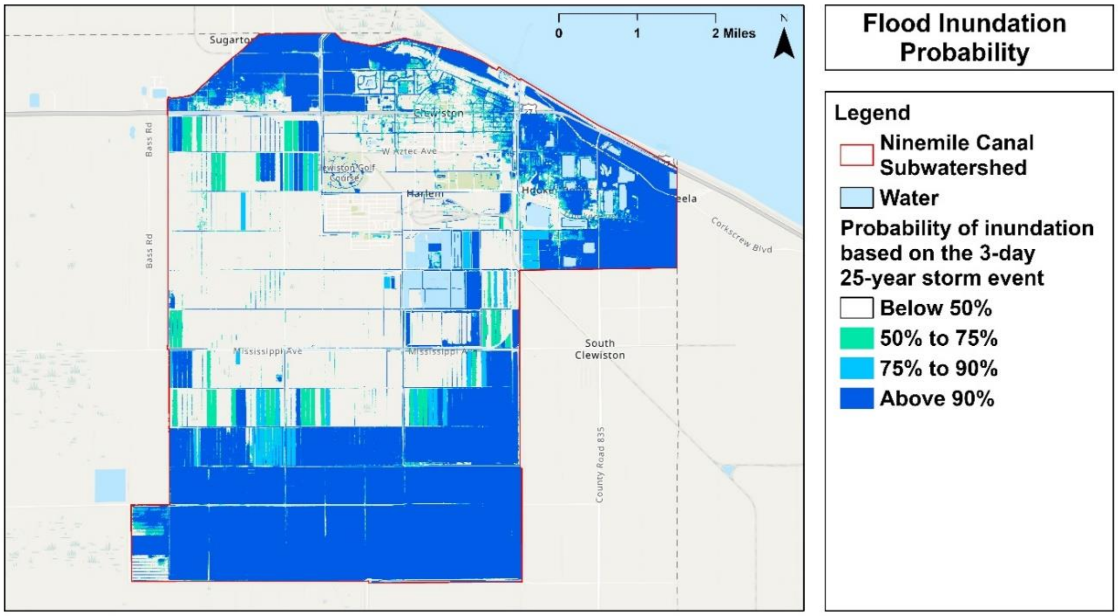

Figure 63. General locations of flood risk in the study area, based on the 3-day, 25-year storm, as processed by FAU. Note this scenario assumes the drainage system is full, and therefore the ability to discharge water is limited.

For comparison, 41.5% of Clewiston's total area, or 1.87 mi^2, has ground surface elevations below the maximum headwater height of 16.1 ft, and would therefore be expected to be inundated during a 1-day, 100-year design storm (Figure 64).

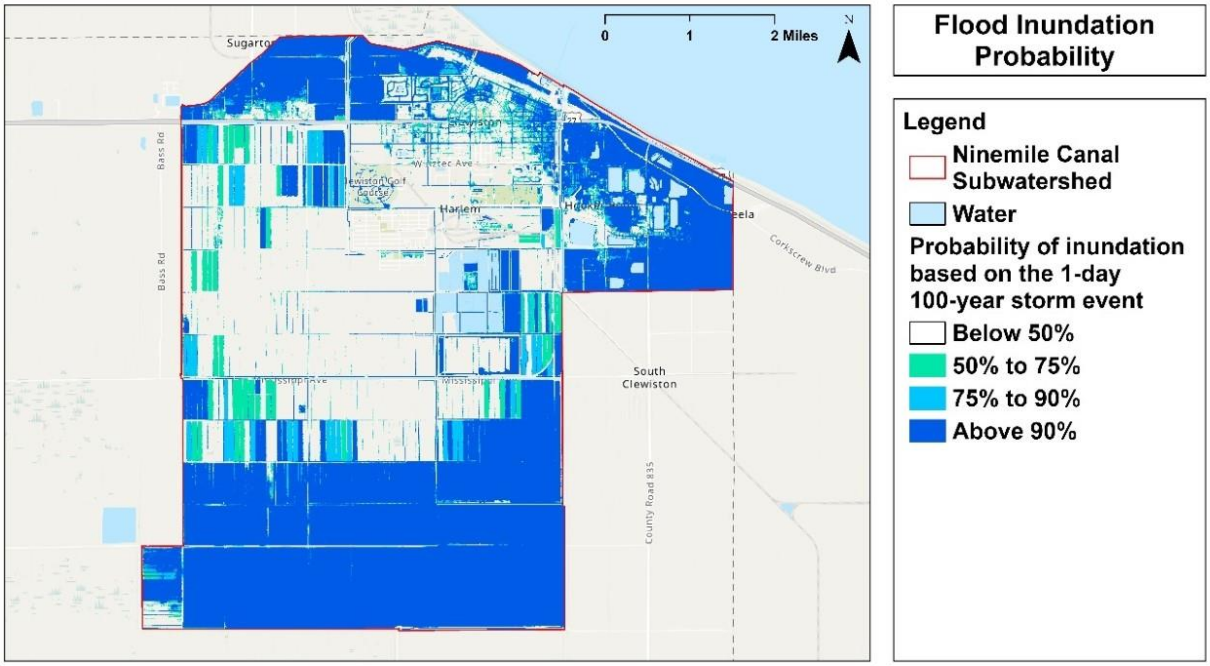

Figure 64. Flood risk map based on the 1-day, 100-year storm event for the study area, as processed by FAU using the current land use

Approximately 20% of Clewiston's total area, or 0.9 mi^2, has ground surface elevations below the maximum headwater height of 14.8 ft, and would therefore be expected to be inundated during a 1-day, 10-year design storm (Figure 65).

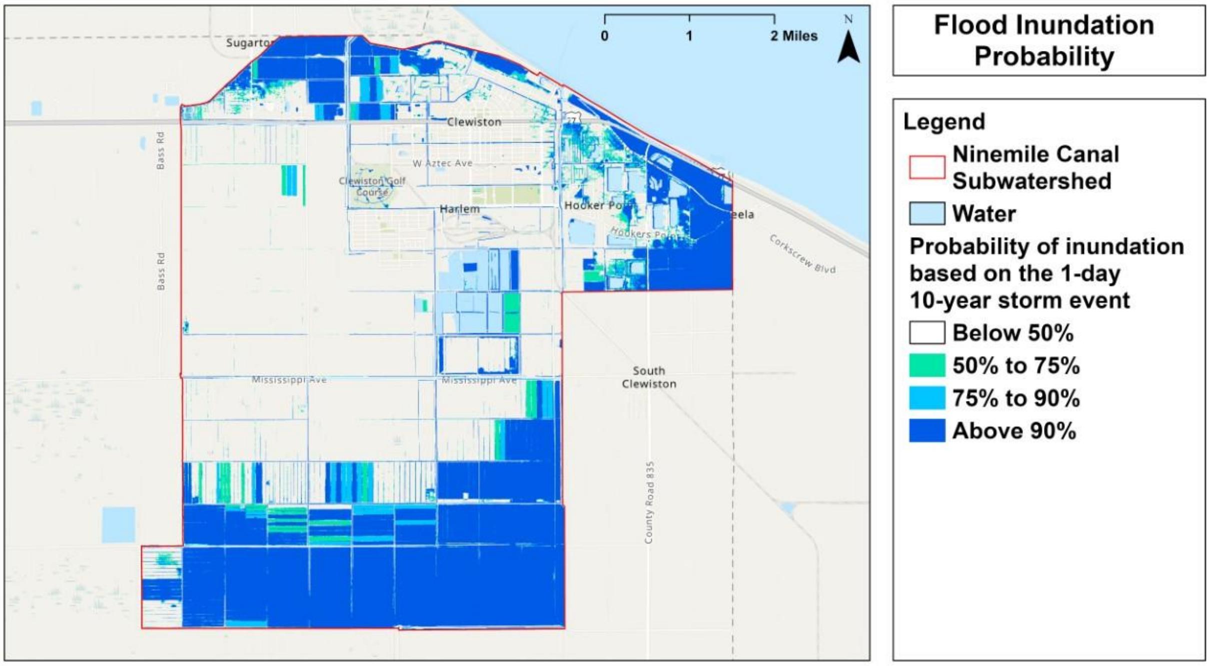

Figure 65. Flood risk map based on the 1-day, 10-year storm event for the study area, as processed by FAU using the current land use

Table 7 compares the three storm events in terms of the maximum headwater height, the total flooded areas, and the percent of the study area flooded utilizing the current land use scenario.

Table 7. Comparison of flooding in the study area during design storm events using current land use.

Design Storm Event	Maximum Headwater Height (ft)	Flooded Area (sq mi)	Percent Flooded
1-day 10-year	14.8	13.2	38.4%
3-day 25-year	15.8	18.5	53.7%
1-day 100-year	16.1	20.2	58.6%

The next series of maps depict the risk of flooding in the study area based on the following scenarios using the projected future land use with the system at full capacity:

1. 3-day, 25-year storm event (Figure 66)
2. 1-day, 100-year storm event (Figure 67)
3. 1-day, 10-year storm event (Figure 68)

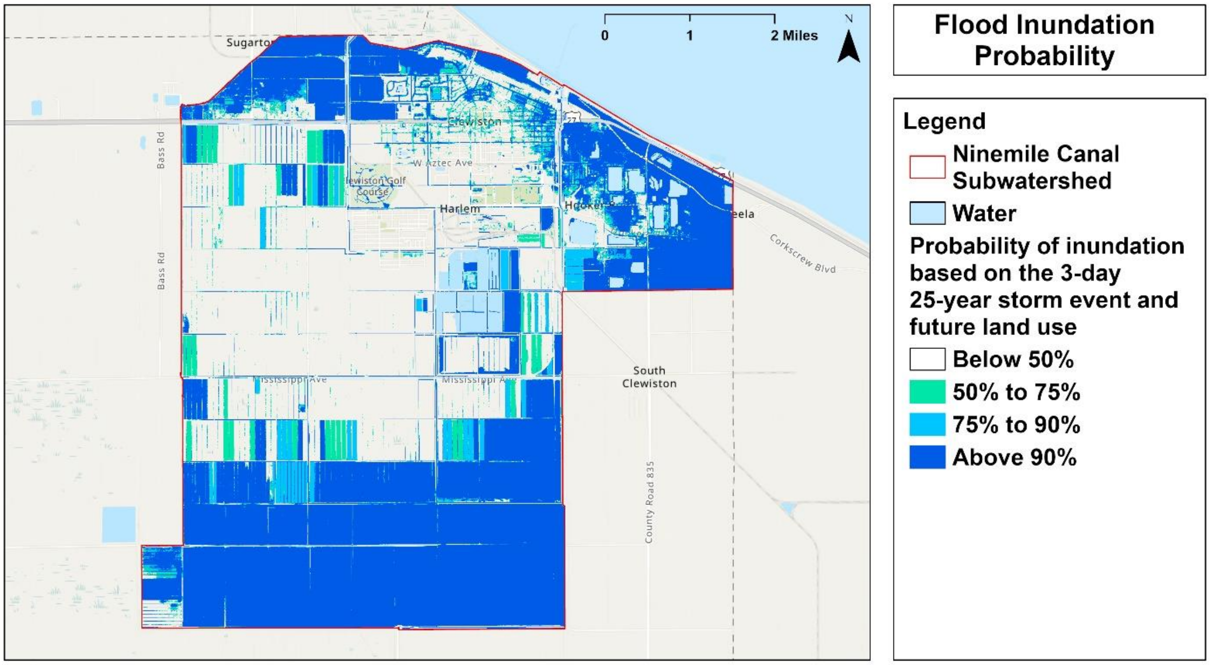

Figure 66. Flood risk map based on the 3-day, 25-year storm event for the study area, as processed by FAU using the projected future land use

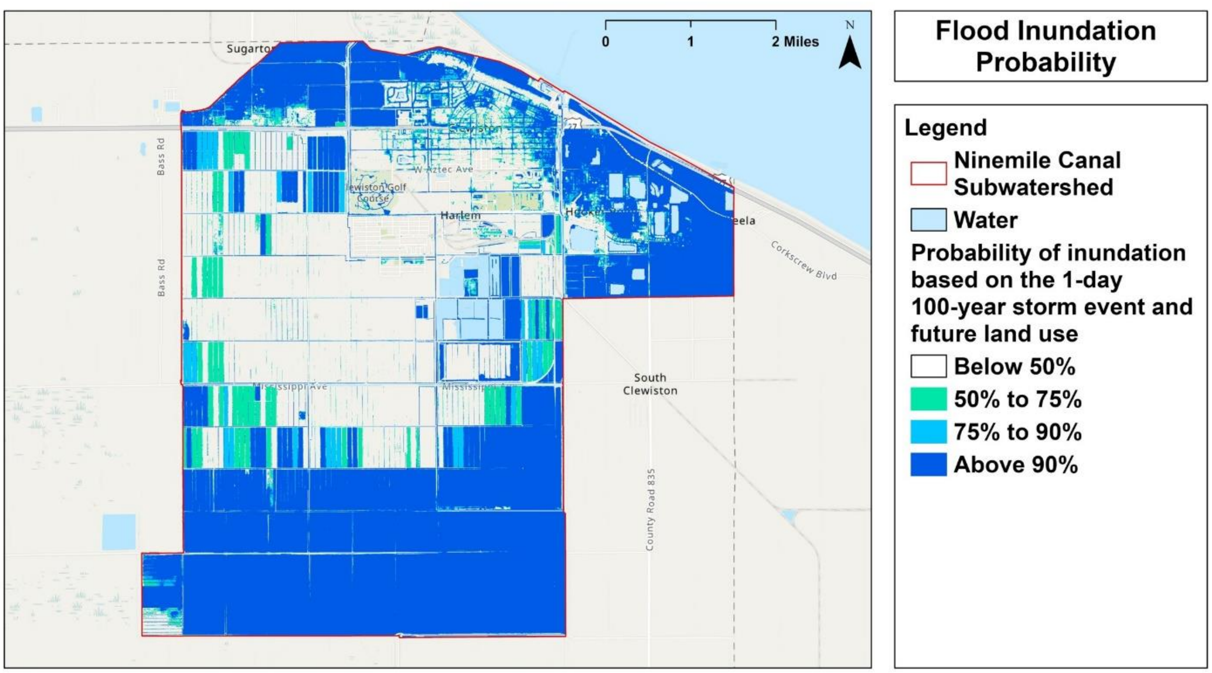

Figure 67. Flood risk map based on the 1-day, 100-year storm event for the study area, as processed by FAU using the projected future land use

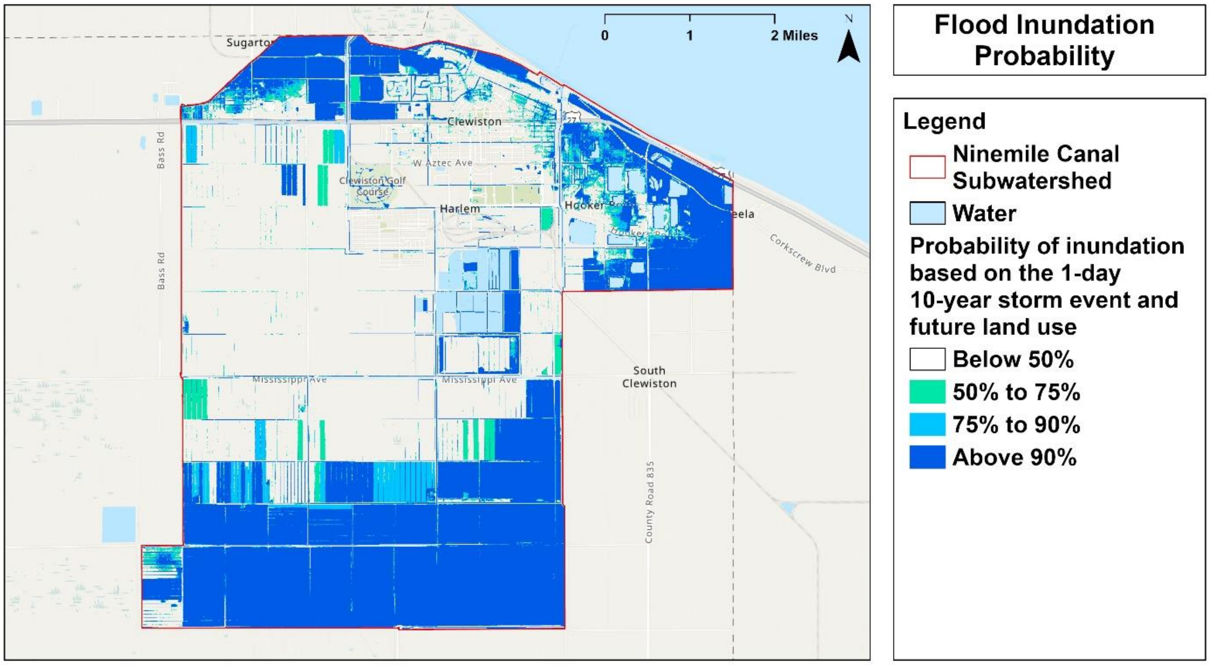

Figure 68. Flood risk map based on the 1-day, 10-year storm event for the study area, as processed by FAU using the projected future land use

Table 8 compares the three storm events in terms of the maximum headwater height, the total flooded areas, and the percent of the study area flooded utilizing the projected future land use scenario.

Table 8. Comparison of flooding in the study area during design storm events using the projected future land use.

Design Storm Event	Maximum Headwater Height (ft)	Flooded Area (sq mi)	Percent Flooded
1-day 10-year	15.3	15.7	45.7%
3-day 25-year	15.9	18.7	54.5%
1-day 100-year	16.2	20.7	60.2%

Note that as a part of the investigation, a comparison of the 3-day, 25-year and the 1-day, 100-year events the Caloosahatchee basin was conducted. Three sub-basins for Caloosahatchee were analyzed separately. Table 9 shows the areal mean of the precipitation from the two different scenarios. The 1-day 100-year precipitation for the three sub-basins is slightly higher than the 3-day 25-year precipitation. The average percentage of increase for the three sub-basins is +8.0%.

Table 9. Precipitation inputs (in inches) for sub-basins to compare flooding between the 3-day, 25-year and the 1-day, 100-year design storm events

Subbasin	**3-day 25-year**	**1-day 100-year**	**Δ**	**% Change**
East Caloosahatchee	9.16	10.24	+1.08	+11.8%
West Caloosahatchee	10.01	10.56	+0.55	+5.5%
Tidal Caloosahatchee	10.64	11.36	+0.72	+6.8%

Two different precipitation scenarios were used to drive the Cascade 2001 model to simulate flooding in the local regions. The 1-day, 100-year design storm simulation yields a higher high-headwater elevation for all three sub-basins (Table 10). The average increase of the high-headwater elevation is 0.35 feet for the Caloosahatchee basin. The value of one standard deviation (SD) in the inundation modeling suggested by NOAA for the coastal vulnerability assessments is 0.46 ft (NOAA, 2010), which is the value of modeling uncertainty we adopted in our study. The comparison between the two rainfall scenarios shows that the difference of high-headwater elevation from the two scenarios is within the one standard deviation (SD) in the inundation modeling, therefore, the 3-day, 25-year and the 1-day, 100-year design storms are considered to generate essentially the same level of flooding within the inundation modeling uncertainty. Note that since Romah (2011) determined that the best LiDAR available has a vertical accuracy of +/- 4.6 inches (0.4 ft), the difference between design storms is also generally within the error of the LiDAR data.

Table 10. High headwater height (feet) results from Cascade 2001

Subbasin	**3-day 25-year**	**1-day 100-year**	**Δ**
East Caloosahatchee	15.82	16.27	+0.45
West Caloosahatchee	10.53	10.79	+0.26
Tidal Caloosahatchee	6.94	7.27	+0.33

The impact of new development which relates to WMP2 shows that the projected future peak is not greater than current value (Table 11).

Table 11. Effect of future land use on the 1-day, 100-year simulation in the study area

Scenario	**Cascade 2001 Simulation High Headwater Height (ft)**
Current Land Use	16.11
Future Land Use	16.19

5.0 INVENTORY OF POTENTIAL SOLUTIONS

Once watershed master planning assessments are prepared and strategies (both adaptive and hardening) are identified and evaluated, decisions must be made to implement the priority projects. At the center of these planning efforts should also exist the provision for an adequate drainage system, designed to accommodate an increased volume of water and/or increased peak flows.

5.1 Toolbox with Design Guidelines

The process of identifying potential mitigation measures to implement begins with narrowing down the feasible engineering alternatives using threshold criteria and quantifiable selection criteria that include measures of effectiveness, cost, and added benefit to the community. The toolbox describes a variety of strategies that could be used to improve potential flood management conditions. They are community-specific and most require significant engineering and planning to determine the most efficient configuration to achieve the community's goals. Hard infrastructure systems are usually the first systems to be impacted because they are built at lower elevations than the finished floor of structures. In addition, many infrastructure systems are located within the roadways (water, sewer, stormwater, power, phone, cable tv, internet, etc.). At present, most roadway base courses are installed above the water table. If the base stays dry, the roadway surface will remain stable. As soon as the base is saturated, the roadway can deteriorate.

Catastrophic flooding should be expected during heavy rain events if there is nowhere for the runoff to go. Considerations for enhancing resiliency include retrofitting, material protective measures, rehabilitation and, in some cases, relocation of facilities to accommodate sea-level rise impacts. As they are related, groundwater is, similarly, expected to have a significant impact on flooding in these low-lying areas because of the loss of soil storage capacity. The NRCS National Handbook of Conservation Practices (www.nrcs.usda.gov/technical/standards/nhcp.html) provides a list of practices applicable to rural and farming areas. USEPA's National Management Measures guidance documents should be consulted for information about controlling nonpoint source pollution (www.epa.gov/owow/nps/pubs.html) in mining, agriculture, forestry, habitat alteration, marinas, transportation infrastructure, urban areas, wetlands, and riparian zones. The use of native plants that require minimal irrigation is appropriate, see following link for possible plants (http://floridayards.org/fyplants/).

For this document, 36 solutions referred to as the "Periodic Table" menu of green and grey infrastructure technologies (Figure 69) are presented. The menu is organized to address various flooding types, from *pluvial* (rainfall and runoff mitigation in upland areas), *fluvial* (runoff, high ground water, and surface water management in low-lying flood prone areas), *tidal* (flooding associated with storm surge, high ground water, and tidally influenced), and *all* (applies across the spectrum). Table 12 outlines each of these options, their benefits, and limitations.

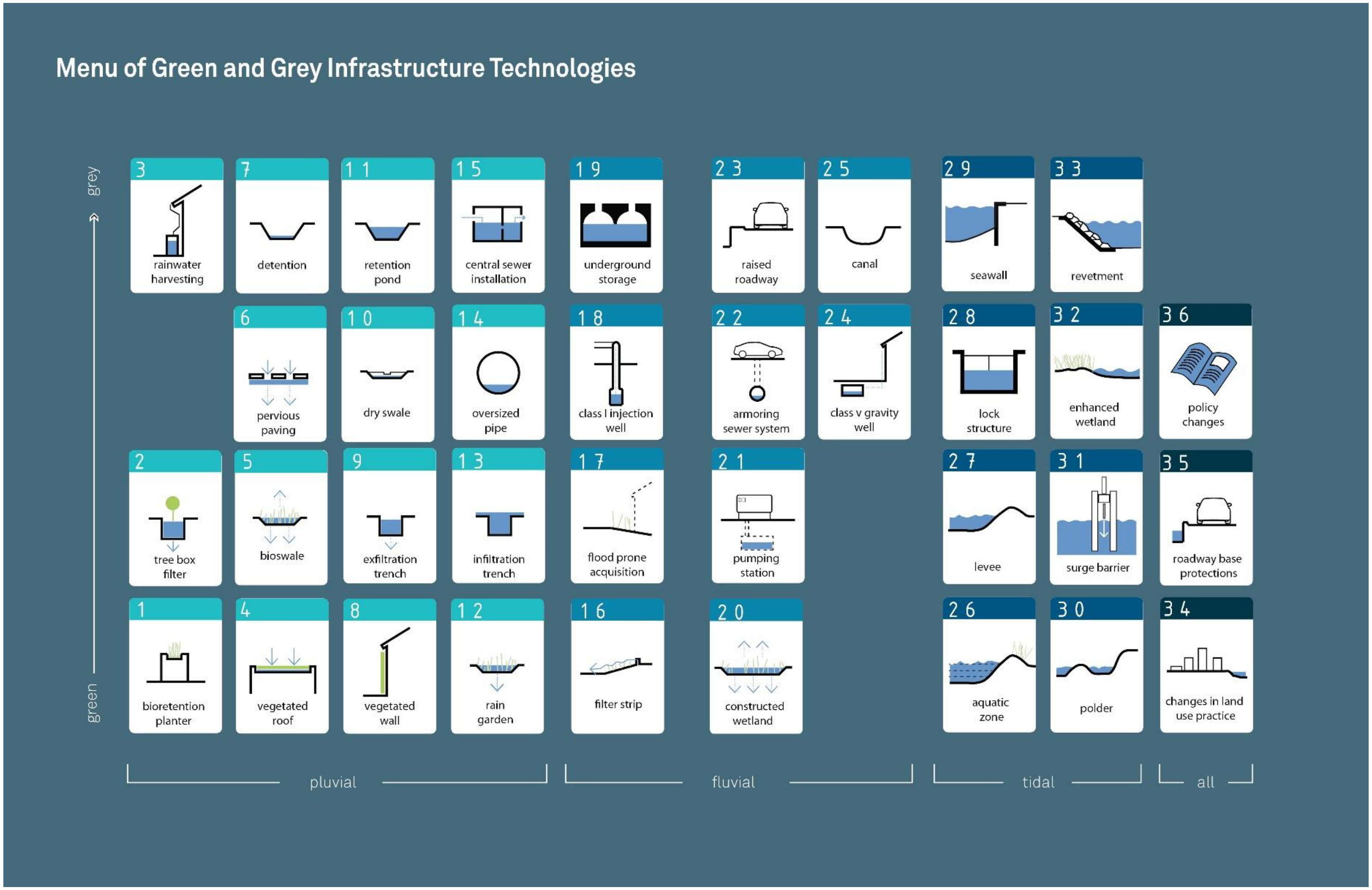

Figure 69. "Periodic table" menu of green and grey infrastructure technology options.

Table 12. Summary of benefits, costs, and barriers for each of the engineering alternatives in the toolbox

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Green	Bioretention planter	Local, small scale, easily implemented in developed areas	Protects property, treats runoff	$2500 each	Limited volume disposed of, so many are needed, maintenance
Green	Tree box filter	Local, small scale, easily implemented in developed areas	Protects property, treats runoff	$2500 each	Limited volume disposed of, so many are needed, maintenance
Green	Rainwater harvesting	Local, small scale, easily implemented in developed areas	Protects property, treats runoff	Under $5,000	Limited volume disposed of, so many are needed, maintenance
Green	Vegetated roof	Specific to a building, absorbs water, reduces runoff	Protects property, treats runoff	$100/sf	Requires irrigation if insufficient rainfall occurs Requires runoff control if too much rainfall occurs
Green	Bioswale	Parking lots, runoff from development - primarily treatment for discharge to another system	Protects property, treats runoff	$20K/acre	Maintenance, limited volume disposed of, used mostly for treatment
Gray	Pervious paving	Parking lots, patios, driveways, anything except paved roads due to traffic loading	Reduces roadway and parking lot flooding	$10-20/sf, requires bumpers and sub-base to maintain paver integrity	Must be maintained via vacuuming or the perviousness fades after 2-3 years
Green	Detention	Common for new development, but difficult to retrofit; limited to open areas	Removes water from streets, reduces flooding	$200K/acre	Land availability, maintenance of pond, discharge location Uses up land that could otherwise be developed

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Green	Vegetated wall	Used on walls of buildings and retaining walls	Protects property, treats runoff	$30/sf	Requires irrigation if insufficient rainfall occurs Requires runoff control if too much rainfall occurs
Gray	Exfiltration Trench	Any low-lying area where stormwater collects and the water table is more than 3 ft below the surface; densely developed areas where retention is not available, roadways	Excess water drains to aquifer, some treatment provided	$250/ft	Significant damage to roadways for installation, maintenance needed, clogging issues reduce benefits
Green	Dry Swale	Parking lots, runoff from development - primarily treatment for discharge to another system	Protects Property, treats runoff	$200K/mile	Maintenance, limited volume disposed of, mostly for treatment
Green	Retention Ponds	Common for new development, but difficult to retrofit; limited to open areas	Removes water from streets, reduces flooding	$200K/acre	Land availability, maintenance of pond, discharge location Uses up land that could otherwise be developed
Green	Rain Gardens	Local, small scale, easily implemented in developed areas	Protects property, treats runoff	$20K/acre	Limited volume disposed of, so many are needed, maintenance
Gray	Infiltration Trench	Low lying areas that collect stormwater, but the water table is just below the surface meaning that retention and exfiltration trenches will not work properly	Excess water is drained to pump stations, creating soil storage capacity to store runoff, soil treatment	$250/ft plus pump station	Significant damage to roadways for installation, maintenance needed, clogging issues - must discharge somewhere (pump station, detention pond)

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Green	Oversized pipes	Local solution - not watershed level, holds water to reduce flooding	Protects property and roadways	$350/ft of more	Sediments, maintenance needs, lack of means to flush, cost
Gray	Central sewer installation	All areas where there are septic tanks. Mostly a water quality issue	Public health benefit of reducing discharges to lawns, canals, and groundwater from septic tanks	$15,000 per household	Cost, assessments against property owners, property rights issues
Green	Filter strips	Localized	Protects property, treats runoff	$50K/mile	Does not address flooding, treatment/water quality measure
Green	Flood prone property acquisition	Regional agency - could be any low-lying areas	Removes flood prone areas from risk	$2K-$100K/acre depending on whether it is already developed	Difficult to implement if occupied, issues with willing sellers, cost, lack of funds for acquisition
Gray	Class I injection wells	Any low-lying area where stormwater collects, and there is sufficient land to permit, install and operate a Class I well - limited	Means to drain neighborhoods - potentially large volumes	$3-6 million depending on size/depth	Needs baffle box, injection zone may not be available, requires a permit, may compete with water users
Green	Underground storage	Common for new developments, but difficult to retrofit	Storage of excess runoff from rainfall, can be used for irrigation, can sit under parking lots, unobtrusive	$2/gallon	If the tank is full, there is no storage

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Green	Constructed wetlands	Where there is low lying flood prone land that can be converted into wetlands	Reduces flooding by providing a low-lying area for water to go	$200-$1M/acre	Water quality, permitting, monitoring costs, maintenance
Gray	Pump stations	Any low-lying area where stormwater collects, and there is a place to pump the excess stormwater to such as a canal; common for developed areas	Removes water from streets, reduces flooding	Start at $1.5 to 5 million each, number unclear without more study	NPDES permits, maintenance cost, land acquisition, discharge quality
Gray	Armored sewer systems	Any area where gravity sanitary sewers are installed	Keeps stormwater out of sanitary sewer system and reduces potential for disease spread from sewage overflows	$500/manhole	Limited expense beyond capital cost
Gray	Raised roadways	Limited to areas where redevelopment is occurring areawide due to ancillary impacts on adjacent properties	Keeps traffic above floodwaters, access for emergency vehicles, commerce	$2 - 4 million/lane mile	Runoff, cost, utility relocation
Gray	Class V gravity wells	Any low-lying areas where stormwater collects and is located where saltwater has intruded the surficial aquifer beneath the site	Means to drain neighborhoods, limited volume	$250K each	Needs baffle box, limited flow volume (1 MGD), zone for discharge may not be available, permits, water supply wells
Gray	Canals	Limited	Means to drain neighborhoods, provides treatment of water	$2 million/mile	Land area, flow volume, maintenance, ownership, capacity issues due to sea level rise pressure

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Green	Aquatic zones	Any low-lying or flood-prone area that is undeveloped and can store large volumes of water	Place to store large volumes of water	$200K/acre	Must be maintained, cost, impact on property owners
Gray	Levees	Regional issue - along rivers, lakes, impoundments	Protects widescale property	$ millions	Must be maintained, must be continuous, must be planned for extreme events (i.e. Hurricane Katrina showed that New Orleans planning horizon was not sufficient)
Gray	Lock structures	Regional (WMD) responsibility	Keeps seawater out, reduces saltwater intrusion	Up to $10 million, may require ancillary stormwater pumping stations at $2-5 million each	Permitting, private property rights arguments
Gray	Sea walls	Barrier islands and downtown coastal areas	Protects property	$1200/ft	Private property rights, neighbors
Green	Polders	Barrier islands and downtown coastal areas	Provides storage for coastal waters	$200K/acre	Permitting, land acquisition
Gray	Surge barriers	Coastal communities – large footprint	Protects property	>$1B	Cost, open ocean access challenges, property rights
Green	Enhanced wetlands	Where there is an existing wetlands area that can be augmented	Reduces flooding by providing a low-lying place for water to go	$200-$1M/acre	Water quality, permitting, monitoring costs, maintenance, ecosystem impacts
Green	Revetments	Retention, helps maintain the storage volume, in conjunction with other measures	Improves walls of retainage	Varies based on material, depth, wall height	Land area, maintenance

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Policy	Changes in land use	Applicable universally	Achieves flood risk mitigation by adjusting permitted land use	Low but may incur private property rights conflicts and litigation	Private property rights conflicts and litigation
Gray	Roadway base protection	Low-lying areas, coastal communities	Protects roads and access routes	$1 million per lane mile	Cost, adjacent properties become uninsurable
Policy	Enhanced elevation of buildings	Developers would implement this for new construction	Reduced flood risk	Varies	Potential issues with building structure or latticework, and existing homes that are not elevated
Policy	Abandon Land for development	Land that cannot be protected would be taken out of circulation	Reduced flood risk	Potentially huge, and loss of tax revenue for local governments	Potential issues with private property rights, potential major reduction in the value of neighboring properties

There are no regulations that would specify certain options from Figure 69. That is the domain of engineers addressing flood issues. WMP7 requires green solutions, but this is not currently in place. There could be some local incentives created to pursue green options (SFWMD might be interested as a source of funding for same).

5.2 Risk and Vulnerability

The screening tool modeling exercise from Section 4.2.2 identified areas within the communities that are vulnerable to flooding. Higher priority concerns should be those properties or assets that are considered essential and need to be kept in service during a flooding event. The major regional issues in the greater watershed are the C-43 reservoir and capital projects associated with the SFWMD plans for controlling discharges that impact the ecosystem in the west end of the watershed. Hence regional water management districts and USACE projects have higher priority due the larger area served. All other improvements are distinctly local. To help with prioritization, the following is suggested:

- Tier 1 - Critical facility protection (water/sewer utilities, public safety, hospitals, schools, power).
- Tier 2 - Essential facilities (groceries, pharmacies, roadways)
- Tier 3 - Economic centers (protecting jobs)
- Tier 4 - At risk communities
- Tier 5 - Other urban/suburban property
- Tier 6 - Agriculture/public property/vacant/undeveloped

Table 13 outlines the US Department of Revenue (DOR) codes from the property appraiser's office and assigns an associated priority level to each parcel. Note that for residential property, identifying at-risk communities (income, age, disability, health) requires a further drilldown to the neighborhood level (i.e. wealthy neighborhoods with few older, poor health individuals would have a lower priority than at risk communities, which generally have lower value housing and denser development). In the latter case, more people are impacted, and those people have less ability to mitigate risk. Based on these priorities, the relative risk priority DOR land use codes were evaluated based on a scale of 1 to 6, where 6 is least vulnerable and 1 is the most vulnerable.

Table 13. Department of Revenue (DOR) land use codes

DOR (use code)	Description	Priority	Delineator
000	Vacant Residential	6	
001	Single Family Residential	Depends	Value, Age, Income
002	Mobile Homes	4	
003	Multi-Family >9 units	4	
004	Residential Condo	Depends	Value, Age, Income
007	Misc. Residential	5	
008	Multi-Family <10	4	
009	Residential Common Area	6	
010	Vacant Commercial	6	
011	One-Story Stores	3	
012	Mixed Use Store	4	
013	Department Store	3	
014	Supermarket	2	
015	Regional Shopping Center	3	
016	Community Shopping Center	3	
017	Office Non Professional	3	
018	Service Multi-Story	3	
019	Professional Services Building	3	
020	Terminals	3	
021	Restaurant	3	
022	Drive-in	5	
023	Financial	2	
026	Laundry	3	
027	Service Station	3	
028	Mobile Home Sales, Parking Lot, Mobile Home Parks	5	
031	Drive-in Theater	5	
032	Auditoriums/Indoor Theaters	5	
033	Bar	5	
034	Skating Rinks, Poolhalls, Bowling Alleys	5	
035	Tourist Attractions	5	
038	Golf Course	6	
039	Hotel	3	
040	Vacant Industrial	6	
041	Light Manufacturing	4	
048	Warehouse Distribution	5	
049	Open Storage	6	
052	Cropland	6	

DOR (use code)	Description	Priority	Delineator
063	Grazing Land	6	
066	Orchard	6	
067	Poultry	6	
069	Ornamentals	6	
070	Vacant without Features	6	
071	Church	5	
072	Private School	3	
073	Private Hospital	2	
074	Home for the Aged	4	
075	Orphanage	4	
076	Cemetery	6	
077	Club, Hall	5	
078	Convalescent Homes	4	
080	Vacant Government	6	
082	Military, Forest, Parks	6	
083	Public School	2	
084	Public College	2	
086	County	Depends	Utilities, Arterial =1
087	State	Depends	Arterial = 1
088	Federal	6	
089	Municipal	1	
091	Utility	Depends	Water/Wastewater Treatment Plants, Public Safety = 1
094	Right of Way	Depends	Florida Department of Transportation (FDOT), Arterial = 1
095	Submerged, lakes	6	
096	Sewage Disposal	1	
099	Other Non-Agricultural Acreage	6	

Having identified the vulnerable properties in Section 4.2.2, by determining the risk priority from 1 to 6 in the DOR codes and the percentage of the parcel that floods during the applicable design storm, properties that are more critical to the function of the community can be identified. The methodology is to first convert the DOR code priority tier to its inverse scale by the following equation to define a consequence of risk factor:

Consequence of risk factor = 7 – DOR Code Priority Tier

The flood risk factor from the screening tool is interpreted based on flooding probability. We take all parcels in tiers #1-4 that have greater than 50% chance of flooding during a particular design storm and calculate the percent of the parcel that would flood during that event. The percentage is converted to a 6-point scale termed as the Flood Risk Factor, as shown in Table 14.

Table 14. Flood risk factor scale based on percent of parcel flooded

Percent of Parcel Flooded	**Flood Risk Factor**
90-100%	6
80-89%	5
70-79%	4
60-69%	3
50-59%	2
<50%	1

If 75% of the importance is assigned to the consequence of flooding and 25% importance to flood risk, or three times the importance to the consequence of flooding to come up with a composite score as follows:

$$\text{Flood Risk Factor} \times 25\% + \text{Consequence of Risk Factor} \times 75\% = \text{Composite Score}$$

Example:

$$1 \times 25\% + 6 \times 75\% = 4.75$$

Those higher priority properties that received the higher composite score are where the mitigation strategies and financial resources should focus first. **Error! Reference source not found.** and Table 15 show the application of this methodology to Clewiston, which is the only developed part of the study area. Note that there are no pipe systems - they were not ignored (refer to section 2.12).

Table 15. Excerpt of the high-risk critical facilities that are in DOR code priority tiers #1-4 and experience 10-percent or more flooded area during a 1-day, 100-year storm event for the City of Clewiston, FL

Parcel ID	Legal Description	Priority Tier	DOR (code)	DOR Use Code Description	Facility	Total Area (acres)	Percent-Flooded (1d 100y)	Flood Probability Factor (25%)	Consequence of Risk Factor (75%)	Composite Score
3 34 43 15 A00 0001.0500	CLEWISTON BEG 1134.75 FT S OF	1	086	Other counties	Floodgate	1.496	43.2%	1	6	4.75
3 34 43 01 010 0123-001.0	CLEWISTON BLK 123	1	083	Public schools	Clewiston Adult School and Clewiston Intermediate School	4.754	39.3%	1	6	4.75
3 34 43 01 010 0345-001.0	CLEWISTON BLKS 343-344 + BLK 3	1	085	Public hospitals	Hendry Regional Medical Center	9.126	25.2%	1	6	4.75
3 34 43 15 A00 0001.0300	CLEWISTON BEG 2252.5 FT E + 10	1	083	Public schools	Clewiston High School	47.263	18.7%	1	6	4.75
3 34 43 16 A00 0005.0100	CLEWISTON BEG INTERSECTION OF	2	023	Financial institutions	Everglades Federal Credit Union	0.950	61.4%	3	5	4.50
3 34 43 01 010 0155-001.0	CLEWISTON BLK 155	3	027	Automotive repair, service, and sales	Kelly Tractor Co.	0.577	100.0%	6	4	4.50
Roadway: 7000011, OLYMPIA STREET (Begin Post = 0, End Post = 0.485)		2	N/A	Urban: minor arterial	Olympia Street	3.847	54.8%	2	5	4.25
Roadway: 7030000, US-27/SR-80/SUGARLAND HWY (Begin Post = 2.147, End Post = 4.711)		2	N/A	Urban: principal arterial - other	Sugarland Hwy	19.760	49.4%	1	5	4.00
3 34 43 01 010 0362-007.0	CLEWISTON BLK 362 LOTS 13 TO 2	2	023	Financial institutions	First Bank	0.505	33.0%	1	5	4.00
3 34 43 01 010 0152-001.0	CLEWISTON BLK 152 LOTS 1 TO 3	4	012	Mixed use, i.e., store and office	Martinez Tire	0.215	100.0%	6	3	3.75

After this analysis, if some of the identified parcels meet the threshold requirements established by the stakeholder group, then they will qualify to be placed on the prioritized project list for capital improvement (see Section 6.4.3). If, however, none of the identified vulnerable areas meet the minimum threshold score, then none of the parcels will be added to the prioritized project list. The exact decision of the various implementation projects will vary from watershed to watershed, but this process should identify those projects that should be prioritized. This process is systematic and objective rather than subjective. However, it is ultimately up to the stakeholder group to assign the weights of the flood probability factor and the consequence of risk factor as well as the tie breaker procedure and regional priorities, so that the process best meets the needs of the community. Using a matrix table and including costs, allows for rapid prioritization to assign the proper resources that will make the most impact with limited funds (refer to Table 16 in Section 6.4).

5.3 Mitigation Strategies

Infrastructure improvements are necessary to harden properties and reduce flood risks. These may come in the form of 1) hard improvements like pump stations, dikes, and piping (termed gray infrastructure), 2) retention areas, swales, and the like (termed green infrastructure), 3) policy improvements (paper infrastructure), and 4) concepts that revise how development occurs modeled to a future time (changes in flood elevations for buildings, etc.).

For the community of Clewiston, FL, the eastern portion of the city is identified by the screening tool as flood-prone (refer to Section 4.4). Note the shallow swales are really the only structures (refer back to Figure 7 and Figure 47), as there are very few street inlets and no culverts under roadways in the vast majority of the city. Hence there is no master stormwater system. There are canals that traverse the city, as previously shown in Figure 48, which were used in the screening model. A recent program to seal the sanitary sewer network eliminated inflow of rainwater to the sewage collection system. At present, stormwater drainage relies on sheetflow to low lying areas and percolation into the soils. As a result, the efforts of the City are focused on those eastern properties that are most vulnerable. One solution under consideration is a pump station to resolve the flooding in the northeast quadrant of the City. In Figure 70, the areas shaded in blue correspond to those properties that are expected to be flooded during the 1-day, 100-year storm event (see previous discussion in Section 4.4 regarding the similarity between the 3-day, 25-year storm and the 1-day, 100-year storm).

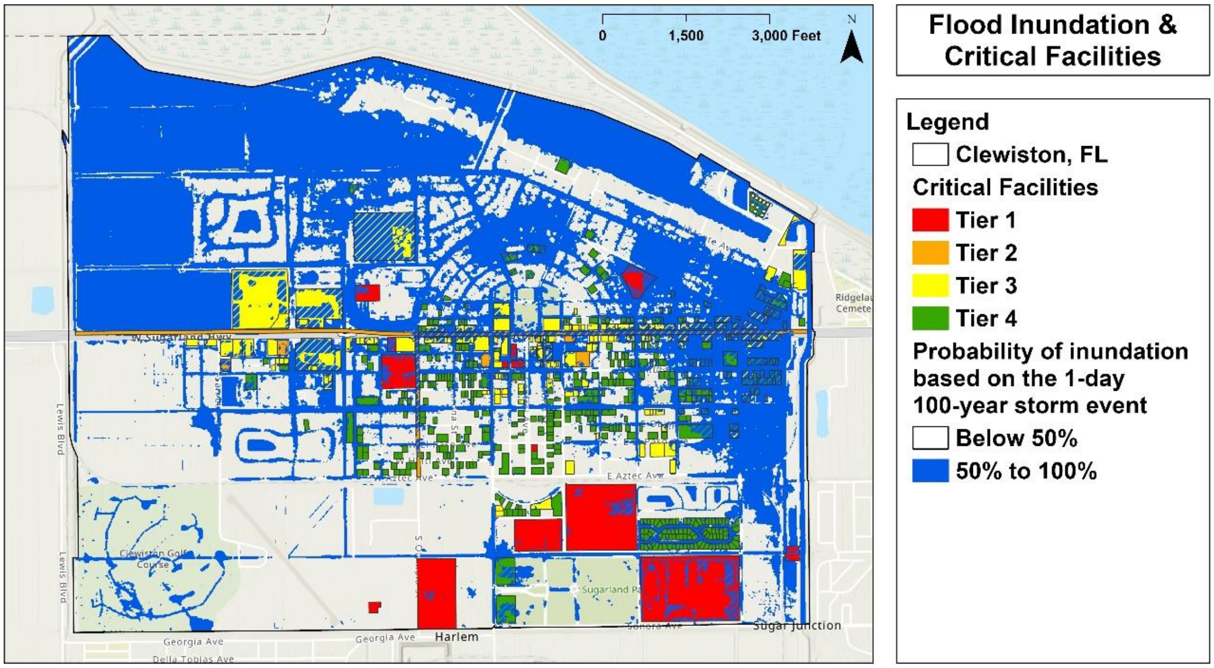

Figure 70. City of Clewiston critical infrastructure map superimposed on the flood risk for the 1-day 100-year storm event

To address the flooding concern for the eastern portion of the City, a flood control pumping station is proposed. The details of the pumping station layout used in the subsequent simulation are shown in Figure 71 to route the excess water to a proposed retention site located just east of the Clewiston Golf Course.

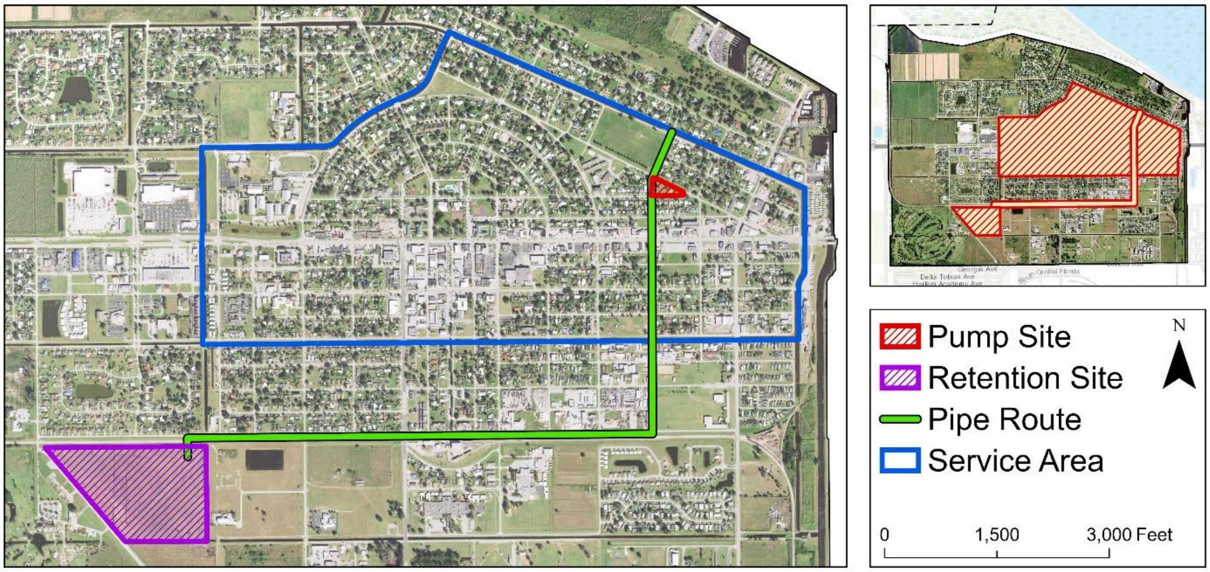

Figure 71. Proposed site layout of flood control pump station for eastern Clewiston, FL

A post-improvement simulation of installing the proposed pump station shows a substantial difference to the expected flooding. The results of the simulated design storm after the improvements are installed are shown in Figure 72 in which the amount of flooding in the northeast quadrant of the City is alleviated.

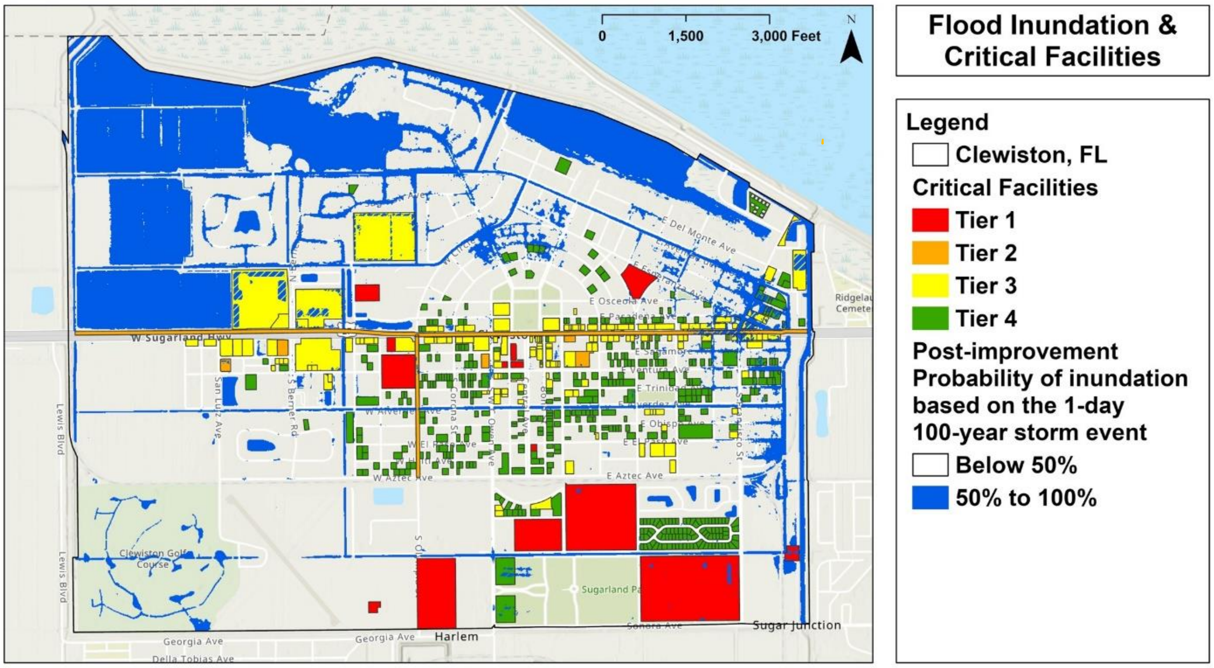

Figure 72. City of Clewiston flood risk and critical infrastructure for the 1-day 100-year storm event with infrastructure installed.

6.0 ACTION PLAN

The key components of the implementation phase are: 1) the implementation team, 2) information/education, 3) capital improvement projects, 4) maintenance, 5) monitoring, and 6) evaluation and adjustments. A watershed implementation team made up of key stakeholder partners from the planning team, particularly those whose responsibilities include making sure tasks are being implemented, reviewing monitoring data, ensuring technical assistance in the design and installation of management measures, finding new funding sources, and communicating results to the public.

6.1 Information/Education Plan

Every WMP should include an outreach component that involves the community. Because individual actions and voluntary practices are involved in the solutions outlined in the plan, effective public involvement and participation will promote adoption of management practices, ensure sustainability, and encourage changes in behavior that will help to successfully achieve the goals and objectives. This comprehensive guide has six critical steps of outreach:

1. Defining goals and objectives
2. Identifying target audiences
3. Developing appropriate messaging
4. Selecting materials and activities
5. Distributing the messages
6. Conducting evaluation and continuous improvement

Although awareness of the issues is a good first start, the public should be educated on the challenges facing the watershed and become invested in the solution by knowing what specific actions they can take to participate in successful implementation. An example for Lee County is provided in Appendix A.

6.2 Maintenance Plan

The goal of managing stormwater is to protect public health, welfare, and safety by reducing flood impacts on a community, the potential for waterborne disease from flooding, and to lessen the potential for property damage if flooding occurs. Public and private property may include homes, businesses, roadways, railroads, bridges, utilities, etc., so the first objective is to remove excess water in a timely manner, to a place where it will not adversely impact the public and the economy. To prevent flooding and the potential for health risks associated with stagnant water, stormwater runoff must be managed in an organized and systematic manner if property owners are to enjoy the full use of their property and roadways are to be clear. As a result, stormwater facilities must be constructed and maintained to reduce the negative impacts of runoff.

The burden of managing this stormwater typically falls to a local community stormwater organization – typically a special district, stormwater utility or a division of a local government. For this study area, these entities are:

- Hendry County
- City of Clewiston

Federal programs created under the Clean Water Act specify that those communities with local stormwater infrastructure – pipes, pumps, catch basins, exfiltration trenches, retention basins, etc. – are required to fund and perform the following:

- Annual Maintenance
    - Disk dry retention area bottoms
    - Disk swale bottoms
    - Correct stormwater wet retention area

- Semi-Annual Maintenance
    - Correct areas of erosion, undercutting or dead grass in wet and dry retention areas and swales
    - Take appropriate action on petroleum or other pollution spills noted
    - Swale cleaning
    - Remove invasive plants
    - Remove sediment from exfiltration trenches
    - Clean exfiltration trench

- As Needed Maintenance
    - Mow wet and dry retention areas and swales
    - Stabilize banks of wet and dry retention areas
    - Rehabilitate exfiltration trenches every 10 years
    - Correct wet and dry retention area equipment
    - Correct dry retention area bottoms
    - Nutrient/pesticide management
    - Clean bottom debris
    - Re-sod banks of wet and dry retention areas as needed
    - Inspect all retention ponds

Such maintenance activities also require good record-keeping to develop and maintain accurate mapping of the drainage system and track improvements in areas with ongoing stormwater issues.

Budgets are a necessary part of services and are statutorily required for most jurisdictions. Coordination between the financial, budget, and operating policies of a utility allows managers to properly allocate resources to those benefiting from the service, develop pricing strategies that can be clearly explained to the public, and prevent challenges to allocation methodologies. Every infrastructure agency has a budget to operate and maintain the system – agencies involved in flood protection are no different, and they all spend money on operations, debt, and capital outlays. Operations, capital programs, and long-term variability of the utility system operation require financial and facility planning. Multi-year economic forecasts and financial plans are standard tools in business and are worthy of consideration by watershed and flood protection agencies.

In most cases, local governments establish an enterprise fund to pay for maintaining and modernizing infrastructure – examples are enterprise funds for water and sewer. The same is often done for stormwater where assessments are collected monthly or annually to pay for stormwater needs and operations. However at present, both Hendry County and Clewiston rely on general fund revenues for this purpose. It is recommended that both entities consider a separate dedicated cashflow enterprise such as a stormwater utility to pay for stormwater infrastructure improvements.

6.3 Monitoring and Compliance Requirements

Because stormwater protection is often more regional than local in many cases, most communities participate in programs under permits secured by a regional agency (county level is common) to address the interconnectedness of waterbodies through neighboring jurisdictions. Monitoring programs are primarily an administrative feature of watershed management. A good environmental monitoring program (EMP) will assess the effectiveness of the overall practices and provide necessary information to prevent failures or property damage, or at least reduce the risk. The following are typical monitoring program elements:

Inspections:

- Annual
    - Wet retention area
    - Swale bottoms
    - Disk bottom

- Semi-Annual

- Dry Retention areas
- Exfiltration trenches
- Swales
- Sediment in wet retention, dry retention, and swale areas

- Quarterly
  - Catch basins

Stormwater Management Program:

- Submit annual inspection and maintenance report
- Conduct required inspections and maintenance
- Develop and maintain record-keeping system

New Development:

- Implement state, local, and regional policies with regard to stormwater and drainage management controls
- Review Land Development Regulations to determine where changes must be made, especially to swales, low impact development, stormwater reuse and landscaping

Roads:

- Litter control
- Implement Best Management Practices ("BMPs"), also called Best Stormwater Practices
- Perform maintenance of catch basins, grates, storm drains, structures, swales gutters and other features

Flood Control:

- Ensure new development flood control meets performance standards in 62-40 F.A.C.
- Strengthen local comprehensive plans and submit them to the County
- Maintain a GIS layer with water quality information
- Ensure flood control meets with water management district rules

Pesticides and Herbicides:

- Provide certification and licensing of applicators to the County

Illicit Discharges:

- Conduct assessment of non-storm discharges
- Provide copies of newly adopted ordinances prohibiting illicit discharges and dumping
- Continue random inspection program
- Define allotment of state and resource to stormwater program
- Report and prosecute all violators
- Conduct periodic training to staff on identification and reporting of illicit discharges
- Terminate illicit discharges and document same.
- Develop municipal procedures for handling and disposing of chemicals and spills, including training of staff on emergency response
- Distribute brochure to public on appropriate disposal of hazardous materials
- Develop public outreach effort for oil, toxic and hazardous waste for public
- Promote Amnesty Day for hazardous materials
- Develop voluntary storm drain marking program
- Continue infiltration and inflow program on sanitary sewer system
- Investigate septic tank discharges to stormwater system

Industrial Runoff:

- Maintain inventory of high risk discharges, including outfall and surface waters where discharge occurs.
- Provide ongoing inspections of high risk facilities
- Provide annual report to appropriate agency for enforcement
- Monitor high risk facility discharge water quality

Construction Sites:

- Ensure stormwater system meets treatment performance standards in 62-40 FAC
- Continue construction site inspection program to ensure reduction of off-site pollutants
- Implement standard, formalized checklist of stormwater management and water quality inspection items
- Maintain log of stormwater management activities at construction sites
- Provide detailed description of inspection program and forms
- Provide summary of activities
- Continue inspection certification program to stormwater management, erosion and sediment control for operators, developers, and engineers
- Develop outreach program for local professional organizations

Monitoring programs should verify ongoing demonstration of maintenance through the use of logs, work orders, photographic documentation, and geographic information systems (GIS) support to insure all of these facilities not only operate properly, but also reduce pollutants. These requirements mean that the community needs funds to ensure proper execution of the program for compliance. Significant effort is required to maintain functioning of stormwater systems, many of which have been neglected with time. Extra effort may be recommended prior to rainy seasons to limit flooding potential from unmaintained facilities.

6.4 Capital Plan

Once the vulnerability assessment and mitigation measures have been determined, the next step is to implement the plan to address these issues—in other words, it is often possible to add mitigation measures to existing capital improvement programs. Every infrastructure agency will spend money to operate and maintain the system. Agencies involved in flood protection are no different, they all spend money on operations, debt, and capital. These factors are brought together in annual budget documents. Budgets are a necessary part of operations and are statutorily required for most jurisdictions. In most cases, all infrastructure agencies should be set up as an enterprise fund to allow the organization to pay its own way, which will also make it easier to evaluate the operational aspects of an infrastructure system.

Coordination between the financial, budget, and operating policies of a utility system allows managers to properly allocate costs to those benefiting from the service, develop pricing strategies that can be clearly explained to the public and prevent challenges to allocation methodologies. Operations, capital programs, and long-term variability of the utility system operation require financial and facility planning. Multi-year economic forecasts and financial plans are standard tools in business and are worthy of consideration by flood protection agencies and elected officials.

6.4.1 SFWMD/USACE Regional Capital Improvement Projects

CERP is a hydrologic restoration project for the water resources of central and south Florida that was authorized by Congress in 2000. Through June 2018, the State of Florida and SFWMD have invested more than $2.3 billion in CERP-related project design, engineering, construction, and land acquisition. Florida has now designated consistent funding for restoration through the Legacy Florida Act (Laws of Florida, Chapter 2016-201) and the Water Resources Law of 2017 (Laws of Florida, Chapter 2017-10, Senate Bill 10) and through advancement of other projects. Of note, CERP was envisioned as a partnership between USACE and the State of Florida, with SFWMD acting as the local sponsor on behalf of the state. While Florida's funding commitment has outpaced the federal government's in the 18 years since the plan was approved, cost sharing on the larger components is lacking. As a result, none of the major project components described in CERP has been completed.

The SFWMD and USACE are spearheading the Caloosahatchee East/Clewiston subwatershed Protection Plan, which is being coordinated with the Lake Okeechobee Watershed Construction Project Phase II Technical Plan. This plan will address pollutant load reductions based on adopted TMDLs. It will also include a goal for salinity levels and freshwater inflow targets for the Caloosahatchee Estuary. Components of the multi-phase plan include:

- Policy
    - Implementing agricultural best management practices on more than 1.7 million acres of farmland
    - Adopting new regulations that will reduce the impacts of development on water quality and flow
    - Using green infrastructure nutrient control technologies to reduce phosphorus loads from the watershed
- Infrastructure
    - Building treatment wetlands to pretreat water flowing into Lake Okeechobee
    - Creating between 0.9 – 1.3 million acre-feet of water storage north of Lake Okeechobee through a combination of above-ground reservoirs, underground storage, and alternative water storage projects on public and private lands

Note that the C-43 reservoir project will solve some of the storage issues. Utilizing funding from the Florida Legislature, SFWMD is building the Caloosahatchee (C-43) West Basin Storage Reservoir (WBSR) and has taken the lead on construction of components of the C-44 Reservoir and Stormwater Treatment Area. SFWMD is also expediting planning for the Everglades Agricultural Area (EAA) Storage Reservoir. WBSR is a component of CERP that is designed to store approximately 170,000 acre-feet of local basin stormwater runoff and releases from Lake Okeechobee to reduce the volume of discharges from Lake Okeechobee to the Caloosahatchee Estuary during the wet season and provide a source of freshwater flow to the estuary during the dry season to help balance salinity levels and provide flows to plants and wildlife when needed (Figure 73). The reservoir is under construction on a 10,500-acre parcel owned by SFWMD. Depending on storage needs, water depth in the reservoir will range from 15 to 25 feet and will comprise a significant portion of the overall water storage requirement for the greater Caloosahatchee watershed. In addition, the project is envisioned to provide public access and recreational opportunities, as well as maintain allocated water supply to the local agricultural areas adjacent to the reservoir.

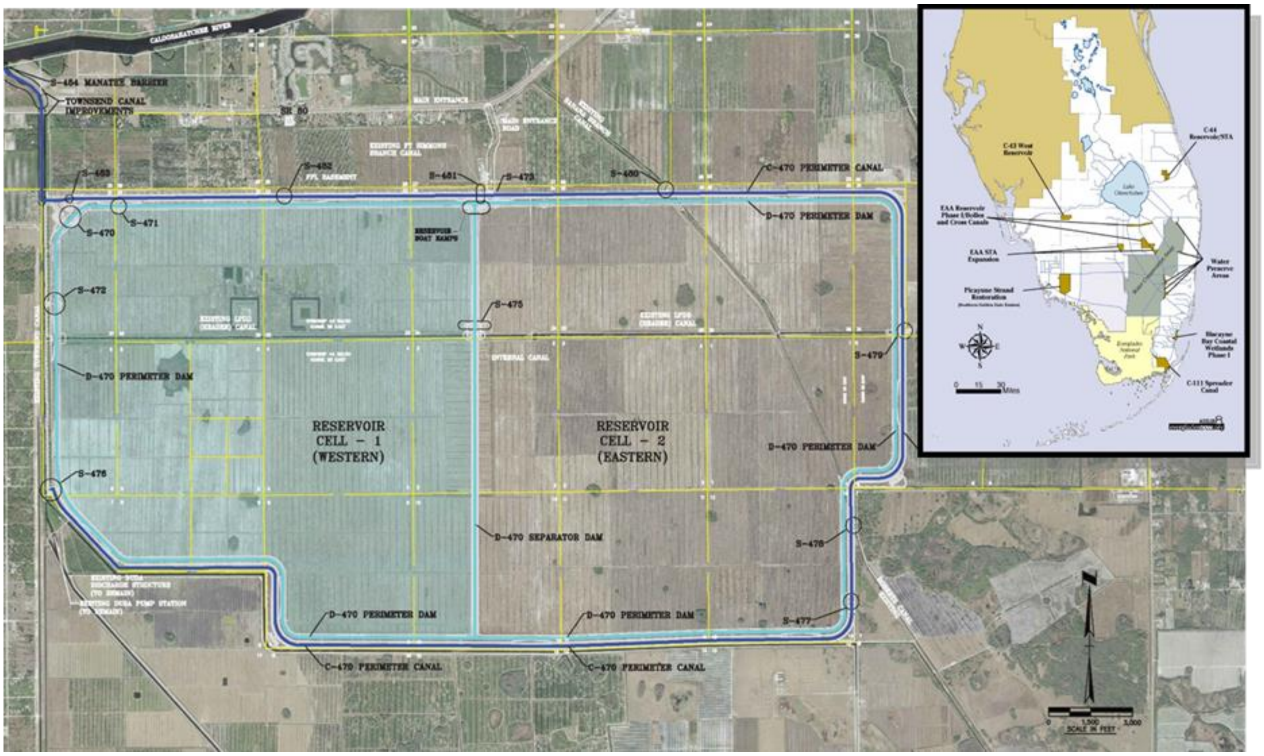

Figure 73. C-43 West Basin Storage Reservoir

The Lake Okeechobee Watershed Construction Project (LOWCP) was undertaken to identify issues that are affecting water quality and/or quantity in each of the subwatersheds and basins within the Lake Okeechobee Watershed (and downstream), and then, determine if projects, also known as management measures, are adequately addressing those issues. The water quality issues in Lake Okeechobee are critical to the Caloosahatchee East/Clewiston subwatershed because the lake is drained in part through the basin. Nutrient-laden water from Lake Okeechobee creates significant downstream water quality impacts.

The Lower West Coast Water Supply Planning Area includes Lee County and portions of Charlotte, Collier, Glades, Hendry, and Monroe counties. The SFWMD 2017 Update to the Lower West Coast Water Supply Plan (SFWMD, 2017) assesses projected water demands and potential sources of water for the period from 2014 to 2040. This plan update is used by local governments, water users and utilities to update and modify local comprehensive plans, facility work plans and ordinances. Storage reservoirs like C-43 will in part support water supply needs in the dry season, while reducing flooding and ecosystem impacts.

6.4.2 County-Wide Capital Improvement Projects

Hendry County has about $5 million in improvements in their transportation (roads and bridges) fund, but little of this is stormwater-related beyond replacing existing culverts.

6.4.3 Local Capital Improvement Projects

Clewiston has no specific capital plans for stormwater. However, the City of Clewiston is investing in upgrades to deteriorated culverts. SRF funds are a potential source of funding, but the project is still in the conceptual design stage. This would not be a regional project. In addition, Clewiston could install a pump station to move water from the northeast section of the City. There is no feasibility plan beyond a mention in the upcoming CRS plan for the City.

According to the 2020 Local Mitigation Strategy document for Hendry County, the existing drainage system in and around the City of Clewiston appears to be adequate to contain and control most extreme rainfall events. However, City officials have expressed concern regarding the possibility of electrical outages or mechanical failures at the city's wastewater treatment plant, in conjunction with heavy rainfall. Such an incident could cause overflow of the effluent holding areas into the city drainage-ways. This creates a potential health hazard from human contact with the effluent.

Programs for monitoring operations and ensuring that ongoing inspections take place are needed. FDEP can coordinate the regulatory compliance aspects of these Clean Water Act requirements. In addition, upon completion of the regional reservoir projects, re-modeling of the subwatershed should be conducted incorporating these planed features. That will permit a change to the impact maps, allowing for some potential reductions to impacted areas. The impact of sea level rise must also be considered as it may mean effort in the east to reduce flooding from Lake Okeechobee discharges are replaced by prioritizing flood reduction from sea level rise in the west.

Large flood protection/storage projects are designed to reduce risk and are likely to score high on a priority scale. Localized infrastructure will tend to score lower due to the scale. In this subject area, there were no high-risk projects identified in the capital plans for any agency. However, SFWMD has several projects that provide substantial benefit, so these are deemed to have important consequences. Note that neither Clewiston nor Hendry County have current capital plans for flood control.

6.4.4 Study Area Level Capital Improvement Projects

Table 16 outlines the projects mentioned in the capital plans (refer to Section 3.5.5 for details) and the vulnerable properties identified using the methodology in Section 4.2.2 and the reported in Section 5.2. Specific details can be found in the community capital plans. The scale (regional or local) and an estimate of the consequence of flooding risk and the probability of flooding risk are used to create a composite score for prioritization in Table 17.

Ultimately, it is up to the stakeholder group to assign the weights of the flood probability factor and the consequence of risk factor as well as the tie breaker procedure and regional priorities, so that the process best meets the needs of the community.

Table 16. Current local/regional capital plan

In Subwatershed ?	Name of Project	Project Location	Agency	Hazards Mitigated	Funding Source	Cost (000)	New, Deferred, Completed, or Deleted	Why?	Timeframe for Completion
partial	Caloosahatchee Storage 2	Hendry County	SFWMD	Storage/Flooding	CERP	$45,000	New	N/A	TBD
partial	C43 Distr. Reservoirs	Lake Hicpochee South	SFWMD	Storage/Flooding	CERP	$450,000	New	N/A	TBD
no	Carlos Waterway/C43	Lake Hicpochee South	SFWMD	Reduce Flooding	CERP	$1,200	New	N/A	TBD
no	Public Land ASR Study	Okeechobee County	SFWMD	Reduce Flooding	CERP	$500	New	N/A	TBD
no	Agricultural BMPs	Hendry County	SFWMD	Reduce Flooding	General Fund	TBD	New	N/A	TBD
yes	Stormwater Master Plans	Hendry County	County	Reduce Flooding	General Fund	TBD	New	N/A	TBD
yes	East Clewiston Pump Station	East Clewiston	Local	Reduce Flooding	General Fund	$1,400	New	N/A	10 years
yes	Clewiston Adult School	NE Clewiston	Local	Reduce Flooding	General Fund	TBD	New	N/A	TBD
yes	Hendry Regional Medical Center	Central Clewiston	Private	Reduce Flooding	Private Funds	TBD	New	N/A	TBD
yes	Clewiston High School	Central Clewiston	Local	Reduce Flooding	School Board	TBD	New	N/A	TBD

Table 17. Prioritized capital plan

Consequence of Risk Factor	Flood Risk Factor	Score	Priority	Name of Project	Project Location	Agency	Funding Source	Cost (000)	Timeframe for completion
6	5	5.75	1	East Clewiston Pump Station	East Clewiston	Local	General Fund	$ 1,400	10 years
6	1	4.75	2	Hendry Regional Medical Center	Central Clewiston	Private	Private Funds	$ 500	TBD
5	2	4.25	3	Clewiston High School	Central Clewiston	Local	School Board	$ 700	TBD
4	1	3.25	4	Clewiston Adult School	Northeast Clewiston	Local	General Fund	$ 100	TBD

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APPENDIX A

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