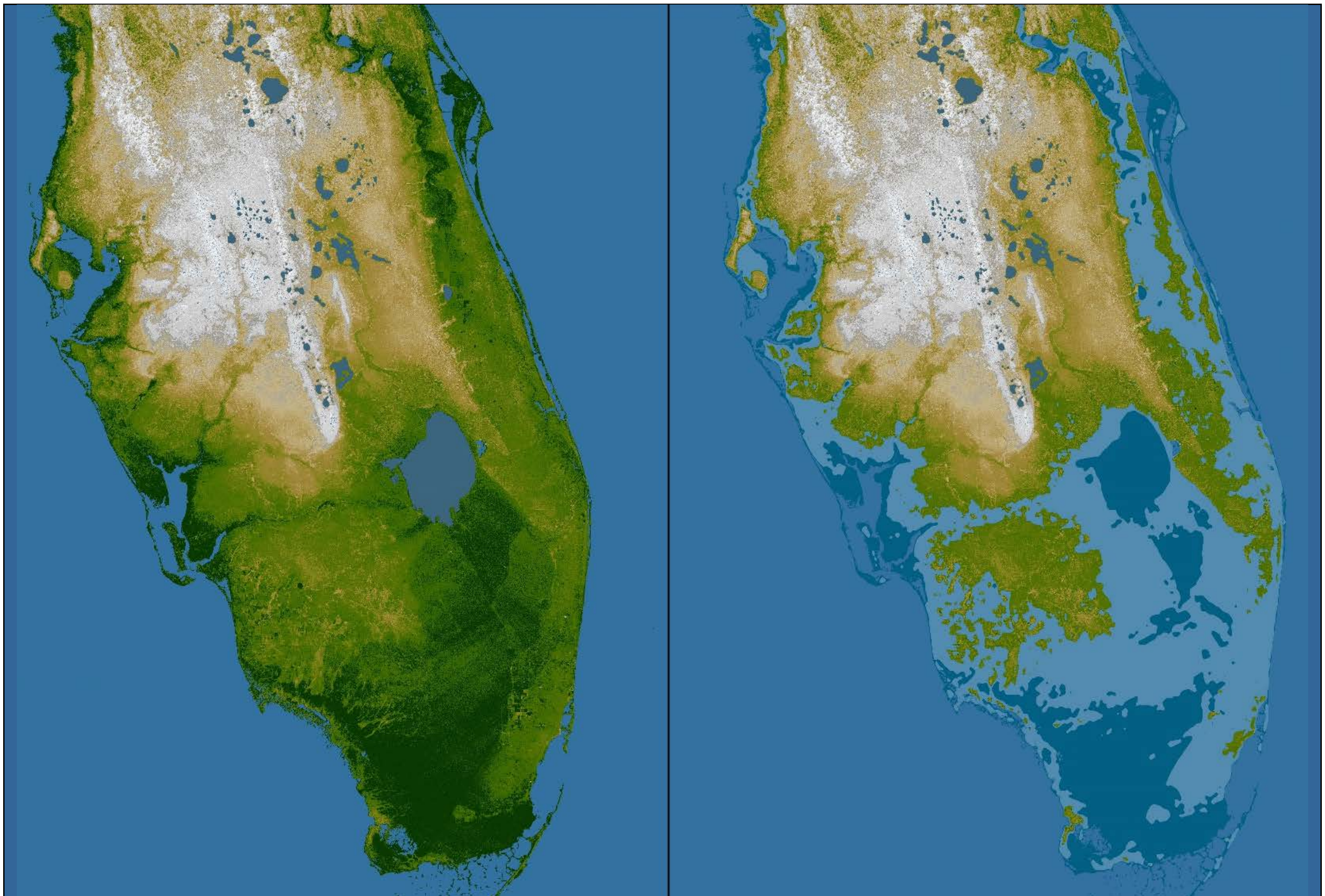

[DRAFT]

WATERSHED MASTER PLANNING TEMPLATE

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FLORIDA ATLANTIC UNIVERSITY

Image credit: NASA/JPL/NGA

[DRAFT]

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Disclaimer

This document provides guidance for developing watershed master plans. This document refers to regulatory provisions that contain legally binding requirements. However, this document does not impose legally binding requirements and may not apply to all governments Local government decision-makers retain the discretion to adopt or modify the approaches described in this guidance document. Adoption of the suggestions or recommendations herein will not necessarily constitute approval during 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 or not the recommendations in this guidance are appropriate in that situation in order to make changes to this guidance document in the future.

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List of Acronyms

3DEP	3D Elevation Program
AWS	Available Water Storage
BMAP	Basin Management Action Plan
BWA	Biggert-Waters Flood Insurance Reform Act of 2012
CAAP	Climate Adaptation Action Plan
CERP	Comprehensive Everglades Restoration Plan
CFU	Colony Forming Units
CRS	Community Rating System
CWA	Clean Water Act
DEM	Digital Elevation Model
EMAP	Environmental Monitoring and Assessment Program
ESRI®	Environmental Systems Research Institute, Inc.
FAC	Florida Administrative Code
FAU	Florida Atlantic University
FDEP	Florida Department of Environmental Protection
FDIC	Federal Deposit Insurance Corporation
FDOT	Florida Department of Transportation
FDPA	Flood Disaster Protection Act of 1973
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Studies
FLUCCS	Florida Land Use, Cover, and Forms Classification System
FMP	Floodplain Management Plans stormwater master plans, local ordinances and
LMS	Local Mitigation Strategy
FRR	Flood Risk Reports
GIS	Geographic Information Systems
GO	General Obligation
GPS	Global Positioning System
GW	Ground Water
HUC	Hydrologic Unit Code
IPCC	Intergovernmental Panel on Climate Change
LEED	Leadership in Energy and Environmental Design
LiDAR	Light Detection and Ranging
LOS	Level of Service
MFL	Minimum Flows and Levels
MINWTE	Minimum Water Table Elevation
MLR	Multiple Linear Regression
MRLC	Multi-Resolution Land Characteristics Consortium
MS4	Municipal Separate Storm Sewer System
NCDC	National Climatic Data Center
NCSS	National Cooperative Soil Survey
NCUA	National Credit Union Administration

NeXRAD	Next-Generation Radar
NFIA	National Flood Insurance Act
NFIP	National Flood Insurance Program
NLCD	National Land Cover Database
NOAA	National Oceanographic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRI	Natural Resources Inventory
NWFWMD	North West Florida Water Management District
NWI	National Wetlands Inventory
OCC	Office of the Comptroller of the Currency
QL2	Quality Level 2
RCAP	Regional Climate Action Plan
RDA	Rural Development Administration
RiskMAP	Risk Mapping, Assessment, and Planning
RMSEz	Vertical Root Mean Square Error
SAR	Synthetic Aperture Radar
SCS	Soil Conservation Service
SFHA	Special Flood Hazard Area
SFRCCC	Southeast Florida Regional Climate Change Compact
SFWMD	South Florida Water Management District
SJWMD	St. Johns River Water Management District
SQL	Standard Query Language
SRF	State Revolving Fund
SRWMD	Suwanee River Water Management District
SW	Surface Water
SWFWMD	South West Florida Water Management District
SWIM	Surface Water Improvement and Management
SWPPP	Stormwater Pollution Prevention Plans
TMDL	Total Maximum Daily Loads
ULDR	Unified Land Development Regulations
USACE	United States Army Corps of Engineers
USDA	Unites States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WMD	Water Management District
WMP	Watershed Master Plan
WTE	Water Table Elevation

1.0 DEFINING THE WATERSHED PLANNING PROCESS

The purpose of this document is two-fold: 1) to define Watershed Master Plans (WMPs) and 2) to provide a template outline for communities interested in producing or adopting a WMP for the purposes of planning projects to reduce local flood risk and maximize Community Rating System (CRS) credits. According to the CRS Coordinator's Manual (FEMA, 2017), "the objective of watershed master planning is to provide the 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 (Association of State Floodplain Managers, 2020):

1. Evaluation of the watershed's runoff response from 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

Although each watershed master plan emphasizes different issues and reflects unique goals and management strategies, every watershed master planning process is iterative, holistic, geographically defined, integrated, and collaborative. The Federal Emergency Management Agency (FEMA) has encouraged the State of Florida to develop statewide watershed master planning frameworks that integrate and coordinate plans for large drainage areas. It is likely that federal, state, tribal, and local planning efforts are occurring simultaneously with the watershed. Ideally, these other plans should be integrated within the comprehensive watershed master plan effort through stakeholder participation, data sharing, and implementation of management measures.

1.1 Partnerships

The United States Environmental Protection Agency (USEPA) (2013) notes that the first step in watershed master planning is to build partnerships with surrounding communities. For example, water may enter a community watershed from upstream and leave to impact another community downstream, overwhelming their system. To start building partnerships, communities should first engage their neighbors to exchange relevant information on existing regulations, policies, and future goals. One major challenge is that the geographic boundaries of most administrative units (for example, municipalities) do not follow the geographic boundaries of the watersheds in which the units are located. Accordingly, WMPs will likely need to be created in partnership with other administrative units with overlapping geographic interests. This means that the key communities/agencies/jurisdictions within the watershed must be identified, including stakeholders, experts, and members of the public with local knowledge. One barrier to developing watershed level plans in Florida is the difficulty in getting any specific entity to take on the leadership role to accommodate such efforts. Hence, the Florida Division of Emergency Management (FDEM) undertook this project to help create the framework for watershed master plans for all 29 watersheds in the state.

Working with neighboring communities will help to maximize CRS credits because of the way the impact adjustment is calculated in the CRS Coordinator's Manual. In addition, by working with neighboring communities, the costs associated with completing the hydrologic modeling necessary to earn credit for this element could be shared.

Specific programs that have a planning component or conduct related activities that might to integrate with the watershed planning effort include the following:

- Water quality management reports (TMDL implementation plans, BMAPs, SWIM Plans)
- Flood insurance studies
- Floodplain management plans
- Florida "Peril of Flood" guidance
- Comprehensive plans
- Unified land development regulations
- Stormwater management policies
- Local mitigation strategies
- Intergovernmental cooperative agreements
- Special watershed restoration plans
- Stormwater pollution prevention plans
- Post-disaster redevelopment plans
- Climate adaptation action plans
- Other Plans

It may be advantageous to include staff from these programs as partners in developing the watershed master plan. This approach can help in gaining additional technical expertise, leveraging resources, and sharing responsibilities for implementation. It also helps provide buy-in from those who are charged with implementation of these plans and policies in the context of the larger planning vision. More about these parallel planning efforts is found in Section 3.5.

In terms of identifying key stakeholders to include, those who are in positions of decision-making and authority and resources to implement projects should be considered, but also it is important to include representatives from vulnerable communities that are likely to be impacted, and those with specialized knowledge that can assist in the overall effort. As such, examples of key stakeholders other than those described earlier might include: landowners, local government and/or tribal representatives, regulatory agencies, citizen advocacy groups and volunteer monitoring groups, local business, community service organizations, faith-based groups, academia, regional planning councils, soil/water conservation districts, water management districts, utilities, cooperative extension offices, and fishing/boating/recreational/birding groups. It is important to involve the public early in the process to build trust and buy-in with the plan. This is the key to a successful information/education component of public outreach as you navigate the planning process.

1.2 Overview of the Watershed

By definition, watershed master planning focuses on a watershed, which is a geographic area that is defined by a drainage basin. A watershed plan should address a geographic area large enough to ensure that implementing the plan will address all the major sources and causes of impairments and threats to the waterbody under review. Although there is no rigorous definition or delineation of this concept, the intent is to avoid focus on single waterbody segments or other narrowly defined areas that do not provide an opportunity for addressing larger scale watershed stressors in an efficient manner. As an example, there are 29 defined basins in Florida, with 55 smaller basins defined within the 29. Clearly the scale is far larger than any single jurisdiction.

Information on the physical and natural characteristics of the watershed will define the watershed boundary and provide a basic understanding of the watershed features that can influence watershed sources and pollutant loading.

1.2.1 Geomorphological Considerations

It is important to note agricultural and industrial activities, urban development, habitat, protected open space, water recharge zones, and geomorphology of stream/rivers (i.e. streambanks, shorelines, riparian zones, channel dimensions, slope, stream conditions, etc.). Examples of standard geomorphic protocols are as follows:

- USEPA's Environmental Monitoring and Assessment Program (EMAP) (www.epa.gov/emap)
- Vermont's Stream Geomorphic Assessment Protocols (www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassesspro.htm).

1.2.2 Hydrologic Boundaries

One way to identify the geographic extent of the watershed master planning effort is to consult the United States Geological Survey (USGS) map of hydrologic units. A hydrologic unit is part of a watershed mapping classification system showing various areas of land that can contribute surface water runoff to designated outlet points, such as lakes or stream segments. USGS designates drainage areas as sub-watersheds (including smaller drainages) numbered with 12-digit hydrologic unit codes (HUCs), nested within watersheds (10-digit HUCs). These are combined into larger drainage areas called sub-basins (8 digits), basins (6 digits), and subregions (4 digits), which make up the large regional drainage basins (2 digits).

Region>>Sub-region>>Basin>>Sub-basin>>Watershed>>Sub-watershed

Watersheds divide sub-basins and usually range in size from 40,000 to 250,000 acres, while sub-watersheds divide or may be equivalent to watersheds and usually range in size from 10,000 to 40,000 acres (USEPA, 2008).

Florida has a HUC-TMDL boundary layer (Figure 1) that was modified for the purposes of this document and is available at cwr3.fau.edu. This map was compiled from the USGS HUC basins and the TMDL boundary maps developed by the Florida Department of Environmental Protection. These have also been cataloged by USGS nationally as HUCs at http://water.usgs.gov/wsc/index.html. The appropriate HUC can also be found at the USEPA "Surf Your Watershed" website (http://cfpub.epa.gov/surf/locate/index.cfm).

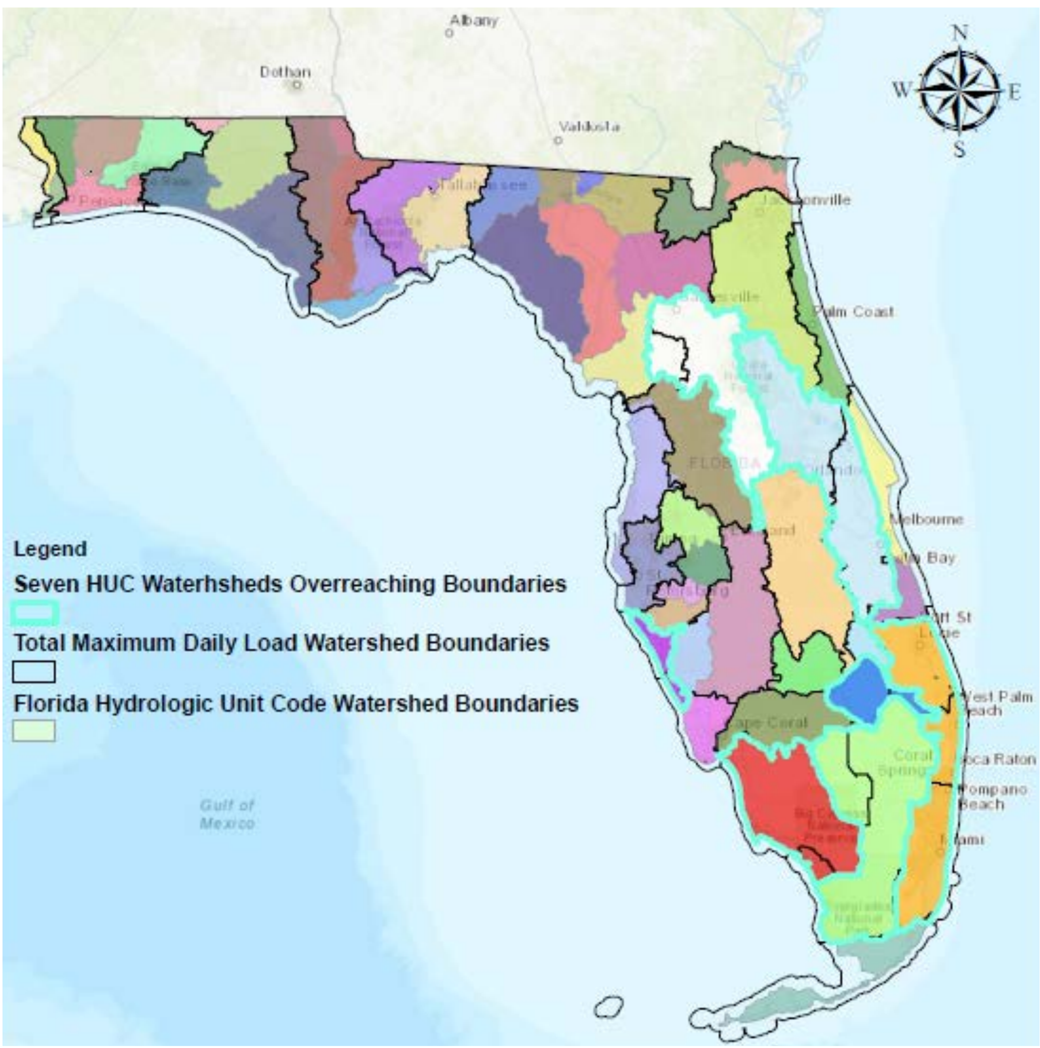


Figure 1. Revised HUC-TMDL map such that TMDL regions match with HUC boundaries as created by FAU to delineate boundaries for screening tool development

The HUC boundaries may not have sufficient resolution for watershed master planning, so dividing into sub-watersheds will permit better resolution on flood vulnerability. An example map showing all sub-watersheds that drain into the larger community of Broward County is illustrated in Figure 2.

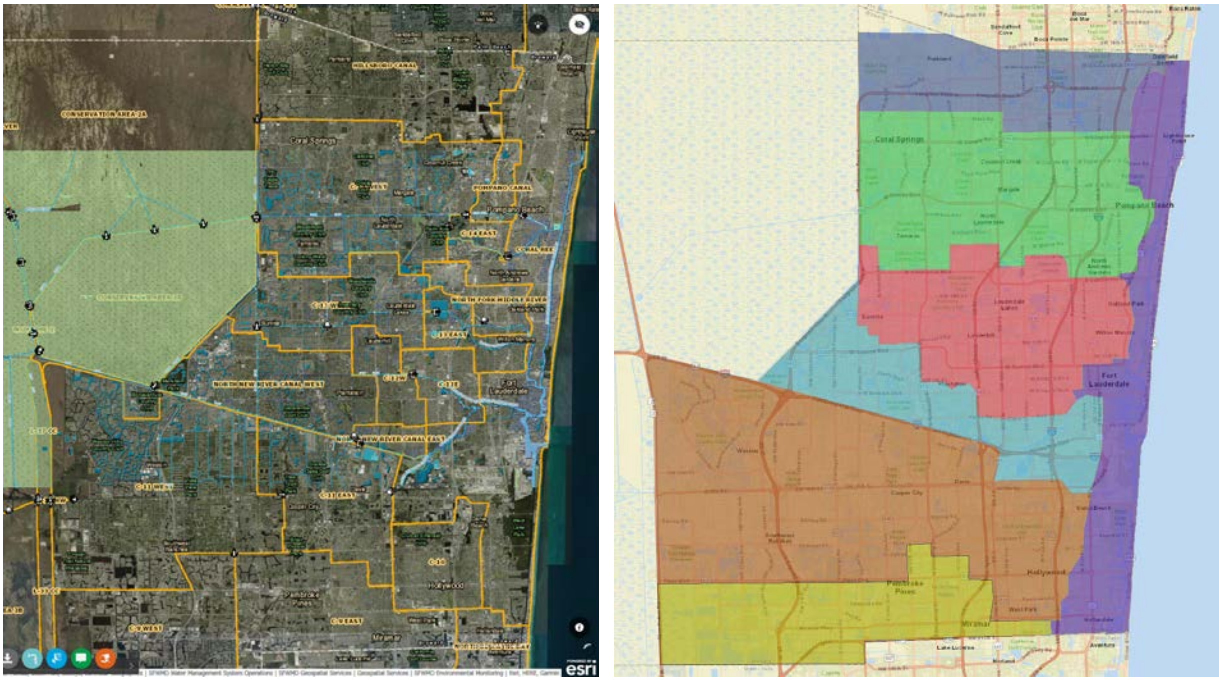


Figure 2. Watershed map of Broward County, FL (Rojas, 2020)

Another way to identify watershed boundaries more precisely is to use a topographic map. The raw data are available at USGS (usgs.gov/core/science/systems/ngp/tnm-delivery/topographic-maps) and the processed data and maps are available at cwr3.fau.edu. When working in very small watersheds of just a few square miles, more detailed topographic information should be obtained from municipal planning departments, if possible. From these maps, lines can be drawn following the highest ground between the waterways to identify the watershed boundaries, or ridge lines, as shown in Figure 3.

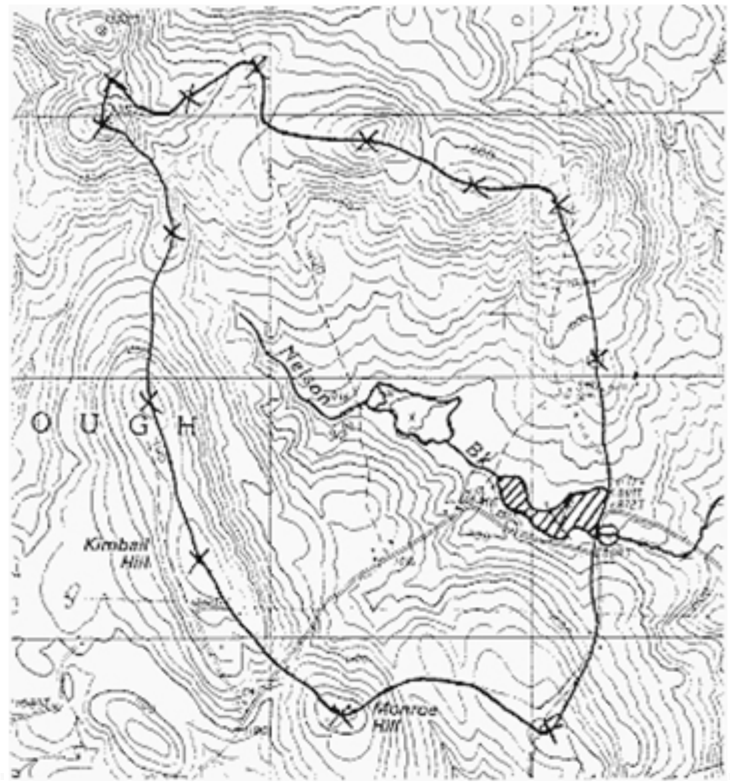


Figure 3. An example of a USGS topographic map used to define a watershed. (https://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs144p2_014463.jpg)

1.2.3 Wetlands and Natural Areas

According to Florida Administrative Code (FAC) 62-340, the State of Florida defines wetlands as "those areas that are inundated or saturated by surface water or ground water at a frequency and a duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soils." Florida wetlands generally include swamps, marshes, bayheads, bogs, cypress domes and strands, sloughs, tidal marshes, mangrove swamps, and other similar areas.

Wetlands serve many purposes, including acting as recharge areas, filters for contaminants, buffers that mitigate temperature changes in adjacent areas, and habitat for wildlife. Hydrologic functions include receiving and storing surface water runoff, which is important in controlling flooding, erosion, and sedimentation. Surface water that enters a wetland is stored and percolates into the ground or until the wetland's overflow capacity is reached and thereafter water is slowly released downstream to a receiving waterbody. As the flow of water is slowed by wetland vegetation, sediments in the water (and pollutants bound to the sediments) settle out of the water column, improving water quality. Additionally, within cypress wetlands, the trees are deciduous, which reduces water loss due to transpiration during the dry season. Wetlands also function hydrologically as groundwater recharge-discharge areas when the water level of a wetland is higher than the water table.

Biological wetland functions include providing habitat for fish and wildlife, including organisms classified as endangered, threatened, or species of special concern. Some species depend on wetlands for their entire existence, while other semi-aquatic and terrestrial organisms use wetlands during part of their life cycle. Their dependence on wetlands may be for seasonal migration, residence, feeding, reproduction, nursery areas, or corridors for movement. Wetlands are also an important link in the aquatic food web. They are important sites for microorganisms, invertebrates, and forage fish, which are consumed by predators such as amphibians, reptiles, wading birds, and mammals.

The National Wetlands Inventory (NWI), maintained by the United States Fish and Wildlife Service (USFWS), provides information on the characteristics of wetlands, deep-water habitats, and other wildlife habitats. The Emergency Wetlands Resources Act of 1986 requires USFWS to conduct national wetlands studies and report comprehensive estimates of wetlands on public and private lands in the United States to Congress every 10 years. The latest reports are published in https://www.fws.gov/wetlands/status-and-trends/index.html. The NWI has a *Wetlands Mapper* tool (Figure 4) that allows a user to map wetland habitats (www.nwi.fws.gov). Other key information can be obtained from wetlands assessments or surveys that include global positioning system (GPS) coordinates, plot descriptions, canopy information, flora/fauna diversity, and land use impacts.

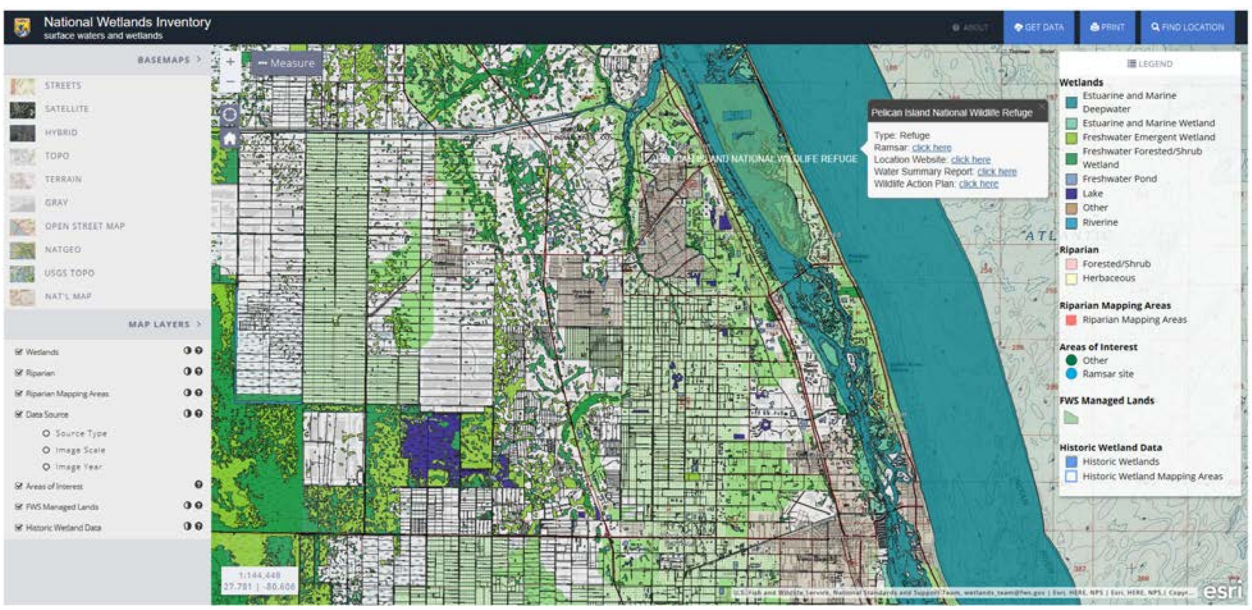


Figure 4. Screenshot of NWI map product that shows wetlands delineation (https://www.fws.gov/wetlands/data/mapper.html)

State Wetland Conservation Plans will describe regulations relating to wetlands protection. Florida has adopted a unified wetlands delineation methodology that is binding to all state, regional, and local governments throughout the state (FAC 62-340). This methodology is specific to Florida and recognizes the unique vegetation, hydrology, and soil features that characterize

Florida wetlands. Although the Florida methodology differs from the United States Army Corps of Engineers' (USACE) 1987 Wetland Delineation Manual, state and federal wetland delineation lines are very similar. FDEP publishes wetlands delineation guidance at:

- https://floridadep.gov/sites/default/files/delineationmanual.pdf
- https://floridadep.gov/water/submerged-lands-environmental-resources-coordination/content/wetland-delineation-and-umam

Other natural areas also have value such as the upland ecosystems, which include the hardwood forests in both the panhandle and the peninsula, pine forests, various scrub, dry prairie, rangeland and the rocklands of the extreme southern tip of Florida (https://www.floridasnature.com/florida_uplands.html). Flatwoods are the most widespread ecosystems in Florida, occupying as much as 50% of the state's land area. The topography of a flatwoods region is low and relatively uniform. The soil is sandy, acidic, has very little organic content with an underlying layer of marl or hardpan that not only inhibits drainage, it also prevents deep moisture from coming to the surface soil layer resulting in alternating seasonal periods of flood and drought. The dominant pine canopy is open, allowing plenty of sunlight to reach under-story shrubs, herbs and grasses. Upland areas are characterized by pines and palms that provide habitat for certain species like the Florida Panther. Many of these areas are either protected or have limitations on development to support endangered or threatened species. It is common for upland and wetland areas to lie adjacent to one another, providing the opportunity for species to migrate between the two ecosystems. Tropical hardwoods, hardwood hammocks, coastal scrub and dry prairies are other habitats located in upland regions (https://www.floridasnature.com/florida_uplands.html).

Natural areas and open space are defined herein as areas that are exempted from development. Generally, it means one or more of the following qualifiers exist:

1. Valuable for recreation, forestry, fishing, or conservation of wildlife or natural resources
2. A prime natural feature of the state's landscape, such as a shoreline or ridgeline
3. Habitat for native plant or animal species listed as threatened, endangered, or of special concern
4. A relatively undisturbed outstanding example of an uncommon native ecological community
5. Important for enhancing and conserving the water quality of lakes, rivers, and coastal water
6. 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 bodies of water that naturally absorb significant amounts of carbon dioxide

Permanent protection of sensitive areas can provide critical water quality protection and can be achieved through partnerships with landowners, municipalities, land trusts and state agencies. Land within the watershed that has been protected via acquisition by federal, state or local agencies, has conservation easements or is designated as wetlands or areas of critical concern should be clearly marked on maps. An example map of Florida panther habitat is shown in Figure 5.

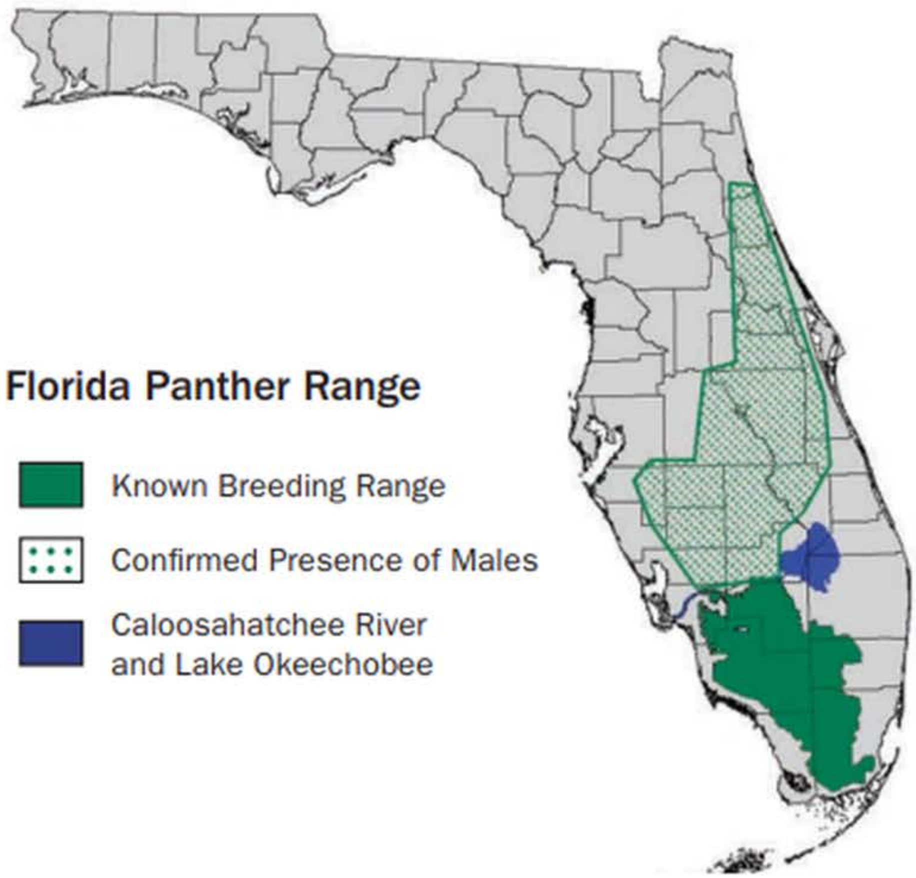


Figure 5. Florida panther habitat range (Florida Fish and Wildlife Conservation Commission, 2018)

1.2.4 Floodplains

A floodplain is a generally flat area of land next to a river. An example of a floodplain from the Suwanee River watershed is shown in Figure 6. Floodplain identification and mapping is important for flood protection of property/damage reduction. Because floodplains are expected to flood periodically, local governments are expected to develop regulations that either prohibit development in floodplains or permit development that follows standards that make the structures/property flood resilient. Floodplain identification and mapping is also important for water quality protection and restoration because inundated floodplains provide habitat for fish and wildlife, act as an important removal mechanism for nutrients and sediments and provide storage to reduce the severity of downstream flooding. Streams that are actively connected to their floodplains are less likely to suffer severe erosion.

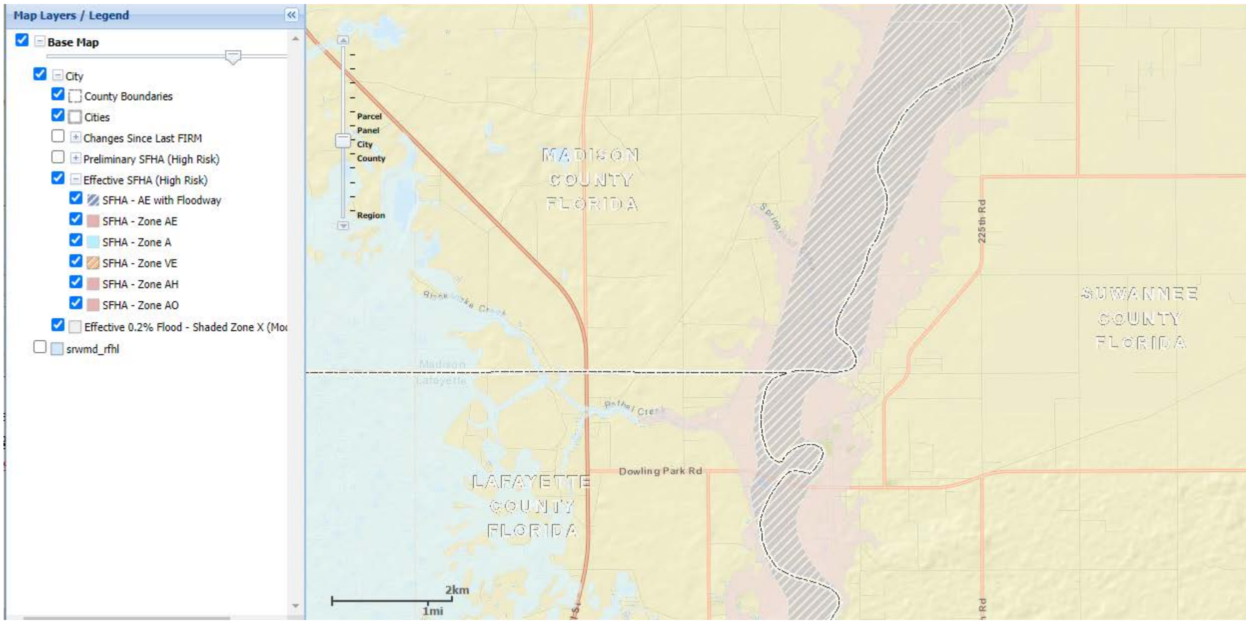


Figure 6. Natural channel of the river (dark line), river floodplain (black hatch) and fringe area (pink shaded area) within flood zones map. Note in Florida, the lack of topography makes delineating the flood plain and bluff lines a challenge, but the concept still applies (http://www.srwmdfloodreport.com)

Beyond the floodway is the flood fringe, which extends from the outer banks of the floodway to the bluff lines of a river valley. When a channel receives too much water, the excess flows over its banks and into the adjacent floodplain. Flooding that occurs along a channel is called riverine flooding (black hatched area in Figure 6). Overbank flooding occurs when downstream channels receive more than normal precipitation from their watershed. Excess water overloads the channels and flows out onto the floodplain. Overbank flooding varies with the watershed's size and terrain. One measure of a flood is the velocity of its moving water. Depending on the size of the river and terrain of its floodplain, flooding can last for days and cover wide areas. In urban areas, flash flooding can occur where impervious surfaces, gutters and storm sewers increase the speed runoff.

1.2.5 Flow Paths and Natural Channels

Natural channels are defined features on the ground that carry water through and out of a watershed. They may be rivers, creeks, streams or ditches. They can be wet all the time or dry most of the time. Beyond the floodway is the flood fringe that extends from the outer banks of the floodway to the bluff lines of a river valley.

ArcHydro is an available extension in ArcMap with a set of tools design to create the catchment drainage areas using a digital elevation model (DEM) as input. The ArcHydro function also permits the delineation of routing and sub-basins, which may need to be modeled separately. Figure 7 shows an example map illustrating the flow channels for the Caloosahatchee basin based on the modeling by Florida Atlantic University.

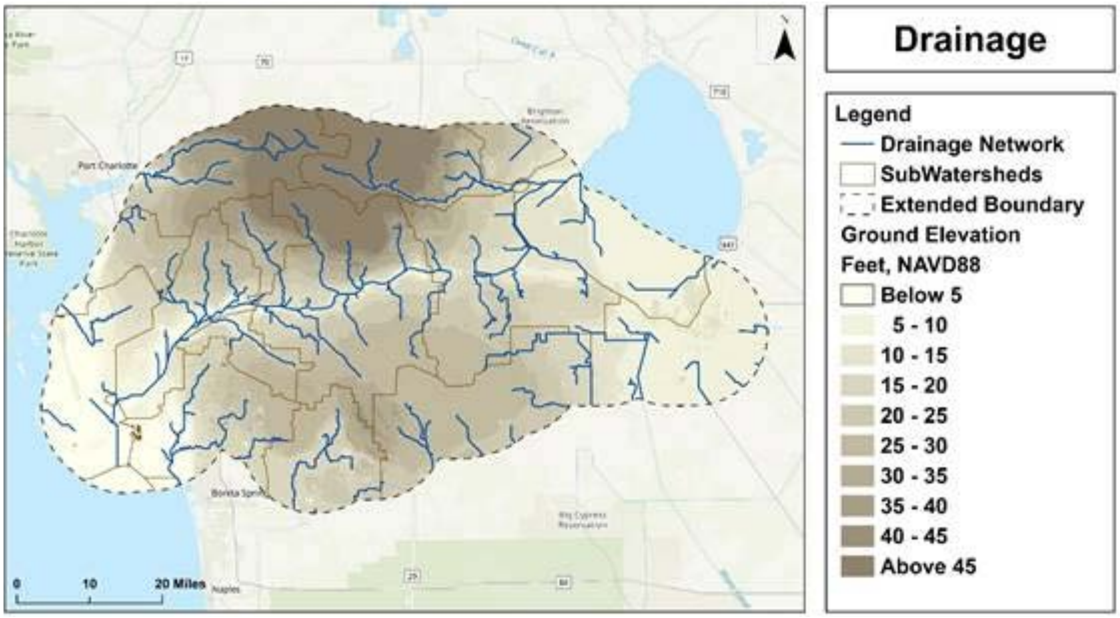


Figure 7. Example of a flow paths map for the Caloosahatchee basin

1.3 Planning Goals and Scope

To ensure the watershed planning effort remains focused, the planning goals and scope of the effort must be clearly defined. If the scope and goals are established early in the planning process, it will become easier to implement and monitor the plan. The goals and scope will also impact the planning horizon, which is typically 5 to 10 years. Factors such as changes to the watershed, development pressure, impacts of climate change, availability of new technologies and mitigation strategies, etc. will make the plan obsolete within a 10-year window or less, requiring periodic updates. Therefore, it makes sense to update the plan before then (e.g. every five years).

The stakeholders/partners identified in Section 1.1 will provide critical input into the watershed master planning process to identify issues of concern, develop realistic goals, and propose management strategies for implementation to help shape the scope of the WMP effort. For each goal identified during this process, specific management objectives should be developed that include measurable targets and specific indicators to track progress toward meeting the goal. The more specific the goals and objectives are, the easier it will be to achieve them. For example, one goal for a riverine community might be to restore recreational uses (fishing and swimming). This goal might be further defined as improving freshwater fisheries by reducing sediment and nutrient loading in runoff by 20% compared to a baseline value, increasing dissolved oxygen concentrations to an average of 7.0 mg/L as O_2, reinstating swimming by lowering fecal coliform counts during the summer to a geometric mean < 200 CFU/100 mL, and reducing peak flow for a 24-hour, 1-year storm event to <400 cfs (USEPA, 2008).

Preserving lands, wetland protection, limiting development, requiring the use of low impact development techniques and similar regulatory goals can also be established as a means to achieve up- and down-stream goals. Some examples of projects implemented to address watershed goals are listed in Table 1, some of which are discussed further in Chapter 5.

Table 1. Sample goals related to flood protection on a watershed basis

Sample Goal	Indicator	Management/Project
Reduce Overbank Flooding	Repetitive Loss Claims	Revetment
Restore Wetlands	Wetland Species Population Counts	Restore Water Flow
		Increase Regulatory Protection
		Acquire Properties
Reduce Flood Levels	Repetitive Loss Claims Changes to Flood Maps	Install Pump Stations
		Install Weirs/Gates
		Install Piping
Increase Water Supply	Water Restrictions	Construct Upstream Reservoir

1.4 Public Participation

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

- Create and implement a meaningful public involvement process that communicates effectively and engages with the diverse communities and stakeholders
- Develop a list of public and regional benefits
- Create public forums and collateral materials that provide clear, concise and easy-to understand information to enable the public to make informed decisions and provide input
- Publish and distribute the draft environmental documents for review and also notify the public, elected officials and other stakeholders of upcoming community meetings and public hearings
- Respond to public and stakeholder feedback in an accurate, consistent, and timely manner
- Evaluate the public involvement process on a regular basis

To facilitate community participation, there is a need to develop a database of stakeholders (community groups, residents, local and regional business owners, labor, environmental organizations, employers, academia, cultural and entertainment attractions, emergency responders, media, policy leaders, regulators, other institutions, etc.), as discussed Section 1.1. A successful community outreach program will assess attitudes and perceptions among target audiences and identify barriers, advantages and levels of support.

Communication must be public, and all input recorded in terms of who is in attendance and the content of educational materials. A website should be created as a clearinghouse of documentation for all meetings, including: agendas, notices, meeting materials, meeting summaries or minutes, public comment logs, plan documents, and supplemental materials used to develop the plan. Because not all stakeholders can participate in many daytime meetings in person, options to provide input should include: 1) commentary tool on the webpage, 2) virtual meetings using Zoom, WebEx, Teams or other platforms, 3) surveys, 4) local news media outlets, and 5) community discussion boards. Such forums must be monitored continuously to be able to incorporate comments into revisions of the plan. All outreach programs should incorporate a news media outlet to reach as many stakeholders and members of the public as possible.

Every watershed master plan should include an information/education component that involves the watershed community. Because many water quality issues result from individual actions and the solutions are often voluntary practices, effective public involvement and participation promote adoption of management practices, help to ensure the sustainability of the watershed master plan, and encourage behaviors that will help to achieve planning goals and objectives (see Section 6.1). Examples of outreach materials using the CRS Coordinator's Manual to identify those CRS activities that require outreach effort(s) for credit. A draft outreach plan and supporting documents are included in Appendix E.

2.0 WATERSHED CHARACTERIZATION

Once the planning team has been assembled and the overarching planning goals, scope, and objectives established, the watershed must be characterized to identify the most vulnerable areas and to mobilize resources to implement the action plan. Understanding how the watershed works will involve gathering existing information and data sets from previous planning efforts involving water quantity and water quality in the watershed. This effort includes creating a data inventory, identifying any critical data gaps, and analyzing the data with screening tools and modeling to identify and prioritize areas of flood risk that should be addressed by the plan. It is important to note that this step is iterative and ongoing as new data are generated and projects are implemented and monitored.

2.1 Inventory of Existing Data

To assess the historical and current conditions, it is critical to gather existing data sets that characterize the physical and natural features of the watershed in the following categories:

- Topographic data
- Groundwater
- Surface water/tides
- Soils data
- Land cover/land use identification including vacant land, wetlands, waterbodies, etc.
- Precipitation records
- Open space
- Impervious areas
- Waterbodies
- Locations of stormwater infrastructure
- Natural resources
- Demographics

The data sources used by FAU to develop the mapping tools and algorithms are provided in Appendix F. Each of these are explained in further details in the sections that follow.

2.1.1 Topography/Elevation Data

Topography is a key parameter that influences many of the processes involved in flood risk assessment, and up-to-date, high-resolution, high-accuracy elevation data are required. Fortunately, high quality, aerially extensive electronic databases are available, a major improvement over old topographic maps. These high-quality datasets are in the form of *"light detection and ranging"* (LiDAR) files. LiDAR is a method for measuring distances by illuminating the target with laser light and measuring the reflection with a sensor. Differences in laser return times and wavelengths can then be used to make digital 3-D representations of the target.

FEMA has adopted as a standard Quality Level 2 (QL2) data as defined in the USGS LiDAR Base Specification v1.2 (Heidemann, 2018), which is provided through the USGS 3D Elevation Program (3DEP) (FEMA, 2016a). 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) can be acquired from the USGS 3DEP Elevation Products Program available through the National Map Viewer (https://viewer.nationalmap.gov/basic/) or cwr3.fau.edu. QL2 LiDAR specifications are found in the USGS LiDAR Base Specification: Version 1.0 (2012), Version 1.1 and 1.2 (2014), and Version 1.3 (2018) (Heidemann, 2018). QL2 data from the National Enhanced Elevation Assessment (NEEA), which serves as the basis for the 3DEP, was developed using airborne LiDAR point density of 2 points per square meter allowing for high accuracy and enhanced resolution of derivatives. The 1-meter DEM has a target non-vegetated vertical accuracy of is 19.6 cm at the 95% confidence level (Arundel et al., 2015). This accuracy meets the 3DEP QL2 vertical accuracy threshold of ±10 cm root mean square error (RMSEz) (Arundel et al., 2015). In vegetated areas, the vertical accuracy might be slightly diluted (showing larger RMSEz values), but nevertheless the 1-meter DEM products retain a high level of accuracy in all segments. The 3-meter DEM products have a vertical accuracy between 22 cm and 30 cm, which meets the specifications of FEMA Elevation Guidance (Document 47) for flood risk analysis and mapping (FEMA, 2016a). The FEMA specifications for vertical accuracy of elevation datasets are shown in Table 2 (adapted from FEMA 2016a, p. 6).

Table 2. FEMA vertical accuracy requirements based on flood risk and terrain slope

Flood Risk Level	**Terrain Characteristics**	**Specification Level**	**Vertical Accuracy**	**LiDAR Nominal Pulse Spacing (NPS)**
High	Low-lying flat areas	Highest	24.5 cm / 36.3 cm	≤ 2.0 meters
High	Rolling slopes	High	49.0 cm / 72.6 cm	≤ 2.0 meters
High	Hilly terrain	Medium	98.0 cm / 145 cm	≤ 3.5 meters
Medium	Low-lying flat areas	High	49.0 cm / 72.6 cm	≤ 2.0 meters
Medium	Hilly terrain	Medium	98.0 cm / 145 cm	≤ 3.5 meters

The extent of high-resolution DEM datasets available through the USGS 3DEP elevation program for the State of Florida are: a) 3-meter DEM; and b) 1-meter DEM, as shown in Figure 8.

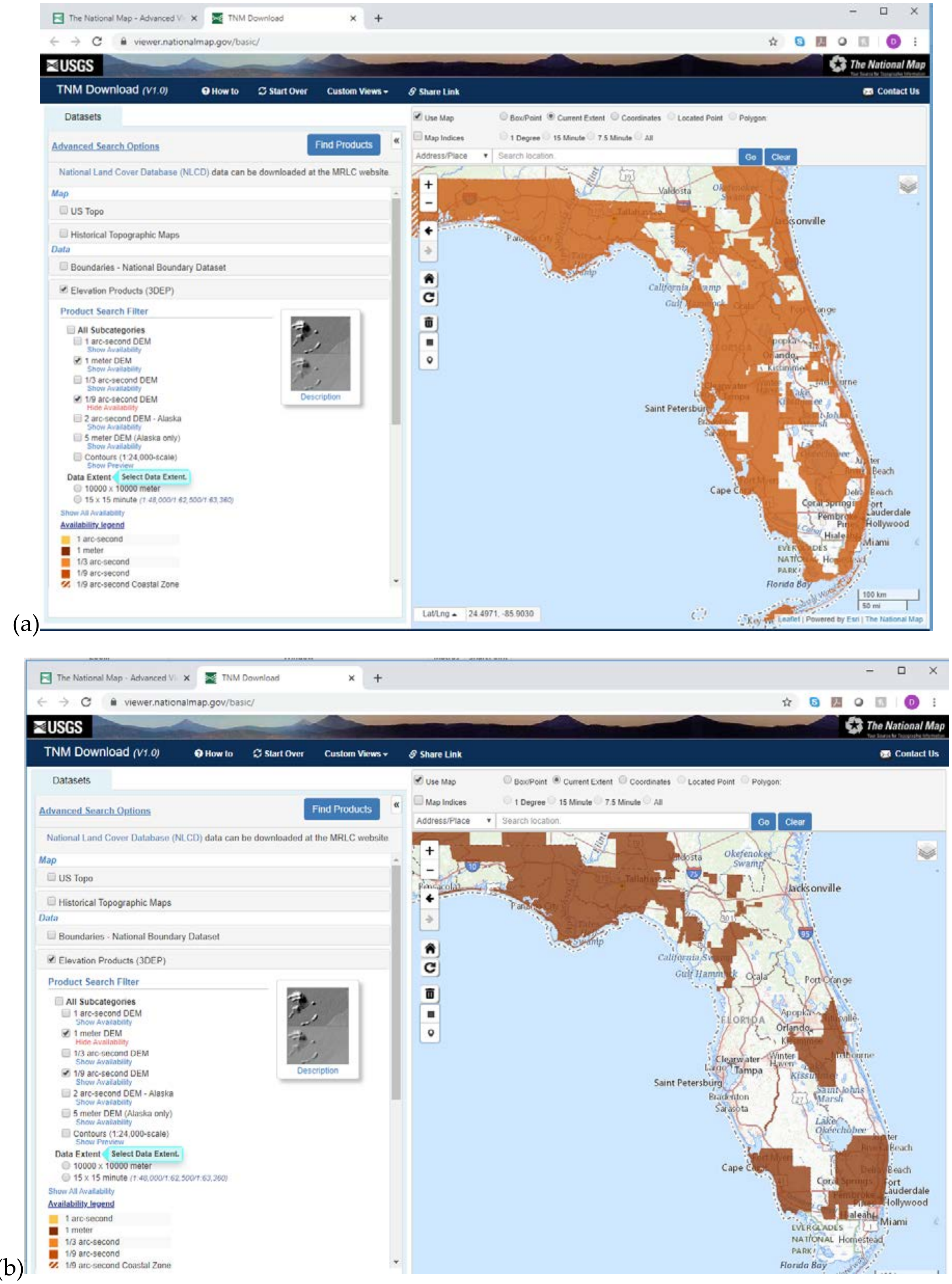


Figure 8. Extent of high-resolution DEM datasets available through the USGS 3DEP elevation program for the State of Florida: a) 3-meter DEM and b) 1-meter DEM

Additional high resolution LiDAR DEM datasets (1-meter and 3-meter) can also be obtained from the NOAA Data Access Viewer (https://coast.noaa.gov/dataviewer/#/lidar/search/) and cwr3.fau.edu. These datasets can be combined with datasets acquired from the USGS National Map Viewer to improve the extent of the coverage, which is incomplete in certain parts of the State of Florida (mostly for inland rural counties and the Suwannee River Basin). Furthermore, the USGS 1/3 arc-second (approximately 10 meters) National Elevation Datasets can also be obtained from the USGS National Map Viewer. Newer 1/3 arc-second data are increasingly derived from LiDAR and other high-resolution data sources. Reported accuracy of the 1/3 arc-second DEM is approximately 1.16 m (Haneberg, 2006), which meets FEMA specification for high to medium flood risk on hilly terrain. An example of a kriged topographic layer derived from these products is shown in Figure 9.

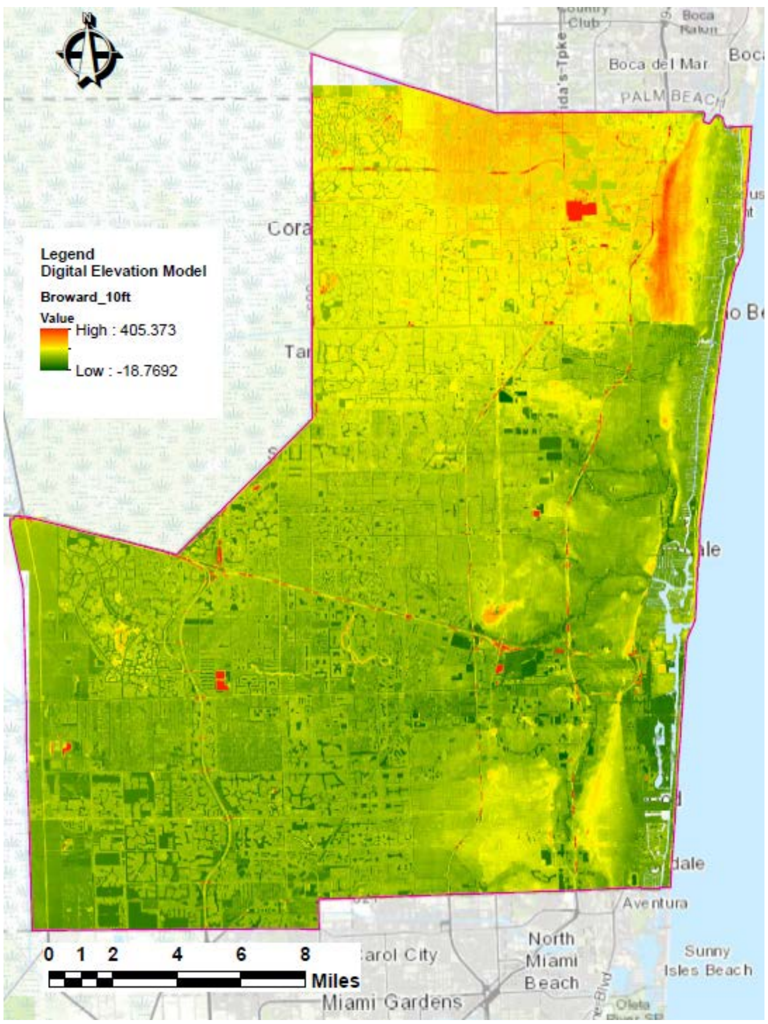


Figure 9. Kriged topographic layer for the Broward County, FL watershed processed by FAU

2.1.2 Groundwater

Groundwater plays a key role in determining the soil storage capacity, which is the ability of the soil to absorb precipitation. Knowledge of the soil storage capacity can provide insight into the tendency for ponding. The underlying concern is that the combination of a high groundwater table, heavy rains, and impervious conditions can lead to localized nuisance flooding events that may be too difficult to predict with a model of predicted averages of groundwater/surface water values. Coastal tidal conditions can also exacerbate flood concerns in areas with shallow groundwater tables. Thus, groundwater conditions are conceptualized as an average of the observable extremes due to those factors in situ.

An acceptable Level of Service (LOS) for a community must be defined to identify priority areas. A LOS would indicate how often it is acceptable for flooding to occur in a community on an annual basis. Local officials realize that there are no examples where there is never flooding. In a survey of public officials conducted by E Sciences (2014), the number of days of continuous nuisance flooding that the public will tolerate before the event is considered destructive is about 4 days, which means that roughly 1% (4/365) of the highest daily groundwater elevation values on an annual basis represents the time of the year that a given area is at greatest risk of experiencing a destructive-nuisance flooding event. As Figure 10 indicates, when the tidal (or groundwater) data is tallied from smallest to largest, the top 1% is the 99th percentile.

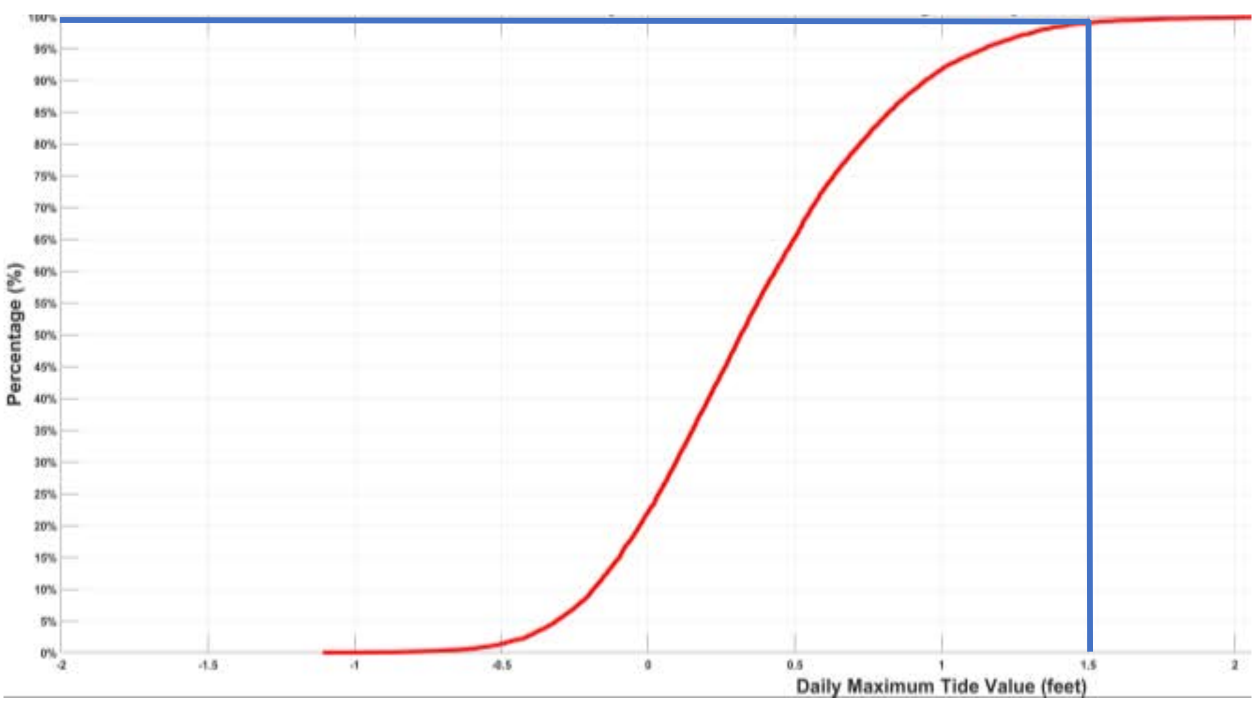


Figure 10. Definition of the 99th percentile value from the daily maximum tide data in the Virginia Key station from 1994-2019

Because for certain areas of Florida, the surface and ground water levels interact as one, there is a need to capture groundwater data. Romah (2011), Bloetscher and Wood (2016) and others have noted that both tides and groundwater are increasing with time (Figure 11). Pertinent groundwater information can be obtained from the 5 Florida water management districts (WMDs) and the Florida Department of Environmental Protection (FDEP) to identify watershed characteristics necessary to inform an effective framework for a statewide watershed master planning initiative.

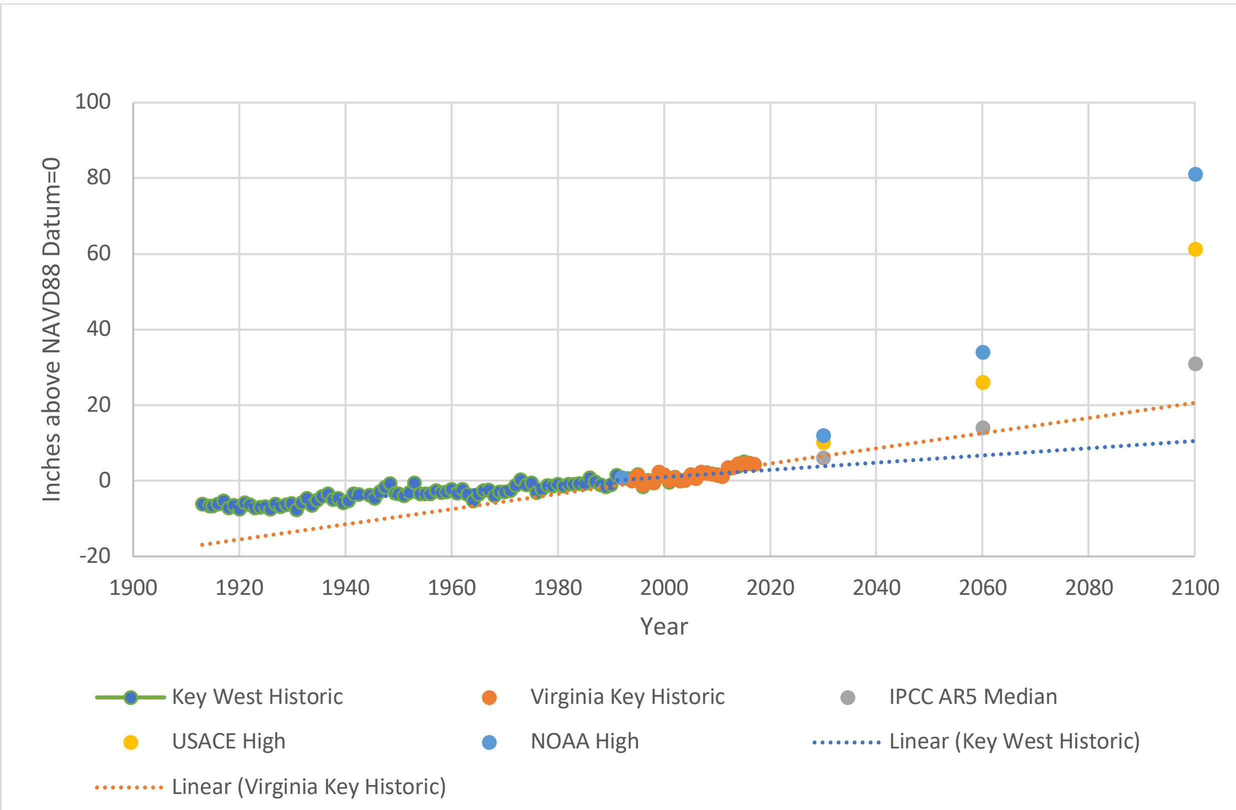


Figure 11. Increasing tides and projected future increases – 99th percentile

Table 3 summarizes the groundwater datasets collected by FAU and made available at cwr3.fau.edu. Over 4400 wells were identified and downloaded, but only 35% (*n*=1500) provided data applicable for screening (surficial aquifer and continuous data collection since 2000). Note that as many as one-third of wells in a given area may not be useful for modeling purposes because they are either offline, stopped recording years ago, temporarily out of service, or other mechanical reason.

Table 3. Location of groundwater datasets

Agency	GW Parameter	Date Range	No. of Wells	Source Data Format
SFWMD	Daily maximum	2000 - 2019	844	CSV files downloaded (and processed)
SWFWMD	Daily maximum	2000 - 2019	469	Access database provided by District
SRWMD	Daily maximum	2000 - 2019	197	Data portal (downloaded and processed)
SJWMD	Daily maximum	2000 - 2019	717	Provided by the District for a fee
NWFWMD	Different temporal resolutions (max processed)	2000 - 2019	92	Provided by the District (required processing)
FDEP	Upper Floridan Aquifer water level	2012-2017	1564	FDEP Open Data Portal: https://geodata.dep.state.fl.us/ https://geodata.dep.state.fl.us/datasets/unconfined-aquifer-wells-well-list-frame/data

The groundwater surface elevation (hydraulic gradient) mapping is a critical effort because to krig a groundwater surface elevation, a common date is needed. First, there needs to be enough well/station-based groundwater data to create a groundwater surface in GIS. Having less than 20 wells that are aerially extensive is insufficient for developing a groundwater layer in GIS using stochastic variance-dependent spatial interpolation (e.g., ordinary kriging). Prior work by Romah (2011) indicates that while different interpolation methods can be used, ordinary kriging methods are adequate and representative. A subset of available data is used for the creation of a validation dataset, and the rest of the data is used for calibration (i.e., estimation of parameters of the interpolation model). Where the coast is present, the coast is used as a constant head boundary. For regions with spatially sparse or non-uniform groundwater wells, the groundwater levels are estimated using a multiple linear regression approach from auxiliary variables in addition to the limited ground well observations in a watershed (Zhang et al., 2020).

Based on locating the 99th percentile value as noted earlier, the top 2% of values, the 98-100th percentile, are trimmed and then tabulated in ascending order and reviewed to determine a common date over all remaining wells in the set. The 99th percentile should avoid outlier dates that occurred during historically rare storm events. Outliers and anomalous groundwater levels in the database are initially evaluated, identified and if found to be faulty, are 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 is not used in the generation of the groundwater surface. FAU has created groundwater layers for all 29 watersheds in Florida (available at cwr3.fau.edu). An example of one such groundwater surface krig is shown in Figure 12.

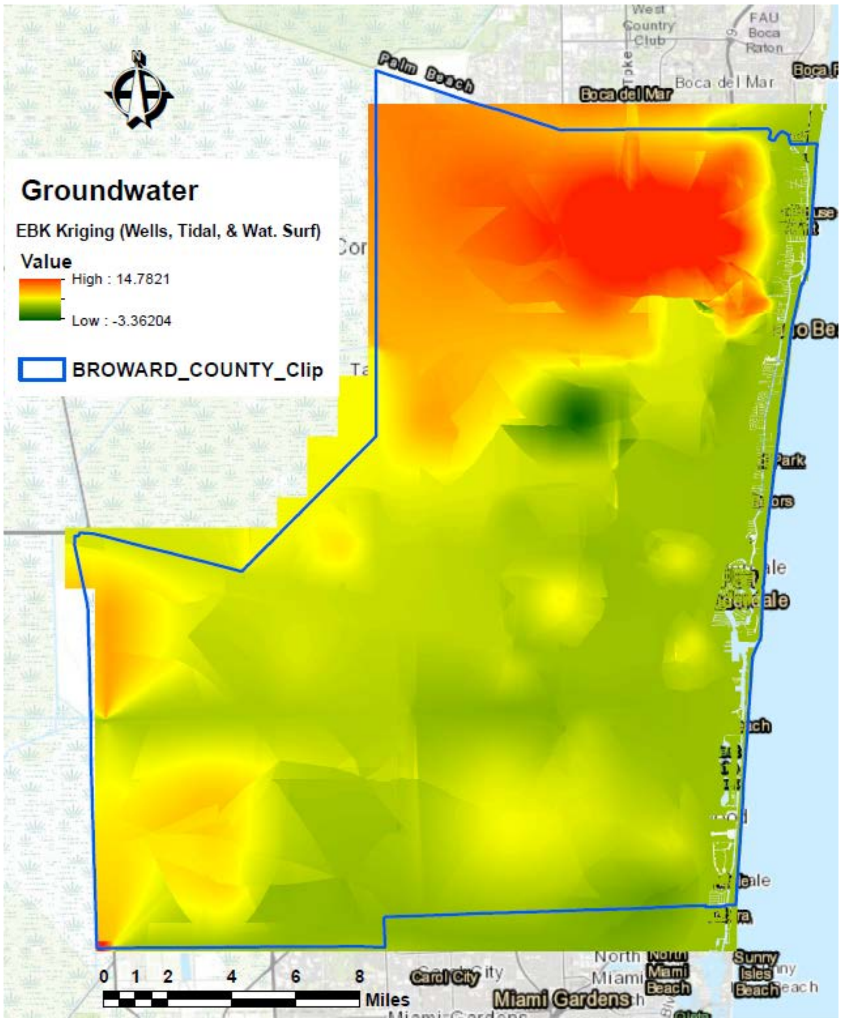


Figure 12. Example output of a kriged groundwater surface map for Broward County, FL

In flat or coastal areas, like south Florida, there is very limited topography and a direct relationship between ground and surface waters exists. Prior work by Bloetscher and Wood (2016), Bloetscher and Romah (2015), Wood, (2016), E Sciences (2013), Romah (2011) and others related to the research team have extensively studied this issue. Each demonstrated that low relief, coastal areas may see increased flood risk due to increasing sea levels, so as a result, predicting how areas with low elevations may be affected by inundation in three ways: 1) from direct surface flooding, 2) from rising groundwater levels, and 3) from the inability of inland areas to drain.

There are however scenarios when the groundwater layer is less important to surface flooding screening. For coastal regions that also have some degree of topographic relief, there may be a separation of surface water from groundwater. The further away from the coast, the topography creates a separation whereby the ground and surface waters may be many feet apart and rivers do not intersect the groundwater table at the upper reaches of the watershed. Tampa Bay is an example in Florida. Another possibility is where the groundwater and surface waters are not related and rarely intersect. Examples exist in the center of the state, and widely outside of the state. Groundwater is less important in these areas, especially if clay or rock exists near the surface (i.e. confined aquifers). See Section 2.1.3 for more details.

2.1.3 Surface Water/Tides

Surface water data is gathered from stream gages. Figure 13 shows stream gage locations provided by SFWMD. However, it may be helpful to review temporal trends and relative minima and maxima in surface water elevations.

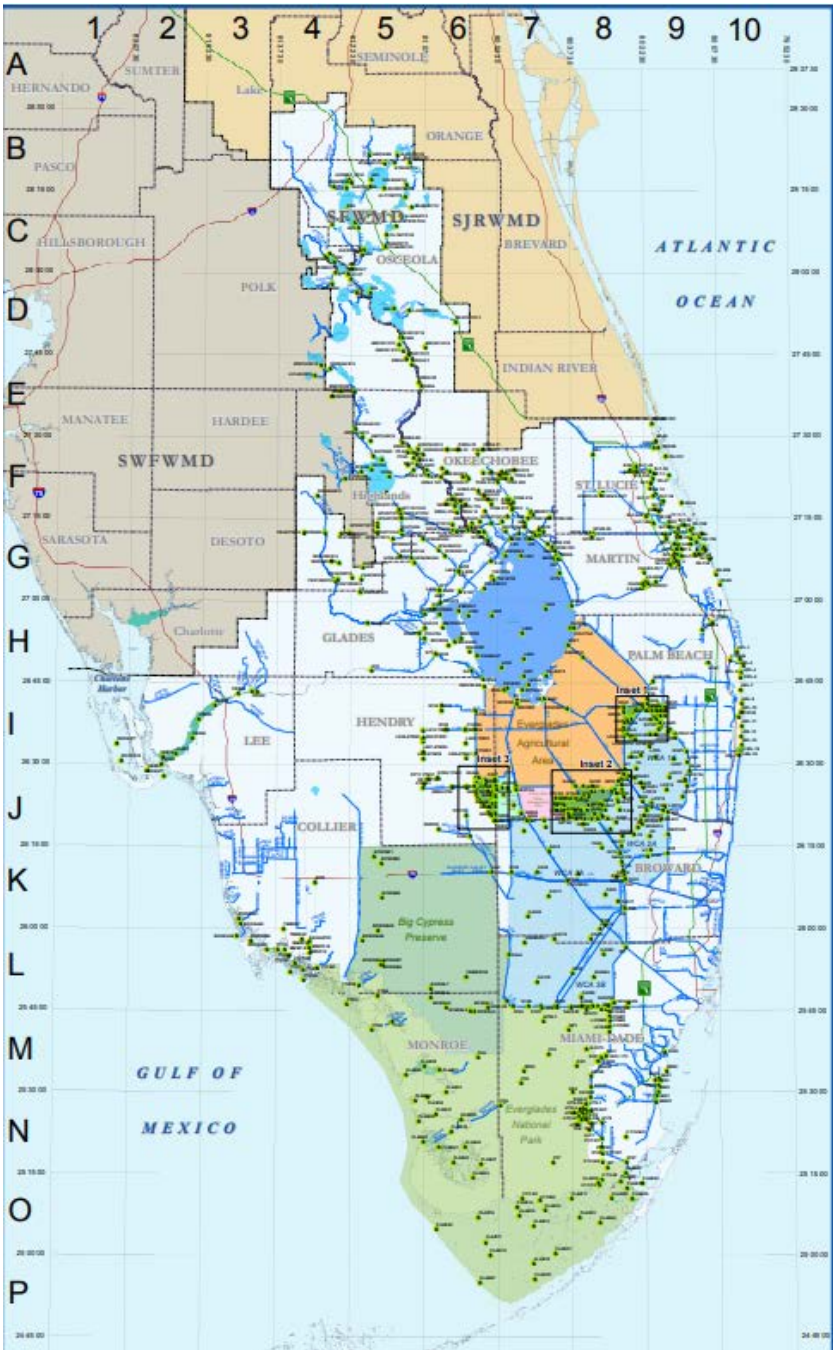


Figure 13. SFWMD stream gage stations for surface water data (https://www.sfwmd.gov/sites/default/files/documents/em_stage_monitor_map_2.pdf)

There are four issues with surface water data sets:

1. **The southern Florida coastal condition is characterized by direct interaction between groundwater and surface water**. Bloetscher et al. (2012) found that the groundwater elevation would seek high tide as opposed to average tides for the coastal boundary condition. Tidal

data can be gathered from NOAA tidal gages and other gages monitored by local governments. The location of tide gages is important to ensure they accurately depict tides, as opposed to inland waters. Figure 14 shows the location of tide gages in Florida. These tide gages record high and low tides by cycle each day.

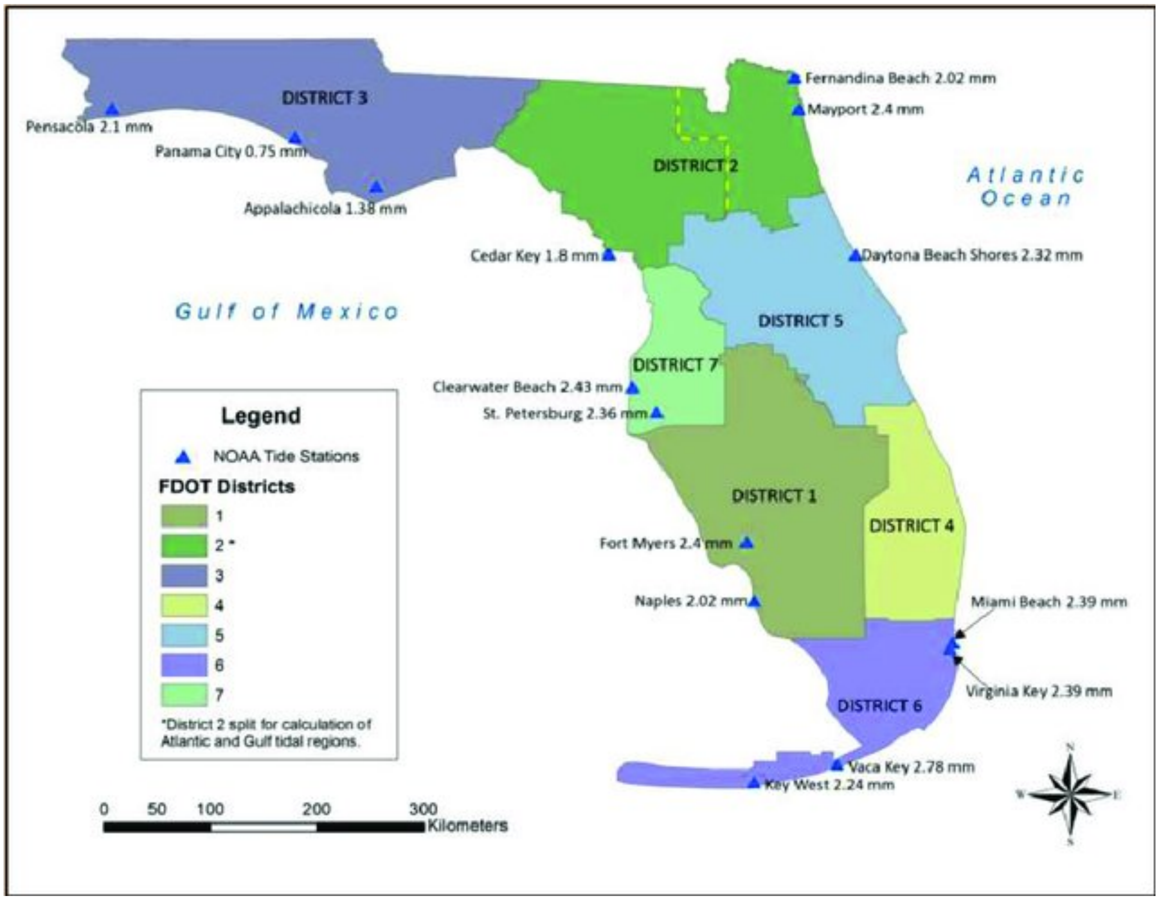


Figure 14. Locations of Florida tidal stations maintained by NOAA in FDOT Districts (https://www.researchgate.net/publication/330637496_Sea_Level_Rise_Projection_Needs_Capacities_and_Alternative_Approaches_Sea_Level_Rise_Projection_Needs_Capacities_and_Alternative_Approaches/figures?lo=1)

The tidal peak condition in the peninsula tends to occur with the king tides in the fall, which is close to the point when the groundwater levels are also highest. In north Florida, the highest tides could also be in the spring due to runoff conditions. To set a boundary for the coastal areas, the high tide on the common data should be chosen. The land has relatively flat terrain, and groundwater elevation is controlled by canals and tides. Resolving the south Florida situation is straightforward. Once a common time period is determined across the majority of wells, canal data can be gathered for that date (and two days prior in the event the canals were deliberately lowered) from database sites for surface waters. Between stations, an ArcGIS tool permits a line to replicate the canals and establish points in a gradient between stations. The same is true for the ocean, but it is a constant head boundary. The canals form boundary conditions for the screening tool on the edges of the basin and affect localized groundwater. Using the water levels in the groundwater and canals, the only remaining boundary is the ocean. The tide issue is resolved by using the same groundwater date for high tide. FAU has the tidal information available at cwr3.fau.edu.

2. **Coastal areas with topography inland with direct interaction of groundwater and surface water only along the coast (e.g. Hillsborough County condition)**. Current kriging spatial interpolation techniques cannot resolve regions with sparse or no well observations. Thus, an ideal groundwater table map/raster layer cannot be produced. The multiple linear regression (MLR) approach has been well established for groundwater elevation estimation (e.g., Sepulveda, 2003; Chung and Rogers, 2012). It assumes that the exposed water surface such as lakes, streams, rivers, and canals have the elevation of a local minimum water table referred to as MINWTE in literature. The water table elevation (WTE) is closely related to MINWTE and the depth-to-MINWTE that can be derived by subtracting MINWTE from DEM. The WTE is estimated via a multiple linear regression model as follows (Equation 1):

   Equation 1 $\mathbf{WTE = \beta 1(MINWTE) + \beta 2(Depth\ to\ MINWTE) + \varepsilon}$

   where ε = statistical error

The tidal and groundwater dates need to be obtained the same way they are for the south Florida condition. Second, for points from streams, rivers, canals, and inland water boundaries (e.g., lakes), the elevation of these points are assigned as DEM using the “extract value to point” function in ArcGIS. For points along ocean shorelines, elevations are assigned to the closest tidal station observed elevation using point to point spatial join function in ArcGIS. Since the value of “depth to MINWTE” is created by subtracting MINWTE from DEM, the conditional function in ArcGIS should be used to set negative values to 0. This effort is available for some Florida watersheds at cwr3.fau.edu.

3. **Locations where there is no direct interaction between groundwater and surface water/tidal conditions, and groundwater and surface water are not related**. This is the north Florida condition. In addition, there are two possible high groundwater levels: 1) post rainy season and 2) spring season. The spring groundwater levels may be more related to spring runoff.

4. **Inland, non-coastal basins that have no boundary along the coast**. For watersheds with no coastal connection, the challenge is determining if the groundwater and surface waters are linked, and how fluctuations are controlled (versus tides affecting them). It will require obtaining information from adjacent watersheds as a means of smoothing edges within the watershed of interest. Otherwise the boundaries will not provide useful results.

For all watersheds, the outlets need to be defined. Coastal communities will have the coastal ocean as the outlet. Areas that do not discharge to the coastal ocean will have outlets that become inlets for downstream watersheds. For example, as Figure 15 shows, the Caloosahatchee basin has an inflow from Lake Okeechobee on the east. It also has contributions from various swamps along the river as it flows west. The outlet is to the Gulf of Mexico and the east side of Sanibel Island. A more inland watershed may require a substantially expanded area of investigation to address incoming water and limits on the outlet end). This requires using a screening model (see Chapter 4).

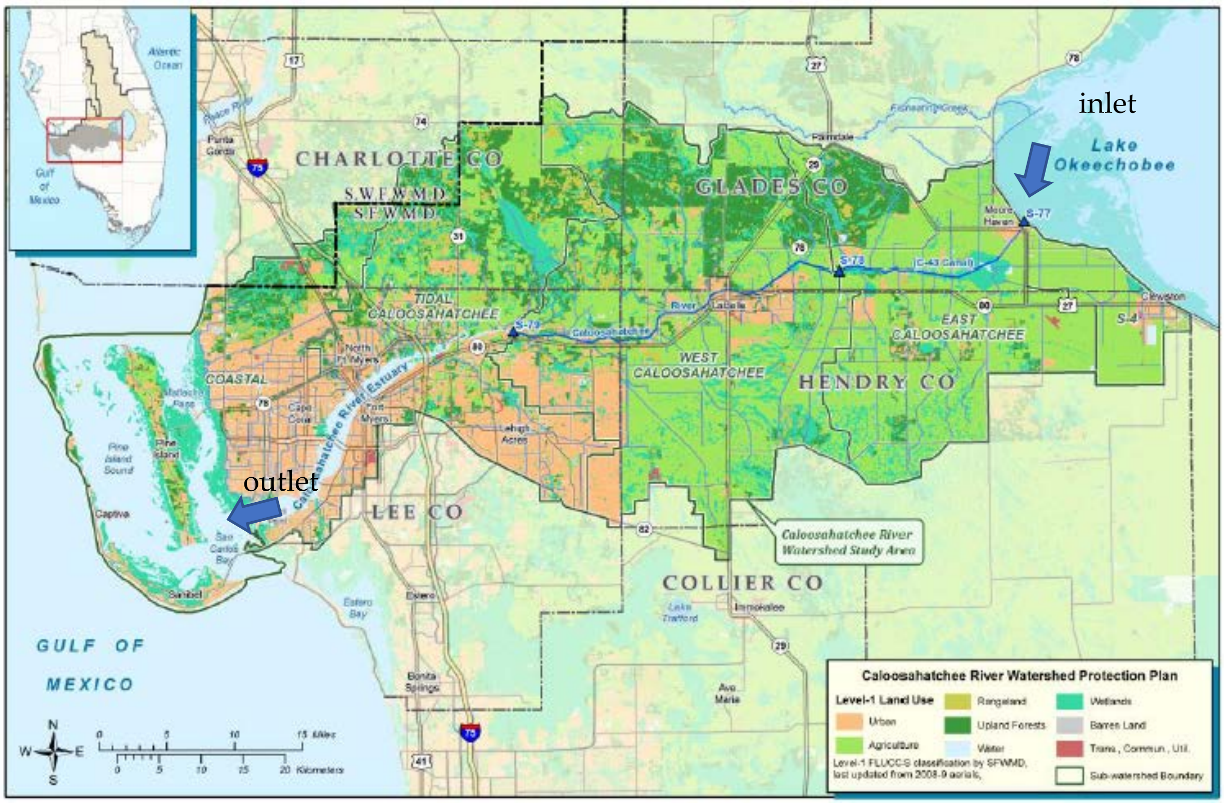


Figure 15. Land use in the Caloosahatchee watershed (SEWMD, 2009) and note the 3 lock structures are shown on the map – S77, S78 and S79

2.1.4 Soils

Soil can store water if there is adequate distance between the topographic surface and the groundwater table elevation and the soil itself is capable of infiltrating the water. Soils data is available from 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, which is similar to the standard product from the USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database but is available in the Environmental

Systems Research Institute, Inc. (ESRI®) file geodatabase format, 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) (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/survey/partnership/ncss/).

An important addition to this format is a 10-meter raster (MapunitRaster_10m) of the map unit soil polygons feature class, which provides statewide coverage of soil data in a single GIS layer. In order to create a true statewide soils layer, some clipping of excess soil survey area gSSURGO data may be required. The format also includes a national Value Added Look Up (valu) Table that has several new "ready to map" attributes. However, file geodatabases such as gSSURGO are not compatible with the NRCS Soil Data Viewer application and only support a limited subset of the standard query language (SQL) that the Microsoft® Access® database format or Microsoft® SQL Server® uses. These conversions were made by FAU for all basins in Florida and are available at cwr3.fau.edu. Statewide available water storage derived for the soil layer (0-150 cm) is shown in Figure 16.

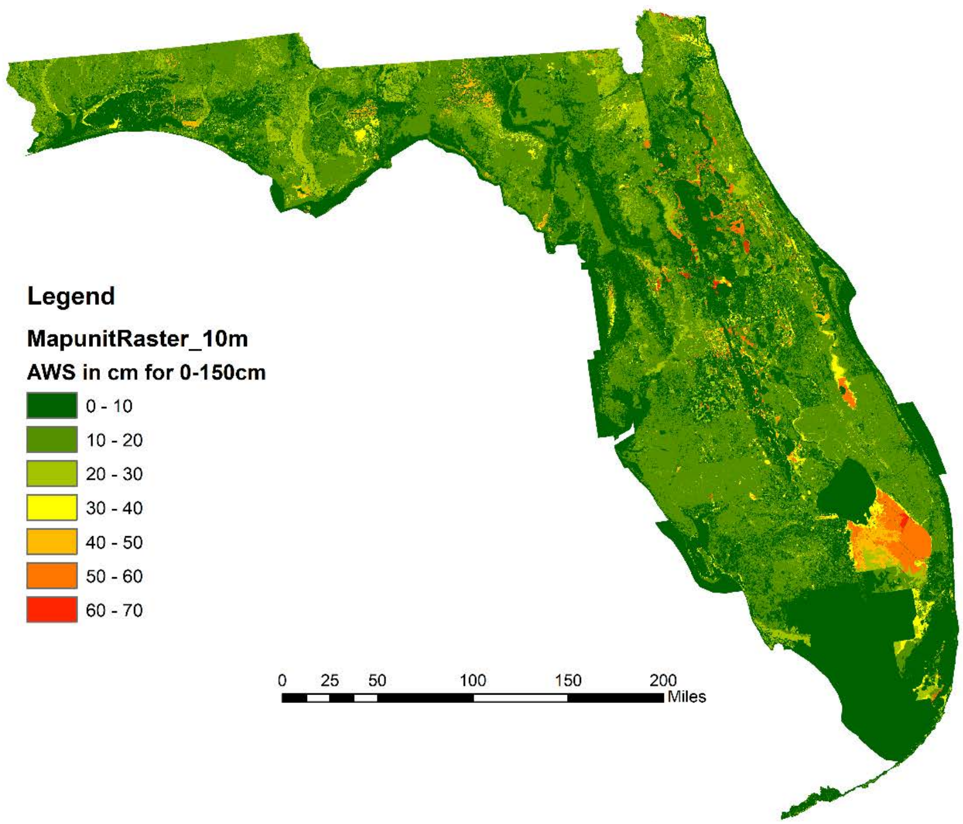


Figure 16. Florida available water storage map processed by FAU

According to the Plant and Soil Science E-Library of the University of Nebraska-Lincoln (https://passel2.unl.edu/view/lesson/0cff7943f577/10), water holding capacity refers to the amount of water held between field capacity and wilting point. Available water storage (AWS) is that portion of the water holding capacity that can be absorbed by a plant. As a general rule, plant available water is considered to be 50% of the water holding capacity. The water holding capacity (ratio) is calculated using Equation 2:

Equation 2 Water holding capacity = 2 × (AWS for a soil layer of 0-150 cm) / 150 cm

Figure 17 shows the water holding capacity (ratio) map for Florida. Water holding capacity here is dimensionless.

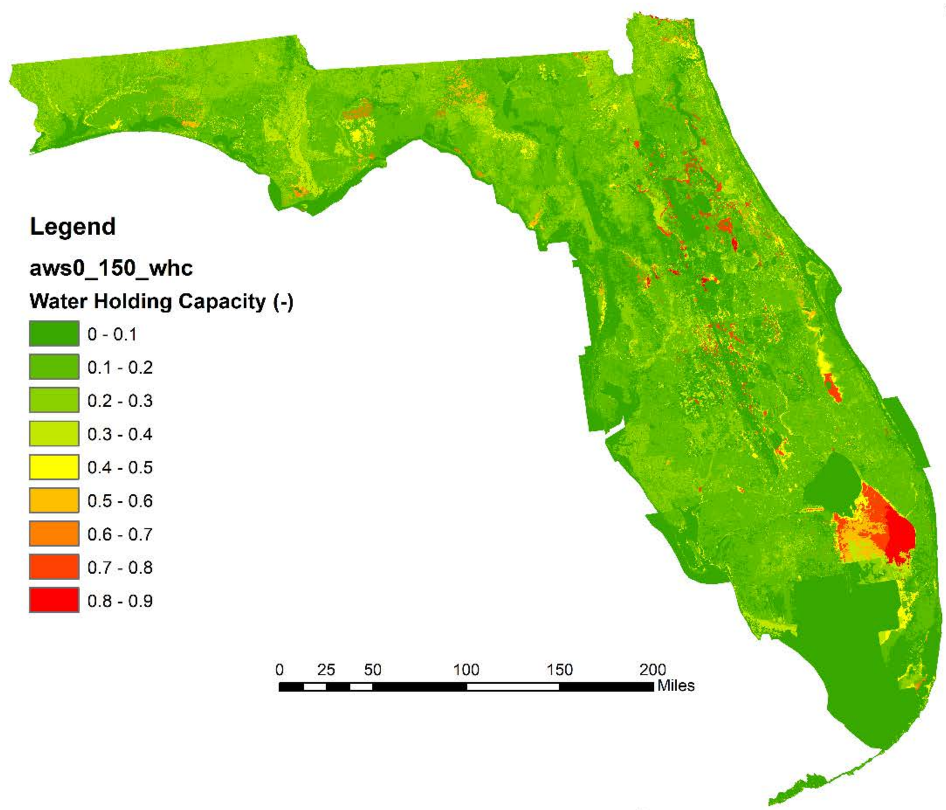


Figure 17. Florida water holding capacity ratio map processed by FAU

2.1.5 Land Cover/Use

The USGS produces the National Land Cover Database (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. The database is designed to provide cyclical updates of United States land cover and associated changes. Systematically aligned over time, the database offers the ability to understand both current and historical land cover and land cover change, and enables monitoring and trend assessments designed for application in biology, climate, education, land management, hydrology, environmental planning, risk and disease analysis, telecommunications, and visualization. Using the NLCD 2016 dataset, a GIS layer can be created by using only three categories out of the 13 to identify impervious areas such as primary roads in urban areas, secondary roads in urban areas, and tertiary roads in urban areas.

NLCD is coordinated through the 10-member Multi-Resolution Land Characteristics Consortium (MRLC), a two decades-long interagency federal government collaboration that has proved an exemplary model of cooperation among federal agencies to combine resources to provide digital land cover information nationwide. The database is designed to provide cyclical updates of United States land cover and associated changes to assess both current and historical land cover. 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. Data are available on *mrlc.gov/data/nlcd-2016-land-cover-conus* either as prepackaged products or custom products. Processed data is available at cwr3.fau.edu.

In addition to the NLCD land cover dataset, FAU also collected the statewide land use land cover dataset compiled by FDEP. This dataset integrates land use land cover data products provided by the five water management districts in Florida based on manually interpreted fine resolution aerial photography: North West Florida Water Management District (NWFWMD) 2012-2013, Suwannee River Water Management District (SRWMD) 2010-2011, St. Johns River Water Management District (SJRWMD) 2009, South West Florida Water Management District (SWFWMD) 2009, and South Florida Water Management District (SFWMD) 2004-2005 and 2008-2009. Codes are derived from the Florida Land Use, Cover, and Forms Classification System (FLUCCS-DOT 1999) but may have been altered to accommodate regional differences. Compared to the NLCD dataset, this land use land cover product has a finer delineation of land cover types but is not up to date. This dataset can help further refine water bodies and impervious surfaces where soil water holding capacity is considered as zero in the screening tool.

At 30 m resolution, the NLCD and the FLUCCS-DOT datasets complement each other. Small waterbodies and impervious surfaces have not been well delineated in the NLCD 2016 dataset, but can be delineated better using the statewide land use land cover dataset. Large water bodies such as Tampa Bay and canals have not been fully delineated by the statewide land use land cover dataset but delineated by the NLCD 2016 dataset. The solution is to use the impervious surface from the NLCD 2016 to set the soil water holding capacity to zero in screening tool simulations, and water bodies defined in the statewide land use land cover dataset were used to set soil water holding capacity to zero. Waterbodies are re-delineated by using both NLCD 2016 and statewide land use land cover datasets (available at cwr3.fau.edu). Note that tiny waterbodies may be missing from WMD files. The 2016 NLCD land cover map for Florida is shown in Figure 18 with an overlay of county boundaries. The impervious surface mainly includes the classes 21, 22, 23 and 24. The 30 m resolution can be re-pixelated to 3 m.

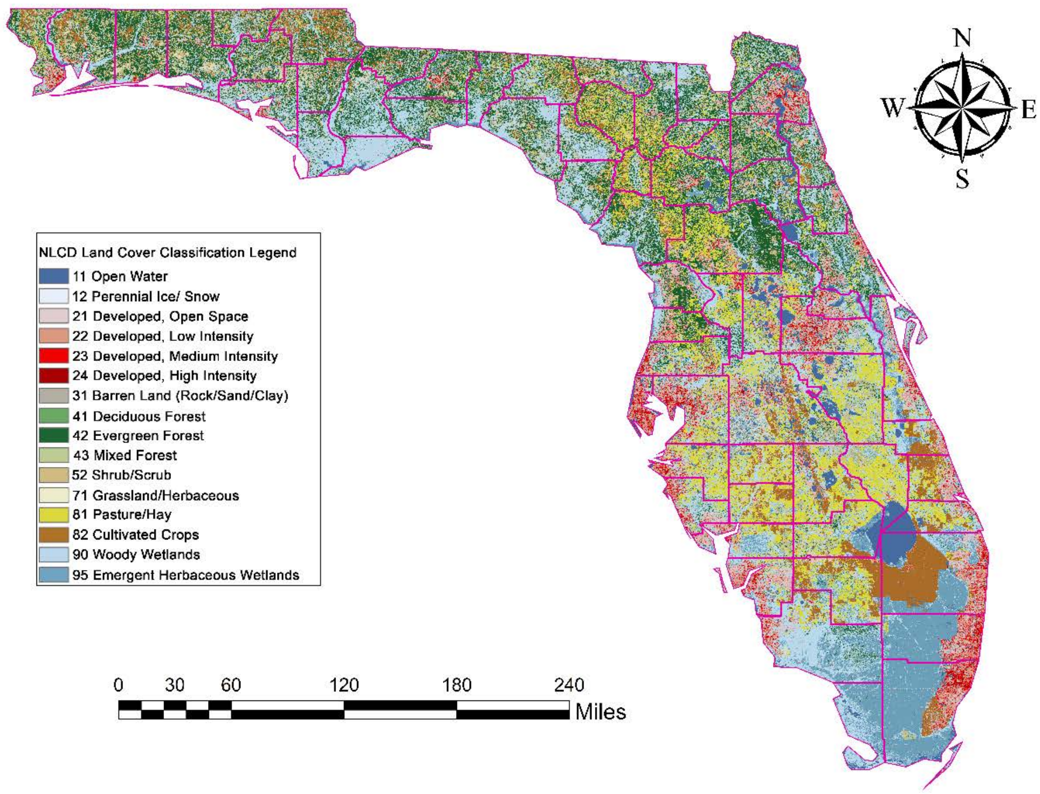


Figure 18. Florida NLCD 2016 land cover map processed by FAU

The point of land cover is to determine the extent to which water can infiltrate the soil (natural condition), versus more developed areas, where the land cover type will discourage infiltration. For example, cropland, pastureland, rangeland, forestland, agriculture, developed, federal land, etc. are primarily conditions where the land has considerable permeability. As a result, when modeling runoff from storms, these areas will create less intensive runoff curves. In contrast, developed areas will have more imperviousness, which may vary at the parcel level. For example, typical residential communities may have less than 30% imperviousness, whereas downtown business districts may be upwards of 80%. In such cases, the runoff curve associated with highly developed areas causes higher peak runoff that occurs faster than that associated with undeveloped properties.

Future land use plans normally address what communities expect for development intensity and include regulations to mitigate the higher intensity runoff events. Waterbodies are impervious properties per the land use codes. This information is needed to develop runoff models to replicate flooding in a given watershed. Note that political boundaries and watershed boundaries tend not to line up, but the political boundaries are needed to identify potential stakeholders.

2.1.6 Precipitation Records

Relevant precipitation data are needed to understand the local water budget for the watershed and also for modeling purposes. Historical data can be obtained from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC). Stations within or near a watershed can be found in the NCDC database, and data can be provided for a fee. Local or regional-level stormwater management districts will also collect rain gage data. Hourly or daily precipitation data will be required in modeling runoff routing. These precipitation records will provide critical information about wet and dry seasonal variations.

The precipitation data used in screening can be modified for any rainfall event using the accumulated rainfall data table obtained from NOAA Atlas 14 Point Precipitation Frequency Estimates (https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html). Figure 19 shows the 3-day, 25-year precipitation map based on the NOAA Atlas 14 dataset for Florida.

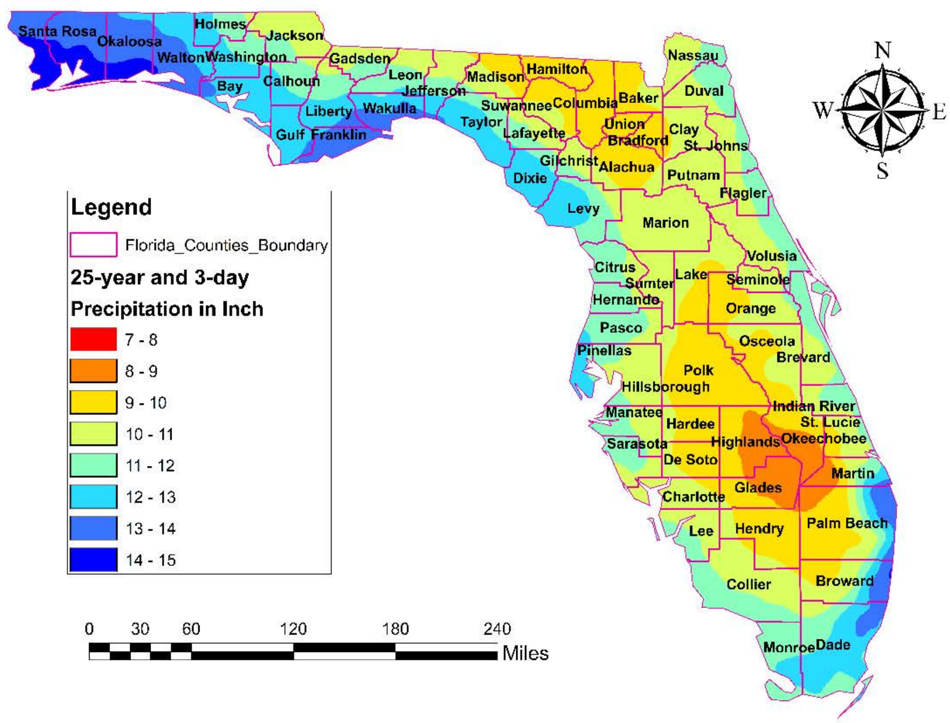


Figure 19. NOAA Atlas 14 expected precipitation from the 3-day, 25-year storm event processed by FAU

2.1.7 Stormwater Infrastructure Inventory

Accumulated stormwater runoff from developed property must be managed in an organized and systematic manner if property owners are to enjoy the full use of their property and public services are not to be disrupted. Stormwater facilities must be constructed and maintained to reduce the negative impacts of runoff. Local community stormwater systems consist of structures that help channel the stormwater to these canals but also directly into the ground to help resupply groundwater. These stormwater structures include catch basins, curb inlets, culverts, canals, swales, pump stations, ditches, manholes, levees, dams, locks, etc. A question to ask is whether maintenance or capital is required to address flooding.

Municipal separate storm sewer system (MS4) stormwater permits require additional record-keeping, policy development, inspections and maintenance, associated with an asset management plan that requires an inventory of assets like the example illustrated in Figure 20. Depending on the accuracy desired, the data can be gathered in many ways such as onsite field investigation, using existing maps, using maps while verifying the structures using aerial photography and video, or field investigations. It is important to note that highly localized infrastructure (i.e. culverts, bioswales, etc.) is unlikely to be significant in a watershed-level screening analysis. However, the analysis will identify where local infrastructure may be required to achieve the goals.

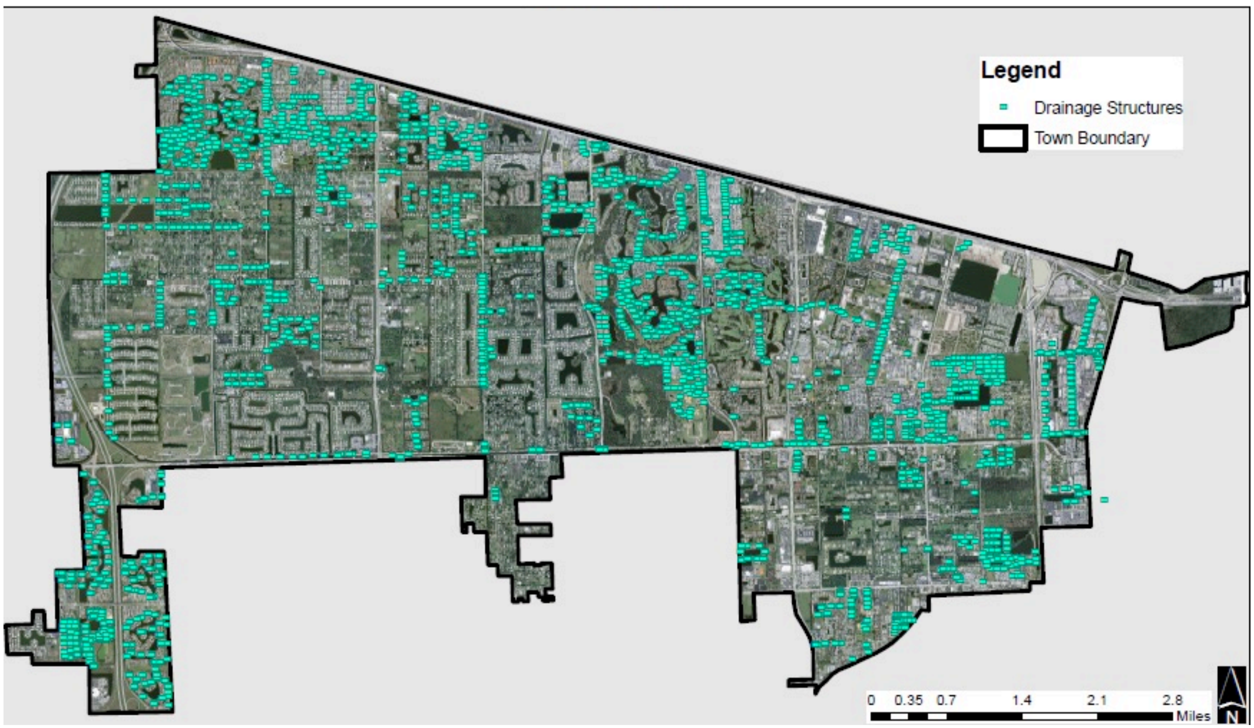


Figure 20. Mapped drainage structures for Stormwater Master Plan for Town of Davie, FL (FAU 2017)

The watershed screening tool model that is available using the databases described previously is generally applicable to large, aerially extensive areas. The operations of rivers, large streams, canals or other major waterways will tend to dwarf that of culverts along roadways. As a result, the watershed view should focus on the dams, canals, pump stations, gated spillways, and similar structures as needed by the modeling software that impact the operation of major waterways identified in ArcHydro (see Section 1.2.5). Making sure that all major infrastructure is accounted for is key to this effort. Once completed and modeled, drilldown analysis of the vulnerable areas will require added data, which is when the local infrastructure databases become more relevant. This infrastructure is needed for modeling the watershed (see Chapter 4). An example of the infrastructure map is shown in Figure 21.

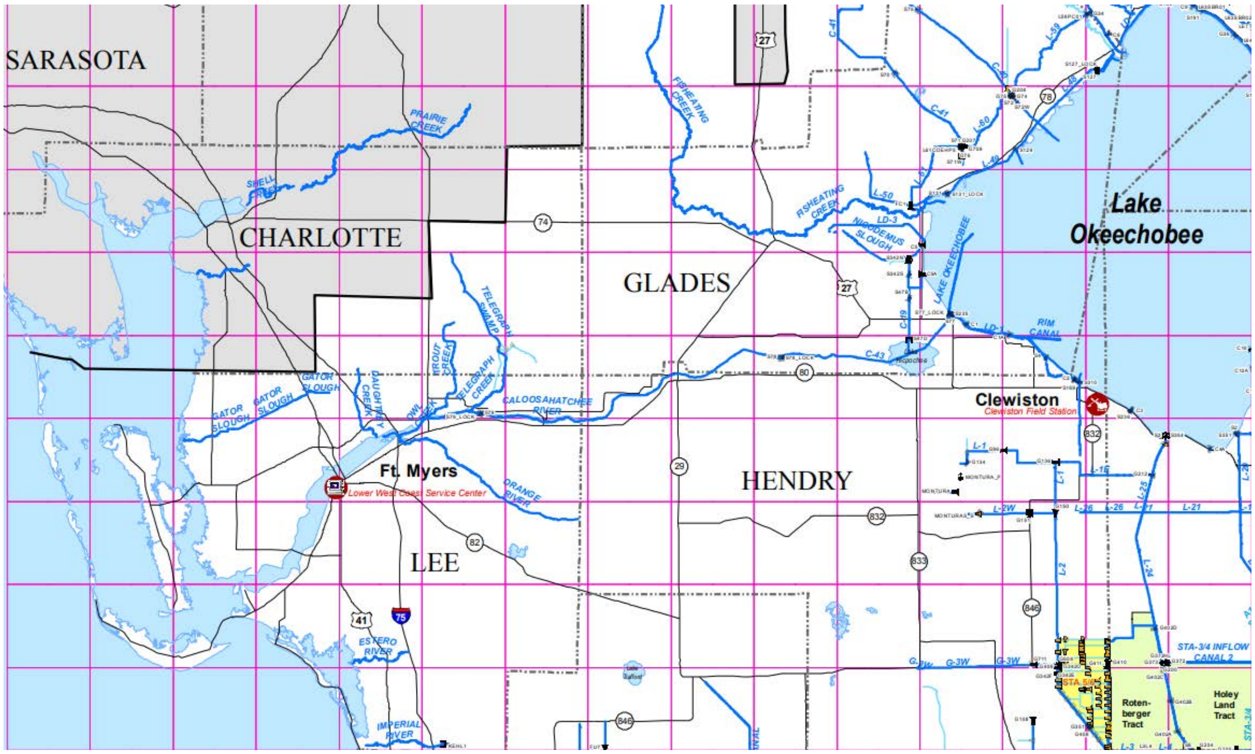


Figure 21. Location of major watershed level stormwater infrastructure in parts of southwest Florida

2.1.8 Open Space

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

1. Valuable for recreation, forestry, fishing, or conservation of wildlife or natural resources
2. A prime natural feature of the state's landscape, such as a shoreline or ridgeline
3. Habitat for native plant or animal species listed as threatened, endangered, or of special concern
4. A relatively undisturbed outstanding example of an uncommon native ecological community
5. Important for enhancing and conserving the water quality of lakes, rivers, and coastal water
6. 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 bodies of water that naturally absorb significant amounts of carbon dioxide

Permanent protection of sensitive areas can provide critical water quality protection and can be achieved through partnerships with landowners, municipalities, land trusts and state agencies. These regions are primarily shown on conservation maps and added to this will be the waterbodies in Section 2.1.10, which serve a related condition to open space. Agricultural land and other land cover will come from the land cover map described in Section 2.1.5.

2.1.9 Impervious Area

As noted in Section 2.1.5, impervious areas do not permit the infiltration of precipitation to groundwater, and because the water cannot infiltrate, it runs off faster, which means that peak flows to waterbodies and storm sewers occur faster, and with higher peak volumes. The result is a disruption of the natural, and potentially the planned, hydrology. Impervious areas include pavement, buildings, and other areas that have been compacted that lessen runoff capacity. In other words, developed areas have much higher imperviousness than areas that are natural or agricultural. The state has a land development database labeled NLCD2016 that designates imperviousness. Figure 22 shows the impervious areas derived from the NLCD2016 in Section 2.1.5.

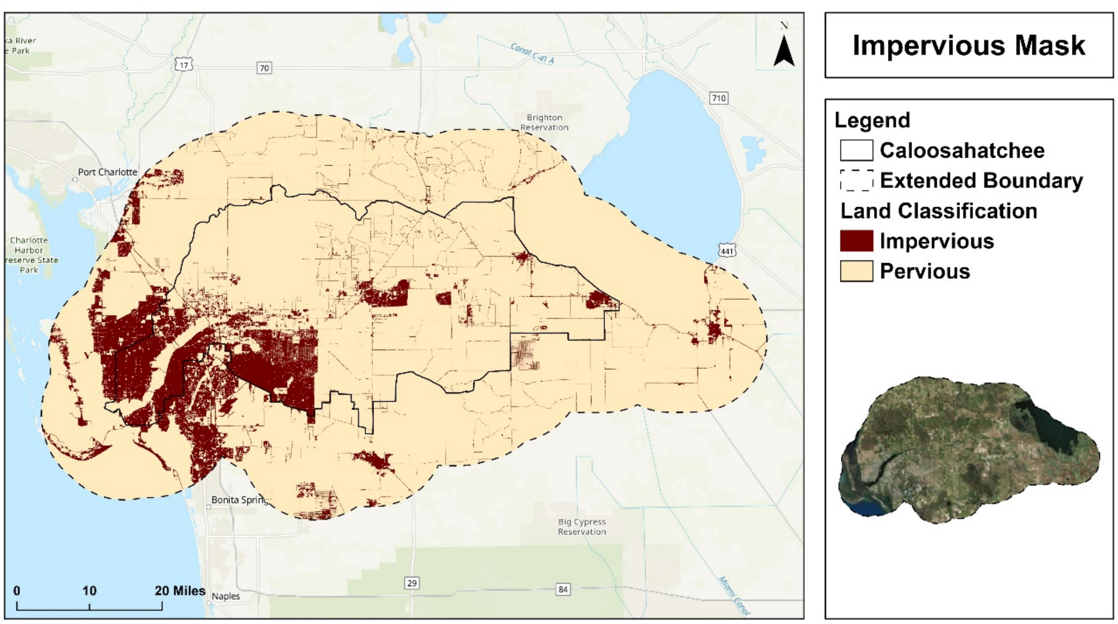


Figure 22. Example of an impervious area map for the Caloosahatchee basin

2.1.10 Waterbodies

Waterbodies are defined in the statewide land use land cover dataset (Figure 23). Note that tiny water bodies may be missing from water management district files. Soils were discussed in Section 2.1.4.

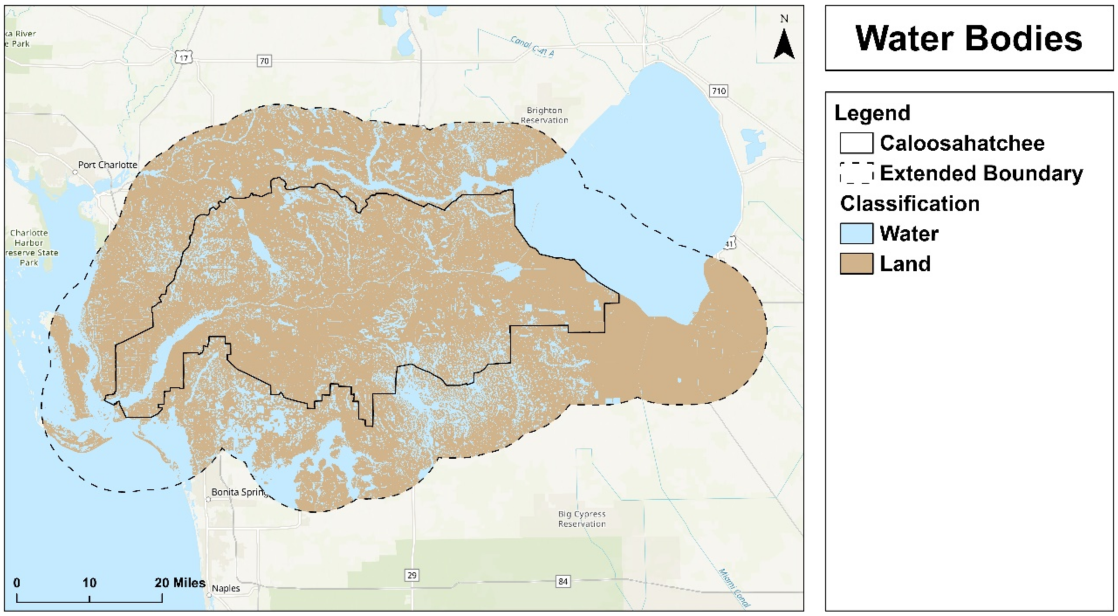


Figure 23. Example of a waterbodies map for the Caloosahatchee basin, as processed by FAU

2.1.11 Natural Resources

Understanding the watershed's natural resources is critical to identifying potential sources of water quality degradation and areas to designate for conservation, protection, and restoration. One possible goal of watershed master planning is to protect terrestrial wildlife, aquatic habitat, and buffer zones.

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, at the watershed level, 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 provided as inventories, not GIS layers. Key natural resources include the following:

- Wetlands and open areas (refer to Chapter 1.2.3)
- Waterbodies (refer to Chapter 2.1.3)
- Soils (refer to Chapter 2.1.4)
- Land cover/use (refer to Chapter 2.1.5)
- Fish and wildlife
- Ecosystems
- Some WMPs will also note culturally sensitive areas such as Native American sacred sites, historic buildings, archeological sites, etc.

Identification of the types of fish and wildlife and their habitats can assist in evaluating areas targeted for protection and conservation in the watershed master plan. Local and state fish and wildlife offices (http://offices.fws.gov/statelinks.html) can provide information on wildlife species and distribution within their jurisdictions. Within Florida, the contacts range from FDEP, Florida Fish and Wildlife Conservation Commission, and USFWS local offices. The Nature Conservancy also has eco-regional plans and other reports that provide valuable information. The potential for endangered or threatened species should be verified at http://endangered.fws.gov. Also any exotic or invasive plant or animal species should be noted. The importance of fish and wildlife and habitat on the state of the watershed is why it is included in the critical data needed for WMPs.

Ecosystem management requires that all aspects of a watershed (e.g., land, water, air, plants, wildlife, etc.) be managed in a holistic approach. Successful, effective ecosystem management strategies require partnerships (refer to Section 1.1) within the watershed. There are a number of available resources for assisting in ecosystem management plan development and adapting or integrating those recommendations into the WMP. The need is to identify the key networks of wild landscapes, reserves, buffer zones, and the native species to be able to delineate, protect and restore wilderness corridors, particularly when impacted by human activities and development pressures.

2.1.12 Demographics

Demographics data is important for determining 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 (Figure 24) and block level.

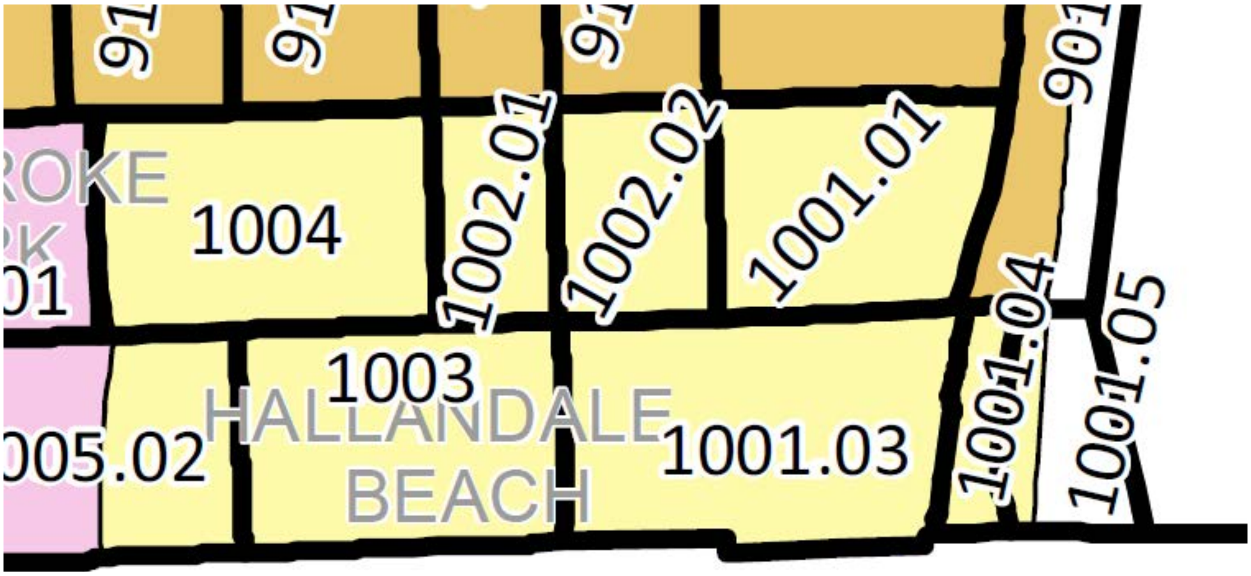


Figure 24. US census tract map (2010)

The data includes age, income, race, language spoken, number of people in the household, and education level. All of these might be useful. An example is as follows:

> As of the 2010 census, there were just over 37,000 people in the City, down over 7,000 (20%) from 2000. There were over 27,000 housing units at an average density of 6,000 per square mile (2,294.8/km²). In 2010, the racial makeup of the city was 47.7% White/Non-Hispanic White, 31.8% Hispanic, 18.7% African American, 0.2% Native American, 1.4% Asian, and 2.6% from two or more races. 44.3% were foreign born, and 51.8% speak a language other than English at home. Other languages spoken are Spanish by 19.5%, French by 5.2%, with the majority being French Canadians, Romanian at 2.7%, Italian at 2.0%, French Creole at 1.8%, Yiddish 1.7%, Russian 1.3%, German 1.3%, Hungarian at 1.2%, Polish at 0.9%, Hebrew at 0.8%, and Portuguese is spoken by 0.7%.
>
> Home ownership was 60.6%. About 82% of dwelling units are multi-family. In 2010, there were 17,782 households with an average of 2.07 persons per household, up from 1.88 in 2000. The median per capita income in the City was $25,168 up from $22,464 in 2000. According to the 2010 census, the total household income was $34,645, down from $37,171 in 2000 and far lower than the State average of $47,827. The cause is likely fewer people per household or higher unemployment. In 2010, 20.6% of the population in the City lived below the poverty line.

FAU has some of this key information available at cwr3.fau.edu.

2.1.13 Data Gaps

All of the data collected must be reviewed to determine its quality and any major gaps. A true data gap is when the information is missing or lacks sufficient resolution in space or time to properly identify and characterize a key component of the watershed. Examples of common data gaps include: 1) missing baseline data, 2) missing correlation data (i.e. flow rates that correspond to specific water quality sampling event timing or locations, 3) non-representative sampling, 4) insufficient data points, 5) dataset age, 6) lack of adequate resolution, 7) lack of upstream or downstream data points, 8) poor spatial coverage, 9) lack of accuracy and precision, 10) bias, and 11) variable detection/quantitation limits or collection procedure. Knowing where the data gaps are will permit planners to develop a strategy to overcome them.

There are some known issues. In some regions of Florida, the groundwater monitoring well density is not spatially uniform or spatially extensive. Some important areas like the Keys and the Everglades have limited (if any) well coverage. Spatial interpolation using a stochastic variance-dependent interpolation (e.g., Ordinary Kriging) can be used to estimate groundwater levels at points of interest or for the generation of the surface. A subset of available data is used for the creation of a validation dataset, and the rest of the data is used for calibration (i.e., estimation of parameters of the interpolation model). Where the coast is present, the coast is used as a constant head boundary. For regions with spatially sparse or non-uniform groundwater wells, the groundwater levels are estimated using a multiple linear regression approach from auxiliary variables in addition to the limited groundwater well observations in a watershed.

Outliers (very high or low groundwater levels attributed to a variety of reasons) are noted at several sites. Outliers and anomalous groundwater levels in the database are initially evaluated, identified and if found to be faulty, are replaced by region-specific mean values based on observations available from the nearest well. Missing data is also an issue at some monitoring 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 large amounts of missing data, it is not used in the generation of the groundwater surface.

The king tides in south Florida happen within the same period every year between the months of September and November. This period happens to coincide with the end of the wet season and the height of the hurricane season. The culmination of these phenomena means that groundwater related flooding risks are greatest at this time and it also allows us to assume that, generally speaking, rainfall and tidal influences on groundwater are most correlated at this time and can be quantified indirectly through observable groundwater levels alone. However, since this is an observation driven modeling effort with spatially explicit implications, discrete, observational values of groundwater, surface water, rain, tides, etc. are also required to inform a spatial model.

The watershed scale does not permit detailed analysis down to the level of a bridge culvert from the current data sets due to spatial extent. Low resolution LiDAR limits the interpretability of results; however, some assumptions can still be made by simply comparing tidal and rain influences on observed flooding events. Data must be in the same datum (the datum used here is NAVD88) and units (ft). Spatially explicit rainfall data (NeXRAD) and storm surge input are needed, but the records are lacking for some areas of the State.

If there are concerns about data gaps, the first step is to make an assessment if the data are essential to the understanding of the problem. If the necessary datasets are available, then determine if the data quality is acceptable (sufficient resolution, long enough time series, recently updated, level of accuracy, etc.). The level of detail necessary will vary depending on the modeling and tracking goals and is usually found along a spectrum, as summarized in Table 4.

Table 4. Summary of level of detail for certain types of screening data (USEPA, 2008)

Data Type	Low	Medium	High
Flow	Summary statistics (range, average)	Spatial analysis of flow data in GIS	Spatial and temporal analysis of flow data in GIS often combined with modeling and supplemental monitoring
Land Use	General distribution using broad categories	Specific identification of detailed categories by sub-watershed	Statistical analysis of detailed categories in relation to average flow
Soils	General distribution of soil types	GIS analysis of locations and types of soil	Detailed analysis of soil distribution in relation to streams and erosion potential
Habitat	General distribution of habitats	Mapping of critical habitats and buffers	Landscape pattern measurement near critical habitat with GIS modeling

Using data of low quality will make it difficult to make the correct management decision and defend allocating the resources to implement the action plan and monitor its beneficial impacts. Note that the level of detail necessary will vary depending on the modeling and tracking goals. Although data gaps can be identified during the data inventory process, more specific requirements are often discovered during modeling.

2.2 Screening Tool Modeling to Identify Vulnerable Areas

In order to complete a flood risk assessment, a community needs sufficient knowledge of its local hydrology and water supply needs and the tools to assess changes. In general, a diversified approach to stormwater is the best method to minimize future risks associated with climate change uncertainties. This includes the development of surface water flow forecasting models, demand forecasting models, and an integrated surface water – groundwater hydrologic model, which all incorporate rainfall and temperature variables as driving forces. These models can take output of downscaled climate models that provide different rainfall and temperature time series and make assessments of the effects of changes in these parameters and how they affect the service area.

Hence, the purpose of collecting all of the watershed-level technical data and pertinent information in Section 2.1 is to use it to inform an effective framework for watershed master planning that identifies critical areas in the watershed where improved management efforts are needed. The boundary conditions and design storms must be selected for calculation purposes during this exercise.

Several methods can be used to delineate flood-prone areas, depending on the level of detail and accuracy required, the types of floodplain management measures to be used, land values, political considerations, and other factors. The method used here relies on engineering principles of precipitation routing to calculate flood levels for a given design storm to provide the basis for delineating flood-prone areas.

2.2.1 Modeling the Watershed

To evaluate a watershed's runoff response from design storms of various magnitudes and durations under current and predicted future conditions, modeling software is needed. Modeling software can be highly detailed or macro-scale. The latter permit a better, faster watershed analysis without getting bogged down in local details that may create minimal effects over the entire watershed. Such software must be user-friendly with readily available, easily acquired data, be aerially extensive, include inputs for infrastructure, provide easy-to-interpret results, be compatible with GIS, and adequately describe the macro-level flood response.

The modeling of stormwater routing and flood risk can take a number of forms such as solutions for simple cases or numerical computer codes for more complex cases where a high degree of accuracy is needed. Medium and large communities should have working computer models of their jurisdiction, but most do not. For small communities, it may be sufficient for relatively simple applications, but for more extensive modeling, significantly more data may be needed if surface interfaces and competing users are located in a given basin.

For communities that have a working model, data must be gathered regularly to calibrate to actual conditions. For the basin or watershed approach, data-driven models appear to be more appropriate than simple local modeling. There are numerous resources available that describe, in varying levels of detail, the processes, equations behind, and numerical methods of groundwater modeling including, but not limited to, those listed in the reference pages. Models are also constantly improving, so designating specific models for this exercise is not appropriate.

Unlike engineering designs where precise measurements are turned into something tangible, a flood risk model attempts to "approximate reality" while being transparent regarding its uncertainties and limitations over a potentially open-ended time frame. At the same time, it must be understood that models are mathematical approximations of typical or average conditions estimated for the basin parameters. But there is also a need to understand the limitations of these models.

The simplest representation of floodplain flow is to treat the flow as one-dimensional along the center line of the river channel (DHI, 2003). Many hydraulic situations can make an assumption of 1-dimensional conditions, either because a more detailed solution is unnecessary (e.g. the purpose does not require knowledge in other dimensions) or because a 1-dimensional solution is sufficient to approximate real conditions, such as in a confined channel or in a pipe. One-dimensional models can be used for open surface floodplain flow too, in which case floodplain flow is part of the one-dimensional channel flow, which is assumed to be in one direction parallel to the main channel, and one cross-sectional averaged velocity is used to represent large variations in velocity across the floodplain.

The two-dimensional models represent floodplain flow as a two-dimensional field with the assumption that the third dimension (water depth) is shallow in comparison to the other two dimensions (DHI, 2012, Roberts et al., 2015). Two-dimensional flood models such as ISIS, MIKE 11 and HECRAS represent the channel and floodplain as a series of cross-sections perpendicular to the flow direction and solve either the full or some approximation of the one-dimensional shallow water equations (Bates and De Roo, 2000). These models require less computer effort compared to hydrodynamic models. They are fast, robust, and most desirable for applications that do not require velocity output and have low demands on the representation and accuracy of flow dynamics in the vertical direction.

Most approaches solve the two-dimensional shallow water equations, which represent mass and momentum conservation in a plane, and can be obtained by depth-averaging the Navier-Stokes equations. Two-dimensional numerical models for unsteady shallow flows and various computational techniques using finite difference, finite element and finite volume schemes have been reported (Table 5). Two-dimensional flood models such as TUTFLOW, SOBEK and MIKE 21 solve the two-dimensional shallow water equations by means of appropriate numerical schemes (Mignot, et al 2006; Abderrezzak et al 2009; Dottori and Todini, 2013; Song et al., 2015). Advances in remote sensing technology, particularly through high resolution and high accuracy input data such as airborne LiDAR and Synthetic Aperture Radar (SAR) data, and improved computing capacity seem to have increased the popularity of two-dimensional models.

For many scales of floodplain flow, complex three-dimensional representation of flow dynamics may be regarded as unnecessary, as a two-dimensional shallow water approximation may be adequate, especially given the type and quality of data typically available for model construction and validation (Alcrudo, 2004). However, modeling of vertical turbulence, vortices, and spiral flow at bends is important during catastrophic floods, such as those occurring due to dam breaks, tsunamis, flash floods or embankment and levee breaches.

Table 5. **Available models and their strengths and weaknesses (from Teng et al., 2017)**

Model Name	Author(s), Date	Model Type & Dimensionality	Key Assumptions	Mathematical Framework	Numerical Solutions	Access	Strengths	Limitations
HEC-RAS	USACE, 1995	1-D Hydraulic	Basically, the model solves the one dimensional energy equation for steady flow. However, it can solve the full 1D shallow water equation for unsteady flows.	One-dimensional energy equation to solve for friction and contraction	Implicit finite difference solution	Open source However, user assistance is limited to USACE users	Extensive documentation, suitable for a wide-range of data quality, easily adaptable and easy to set up	Model instability and limitation in environments that require multi-dimensional modelling
HEC-HMS	USACE, 1992	Hydrologic	Primarily designed to simulate the precipitation run-off process of dendritic drainage basins Also capable of solving a range of hydrologic problems	Different statistical and mathematical concepts describing physical processes are used in modelling	Analytical solutions of underlying mathematical representation of hydrologic processes.	Open source However, user assistance is limited to USACE users	Extensive documentation, suitable for a wide-range of hydrologic applications and amenable for integration with other software	Generally fails under dynamic flood simulation conditions
ISIS-2D	Halcrow (now CH2M HILL), 2009	2-D Hydraulic	Designed to work either standalone or within the ISIS suite	Full two-dimensional shallow water equations	Alternating Direction Implicit (ADI) , FAST and Total Variation Diminishing (TVD)	Commercial	Suitable for hydrodynamic flood simulation	Slow simulation speed and requires a high resolution topographic data
ISIS-1D	Halcrow (now CH2M HILL), 2008	1-D Hydraulic	Designed primarily for modeling water flows and levels in open channels and estuaries	Full one-dimensional shallow water equation	Muskingum-Cunge scheme for steady state and 4-point Preissmann scheme for unsteady state	Commercial	Suitable for steady, unsteady, subcritical, supercritical and transitional flows	Assumes velocity is normal to cross section and not suitable for dynamic flood simulation

Model Name	Author(s), Date	Model Type & Dimensionality	Key Assumptions	Mathematical Framework	Numerical Solutions	Access	Strengths	Limitations
ISIS - FREE	Halcrow (now CH2M HILL), 2009	Coupled 1-D/2-D Hydraulic	Provides an advanced one-dimensional (1D) and two-dimensional (2D) simulation engine, analysis and visualization tools	One-dimensional and two-dimensional shallow water equations	Alternating Direction Implicit (ADI) , FAST and Total Variation Diminishing (TVD)	Open source	Suitable for wide range of applications including urban areas, coastal and river channels	Limited to 250 1D nodes and 2500 2D cells
ISIS-FAST	Halcrow (now CH2M HILL), 2011	Simplified 1-D / Simplified 2-D	Quick simulation of flooding using simplified hydraulics	Simplified shallow water equations	FAST solvers	Commercial	Simulation speeds are up to 1000 times quicker when compared to traditional 2-D flood models	Requires high resolution data and is commercial software
LISFLOOD-FP	Bates and De Roo, 2000	Simplified 2-D	A raster-based hydraulic model that is assumed to possess the simplest hydrologic process representation	One-dimensional, kinematic and two-dimensional diffusive wave equations	Explicit finite difference solution	Research	Extensive documentation, easily adaptable and simple to set up	Requires a high resolution topographic data for simulation.
LISFLOOD	De Roo, Wesseling, and Van Deursen, 2000	GIS-based distributed hydrologic model	LISFLOOD is a GIS-based hydrological rainfall-runoff-routing model	One-dimensional, kinematic wave equation	4-point implicit finite difference solution and analytical solutions of other hydrological components	Research	Wide range of applications including simulation of interception of rainfall by vegetation, evaporation of intercepted water and Leaf drainage.	Not a stand-alone code, it requires a base platform of PCRaster modelling environment

Model Name	Author(s), Date	Model Type & Dimensionality	Key Assumptions	Mathematical Framework	Numerical Solutions	Access	Strengths	Limitations
Newer MIKE 11	DHI, 1997	1-D	Full one-dimensional Saint Venant equations, diffusive and kinematic wave approximation	Muskingum method and Muskingum-Cunge method for simplified channel routing	Commercial	complemented by a wide range of additional modules and extensions covering almost all conceivable aspects of river modelling	Limited to rivers and fluvial-related flood events. Model can be unstable under two-dimensional flood conditions	
MIKE 21	DHI, 2003	2-D	Developed to simulate flows, waves, sediments and ecology in rivers, lakes, estuaries, bays, coastal areas and seas in two dimensions	Full two-dimensional shallow water equations	Implicit finite difference techniques with the variables defined on a space-staggered rectangular grid	Commercial	Suitable for hydrodynamic flood simulation. Simulates bulk flow characteristics, flow velocity in various directions of flow	Simulations time steps and model stability are affected by C-F-L condition. Needs to be calibrated
MIKE-FLOOD	DHI, 2003	Coupled	Developed to enhance the independent functionalities of MIKE 11 and MIKE 21	One-dimensional and two-dimensional shallow water equations	Coupled solution of 1-D/2-D shallow water equations	Commercial	Satisfactory real-time simulation of flood inundation in river, coastal and urban areas	Not well adapted in terms of application to many geographic locations, and models require calibration
TUFLOW – 1D	BMT-WBM, 1990	2-D	Simulation of complex hydrodynamics of flood using full 1-D St. Venant equations	Full one-dimensional shallow water equation	Second order Runge–Kutta finite-difference solution	Commercial	Dynamic linking capability between domains. Fast from computational point of view	There are uncertainties in solution and are poor at process representation

Model Name	Author(s), Date	Model Type & Dimensionality	Key Assumptions	Mathematical Framework	Numerical Solutions	Access	Strengths	Limitations
TUFLOW – 2D	BMT-WBM, 1997	Simplified 2-D	Simulation of complex hydrodynamics of flood using full 2-D free surface shallow water equations	Full two-dimensional free surface shallow water equations	Stelling Finite Difference and ADI	Commercial	Dynamic linking capability between domains with satisfactory representation of process	Slow, but dynamically captures bulk flow characteristics
JFLOW	JBA Consulting, 1998	2-D	It is basically a simplified physics flood model	Diffusion wave equation	Explicit finite difference scheme	Commercial	More accurate flood simulation and simple to set up and useful at coarse resolution	Conditional stability through the C-F-L condition Unable to account for effects of small-scale features during flood simulation
DIVAST (depth-integrated velocities and solute transport)	Liang, Falconer and Lin, 2007	2-D	Solution that includes the effects of local and advective accelerations, the earth's rotation, free surface pressure gradients, wind action, bed resistance and a simple mixing length turbulence model	Full 2-dimensional shallow water equations	Implicit finite difference technique and the ADI formulation	Commercial	Unconditionally stable. Constant time steps	Lacks the ability to capture shock resulting from simulation
DIVAST- TVD	Falconer and Xia, 2013	2-D	To address some limitations inherent in the original DIVAST model	Full 2-dimensional shallow water equations	TVD-McCormack explicit finite difference scheme	Commercial	Ability to capture shock	Conditional stability
SOBEK	Deltares, 2019	Scheme. By means of a rectangular grid	Specially designed for overland flow	Two-dimensional Saint-Venant equations	Finite difference	Commercial	Capable of handling wetting and drying, spatially varying surface, roughness and wind friction	Conditional stability

Model Name	Author(s), Date	Model Type & Dimensionality	Key Assumptions	Mathematical Framework	Numerical Solutions	Access	Strengths	Limitations
SOBEK	Deltares / Delft Hydraulics, 2020	1- D	Specially designed for rural, urban and river flows	One-dimensional Saint-Venant equations	Finite difference	Commercial	Breaches can be modelled by means of a complex "river weir" with time dependent properties	Conditional stability
TELEMAC 2-D	Électricité de France (EDF), 2010	2-D	Designed to address the challenges of process representation and limitations in channel and floodplain flood modelling	solves the full two-dimensional shallow water equations	finite-element or finite-volume method and a computation mesh of triangular elements	Open source	It can perform simulations in transient and permanent conditions	Conditional stability
TELEMAC 3-D	Électricité de France (EDF), 2010	3-D	To address some limitations inherent in the 2-D version of the model	Navier-Stokes equations, whether in hydrostatic or non-hydrostatic	finite-element or finite-volume method and a computation mesh of triangular elements	Open source	Ability to capture 3-D hydrodynamic features of an area. Suitable for all flood sources	Conditional stability
TRENT 2000	Nottingham University, 2000	Full 2-D	A flood model that can capture full hydrodynamic properties	Shallow water equations	Explicit Finite difference scheme	Commercial	Shock capturing ability	Stable at CFL condition, using adaptive time stepping
MOD_freeSURF 2D	Martin and Gorelick, 2005	2-D	To obtain a more efficient flood simulation through a more robust numerical scheme	Unsteady state Shallow water equations	Semi-implicit, semi-Lagrangian numerical scheme	Open source	Modularity, computational efficiency and minimum data requirement	Lacks extensive validation
CADDIES	Ghimire et al., 2013	2-D	A model that performs optimally at simulating flooding in urban areas	Rules that govern movement of water in-between cells	Cellular automata	Open source	Fast simulation of flooding	Lacks extensive validation

Model Name	Author(s), Date	Model Type & Dimensionality	Key Assumptions	Mathematical Framework	Numerical Solutions	Access	Strengths	Limitations
FLO-2D v. 2007.06 and 2009.06	O'Brien, 2007	Simple 2-D	Hydrodynamic model for the solution of the fully dynamic equations of motion for one-dimensional flow in open channels and two-dimensional flow in the floodplain.	Full 1-D and 2-D shallow water equations.	Finite difference solutions	Commercial	A combined hydrologic and hydraulic modelling for urban and river flooding	Bridge or culvert computations must be accomplished external to FLO-2D using methodologies or models accepted for NFIP usage
GUFIN	Chen et al., 2009	Simplified model	A model that simplifies the use of distributed models for urban environment	GIS- based	GIS and infiltration functions	Research	Integrates GIS, suitable for urban flooding, results compare well with numerical codes	Lacks extensive validation
MIKE URBAN 2010	DHI Water and Environment, 2010	Coupled 1D and 2D	Has the capability to analyze storm sewer networks. Flow conditions associated with weirs, orifices, manholes, detention basins, pumps, and flow regulators can be reflected.	1-D unsteady flow	Implicit, finite difference numerical scheme.	Commercial	Suitable for flow in urban areas and integrates GIS capabilities	Lacks the ability to capture some hydrodynamic phenomenon such as shock and supercritical flows
USEPA (1971–2005)	SWMM, new versions through 2017	Generic	Designed to represented six major environmental components: external forcing, surface runoff, groundwater, conveyance system, contaminant built-up and (LID) controls.	Kinematic wave model Full dynamic wave system.	Generally, the finite difference scheme	Open source	Extensive documentation, several upgrades, and adaptive to a range of hydrological and hydraulic operations - urban flooding, drainage, etc.	The model requires many add-ons, and a user needs to understand the detailed guidelines

Table 6 outlines three ways the models, regardless of the dimensionality, might calculate results. Empirical models are relatively easy to implement because they are based on observations and can be extrapolated to serve as validation to data assimilation models. They are limited by spatial grids and weather. Simplified conceptual models are computationally simple for computers and can mimic or predict impacts to the floodplain, but dynamic flooding is not possible. Hydrodynamic models can overcome the limitations of the empirical and simplified models, but they are computationally difficult and require extensive memory and time to develop. They also require significant amounts of information to generate results. Thus, they are useful when drilling down.

From the perspective of screening for large areas within a watershed, large amounts of data, integration with GIS, and ease of calculation are important. Highly specific answers that depend on minute details in the basin are not appropriate at a basin wide screening tool level. Hence a simplified model that has capacity to drilldown to local levels with the same data sets, but adding more localized specifics such as pipes, is useful. This is why FAU chose to use Cascade 2001 for screening purposes.

Table 6. Summary of flood screening model options (from Teng et al., 2017)

Method	Strengths	Limitations	Suitable Applications
Empirical methods	• Relatively easy to implement • Based on observation data • Derived inundation estimate is independent • Technology is rapidly improving	• Non-predictive • No/indirect linkage to hydrology (difficult to use in scenario modelling) • Coarse spatial and temporal resolution (although improving) • Engineering limitations (sensors, carriers, transmission devices) • Environmental limitations (clouds, wind, damaging weather conditions, other natural constrains) • Processing limitations (algorithm, artificial errors)	• Flood monitoring • Flood damage assessment • Serve as observations to support calibration, validation and data assimilation for other methods

Method	Strengths	Limitations	Suitable Applications
Simplified conceptual models	• Computationally efficient	• No inertia terms (not suitable for rapid varying flow) • No/little flow dynamics representation	• Flood risk assessment • Water resources planning • Floodplain ecology • River system hydrology • Catchment hydrology • Scenario modelling
Hydrodynamic models	• Direct linkage to hydrology • Detailed flood risk mapping • Can account for hydraulic features/structures • Quantify timing and duration of inundation with high accuracy	• High data requirements • Computationally intensive • Input errors can propagate in time	• Flood risk assessment • Flood damage assessment • Real-time flood forecasting • Flood related engineering • Water resources planning • Riverbank erosion • Floodplain sediment transport • Contaminant transport • Floodplain ecology • River system hydrology • Catchment hydrology

2.2.2 CASCADE 2001

After careful consideration, the FAU team chose to use CASCADE 2001, which is a macroscale, multi-basin, spatial hydrologic/hydraulic routing model developed by SFWMD but appears to be applicable across the state. For the model to work accurately, the basin boundaries must be chosen carefully. The results are three-dimensional. However, the model is not difficult to run and integrates with GIS. A spatial model is distinct from developing a model of *predicted averages* of groundwater/surface water values and can be conceptualized as an average of the *observable extremes* due to those factors *in situ*. The modeling effort addressed by this screening tool combines the extreme conditions of high groundwater levels occurring simultaneously with king tides, heavy rains, and impervious soils that can lead to localized nuisance flooding events that may be too difficult to predict with more abstracted models. The model can be adjusted to average conditions, if desired.

The screening tool starts with a flood response model (CASCADE 2001) whose output is used to develop flood risk/hazard maps at 10 m resolution to identify areas of concern. The screening tool accomplishes this by utilizing pertinent information and technical data to create the input file. Specifically, groundwater table elevations and surface water levels (USGS and WMDs), tidal information for coastal areas (NOAA), soil maps (USDA), and topographic data (described herein) were collected. The design storm for calculation purposes was taken to be the 3-day, 25-year storm, which is the standard used by the WMDs for flood management. The tool can also model other storm events such as the 24-hour, 100-year and the 1-hour, 100-year storm event, as well.

Next, groundwater table elevations and surface water gauges were downloaded from the applicable water management district, tidal information for coastal areas was obtained from the NOAA Tides & Currents website (https://tidesandcurrents.noaa.gov), soil maps were obtained from USDA, and topographic data was obtained from various sources. Figure 25 shows how the GIS layers conceptually interface in the tool and how they are combined for the spatial analysis.

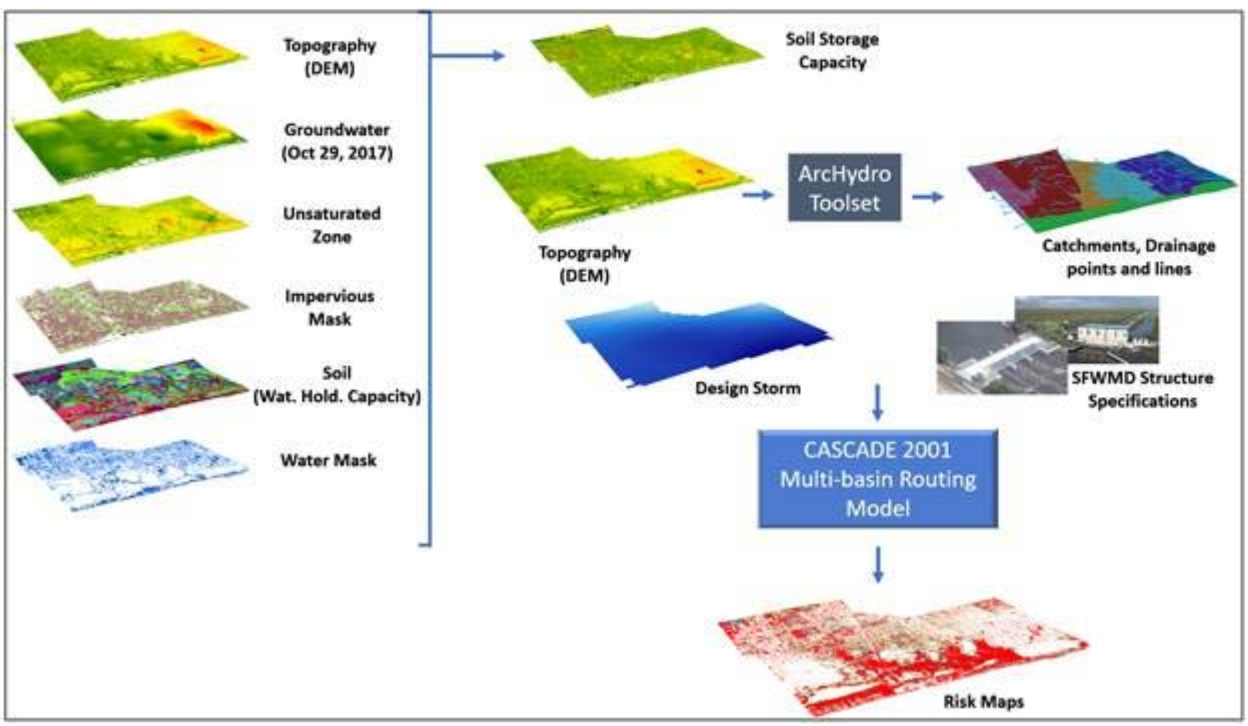


Figure 25. Process for the utilization of data layers to develop a screening tool, using flood modeling software (in this case Cascade 2001).

The following data layers discussed in detail in Section 2.1 are collected and processed as the input files for CASCADE 2001:

- Topography (Section 2.1.1)
- Groundwater elevations (Section 2.1.2)
- Surface waterways/outlet locations from the watershed map (Section 2.1.3, refer to Figure 15)
- Soils (Section 2.1.4)
- Development intensity as it relates to land use cover and imperviousness (Section 2.1.5, and also 2.1.8, 2.1.9, and 2.1.10) refer to Figure 18
- Rainfall event (Section 2.1.6)
- Structure locations (gravity, pump and gated spillways) (Section 2.1.7, refer to Figure 15, Figure 20 and Figure 21). Note only regional infrastructure like dams and structures were included in the watershed level modeling.

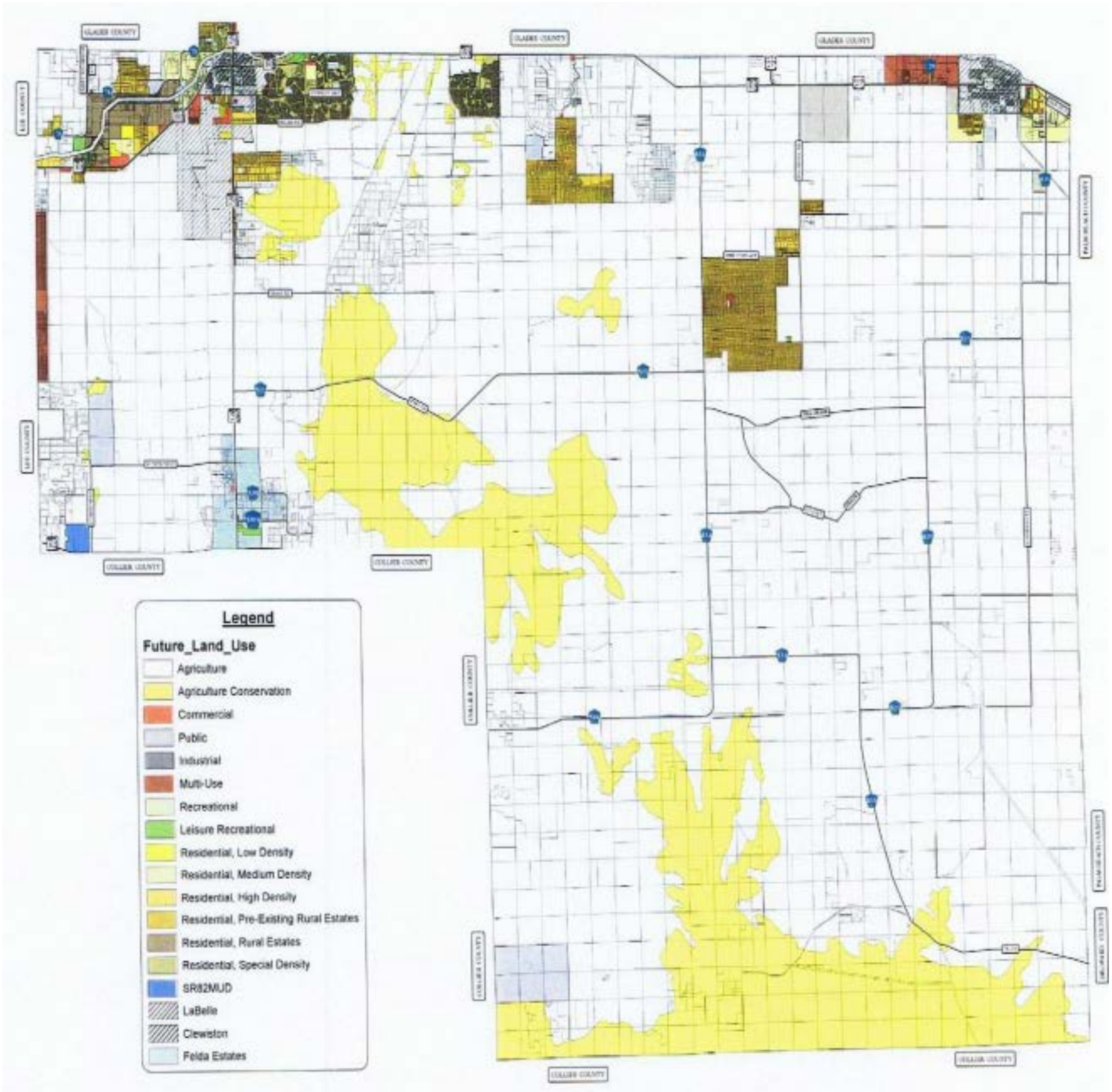


Figure 26. Conservation areas (gray) in Hendry County (Comprehensive Plan)

The general database sources used for this analysis are summarized in Table 7.

Table 7. Summary of database sources for key information needed for modeling used in development of this document

Name	Sources	Date Created or Date Range	Source Data Format
Rainfall	NOAA Atlas 14 Precipitation Frequency Estimates https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_gis.html	1840-2013	Raster image format (downloaded and processed)
Soil	USDA Soil SSURGO gSSURGO Database: https://sdmdataaccess.nrcs.usda.gov/	Released in 2019	Raster image format (downloaded and processed)
Landcover	USGS 30m resolution, derived from Landsat satellites https://www.mrlc.gov/data/nlcd-2016-land-cover-conus	Created for 2016	Raster image format (downloaded and processed)
Waterbodies	NHD24Area_dec07, and nhd24waterbody_dec17, both from National Hydrography Dataset created originally by USGS https://www.usgs.gov/core-science-systems/ngp/national-hydrography/national-hydrography-dataset	Created in 2007	Converted to binary raster image format (downloaded and processed)
Impervious Surface	USGS 30m resolution, derived from Landsat satellites https://www.mrlc.gov/data/nlcd-2016-land-cover-conus	Created for 2016	Converted to binary raster image format (downloaded and processed)
LiDAR Elevations	From USGS, NOAA, Counties and Cities of FL https://viewer.nationalmap.gov/basic/	2000-2019	Raster image format (downloaded and processed)

The software requires identifying the offsite receiving body and creates a glass box model where water rises to a certain level and then discharges. The simulation requires defining the basin (HUC or sub-HUC) and input of the following data:

- Basin area
- Elevation data (by percentage of the basin above certain critical values)
- Initial groundwater stage elevation
- Longest travel time for the runoff to reach the most distant point of discharge
- Available water storage (AWS) for a soil layer of 0-150 cm

Ground storage as estimated from the USDA gridded National Soil Survey Geographic Database (gNATSGO) using Equation 3:

Equation 3 **Ground storage (S) ≈ (Water holding capacity) × (Surface elevation – GW elevation)**

S = 2 × (AWS for a soil layer of 0-150 cm) / 150 cm × (Surface elevation – GW elevation)

The watershed may have, or may plan to implement, stormwater improvements. There are three types of structures available to input in the tool, which include gravity, pump and gated spillways. For a pump, the discharge rate and the head water elevation to trigger a turn-on or a turn-off of the pump must be specified. The result is a dataset that defines the flood level for the basin that can be mapped as a layer in GIS. The output from the model is an elevation that can be used to develop flood maps for the area that can be compared to the repetitive loss property maps uploaded to the GIS platform as a separate layer. Figure 27 is an example output for a watershed using this methodology. The blue shaded areas are the most likely to flood as a result of the conditions from the 3-day, 25-year storm event, seasonal high ground and surface water elevation, surface characteristics, and soil storage.

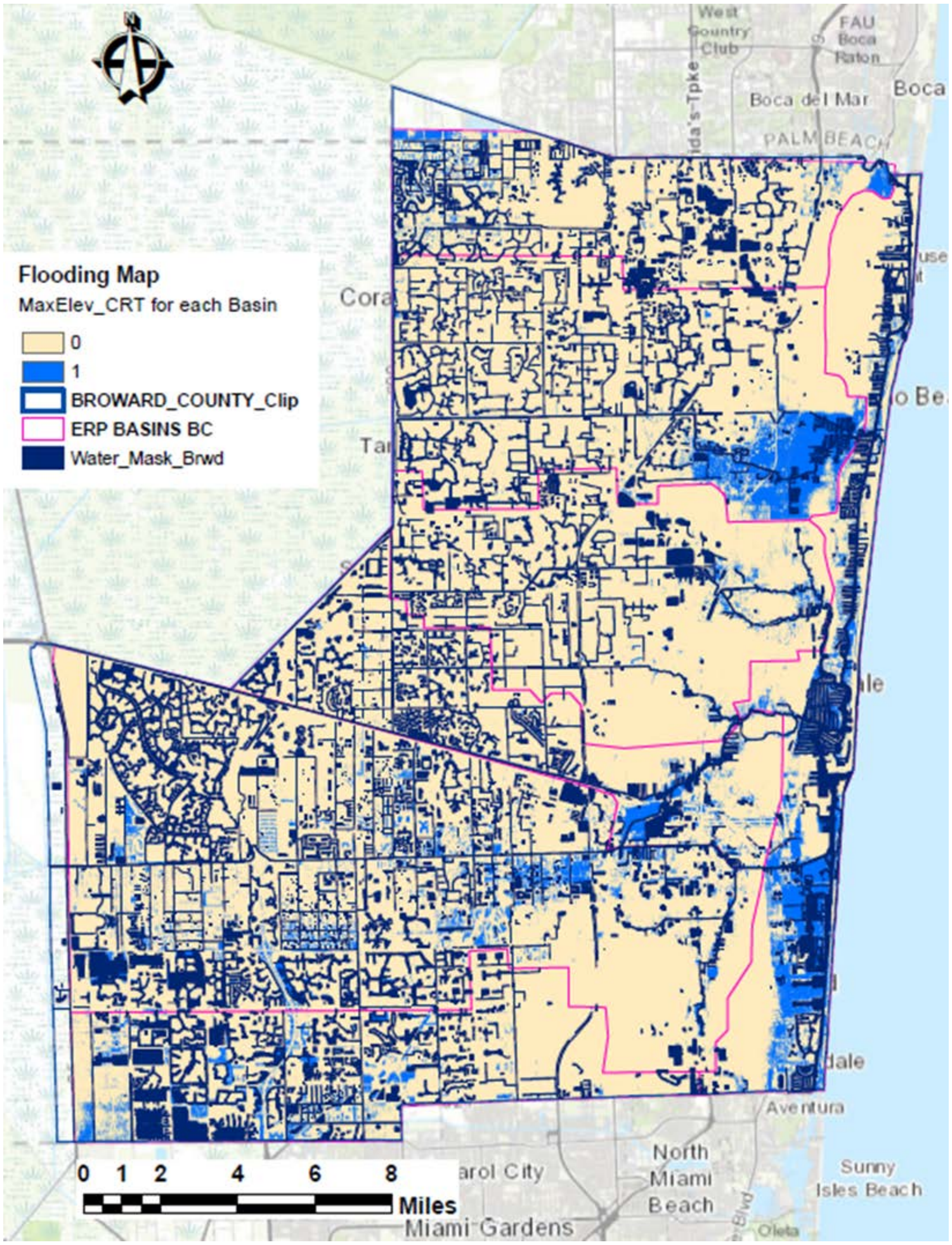


Figure 27. Example of a flood output from CASCADE 2001 for a basin in Broward County, FL (Rojas, 2020)

2.3 Mapping Efforts

To accurately identify and delineate lands in Florida that are vulnerable to floods, high-resolution elevation data was used to predict headwater height. As flood risk is defined as the probability of inundation based on ground elevation data, a means to assess probability of flooding is needed that takes into consideration the vertical accuracy error in the elevation datasets which may vary depending on the available data spatial resolution. The uncertainties associated with the DEM vertical accuracy, estimated depths to groundwater table, and the modeling approach itself are incorporated in the root mean square error (RMSE) computation.

For this purpose, the NOAA process for determining Z-scores was followed (NOAA, 2010) using the following formula:

Probability of Inundation = Standard_Normal_CDF(Z-Score)

Z-Score = [(high headwater height) - (Ground Elevation from LiDAR DEM)] / SQRT(RMSE_LidaDEM^2+RMSE_CRT2001Model^2)

= (Headwater Height – LiDAR DEM Elevation) / 0.46

The value suggested by NOAA for the compact counties coastal vulnerability assessments which is 0.46. Based on the calculated Z-score, probabilities of inundation can be derived. The calculation of the corresponding Z-score can be mapped directly in GIS. For the purposes of this example, we will use the 10%, 25%, 50%, 75% and 90% probabilities. The value of Z for the 75th percentile is 0.675. Thus, one must be 0.675 standard deviations above the mean to be in the 75th percentile. The GIS was then classified into 6 classes with cutoff Z-scores, as shown in Table 8.

Table 8. Z-score GIS layer legend

Risk of Flooding	Description	Range of Corresponding Z values
Below 10%	Unlikely to be flooded	<-1.282
10%~25%	Low risk	from -1.282 to -0.675
25%~50%	Low-moderate risk	from -0.675 to 0
50%~75%	Moderate-high risk	from 0 to 0.675
75%~90%	High risk	from 0.675 to 1.282
Above 90%	Highest risk	>1.282

Using this procedure, the results can look like Figure 28 (depending on the probability desired).

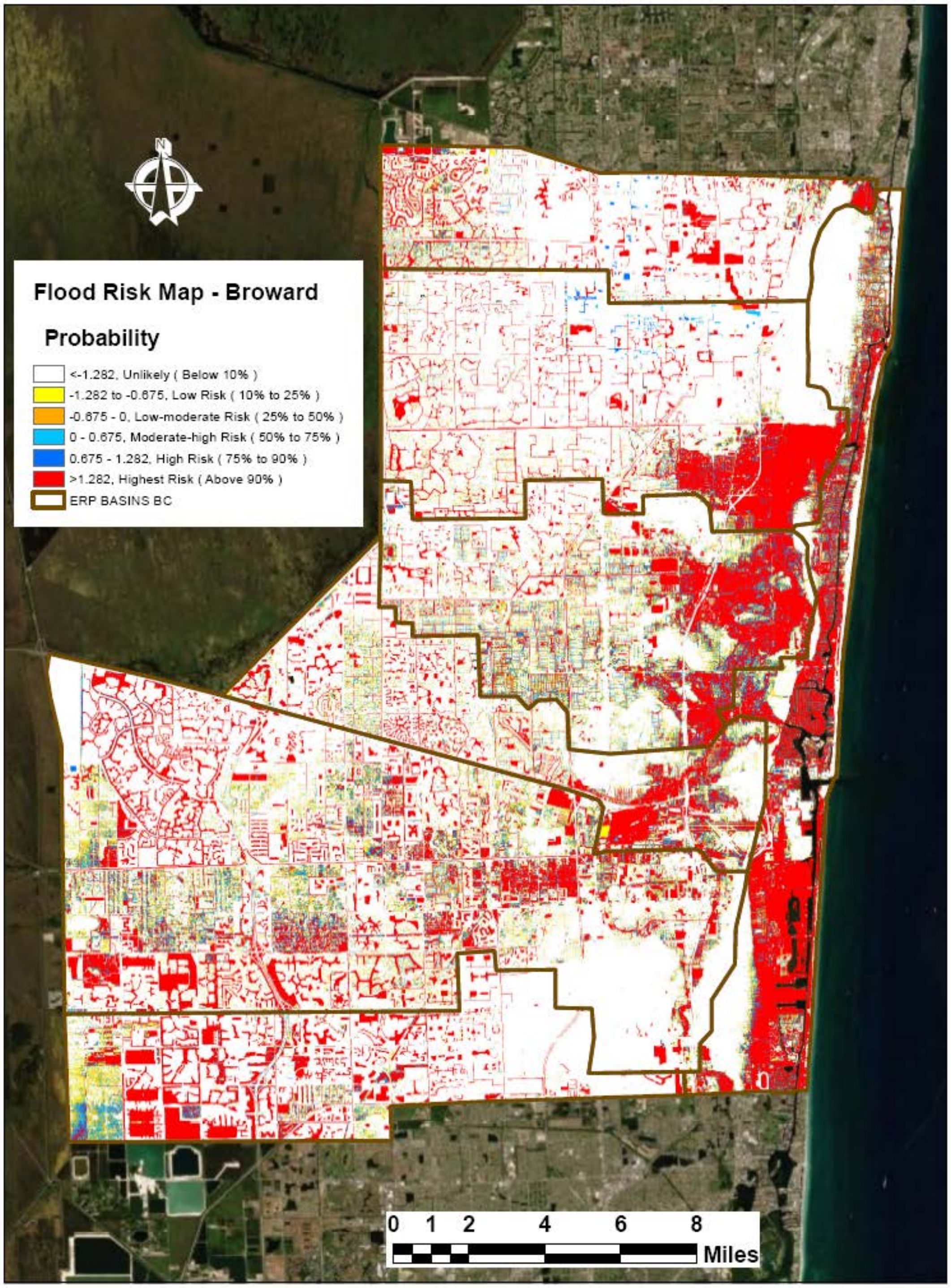


Figure 28. Example application of probability-based flood risk for Broward County, FL (Rojas, 2020)

2.4 Impact Adjustment Map

The flood hazard maps must present flood risk information that is correct and up to date to ensure that they provide a sound basis for floodplain management and insurance rating. FEMA relies heavily on communities to provide notification of changing flood hazard information and to submit the technical support data needed to reflect the updated flood hazards on the NFIP maps. Although revisions may be requested to change any of the information presented on the NFIP maps, FEMA generally will not revise an effective map unless the changes involve modifications to Special Flood Hazard Areas (1% annual chance floodplains or flood elevations). Requests for revisions that involve other information (e.g., roads or corporate limits) will typically be filed for future use. The goal of the watershed master plan is to remodel the basin to determine if there are justifiable changes to the FEMA flood maps.

An impact adjustment map is used to determine how much of the community's Special Flood Hazard Area (SFHA) is affected by a CRS-credited activity or element (refer to Appendices B-D for more details on the CRS activities). The credit is adjusted based on the impact of the element on the community's flood problem. There are 5 components to the impact adjustment mapping process:

1. Impact adjustment base map (Activities 410, 420, 430, and 440)
2. Impact adjustment for open space (Activity 420)
3. Other impact adjustments based on area (Activities 410, 420, 430, and 440)
4. Impact adjustments based on buildings (Activities 310, 520, 530, 610, 620, and 630)
5. Impact adjustments based on watershed area (Activity 450)

To calculate an impact adjustment, the total area of the floodplain or the total number of buildings in the floodplain must be determined (this is the denominator), and second, the area or number of buildings that are affected by the activity must be determined (this is the numerator). The impact adjustment is a ratio from 0 to 1. For example, if a community has preserved 50 acres of its 150-acre SFHA, then the impact adjustment is 50 ÷ 250 = 0.2 or 20%. The community will then receive 20% of the maximum credits for the activity of preserving open space. The base map has the corporate limits of the community showing all of the SFHA on the most current Flood Insurance Rate Map (FIRM) (Figure 29).

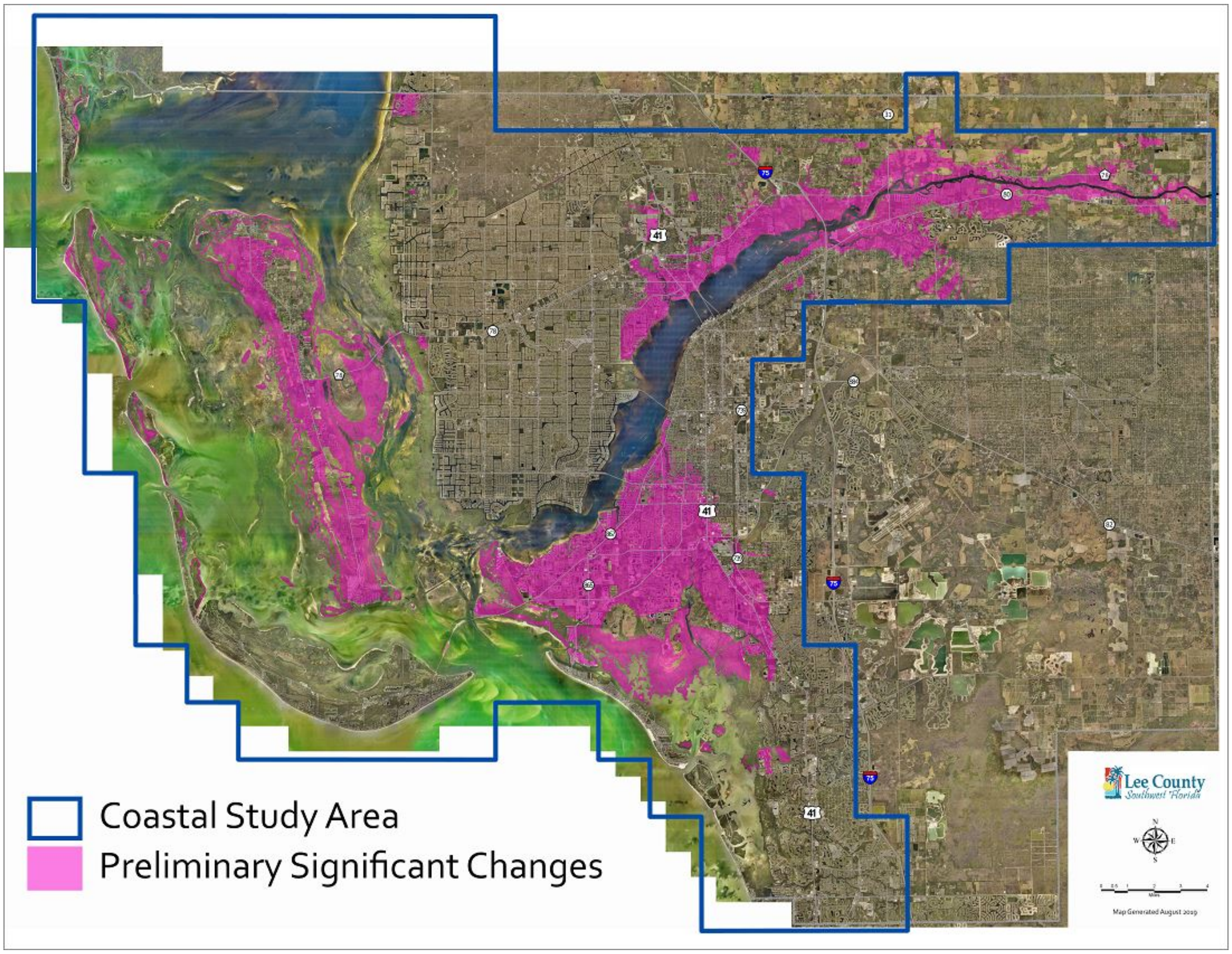


Figure 29. Example of an incomplete, proposed impact adjustment base map for Lee County, FL (Lee County, 2020)

Next, the areas to be excluded from SFHA must be marked out to make sure the denominator accurately reflects the area of the SFHA that is subject to development and also under the community's jurisdiction. The community is not held responsible for areas shown as SFHA on the FIRM that cannot be developed because they are under water or are beyond the community's authority to regulate because it is federal, tribal or state land. A community generally has no authority over state land, but because the CRS credits state activities in a community, if the community would receive more credit by counting state land, it can keep state lands as part of the SFHA.

The following must be marked on the map:

- Waterbodies in the SFHA that are larger than 10 acres. This includes lakes, reservoirs, and river channels, but does not include wetlands, which are not considered waterbodies.
- Federal and tribal lands in the SFHA that are larger than 10 acres.

- State lands in the SFHA that are larger than 10 acres (differentiate state open space vs. all other state-owned property)

3.0 POLICY FRAMEWORK

A Watershed Master Plan (WMP) should be cognizant of all applicable policy guidelines, ordinances, and public policies that relate to water management within the watershed. This section catalogues the various guidelines and policies that a community should include in formulating a WMP.

3.1 Existing Regulations

It is important that the watershed plan identify the control actions, management practices, and regulations as well as the agencies that have authority and jurisdiction, as applicable to the watershed. These will include regulatory standards for new development such that peak flows and volumes are sufficiently controlled and regulations that prohibit development, alteration and modification of existing natural channels. The universe of existing regulations includes federal, state, tribal, regional, and local rules.

3.1.1 Federal and State

The federal and state 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 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. This also includes wetlands. Discharges into surface waters is one of the oldest methods of disposing of waste because surface waters remove the 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…"*

Responsibility for compliance with these regulations lie with water system owners, public officials, managers, and operators. Enforcement action for failure to meet regulations is usually directed against the responsible officials of a water system, water district, municipality, or company. The most common legal liability results from failure to comply with specific regulations. In the United States, much of the enforcement of the federal laws was delegated to the states in the 1980s. Hence the states enforce these rules. In Florida, a series of rules associated with minimum flows and levels, water quality and other issues are discussed in the following sections.

3.1.2 Regional

In Florida, stormwater management systems are regulated at the regional level across the watershed basin by the WMDs. These regulations apply to the design of a stormwater management system that requires a permit as provided in Chapter 62-330, F.A.C., or Section 403.814(12) F.S. The Districts publish regulations and guidance for stormwater management.

Unless otherwise specified by previous agency permits or criteria, a storm event of 3-day duration and 25-year return frequency (Figure 30) or 24-hour, 100-year storm (Figure 31) are used in computing off-site discharge rates. Applicants are advised that local drainage districts or local governments may require more stringent design storm criteria. An applicant who demonstrates its project is subject to unusual site-specific conditions may, as a part of the permit application process, request an alternate discharge rate.

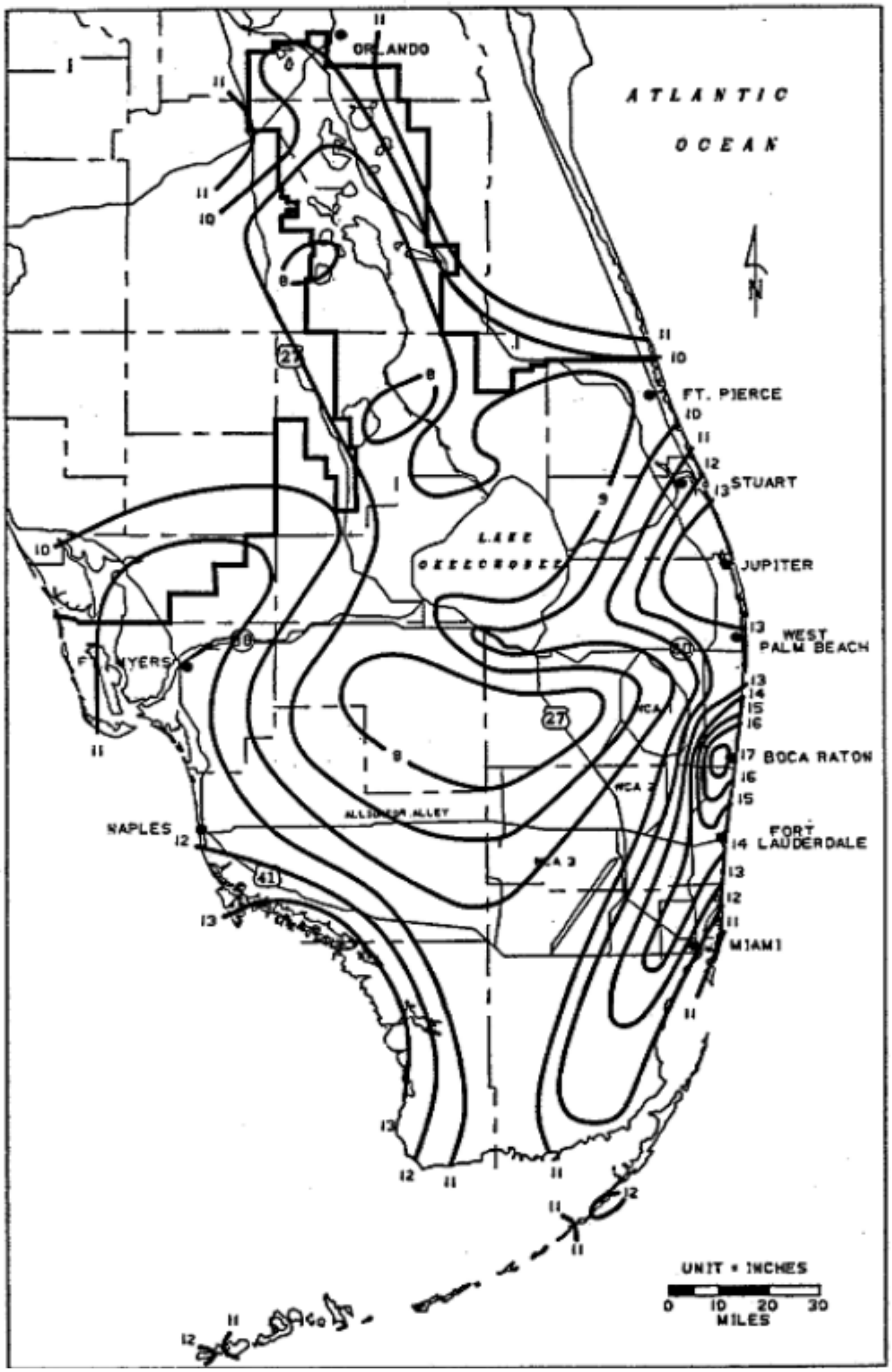


Figure 30. 3-day, 25-year rainfall map (SFWMD, 2014) (https://www.sfwmd.gov/sites/default/files/documents/swerp_applicants_handbook_vol_ii.pdf)

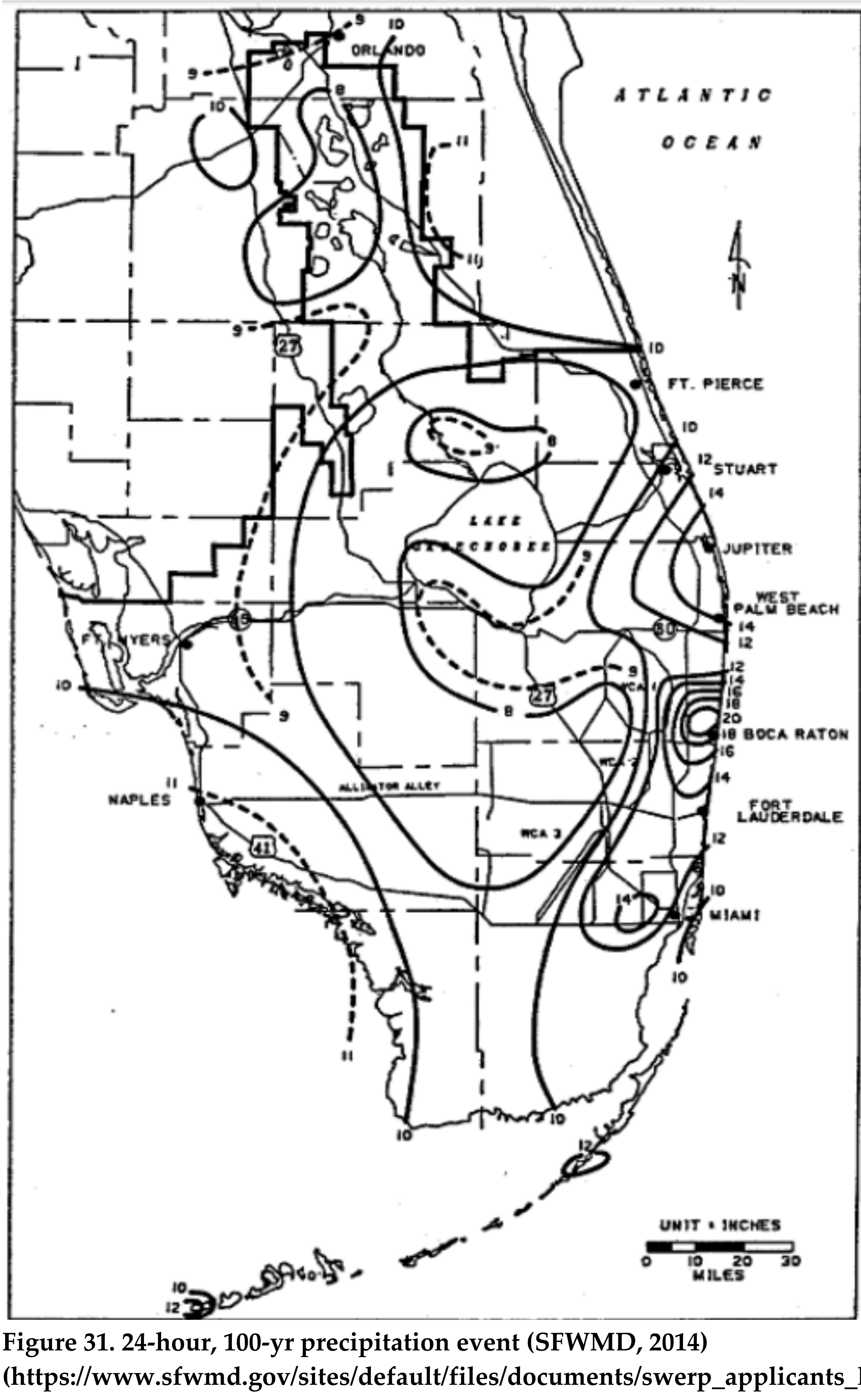


Figure 31. 24-hour, 100-yr precipitation event (SFWMD, 2014) (https://www.sfwmd.gov/sites/default/files/documents/swerp_applicants_handbook_vol_ii.pdf)

Off-site discharge rate is limited to rates not causing adverse impacts to existing off-site properties, and: a) historic discharge rates; or b) rates determined in previous agency permit actions; or c) rates specified in WMD 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. 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 divided into sub-basins according to artificial or natural drainage divides 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. The Peak Rate Factor reflects the effect of watershed storage on the hydrograph shape and directly and significantly 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.

Surface storage, including that available in wetlands and low-lying areas, must be considered as depression storage. Depression storage 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 elevations, as determined from the most appropriate information, including FIRMs. Both tidal flooding and the 24-hr, 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 5-year storm frequency is used for roadways.

With respect to the floodplains, no net encroachment into the floodplain, between the average wet season water table and that encompassed by the 100-year storm event, which will adversely affect the existing rights of others, is permitted. Treatment is required for offsite discharge to many categories of waters. That treatment is normally part of retention/detention. To wit, wet detention volume is required to be provided for 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 dry detention volume must be provided equal to 75% of the amounts computed for wet detention, or retention volume shall be provided equal to 50% of the amounts computed for wet detention. Projects having greater than 40% impervious area and that 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 rules are extensive, but the major point is that added watershed volumetric loadings are not permitted in most circumstances.

3.1.3 Local

Local ordinances establish construction-phase erosion and sediment control requirements, river corridors and wetland buffers, and other watershed protection provisions in the form of stormwater ordinances and permits or development restrictions. Local stormwater ordinances and permits stipulate that applicants to control stormwater peak flows, total runoff volume, or pollutant loading. Stormwater ordinances that apply these requirements to redevelopment projects (not just new development areas) can help mitigate current impacts from existing development. Developers could be required to implement stormwater practices such as bioretention, stormwater retention or detention ponds, or constructed wetlands to meet performance standards.

Local development ordinances and permits stipulate that applicants meet certain land use, development intensity, and site design requirements (e.g., impervious surface limits or open space, riparian buffer, or setback requirements). Although it might be difficult to add open space to the redevelopment plan of an already-developed area, equivalent off-site mitigation or payment in lieu might be required.

3.2 10-year, 25-year and 100-yr and 5-day events

The 3-day, 25-year storm event and the 24-hour, 100-year storm event are noted in the prior section. Other events are available from the WMDs and NOAA. Rainfall events are used to calculate peak flows and volumes.

3.3 Peak Flows and Volumes

Peak volume data is determined as a result of modeling described in Section 2.2.

3.4 Minimum Flows and Levels (MFLs)

The purpose of establishing Minimum Flows and Levels (MFLs) is to avoid diversions of water that would cause significant harm to the water resources or ecology of an area. The Florida Legislature has mandated that all WMDs establish MFLs for surface waters and aquifers within their jurisdiction. Section 373.042(1) defines the minimum flow as "the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." It further defines the minimum level as the "level of ground water in an aquifer and the level of surface water at which further withdrawals would be harmful to the water resources of the area." The WMDs are directed to use the best available information in establishing a minimum flow or a minimum level. The overall purpose of Chapter 373 is to ensure the sustainability of water resources of the state (Section 373.016, F.S.). To carry out this responsibility, Chapter 373 provides several tools, with varying levels of resource protection standards. MFLs play one part in this framework. Determination of the role of MFLs and the protection that they offer, versus other water resource tools available to the WMDs. The scope and context of MFLs protection rests with the definition of significant harm. The following discussion provides some context to the MFLs statute, including the significant harm standard, in relation to other water resource protection statutes.

Section 373.0421 requires that once the MFL technical criteria have been established, the water management districts develop a prevention or recovery strategy for those water bodies that are expected to exceed the proposed criteria. It is possible that the proposed MFL criteria cannot be achieved immediately because of the lack of adequate regional storage.

3.5 Existing Plans

The watershed master plan should be sensitive to local, state, and federal regulatory requirements that may or may not be already in place. Note that watershed master plans are distinctly different than a variety of other plans: Water quality and TMDL plans, local mitigation strategy plans, Flood Insurance Studies (FIS), Floodplain Management Plans (FMP), stormwater master plans, local ordinances and CRS plans, are all examples of plan that are developed for different purposes. 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. Looking at the natural hazards that have the potential to affect a community, assess the possibility for damage, plan for risks and vulnerably, and establish planned actions after such events. LMS follows the FEMA hazard mitigation definitions 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. While municipalities do not have an active role in creating a local mitigation strategy, they can contact the county government to take part in the process of updating the report. To receive funding for mitigation projects and non-emergency assistance, FEMA requires these LMS and their resubmission every five years to stay eligible. 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 as a precondition for receiving FEMA mitigation project grants.

The FAU team has identified the following possible documents that might have relevant information for developing a WMP. Such documents would include the following:

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

Three types of relevant water quality management reports may provide useful information for development of WMPs. These include Total Maximum Daily Loads (TMDLs), Basin Management Action Plans (BMAPs), and Surface Water Improvement and Management (SWIM) Plans.

TMDL. Section 303(d) of CWA allows the USEPA to assist states, territories, and authorized tribes in the process of listing out all impaired waters for developing respective TMDLs. A TMDL is the water quality restoration goal of a specific watershed and serves as the starting point or planning tool in which water quality can be restored. FDEP regulates the quality of watersheds across the State of Florida and determines if they are with an acceptable TMDL of pollutants. TMDL planning efforts are summarized in Figure 32.

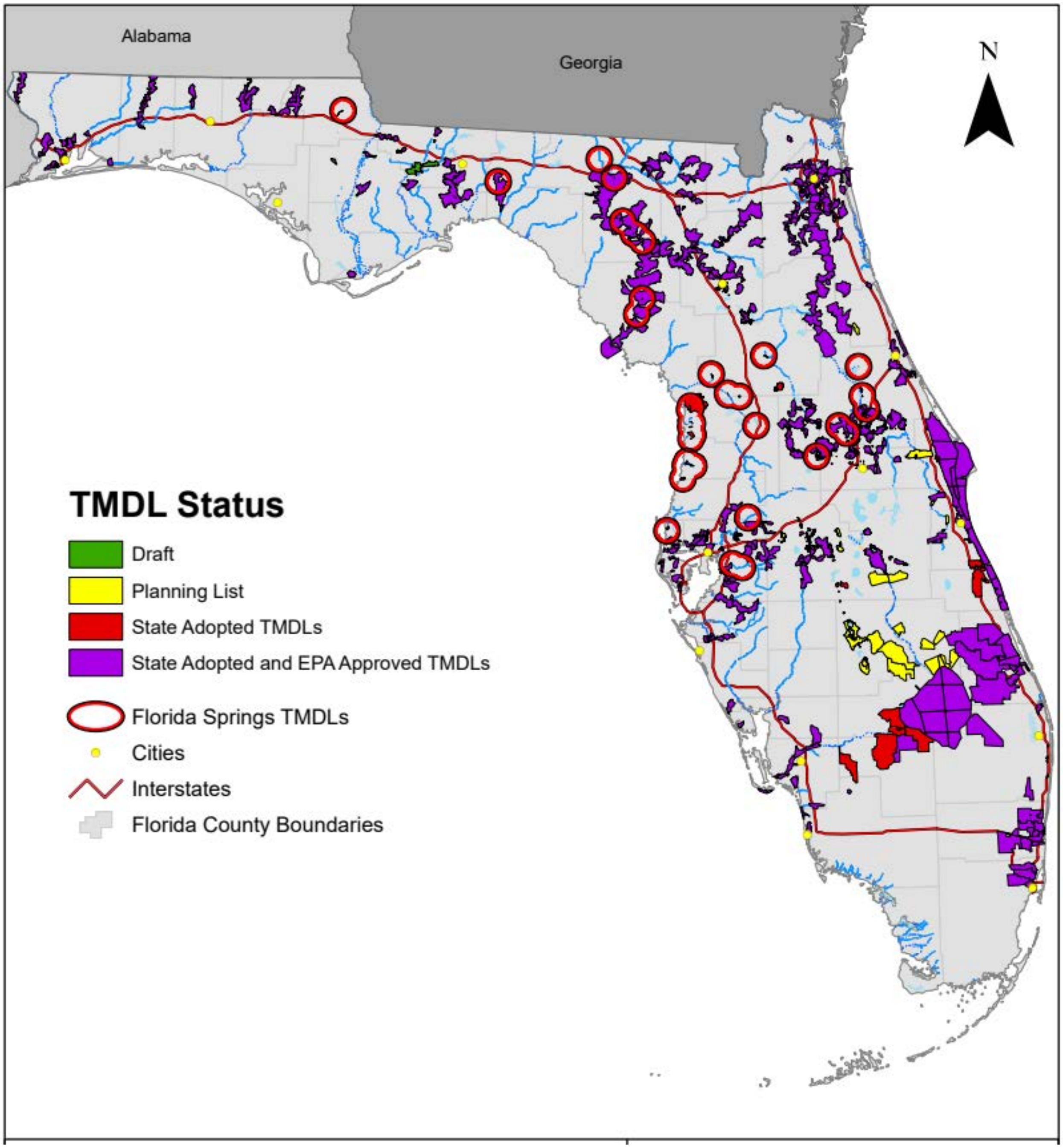


Figure 32. TMDLs across the State of Florida (FDEP, 2017)

BMAP. The BMAP serves as the guidelines for restoring watershed water quality.

SWIM Plans. In 1987, the Florida Legislature passed the Surface Water Improvement and Management (SWIM) Act to protect, restore and maintain Florida's surface water bodies. Under this act, the five water management districts are directed to identify a list of priority water bodies within their authority and implement SWIM plans to improve them. These SWIM plans use strategies for both restoration and protection, employing activities that vary from educational public outreach to resource evaluation to treatment techniques.

Although Water Quality Management Reports focus primarily on water quality, there is still some valuable information that can be obtained from these reports when developing WMPs. These include the following:

- Description of the watershed. A narrative describing the key characteristics, important waterbodies, and physical boundaries of the watershed.
- Hydrology. Identification of basins and sub-basins that fall within the watershed, water discharges, precipitation trends, groundwater/surface water interactions, seepage/storage, and other key factors.
- Historic Groups and Programs. Documents all plans, reports, programs, groups, legislation, or other items that have taken place to evaluate the water quality of the watershed.

3.5.2 Flood Insurance Study (FIS)

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. When a flood study is completed for the NFIP, the information and maps are assembled into a FIS. The FIS report contains detailed flood elevation data in flood profiles and data tables" (FEMA, 2020). FIS are encouraged by FEMA and the CRS program and are commonly used to revise and update information on the severity of flood hazards in geographic areas for specific waterbodies, lakes, and coastal flood hazard areas within a community. Additionally, FIS aid in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. These studies develop flood-risk data for various areas of their respective communities that will be used to establish flood insurance rates and to assist the community to promote sound floodplain management.

Minimum floodplain management requirements for participation in the National Flood Insurance Program (NFIP) are set forth in 44CFR, 60.3. Under Section 60.3 is a requirement for minimum compliance with floodplain management criteria. To wit, communities are required to adopt and enforce floodplain management regulations based on the latest flood maps and data published by FEMA. 44CFR 60.3 contains floodplain management criteria for flood-prone areas based on five possible conditions relating to flood map and property categorization:

1. Subpart 60.3 (a) when there is no floodplain map. In such cases, the community is to require permits for all proposed construction or other development in the community, including the placement of manufactured homes, so that it may determine whether such construction or other development is proposed within flood-prone areas. If a proposed building site is in a flood-prone area, all new construction and substantial improvements shall be designed (or modified) and adequately anchored to prevent flotation, collapse, or

lateral movement of the structure resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy.

2. Subpart 60.3 (b) when there is a map, but no flood elevations, the regulations require that all new subdivision proposals and other proposed developments (including proposals for manufactured home parks and subdivisions) greater than 50 lots or 5 acres, whichever is less, include within such proposals base flood elevation data. Various requirements for manufactured homes to be placed within Zone A of a community's FIRM be installed using methods and practices that minimize flood damage, in addition to applicable State and local anchoring requirements for resisting wind forces.
3. Subpart 60.3 (c), when there are flood elevations, communities are to require that all new construction and substantial improvements of residential structures within Zones A1-30, AE and AH zones on the community's FIRM have the lowest floor (including basement) elevated to or above the base flood level, and provide that where a non-residential structure is intended to be made watertight below the base flood level, the base level is identified. The requirements are that buildings are designed so that below the base flood level the structure is watertight with walls substantially impermeable to the passage of water and with structural components having the capability of resisting hydrostatic and hydrodynamic loads and effects of buoyancy. In addition, no new construction, substantial improvements, or other development (including fill) shall be permitted within Zones A1-30 and AE on the community's FIRM map.
4. Subpart 60.3 (d), when there is a floodway mapped, the community must prohibit encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway to prevent the potential for increases in flood levels. All new construction and substantial improvements in Zones V1-30 and VE, and also Zone V if base flood elevation data is available, on the community's FIRM, are elevated on pilings and columns so that: i) the bottom of the lowest horizontal structural member of the lowest floor (excluding the pilings or columns) is elevated to or above the base flood level and ii) the pile or column foundation and structure attached thereto is anchored to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting simultaneously on all building components.
5. Subpart 60.3 (e), when there is a map with coastal high hazard areas, due to wave impacts, V Zones have special building protection standards in addition to the requirements for A Zones; have the space below the lowest floor either free of obstruction or constructed with non-supporting breakaway walls, open wood lattice-work, or insect screening intended to collapse under wind and water loads without causing collapse, displacement, or other structural damage to the elevated portion of the building or supporting foundation system. Includes design of water and sewer systems to prevent flood waters impacting these systems. Space below the flood elevation will be useable solely for parking of vehicles, building access, or storage.

Section 60.4 discusses floodplain management criteria for mudslide (i.e., mudflow)-prone areas, while Section 60.5 details floodplain management criteria for flood-related erosion-prone areas. Section 60.6 provides for variances and exceptions.

Flood insurance studies have a natural overlap with WMPs with respect to the following:

- Hydrologic Analysis. Establishes the peak discharge-frequency relationships for each flooding source within the study area, including riverine and coastal sources, where applicable.
- Hydraulic Analysis. Documents the hydraulic characteristics of flooding from the sources studied and provides estimates of the flood elevations at the selected recurrence intervals.
- Floodplain Boundaries and Floodways. Identifies areas of encroachment on the floodplain and areas where it is necessary to understand the tradeoffs between the economic gain from floodplain development against the resulting increase in flood hazard.
- Coastal Analysis. Estimates the elevation of flooding along the coastline by way of understanding factors such as wave height, wave runup, and beach erosion in relation to sea level rise.

All counties that take part in the NFIP should have access to a FIS. It is important to remember that flood elevations shown on the FIRMs are primarily intended for flood insurance rating purposes. This is primarily due to the FIRMs evaluating only the historical data that is available to them, WMPs seek to bridge historical data with future projections like in the case of the WMP criteria of "*Evaluate future conditions and long-duration storms*" (FEMA, 2017).

3.5.3 Floodplain Management Plan (FMP)

Floodplain Management Plans (FMP) are found at both the municipal and county level, making them varied in format and content. These plans have varied objectives beyond what is discussed above, but at a minimum, cover similar aspects to a local mitigation strategy that overlap with WMPs. These include a discussion of the flood hazards that the community needs to address. An ideal FMP addresses content relevant to the development of WMPs, including:

- Hazard Identification and Profiling. Identifies flood hazards, discusses threats to the planning area and describes prior occurrences of flood events along with the likelihood of future occurrences.
- Vulnerability Assessment. Assesses the community's exposure to flood hazard events, considering at-risk assets, critical facilities, and future development trends.
- Mitigation Strategies. Provides approaches for reducing potential losses identified in the vulnerability assessment.
- Plan Implementation and Maintenance. Describes the method and schedule by which the monitoring, evaluating, and updating of the mitigation plan will occur.

Orange County, FL has produced a FMP that showcases just how much information can be gathered from a single plan. The Orange County FMP provides details relevant to flood hazard identification, vulnerability assessment, mitigation strategies, and plan implementation, but also briefly discusses the contributions that the County has made to the CRS program by individual CRS activities (Wheeler, 2017). While not all FMPs may have as much information as the Orange County FMP, it is still possible to gather some relevant WMP information from these plans.

3.5.4 Florida "Peril of Flood" Guidance

Following F.S. 627.715, the State of Florida provides guidance regarding the "Peril of Flood" to coastal communities in conjunction with federal guidance from NOAA. The intent of this effort is to help increase coastal resilience by reducing the extent and degree of at-risk coastlines within the state through a variety of analytical and developmental approaches. The force of law concerning Peril of Flood relates mostly to Flood Insurance Studies, flood insurance generally, and other policy factors a local community can take as described in other sections here. However, the state commissioned efforts revolving around Peril of Flood take a step beyond simple insurance risk assessment and attempt to provide communities with guidance pathways to building resilient infrastructure and coastal development. This means involving regional planning councils, academic professionals, transportation planning organizations, and county staff to help identify areas of hazard and to identify possible pathways to resilience and increase capacity among local efforts. The Peril of Flood documentation does this by establishing guidelines through prioritization of local funds, coordinating stakeholder interests, and spearheading projects, such as Capital Improvement Projects and Local Mitigation Strategies. The Peril of Flood provides an online clearinghouse for resources and documentation on completed projects here: https://www.perilofflood.net/

3.5.5 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 was 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 to guide decision-making with regards to development in the community. These plans generally communicate growth projections over a 20 to 30 year planning horizon. The content of a comprehensive plan will address climate change, conservation, water, sewer, transportation, stormwater, recreation, municipal services, housing, natural disasters, and several other items that could be useful in developing WMPs, such as the following:

- Water Management. Takes into consideration major infrastructure areas of water supply, drainage, aquifer recharge, and sewer conveyance.

- Natural Disasters. Evaluates the impact of hurricanes, storm surges, floods, and other natural disasters that threaten the community to ensure that residents, visitors, and vulnerable populations can remain safe during such events.
- Coastal Management. Evaluates the coastline conditions across the community's jurisdiction and makes the decision as to whether these areas should be limited for certain development activities based on environmental, recreational, and economic value that coastlines bring to communities.
- Climate Change. Provides the framework for integration of environmental, economic, and social factors for mitigation efforts related to sea level rise and other climate related issues.

The Broward County Comprehensive Plan uses elements that have been identified as important to the development of a WMP, as such, each element is likely to contain either literature or a policy that will be useful in developing their WMP. In the Water Management element of their Comprehensive Plan, Policy WM1.13 states that:

> "[Water and Wastewater Services] *will assess, identify, and evaluate the costs and benefits of the design, construction, and operation of storm water management facilities within its jurisdiction in a manner that conserves and enhances the availability of potable water and supports environmental resources, while preventing area flooding and protecting from sea level rise and other climate change impacts when evaluating construction of new, or retrofit of existing, facilities.*" (Broward County, 2019)

This policy statement and its eventual execution will be important in addressing several of the WMP criteria, such as, *"Address the protection of natural channels"* or *"Evaluate the impact of sea level rise and climate change*" (FEMA, 2017). This example illustrates why it is important to evaluate local government Comprehensive Plans to understand what policies may already be in place that address WMP criteria.

Both Hendry County (2020) and the City of Clewiston (2015) have produced similar comprehensive plans that can provide a basis for developing a WMP for the city of Clewiston, particularly regarding future conditions. While the modeling of future floodway conditions will largely depend on the analytical approaches used (see modeling sections), projected future land use and land cover will have a direct relationship with how, where, and why water is managed in that future state and the spatial considerations required to make sound decisions regarding the watershed. While not as extensive as Broward's comprehensive plan, Clewiston and Hendry County's respective comprehensive plans describe in detail the current and projected land uses in their jurisdictions with direct implications for how water might be managed in the watershed. Consider the map in Figure 33. Given this information on the extent of public lands and wetlands projected to be realized in the year 2025, the City has enough information to develop plans for Low Impact Development, integrated stormwater management regulations, and other topics related to floodplain management in the watershed.

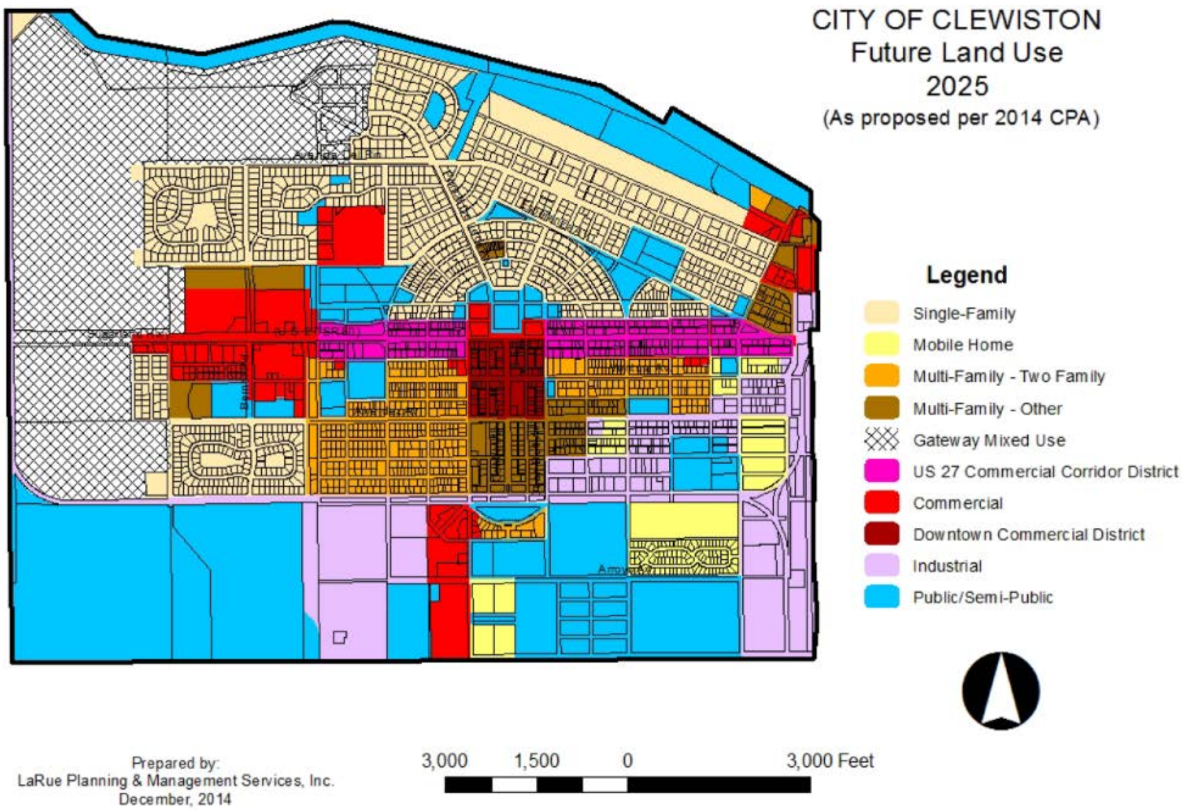


Figure 33. Map from the City of Clewiston's Comprehensive Plan demonstrating projected future land use by the year 2025 (City of Clewiston, 2015)

3.5.6 Unified Land Development Regulations (ULDRs)

The Unified Land Development Regulations (ULDRs) allow implementation of adopted principles, strategies, goals, objectives, policies and maps of their respective Comprehensive Plans as they relate to the regulation of use and development of land and structures per Florida Statutes 163.3202. The ULDRs are expected to cover a wide variety of aspects from the community's Comprehensive Plan, as follows:

- Open Space. Defines the open space policies of the community as they relate to future land use, stormwater, and the conservation of open space for the purposes of recreational opportunity, pedestrian connectivity, and protection of natural resources.
- Regulation of Areas Exposed to Seasonal and Periodic Flooding. Defines and regulates the policies in place that seek to protect and maintain the natural functions of the floodplains, while at the same time establishing minimum regulation requirements for building in such areas so to safeguard public health, safety, and general welfare
- Stormwater Management and Drainage. Defines the standards for design, construction, and operation of stormwater management systems and the conformance with the best overall management practices for regulation of runoff control and treatment of stormwater.

- Low-Impact Development. Defines the design standards by which land planning and engineering design approaches are focused on the management of stormwater and runoff using green infrastructure

A distinction between a ULDR and a Comprehensive Plan is that the former is directly tied to development code, while the former is more aspirational and not always associated with specific regulations. The Broward County ULDR code of ordinance references several of these aspects that align with the implementation of a WMP. One such portion of Broward County's ULRD that already works towards developing a WMP is the following:

> *"The proposed development shall be designed to provide adequate areas and easements for the construction and maintenance of a water management system to serve the proposed development and adjacent public rights-of-way in a manner which conforms to sound engineering standards and principles" (*Broward County Land Development Code, 2016)

This excerpt is the preamble to a section of the Broward County ULDR that addresses the adequacy of their water management and the regulations that the code of ordinance sets in place to ensure that adequacy.

3.5.7 Stormwater Management Policies (MS4)

As a part of the Clean Water Act, USEPA developed regulations relating to stormwater pollution in waterways, which became the basis of the Municipal Separate Storm Sewer System (MS4) program. Stormwater management policies related to the MS4 program regulate publicly owned conveyance systems (i.e., ditches, curbs, catch basins, underground pipes, etc.) for collecting stormwater that discharges to surface water bodies. Essentially, the permit requires reduction of pollutants in the discharge to the "maximum extent practical," to protect water quality (USEPA, 2020). MS4 permits are helpful in the development of WMPs because they identify major outfalls and pollutant loadings, non-stormwater discharges, and pollutant levels in runoff, while setting the guidelines to control and monitor stormwater discharge in new development and redevelopment areas. Phase II of the MS4 program focuses on public education and outreach, public participation, illicit discharge detection, construction site stormwater runoff control, post-construction stormwater management in new development and redevelopment areas, and overall pollution prevention.

3.5.8 Local Mitigation Strategies (LMS)

A county's Local Mitigation Strategy (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 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 the Federal Emergency

Management Agency (FEMA) hazard mitigation definitions 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.

3.5.9 Intergovernmental Cooperative Agreements

Occasionally, regional guidelines and policy can arise from intergovernmental cooperative agreements, bridging numerous municipal and county jurisdictions in support of a common goal. One example of such a cooperative effort relevant to watershed management in Florida is the Southeast Florida Regional Climate Change Compact (SFRCCC), which includes Monroe, Miami-Dade, Broward, and Palm Beach counties and its charter is to help guide these four counties through the inevitable challenges associated with sea-level rise and climate change using science-based guidelines to drive policy decision-making.

From this cooperative came the Regional Climate Action Plan (RCAP) that provides SFRCCC member communities with a guiding tool for coordinated climate action whose mission is to:

> *"serve as a tool for municipal and county local governments, agencies, regional councils, regional resource management districts, and other local planners and practitioners. The plan identifies vulnerabilities, prioritized actions, and integrated policy initiatives to create a clear–though challenging–path forward for the region. The RCAP includes a broad set of best practices to guide implementation of emission reduction and resilience-building actions that each jurisdiction can implement. The RCAP is a framework for concerted regional action rather than a set of directives for specific projects or programs at the local level, recognizing that decisions on the timing and approach are best determined by each local government."* (SFRCCC, 2012)

The RCAP relates directly to watershed management in the south Florida context because sea-level rise presents a host of direct and indirect challenges to the water resources of the densely populated, low-lying urban centers along the coast.

3.5.10 Special Watershed Restoration Plans

Special regional plans can also be directed from the federal level. One such example is the Comprehensive Everglades Restoration Plan (CERP), whose mission is to restore the altered south Florida watershed into a more natural state. This effort directly ties to any WMP effort within CERP's geography and mandates certain management criteria. CERP created an intergovernmental South Florida Ecosystem Restoration Task Force (Task Force) in 1996 with 3 goals in mind: 1) water quality and quantity, 2) habitats and species, and 3) built environments.

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 will be helpful in addressing parts of a WMP with regards to stormwater and runoff management.

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.

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, the coasts 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.

3.5.14 Other Plans

Stormwater Master Plan: The purpose of a Stormwater Master Plan is to identify any deficiencies in the existing stormwater management system and to recommend system improvements to alleviate flooding problems within a public right of way.

Flood Risk Reports (FRR): Provide non-regulatory information to help officials understand flood risk and take steps to mitigate and communicate those risks to their citizens and local businesses.

3.6 Dedicated Funding Sources

Nothing gets accomplished with respect to construction of infrastructure without funding. There are many potential sources and mechanisms. For example, USACE is dependent on funding from Congress. However, USACE and Congress are capable of putting together resources that no local or regional government could possibly provide to fund very large infrastructure projects, like CERP in south Florida. This is not however, a dedicated funding source, but a biennial appropriation from Congress.

Likewise, the State of Florida could create potentially make funds available from its nearly $100 billion budget, including funds for land conservation programs, the most likely contributor to watershed protection efforts in the states. Florida Forever is Florida's conservation and recreation lands acquisition program. It replaced Preservation 2000 (P2000). Since the inception of the Florida Forever program in July 2001, Florida has purchased more than 818,616 acres of land for $3.1 billion. Florida Forever funding is appropriated by the State Legislature and distributed by FDEP to a number of state agencies and programs to purchase public lands in the form of parks, trails, forests, wildlife management areas and more. All these lands are held in trust for the residents of Florida. This is a dedicated funding source from the State.

The Florida Water and Land Conservation Initiative, Amendment 1 was approved in 2014 as an initiated constitutional amendment. The measure designed to manage and restore natural systems and to enhance public access and recreational use of conservation lands by dedicating 33% of net revenues from the existing excise tax on documents for 20 years was designed to dedicate 33% of net revenue from the existing excise tax on documents to the Land Acquisition Trust Fund that acquires and improves conservation easements, wildlife management areas, wetlands, forests, fish and wildlife habitats, beaches and shores, recreational trails and parks, urban open space, rural landscapes, working farms and ranches, historical and geological sites, groundwater recharge zones, drinking water resources, Everglades Agricultural Areas, and the Everglades Protection Area. Nearly 75% of voters were in favor of the measure. On September 9, 2019, the 1st District Court of Appeals ruled that the funds are "not restricted to use on land purchased by the State after 2015."

A host of non-profits and industry-backed groups such as the Nature Conservancy, Conservation Florida, Southern Conservation Trust, the Trust for Public Lands, and other environmental entities like the Bayer-funded Natural Resource Conservation group have in their mission statements to assist in land conversation efforts. However, none have sustained funding sources, and few can raise significant capital for large scale projects.

The Water Management Districts are special taxing districts with the authority to collect *ad valorem* (property) taxes from landowners within their jurisdiction. As a result, there is a dedicated funding source available. In addition to property taxes, the Districts' annual budgets are funded from other sources such as state appropriations, federal and local revenue, licenses, permit fees, grants, agricultural taxes, fund balances, and investment income. This is a somewhat sustained funding source for maintenance, but less so for capital construction.

The budgeting process should include the costs for debt first, repair and replacement dollars second, and operations third, thereby covering the life cycle cost of the asset. It is critical to leverage existing resources. Adjustments can then be made, preferably to the operations budget and not to the capital or repair and replacement budgets. Allocation of these non-operating costs should be apportioned proportionately over the operating budgets or personnel. One traditional option has been to use some form of General Fund appropriation. This is generally an *ad valorem* tax fund. Local officials are increasingly using stormwater utility fees instead. These fees are similar to water/sewer billing fees and are designed so that different users/land use classes may be charged different rates, if the rates can be justified. For example, a distinction can be made in some instances between user classes, i.e., residential customers being charged differently than industrial or commercial customers. The equivalent residential unit-based method to allocate on impervious area or imperviousness are often used. Among the considerations in developing a rate structure are:

- Financial sufficiency - generating sufficient revenues to recover operating and capital costs
- Conservation - encouraging customers to make efficient use of scarce water resources
- Equity - charging customers or customer classes in proportion to the costs of providing service to customer groups and minimizing negative financial effects on utility customers
- Ease of implementation - having the capability to implement the rate structure efficiently without incurring unreasonable costs associated with reprogramming, procedures modification, and redesigning of billing forms

- Compliance with appropriate legal authorities - being consistent with existing local, state, and federal ordinances, laws, and regulations
- Long-term rate stability - producing rates that are reasonably constant from year to year, (i.e., that the methodology does not produce rates that fluctuate widely from one period to another)

Stormwater utility fees are a dedicated funding source option at the local level, but the size of the jurisdiction will limit the amount of funds annually available.

Impact fees are charges imposed against new developments or connections to provide the cost of capital facilities made necessary by that growth. Generally, capital facilities are deemed to be treatment plants and regional infrastructure systems but can be applied to stormwater improvement. The revenues are not always predictable, making pledges toward debt service of these funds difficult without supplemental revenue pledges.

There are several instances where localized infrastructure can be funded in the small area served. These are called assessments. Typical assessment infrastructure would be for small gravity pipelines, neighborhood pump stations, or local retention/detention ponds. Any improvements serving a limited geographical area are generally termed "subdivision infrastructure." Assessments are collected to meet special benefits for a sector of the population, and must represent a fair and reasonable portion of the cost to each of the projects subject to the improvements and the assessment (the assessment version of the rational nexus test). Payment of the assessment bill may be enforced through a lien against the property, most easily accomplished by placement of the assessment on the property tax bill so that failure to pay the property tax bill and assessment (which cannot be separated) will cause the tax collector to pursue liens on the property. While a detailed discussion of assessments is beyond the scope of this document, there are strict requirements established for assessments in state statutes.

A brief description of the other major funding mechanisms for local infrastructure systems include the following (Bloetscher, 2008 and Bloetscher, 2011):

- Grants. Funds that do not have to be repaid in the form of grants are sometimes made by various government agencies. The availability of these funds for stormwater improvements is minimal except to economically distressed, small communities.
- Bonds. Frequently issued to acquire land, replace outdated or failing equipment and facilities, and expand systems, bonds generally lead to rate increases, so pay-as-you-go systems are preferred when practical. The bonds provide large sums of money when needed and permit repayment at a relatively uniform level over a period of 20 to 30 years. Interest rates are based on the creditworthiness of the issuer. Small systems in poor financial condition will have difficulty attracting buyers of their bonds at reasonable interest rates.

There are many types of bonds that may be issued, but the two that are most common are general obligation bonds and revenue bonds (Bloetscher, 2008).

- General obligation (GO) bonds pledge the full faith and credit of the municipality against the bonds, even though the bonds are usually paid off mostly or entirely from revenues. The advantage of a GO bond issue for the bondholder is that the added security of having both revenues and potential tax income to meet the obligation, may secure a more favorable interest rate. The disadvantage of GO bonds is that the bond issue becomes part of the municipal debt and will be included in determining the remaining bonding capacity of the municipality. This obligation can seriously restrict the ability of a small municipality to issue GO bonds for road construction or buildings. A GO bond issue must also be approved by the voters, which may be a challenge.
- Revenue bond issues pledge the revenues of the system to pay the interest and redeem the bonds when due. Revenue bonds can usually be issued much more quickly than GO bonds, because they do not require voter approval. However, because the revenues of the system are the only pledge (which is weaker than full faith and credit), the interest rates are slightly higher and reserve funds are required. Bond attorneys can develop creative revenue bond issues for specific circumstances.

In both types, bonds issued before the project is bid or complete, may need additional revenues that cannot be secured from additional bonds. Therefore any small local government looks to state revolving fund loan programs or other loan options. Low-interest loans are sometimes available to publicly owned infrastructure systems from state/provincial or federal agencies, under varying circumstances. This special funding is often available either for construction of a new infrastructure or specific improvements to an existing system. The principal federal funding sources that may be available are from the State Revolving Fund (SRF) loans and the Rural Development Administration (RDA). Private properties are not generally eligible to receive grants or low interest loans that are available to publicly owned systems. As in any other form of private business, the private system owners must create their own financing, usually bond funds that are taxable. Smaller investor-owned systems must be operated efficiently and continuously and show a good rate of return on investment in order to sustain operations.

- USEPA resources (https://www.epa.gov/nps/funding-resources-watershed-protection-and-restoration)
- Water Infrastructure and Resiliency Finance Center (https://ofmpub.epa.gov/apex/wfc/f?p=165:1::::::)
- Clean Water State Revolving Fund (https://www.epa.gov/cwsrf)
- Environmental Education Grants Program (https://www.epa.gov/education/grants)

3.7 Model Ordinance

Florida Division of Emergency Management has provided a Model Code-Companion Floodplain Management Ordinance for Communities with Inland (Zone A) and Coastal High Hazard Areas (Zone V) dated April 3, 2017. This version found in Appendix A includes inland flood hazard areas (zones shown on FIRMs that start with the “A”) and coastal high hazard areas (zones that start with letter “V”). Contact Technical Support at flood.ordinance@em.myflorida.com for assistance with higher standards.

4.0 ASSESSMENT OF VULNERABLE AREAS

Defining flood probability due to compounding hydrographic influences is the central concern of a WMP. The point is to identify where further study might be needed. A screening tool accomplishes this goal applied to the watershed to designate areas that are susceptible to periodic flooding events. Utilizing the information collected and analyzed in Chapters 1-3, vulnerability can be assessed. For any given watershed, this may mean only small parts of the land area may be at risk. Note that modeling at the watershed level neglects certain localized issues but can identify areas that need further scrutiny.

FEMA develops its flood maps through several processes outlined in https://www.fema.gov/media-library/assets/documents/34953. These guidance documents support current FEMA standards and regulations. For this project, the 3-day, 25-year event was substituted by the 1 day, 100-year storm event, and the CASCADE model was re-run. Figure 34 shows a comparison of the flood probability model using the screening tool and the FEMA Flood Insurance Rate Map (FIRM). The screening tool map (left) shows in cyan the areas at higher risk of flooding (above 10% probability), and the FEMA FIRM (right), is a pdf document downloaded from the FEMA Map Service Center. The approximated area is around +/- 2,750 acres, showing all flood zones and base flood elevations (https://msc.fema.gov/portal/home).

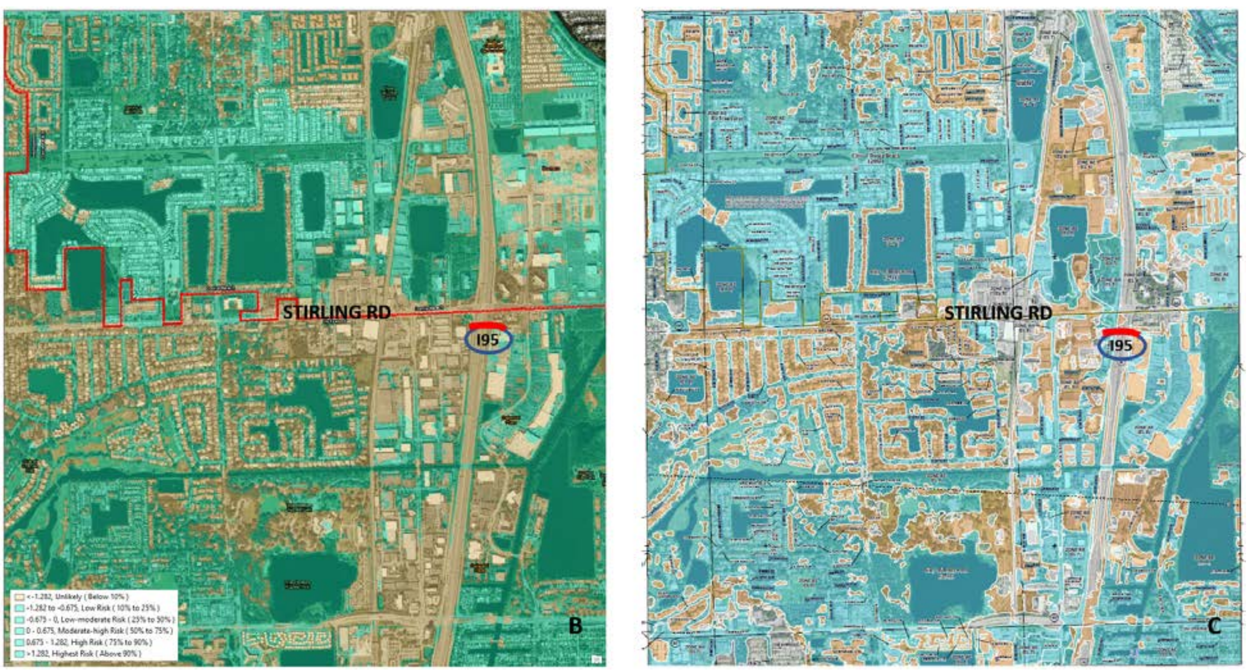


Figure 34 Comparison of screening tool (left) and FEMA FIRM map (right) shows strong similarities (Dania Beach)

Visual inspection shows strong similarities at the parcel scale, demonstrating that the screening tool can achieve its objective. The next step was to quantify the flood probability maps against a digital version of the FEMA FIRMs. The digital version of the FEMA FIRM was obtained from the City of Fort Lauderdale, GIS – Information Technology Services; they provided a partial coverage for Broward County (refer to Figure 35). Figure 36 is the new flood probability map run in CASCADE with the 24-hour, 100-year storm event.

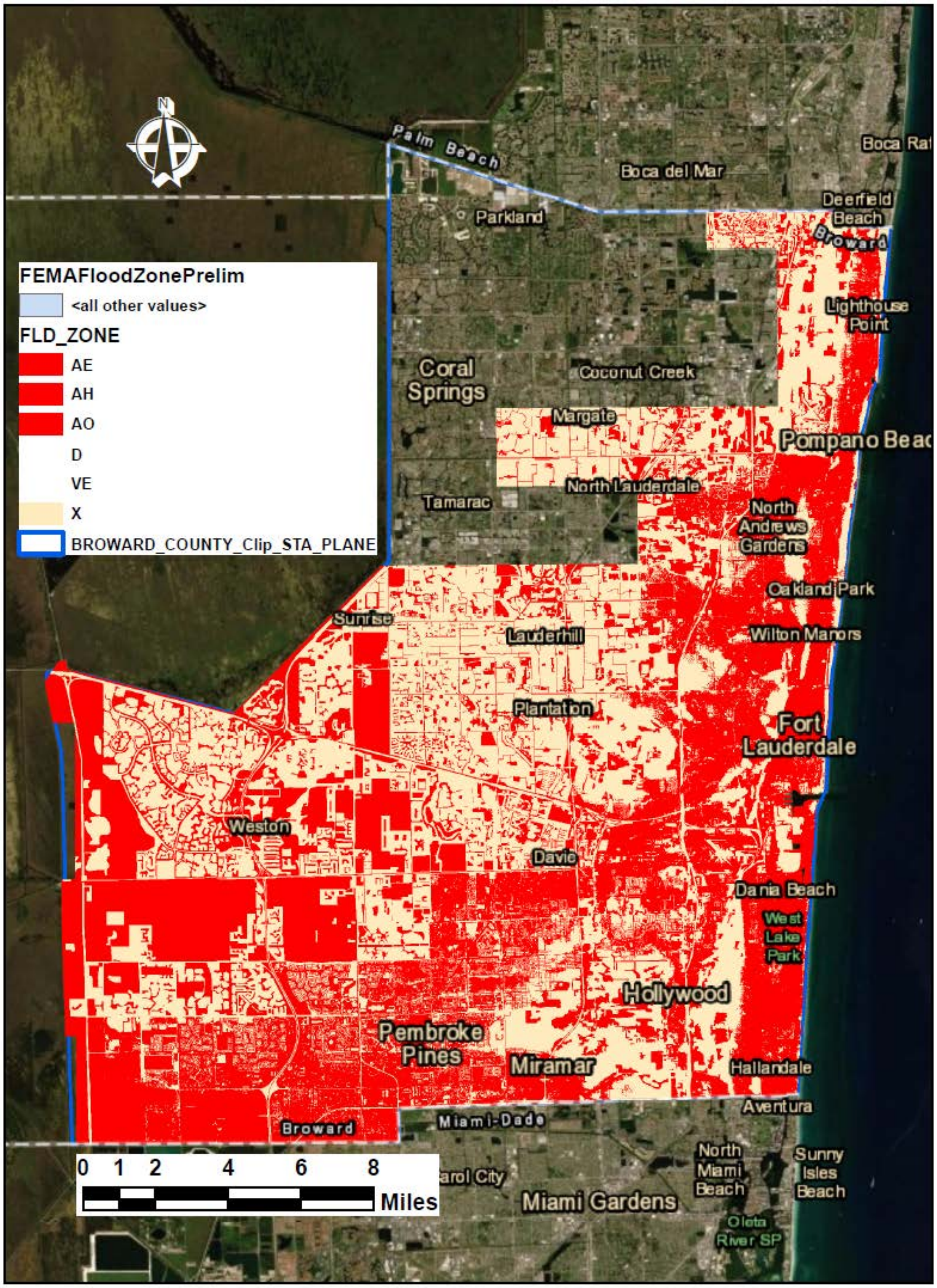


Figure 35. FEMA Flood Zone Preliminary 2019 (Rojas, 2020)

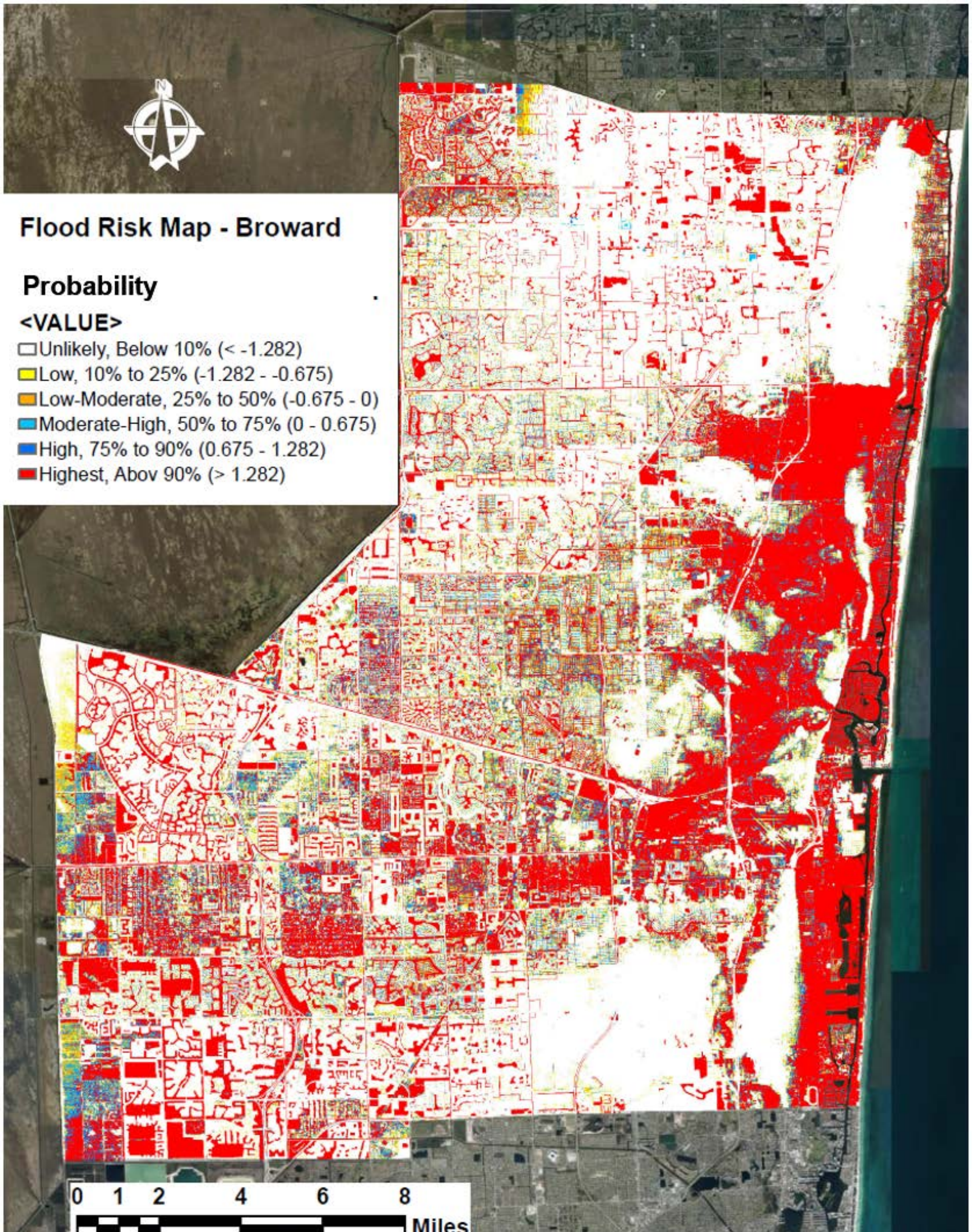


Figure 36. Probability of flooding during the 24-hour, 100-year storm event (Rojas, 2020)

4.1 Historical and Existing Challenges

Historical challenges are most easily articulated through a review of repetitive loss maps. These maps indicate the properties most likely to be at risk because claims have been filed on these properties previously. Other challenges involved politics, development desires and finances. These are very localized and may conflict between neighbors. For example, one community may be very pro-growth, while its neighbor is more flood-conscious. These are issues that need to be negotiated at the local and regional level.

4.1.1 Existing Management Efforts in the Watershed

Before recognizing the need for additional management measures to achieve goals and objectives, the existing programs, management strategies, and ordinances (and responsible parties) already in use in the watershed must be identified. In some cases, the existing management practices themselves might be adequate to meet water quality goals, but they might not be maintained correctly or there might not be enough of them in place or they may not be fully enforced. In other cases, the existing strategy can be modified to be more effective. For example, by increasing stream setback requirements from 25 feet to 100 feet. Typically, at a minimum, evaluate the following existing management efforts:

- Wastewater discharge permits
- Onsite treatment and disposal systems
- Urban stormwater runoff
- Agricultural/forestry practices
- Wetlands and critical habitat protection
- Development codes

4.1.2 Critical Target Areas Identification

By modeling the watershed's flood response to a 3-day, 25-year storm event and further classifying flood risk as the probability of inundation, it is possible to identify critical target areas within the watershed. These areas are particularly vulnerable to flooding and are subject to further study through a more focused modeling approach. The screening tool should first be applied at the 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 watershed. Figure 37 shows how this approach is used to identify the critical flood-prone areas in the Caloosahatchee watershed.

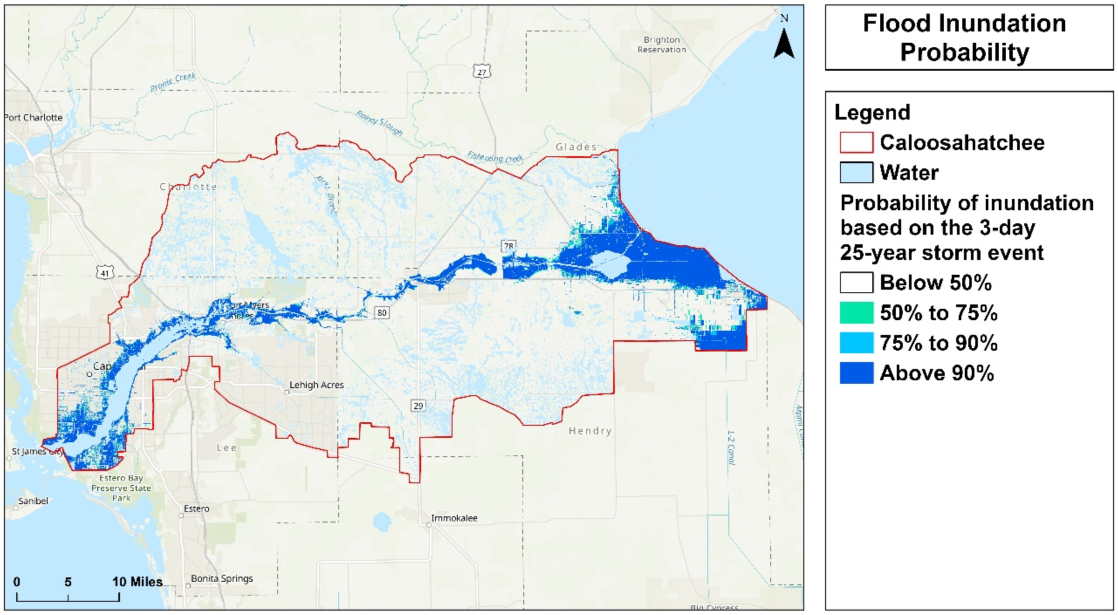


Figure 37. Flooded areas during a 3-day, 25-year storm in the Caloosahatchee watershed

The most vulnerable areas are considered as:

1. Areas that are predicted to flood as defined by z-score in the screening tool
2. Areas with critical assets (e.g. fire, police, hospitals, water, sewer, main roadways, etc.)
3. Economic centers (e.g. dense commercial/industrial/manufacturing)
4. Property risks affecting large populations or populations with limited opportunity to address the risk

Figure 37 only shows probability of flooding but a closer look at the map created for the Caloosahatchee Watershed provides opportunities to narrow down the areas that require more detailed investigation.

The City of Clewiston is located directly southwest of Lake Okeechobee in northeast Hendry County in the headwaters of the Caloosahatchee watershed. The design storm simulation with the screening tool determined that floodwaters will rise to a maximum headwater height of 15.82 feet NAVD88. 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 storm. The flooded areas include agricultural lands in the northwest and wetlands in the north; however, flooding in the east is of more concern as it poses a threat to residential housing, commercial businesses, and existing essential infrastructure. The probability of inundation of all areas within Clewiston, FL is shown on the map in Figure 38.

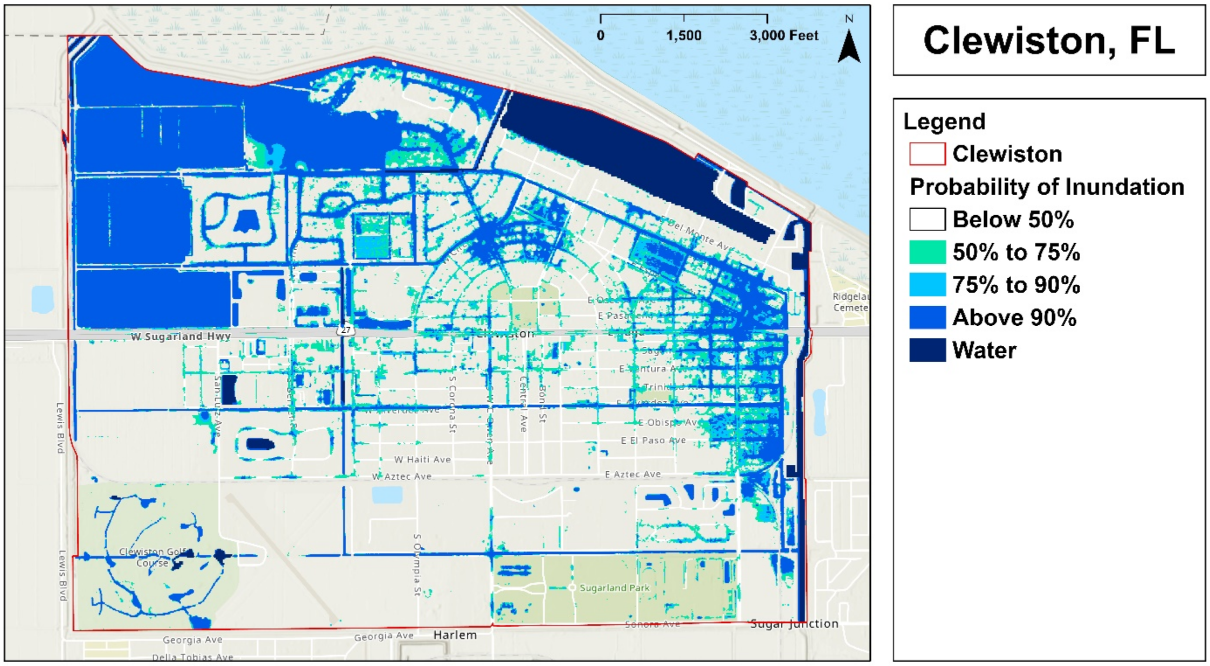


Figure 38. Flood probability map for the City of Clewiston, FL

The City of Fort Myers is a coastal community along the western edge of the watershed on the Caloosahatchee Estuary with a total area of approximately 49 mi^2. Tidal influence was a key parameter in modeling flood probabilities in the city. High tides paired with heavy rains push water into the estuary, further increasing the severity of flooding along the coast. An observed water level of 0.67 feet NAVD88 recorded by NOAA's Fort Myers tidal station was used to determine the initial stage at the beginning of the screening simulation. By combining the observed tide elevation with the modeled groundwater table elevation and soil storage capacity, it is possible to predict localized nuisance flooding. The 3-day, 25-year storm event simulation results indicate that floodwaters will rise to a maximum headwater height of 6.94 feet NAVD88, inundating nearly 20%, or 9.75 mi^2, of the total area. Floodwaters overflowing from the Caloosahatchee can reach anywhere between 0.1 and 0.3 miles inland. Additionally, low-lying areas adjacent to Billy Creek are vulnerable with a high probability of inundation. The flood probability map for the City of Fort Myers is shown in Figure 39.

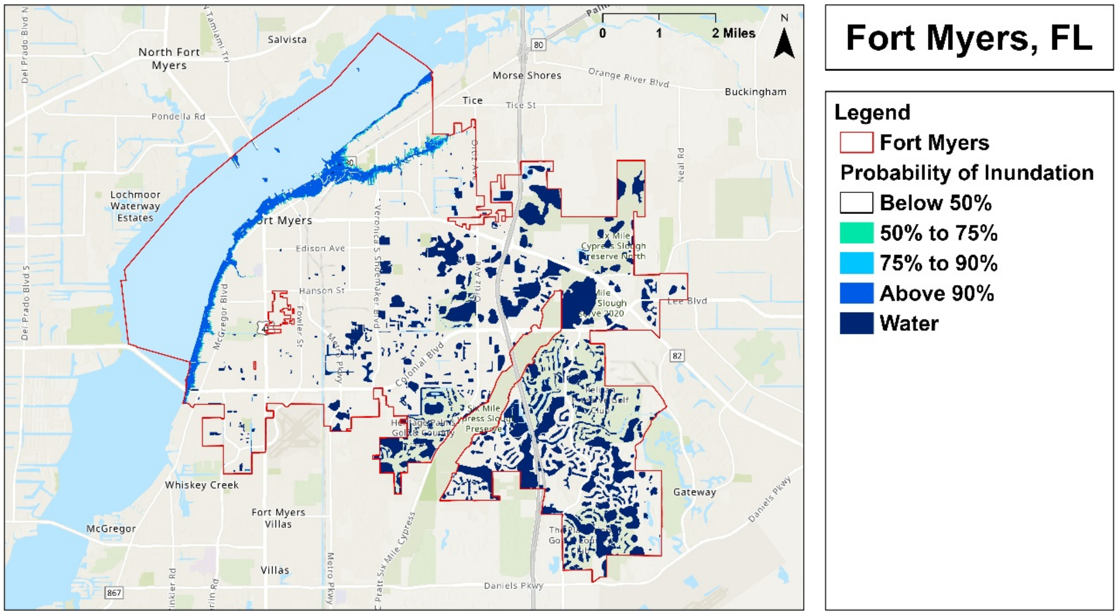


Figure 39. Flood risk map for the City of Fort Myers, FL

The City of Cape Coral is directly west of Fort Myers on the other side of the Caloosahatchee. Its total area of 119.32 mi^2 is split between the Caloosahatchee and Charlotte Harbor Watersheds along State Road 78 and Chiquita Boulevard South. Each watershed was modeled separately before mosaicking the results to generate a complete risk map for the City of Cape Coral, shown in Figure 40. Cape Coral's floodwaters will rise to maximum headwater heights of 6.94 feet NAVD88 in the Caloosahatchee Watershed and 7.25 feet NAVD88 in the Charlotte Harbor Watershed. Approximately 48% of the total area, or 57.04 mi^2, will likely be inundated during a 3-day 25-year storm event. Although floodwaters can extend several miles inland in some places, a large portion of the inundated areas are wetlands along the coast. The intricate canal system carries water further inland into residential areas; however, many homes have been constructed at an elevation above the maximum headwater height, indicating that floodwaters will reach most coastal properties without inundating the buildings themselves.

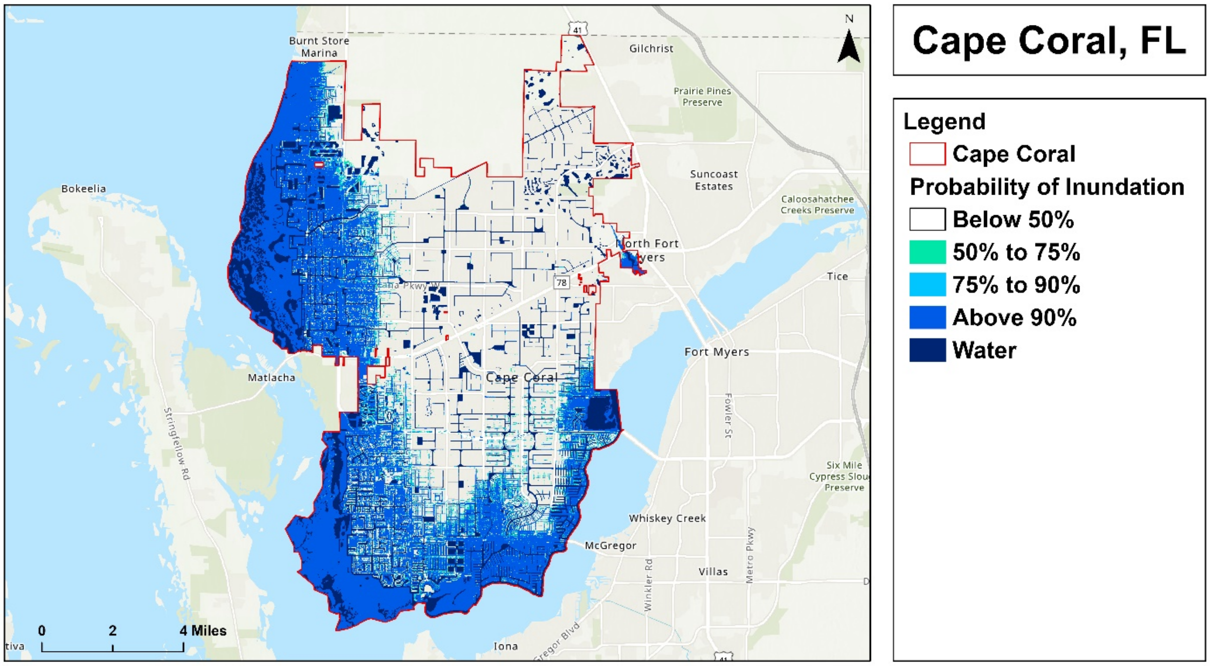


Figure 40. Flood probability map for the City of Cape Coral, FL

Once 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.

4.1.3 Potential Preservation Areas (open space, wetlands, habitat restoration)

Among the flood protection solutions is the preservation of open space, wetlands, etc. Many of these areas cannot be developed, so acquisition of the land by governments to improve flood protection meets the public interest. Habitat restoration is normally part of the acquisition of such lands unless reservoirs are proposed. Reservoirs can be used for water supply solutions that may have habitat restoration benefits by regulating flows. The C43 reservoir near LaBelle, FL is such an example (Figure 41).

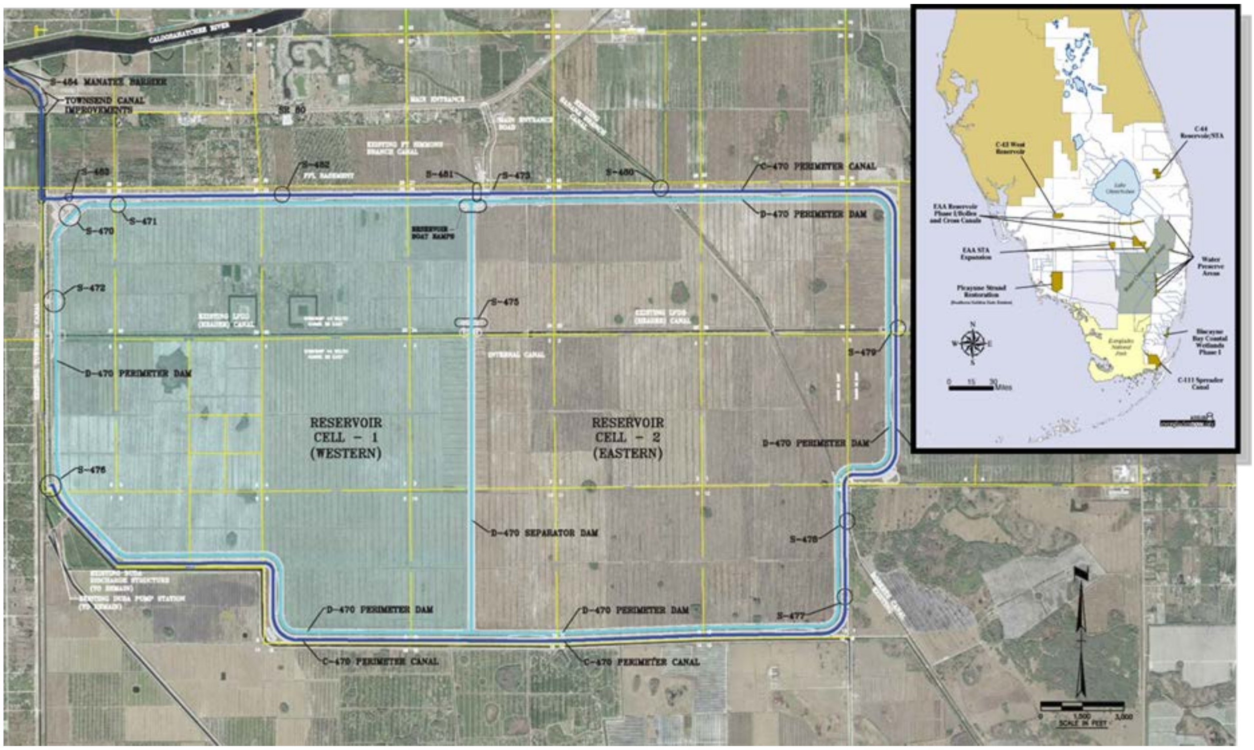


Figure 41. C-43 West Basin Storage Reservoir near LaBelle, FL (SFWMD)

4.2 Selection Process of Management Strategies

Once the targeted areas in the watershed that might benefit from management practices have been identified in the screening process (Section 2.2), it is time to conduct an alternative analysis that is designed to help objectively sort through the challenges to choose the most preferable approach. The criteria used in evaluating viable alternatives should match the goals and objectives defined for the project and agreed upon by all parties. The comparison of alternatives should be clearly delineated using professional judgment. Trade-offs and impacts to social, political and environmental factors should be addressed. Analysis of the alternatives should include:

- Likelihood of success in meeting the goals and objectives
- Efficiency of implementation
- Economic viability
- Sustainability / environmental impacts
- Social and political acceptability

A major note of caution is that many times the benefits may be unknown or difficult to quantify at the time the benefit-cost analysis is conducted.

4.2.1 Alternative Analysis

An objective method for determining the preferred option by using an engineering alternative analysis is described as follows:

Step 1: Define the Problem

a) Write a brief description of the decision that is being analyzed.

Step 2: List Threshold Criteria to Narrow Down to Only the Feasible Alternatives

a) Brainstorm all of the possible alternatives to meet the project goals (use Section 5.1 toolbox as a starting point).
b) Perform research to define the advantages and disadvantages of each alternative (use Table 9 as a starting point).
c) Make a list of the yes/no questions that will help rule out alternatives that do not meet the goals of the project. For example, if the goal is to use only green infrastructure options, then a good threshold criterion might be: "Is the strategy considered a green alternative?" Then if not, the strategy is no longer considered as feasible. Another example might be: "Has the option been implemented successfully in Florida?"

Step 3: Define Selection Criteria

a) Make a list of all the applicable criteria to compare the remaining feasible design solutions. In other words, what are the important design considerations? When evaluating options, the lowest cost option is not always the preferred alternative. It is better to use a more objective approach and employ quantifiable selection criteria for ranking the alternatives. Some examples of effective selection criteria are:
   - Footprint
   - Performance
   - Reliability
   - Longevity
   - Ease of construction
   - Public acceptance
   - Capital cost
   - Maintenance cost
b) Explain how to assign a high score for each criterion. For example, footprint: It is desirable to minimize the footprint of the design, so a high score is assigned to the alternative with the least amount of square footage required, and the lowest score is assigned to the alternative with the largest square footage.
c) Compare alternatives using quantitative (measurable) data to determine the rating factor. Since in the example in b) it was desired to minimize footprint, the option with the smallest square footage requirement is assigned the highest rating factor of 4 among the four alternatives evaluated. Conversely, the option with the largest footprint is assigned the lowest rating factor of 1, as follows:

Alternative	Footprint (ft^2)	Rating Factor
Option 1	2000	3
Option 2	1900	4
Option 3	4000	2
Option 4	5000	1

Step 4: Assign Priority Values (Weighting Factors) to Each Criterion

a) Rank the selection criteria in order of importance. For example, if there are 5 selection criteria, then the most important would be assigned a weight of 5.
b) Alternatively, assign weighting factors by using a survey of stakeholders.

Step 5: Construct a Matrix

a) In the matrix table, order the selection criteria from highest weighting factor to lowest from Step 4.
b) Place the rating factor from Step 3c in the matrix in the appropriate column.
c) Multiply each rating factor by the weighting factor and write this number to the right of the unweighted rating factor in parenthesis for each design alternative.
d) Sum the unweighted (and then also the weighted values in parenthesis) and write them in the corresponding "TOTAL" cell, as follows.

Selection Criteria (ranked in order of importance)	**Weighting Factor**	**Revetment**	**Detention Pond**	**Bioswale**
Capital Cost	**5**	**1 (5)**	**2 (10)**	**3 (15)**
Maintenance Cost	**4**	**1 (4)**	**3 (12)**	**2 (8)**
Pollutant Reduction Efficiency	**3**	**2 (6)**	**1 (3)**	**3 (9)**
Public Acceptance	**2**	**1 (2)**	**2 (4)**	**3 (6)**
Added Benefits	**1**	**1 (2)**	**2 (2)**	**3 (3)**
Total Max Score = 15(45)		**6 (19)**	**10 (31)**	**14 (41)**

It is helpful to provide the maximum possible score (both weighted and unweighted) on the matrix as shown in the lower left cell.

Step 6: Analyze Results

a) The alternative with the highest value (as shown in the "TOTALS" row) both unweighted and weighted is the most preferred alternative from the options evaluated that best meets the goals of the project.
b) Perform a sensitivity analysis by changing the weights, removing one criterion, adding another criterion, etc.

c) If the most preferred alternative remains the same after the sensitivity analysis, then the analysis is robust, and the manager can conclude with a high degree of confidence that the alternative will meet the needs of the project.

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 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 42 shows the accumulated precipitation average prior to 1973 versus 1994.

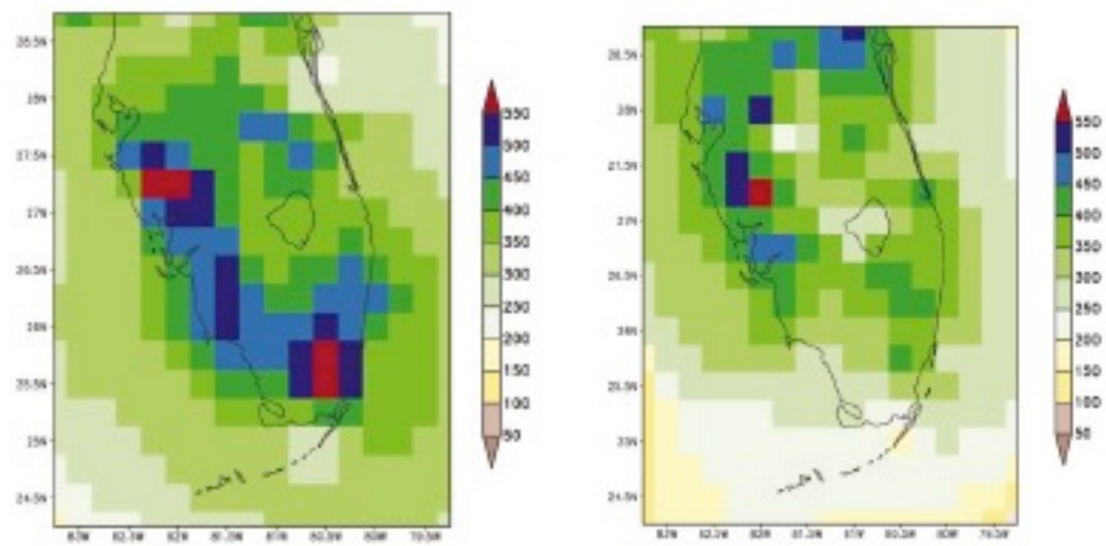


Figure 42. Accumulated precipitation 1973 (left) and 1994 (right) (Marshall et al., 2004)

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, probably as a result of 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 43 shows the 2-month average of the simulated 2-month daily maximum and minimum temperatures. This figure shows that while temperatures are higher, extremes are greater, which explains why despite higher temperatures, the citrus industry has moved south, not north. Frostproof, FL is no longer frost proof, because the lower temperature extreme value is lower.

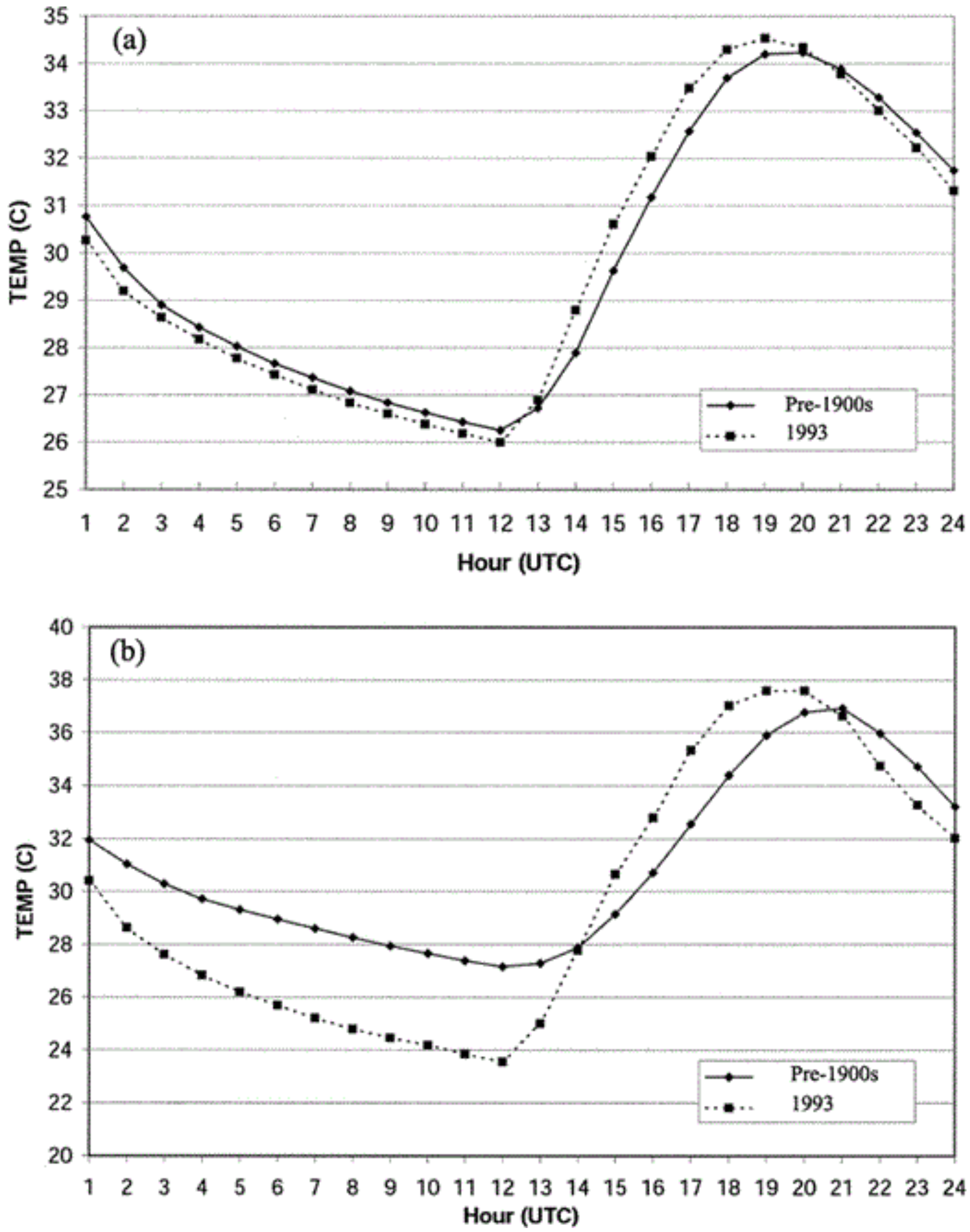


Figure 43. Temperature changes – hotter in summer (left), cooler in winter (right) means more freezes in the winter and both higher temperatures and more evapotranspiration in the summer (Marshall et al., 2004)

Marshall et al. (2004) report that "while there is a great deal of spatial variability in these values, the results show that daytime maximum 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 44 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.

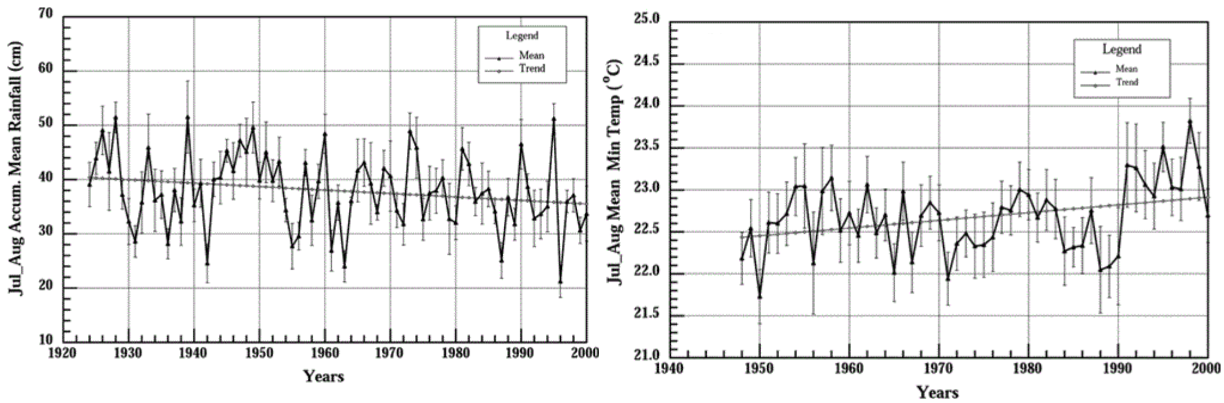


Figure 44. Change in average rainfall (left) and change in average temperature (right) from 1924 to 2000 (Marshall et al., 2004)

Climate change is 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 flood plains. Other issues include a) saltwater intrusion, which may be intensified by sea level rise, b) prolonged droughts that will contribute to water supply shortages and wildfires, and c) heavier rains during the rainy season and higher hurricane storm surge, which may increase the risk due to flooding. More frequent and damaging floods are likely to become an ever-increasing problem as sea level continues to rise because of: a) increasing groundwater table elevations and surface water gage heights, b) reduced groundwater seepage through the aquifer to the ocean, c) increasingly compromised stormwater drainage systems, and d) more frequent inundation of barrier islands and coastal areas.

NOAA and IPCC (2013) predictions suggest that by 2100, global temperatures will be on the order of 2-3°C higher and sea levels will rise by up to 3 feet. Accompanying these drivers are potential changes in storm frequency and intensity, desertification, population migration, ocean acidification and coastal flooding (IPCC, 2007), exacerbated by the land cover and use changes, which are substantially impacted by the fluxes, timing and quality of precipitation (Adrians et al., 2003; Scanlon et al., 2005; Marshall et al., 2004; Salmun and Molod, 2006), and leading to changes in the timing of peak flows and volumes (Richey and Costa-Cabral, 2006). Compounding the challenge, during the past 140 years, an increase in sea levels has been observed (Bloetscher, 2012). Measurements in Florida (Maul, 2008) show an average rate of sea level rise of 2.27 ± 0.04 mm per year from 1915 to 2005 based on tide gauge readings in Key West, which are the Western Hemisphere's longest sea level record. From 1913-1999, sea level in Miami has risen 2.39 ± 0.22 mm/yr (USEPA, 2009). Barrier islands in the Tampa Bay region are experiencing significant beach erosion due to sea level rise (2.3 mm/yr), compounded by high storm surge. Analyzing the tidal gauge readings for Florida shows that:

1. Florida average sea level rise is 2.10 ± 0.49 mm/yr
2. All but one location is within the 95% confidence limit range (the exception is Panama City where there is evidence of submergence and other land-based issues)
3. None of sea level rise rates differ statistically
4. Average global sea level rise for 1920-2000 was 2.0 mm/yr – within 95% confidence limit for Florida locations

As a result, the SFRCCC (2015) adopted USACE's methodology to derive scenarios of sea level change intermediate to high rates of sea level rise for years 2030 (3″ to 7″) and 2060 (9″ to 24″) as the consensus projection to guide future planning in Southeast Florida. The path keeps increasing – now 14 inches since 1929 (refer to Figure 11). The suggested cause of sea level rise is thermal expansion of the ocean due to rising temperatures and melting ice caps (Jevrejeva et al., 2010; Vermeer and Rahmstorf, 2009). Sea level rise is a major concern since nearly half the US population lives within 50 miles of the coast, involving most major commercial, residential, and economic enterprises. The effects of sea level rise are shown in Figure 45 and Figure 46 for Dania Beach, FL.

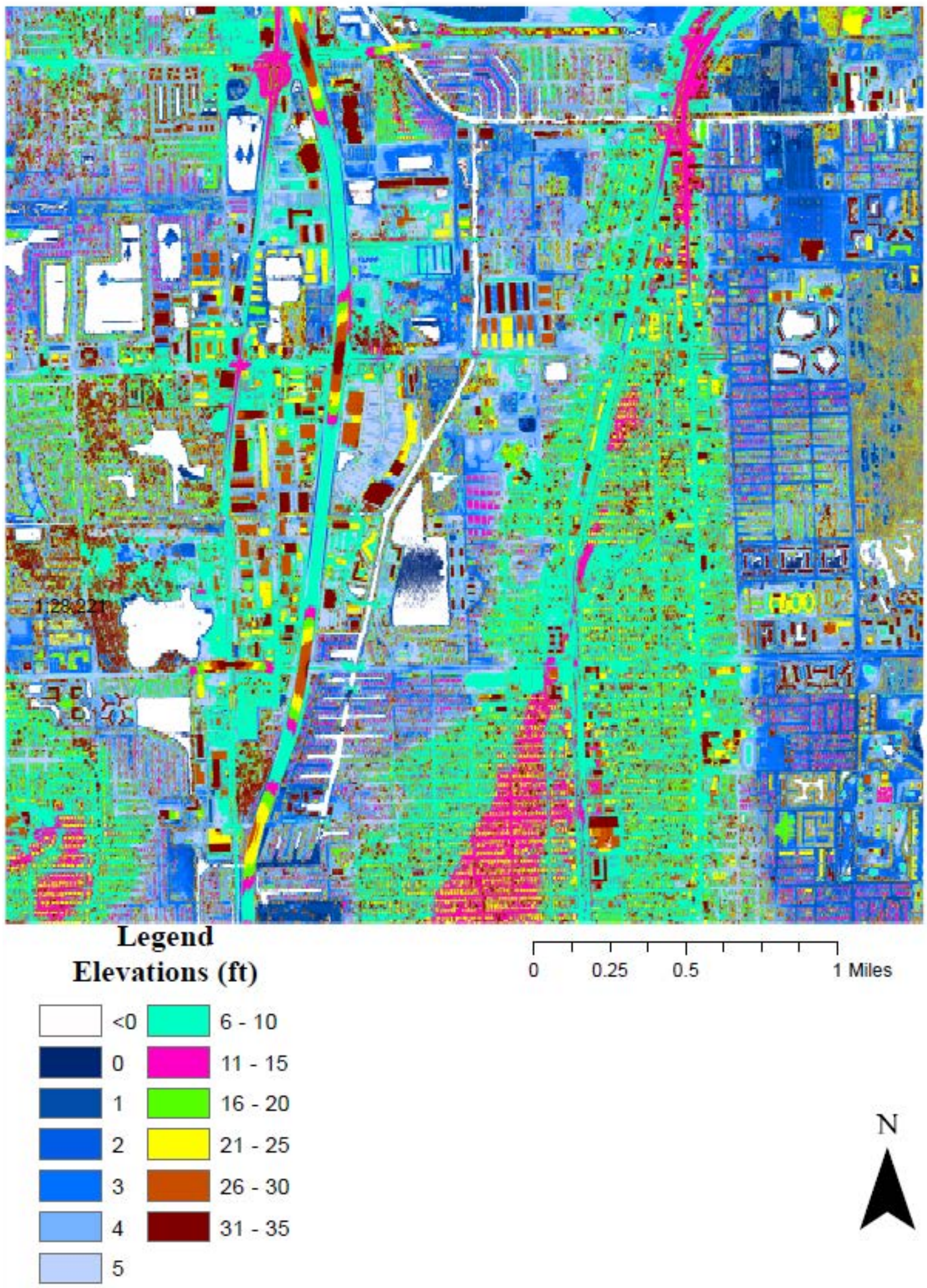


Figure 45. Current elevations of land under the 99th percentile tidal conditions for Dania Beach, FL (Bloetscher, 2011??)

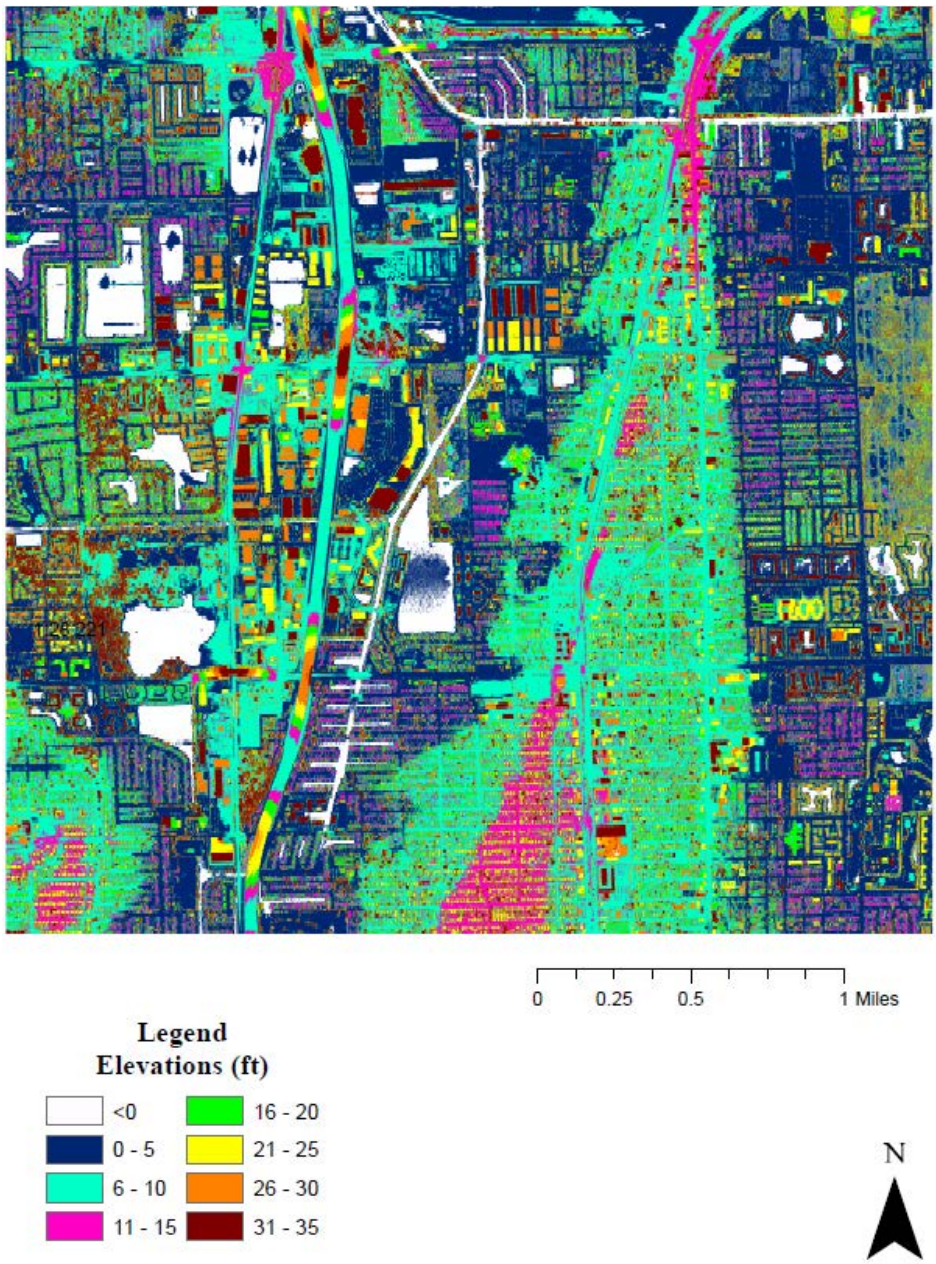


Figure 46. Projected conditions in the year 2100 (dark blue is land under 5 ft NAVD88 and potentially inundated at under the 99th percentile tidal conditions) for Dania Beach, FL (Bloetscher, 2011??)

Adaptation strategies to address sea level rise will be required in light of global changes coupled with funding competition to protect/armor public infrastructure and coastal private property to prevent relocations of population centers. Two categories of adaptation should be considered: protection and accommodation (Deyle et al., 2007). Strategies for infrastructure protection to combat small increases in sea level rise may include:

- Stormwater improvements
- Beach re-nourishment
- Protection of sanitary sewer systems
- Alter wastewater disposal patterns to include beneficial reuse and salinity barriers

5.0 INVENTORY OF POTENTIAL SOLUTIONS

Once watershed master planning assessments are made and strategies (both adaptive and hardening) identified and evaluated, decisions must be made to solve the priority issues. 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 increase 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. The vulnerability of infrastructure will require the design of more resistant and adaptive infrastructure and network systems. This will, in turn, involve the development of new performance measures to assess the ability of infrastructure systems to withstand flood events, and to enhance resilience standards and guidelines for design and construction of facilities. Specifically, considerations include retrofitting, material protective measures, rehabilitation and, in some cases, the 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 as a result of the loss of soil storage capacity. Evapotranspiration in low-lying areas with high groundwater will become more important which is why ecologically based stormwater management that employs natural native vegetation will become more important over time in certain communities.

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 guidance document, 36 solutions referred to as the

"Periodic Table" menu of green and grey infrastructure technologies (Figure 47) are presented and discussed in more detail in the following sections.

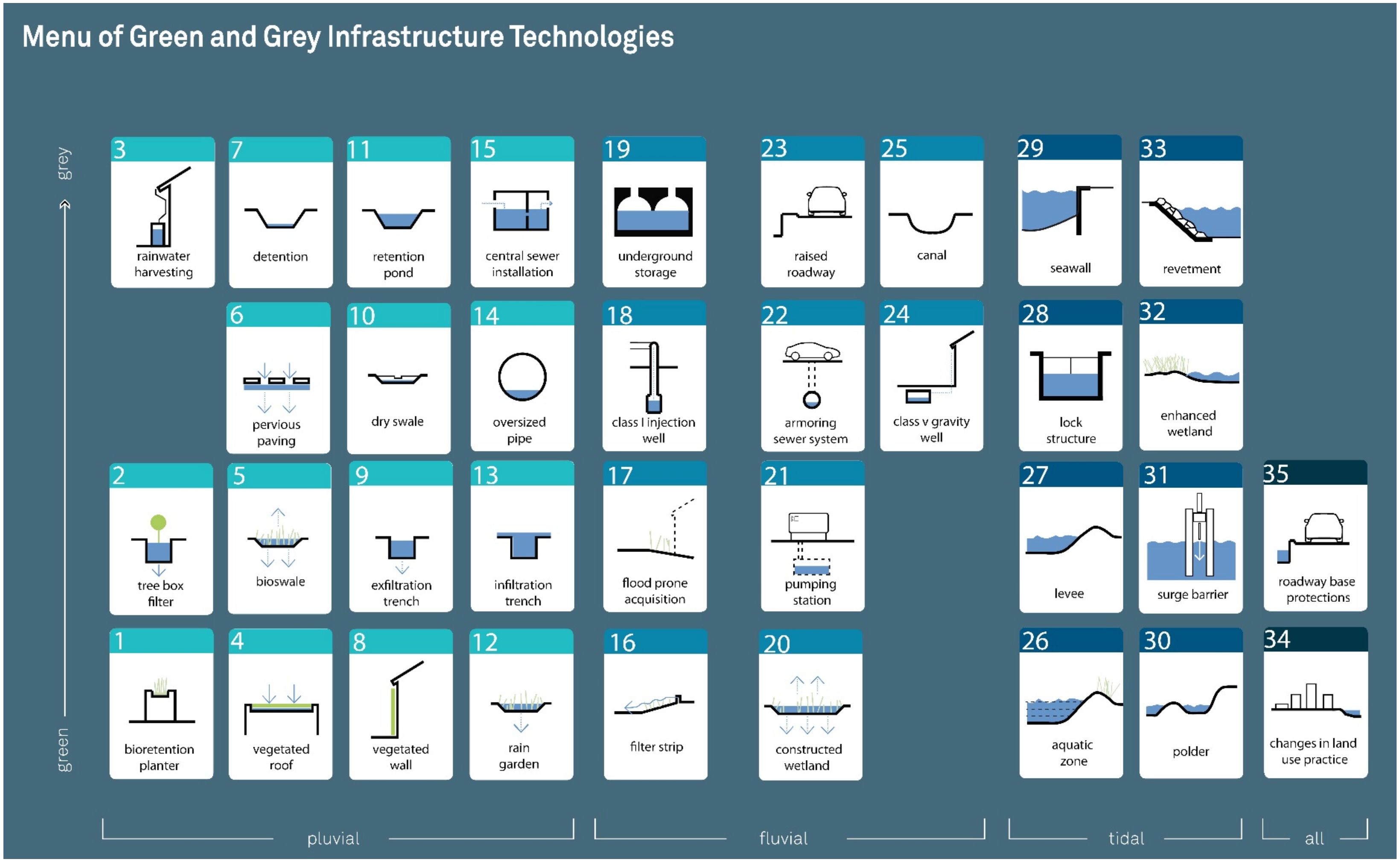


Figure 47. "Periodic table" menu of green and grey infrastructure technology options. The menu is organized to address various flooding types, from *pluvial* (rainfall and runoff mitigation in upland areas), *fluvial* (runoff, high ground water, and surface water management in low-lying flood prone areas), *tidal* (flooding associated with storm surge, high ground water, and tidally influenced), and *all* (applies across the spectrum).

5.1.1 Bioretention Planter

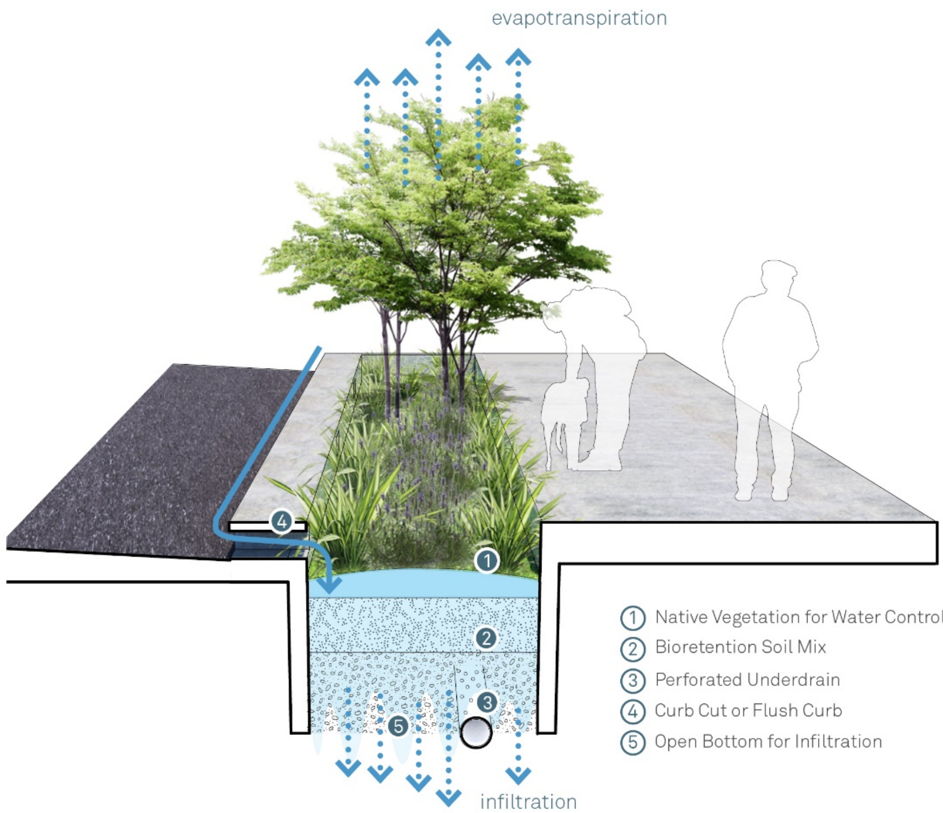
The bioretention planter is a small-scale, urban solution for rainwater management. The concept is to install planters where stormwater can be diverted to and allowed to infiltrate into the ground. A building downspout or parking areas are prime locations for bioretention planters because for urban areas, the lack of green open spaces limits infiltration capacity. Bioretention planters are appropriate in areas that collect runoff from the face of buildings and sidewalks near parking areas as they are a means to address the problem of lack of pervious surfaces for routing and infiltrating stormwater. Figure 48 shows an example of a typical installation. To prevent overflows, the construction typically includes a perforated pipe beneath the planter to allow excess water to be diverted to a stormwater system of some type (retention ponds are normally the discharge points).

Figure 48. Construction of a bioretention planter (https://www.pwdplanreview.org/manual/chapter-4/4.1-bioinfiltration-bioretention)

Bioretention planters can also be sized to improve water quality, as the plants are effective at removing many contaminants, especially petroleum-based contaminants from parking lots. The solution is also cost effective, while also providing a landscaping feature that is often required for new developments, helps reduce urban heat island effects, and increases aesthetics when maintained. The use of native plants (ffl.ifas.ufl.edu) that require minimal irrigation is appropriate. LEED® credits can be gained by using bioretention planters. Figure 49 shows a typical example of a bioretention planter.

Figure 49. Example of an urban bioretention planter installation in Hallandale Beach, FL

Design considerations are summarized in Figure 50.



1. Bioretention Planter

The bioretention planter is a small scale, urban solution for rainwater management. The concept is to install planters where stormwater can be diverted to and allowed to infiltrate into the ground. A building downspout or parking areas are prime locations for bioretention planters because for urban areas, the lack of green open spaces limits infiltration capacity. Bioretention planters are appropriate in areas that collect runoff from the face of buildings and sidewalks near parking areas as they are a means to address the problem of lack of pervious surfaces for routing and infiltrating stormwater. To prevent overflows, the construction typically includes a perforated pipe beneath the planter to allow excess water to be diverted to a stormwater system of some type (retention ponds are normally the discharge points).

Where it can applied
Local, small scale, easily implemented in developed areas

Benefits
Protects Property, treats runoff cisterns

Barriers to implementation
limited volume disposed of so many are needed, maintenance

Cost
varies on size and complexity

Figure 50. Design considerations, benefits, barriers and costs for a bioretention planter

5.1.2 Tree Box Filter

Like bioretention planters, a tree box filter is a small scale, urban solution for rainwater management that also acts as a street beautification component. Many downtown and commercial areas have tree box filters. Embedded adjacent to or in the sidewalk/curb area, the tree box filter (Figure 51) is simply an area where a tree can be planted, but that also has capacity to convey excess stormwater to an appropriate stormwater feature, The concept is to install these units where stormwater can be diverted to and allowed to filter into the ground, while allowing the tree box to filter sediment and pollutants out of the stormwater runoff. Tree box filters also mitigate heat island effects and add aesthetic value to the developed environment.

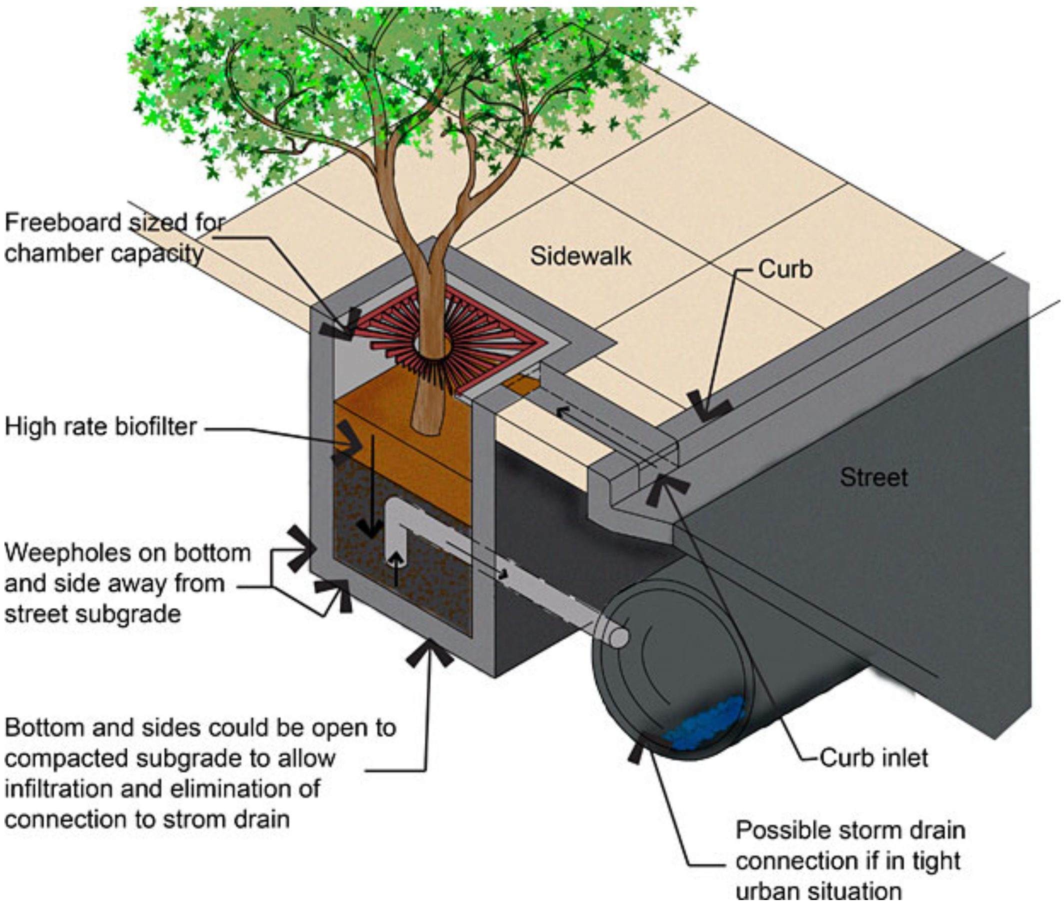


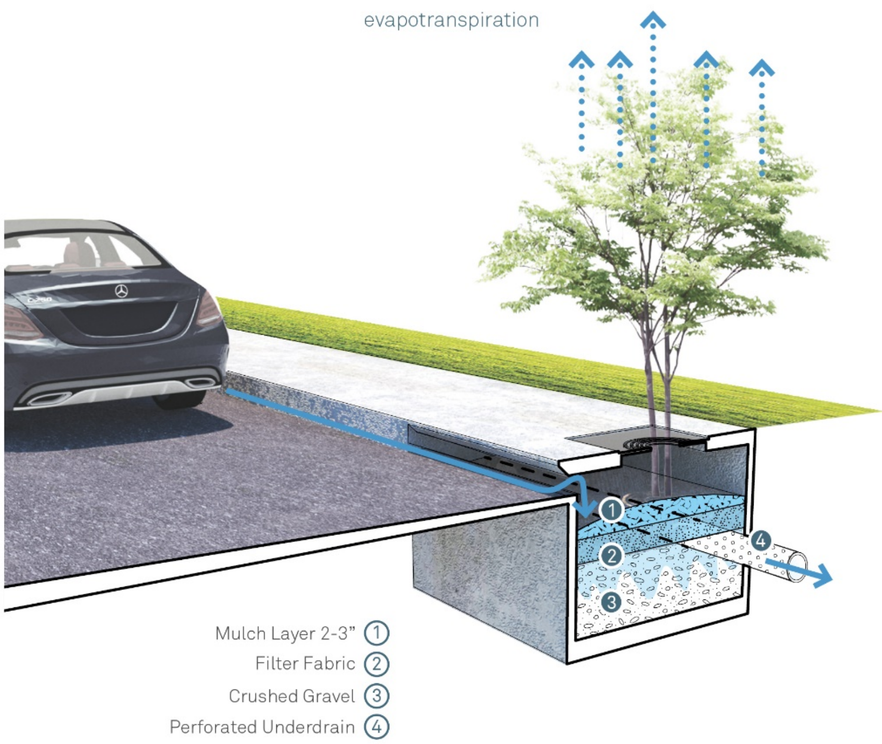
Figure 51. Tree box filter schematic (http://www.ladstudios.com/LADsites/Sustainability/Strategies/Strategies_TreeWell.shtml)

Tree box filters are typically pre-manufactured, concrete structures installed in-ground to control storm runoff quality and volume before entering a catch basin or the surrounding subsoil. The structures are filled with soil filter media and typically planted with trees or shrubs, although smaller vegetation may also be utilized. Vegetation with noninvasive root systems should be selected to maintain soil infiltration rates. The number of units required will depend on site hydrology, climate, topology and tree box filter size. Tree box filters can also help to achieve

LEED® credits through sustainable sites criteria. An example of a tree box filter installation in Alachua County is shown in Figure 52.

Figure 52. Example of tree box filter installation in Alachua County, FL

Design considerations are summarized in Figure 53.



2. Tree Box Filter

Like bioretention planters, a tree box filter is a small scale, urban solution for rainwater management that also acts as a street beautification component. Many downtown and commercial areas have tree box filters. Embedded adjacent to or in the sidewalk/curb area, the tree box filter is simply an area where a tree can be planted, but that also has capacity to convey excess stormwater to an appropriate stormwater feature, The concept is to install these units where stormwater can be diverted to and allowed to filter into the ground, while allowing the tree box to filter sediment and pollutants out of the stormwater runoff. Tree box filters also mitigate heat island effects and add aesthetic value to the developed environment.

Where it can applied
Local, small scale, easily implemented in developed areas

Benefits
Protects Property, treats runoff, small scale

Barriers to implementation
limited volume disposed of so many are needed, maintenance

Cost
$2500 ea

Figure 53. Design considerations, benefits, barriers and costs for a tree box filter

5.1.3 Rainwater Harvesting

Rainwater harvesting is the collection and storage of rain on a site in some form of container, rather than allowing it to run off. Typically, the rainwater is collected from a roof-like surface and redirected to a tank, cistern (Figure 54), or pond for later use for irrigation or other non-potable purpose.

Figure 54. Rainwater harvesting cistern (used for irrigation) at the Pine Jog Environmental Center in West Palm Beach, FL

A common location for rainwater harvesting is at the terminal end of downspouts for buildings. In areas with highly variable rainfall, the ability to store water for non-potable purposes is a well understood means of water conservation. Note because the cistern will only hold a certain volume of water, a means to address cistern overflows is needed. The costs for these systems are low, and maintenance is limited to periodic cleaning to remove roof debris/sediment. Rainwater harvesting can also help a development acquire LEED® credits. Design considerations are summarized in Figure 55.

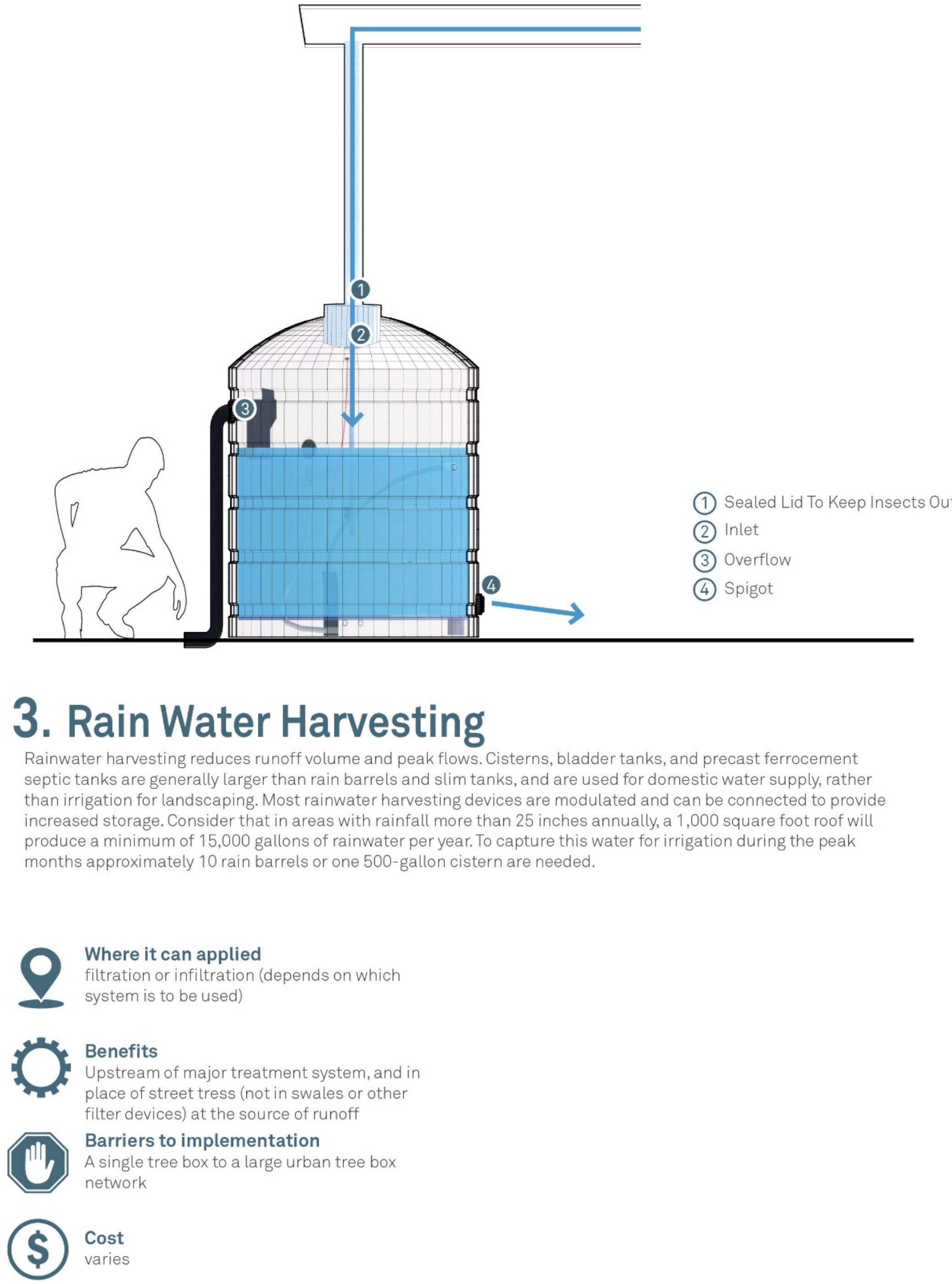


Figure 55. Design considerations, benefits, barriers and costs for a rainwater harvesting system

5.1.4 Vegetated Roof

A vegetated or green roof is located on top of a building, as opposed to on the ground. Green roofs serve two purposes: 1) insulation of the building, thereby reducing heating and cooling costs, and 2) providing a space to store and utilize rainwater. Figure 56 is an example of a cross section of the construction of a green roof. A means of irrigation is needed, as is a means to remove excess rainwater. The green roof adds weight to the structure, so there is a cost for implementation. In very dry or hot areas, the green roof is not likely to survive those conditions, so may not be suitable for all applications sites.

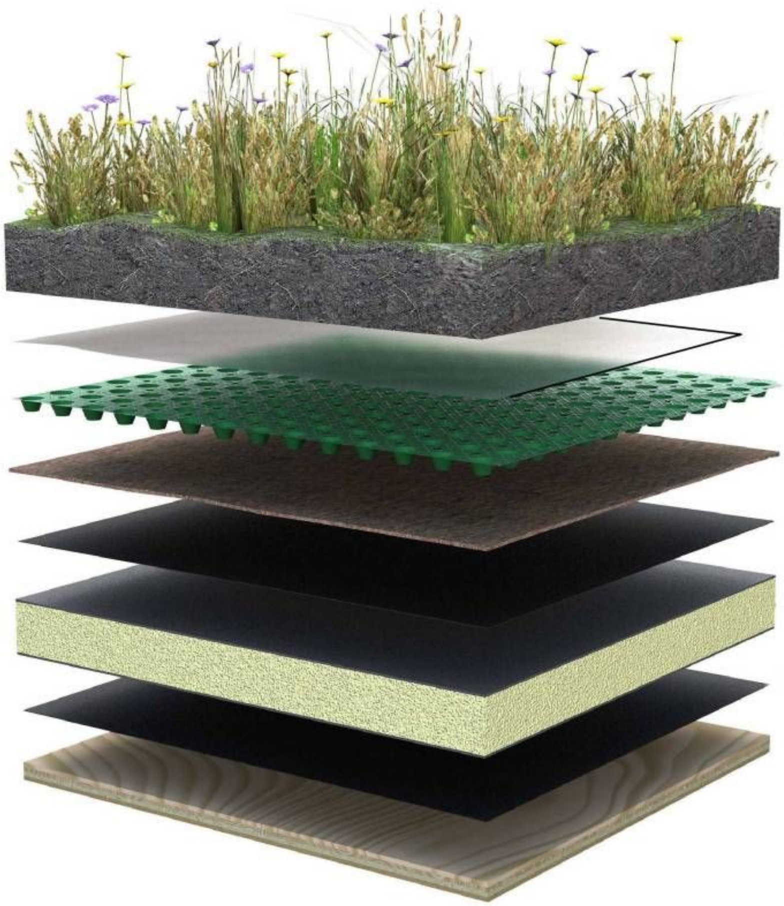


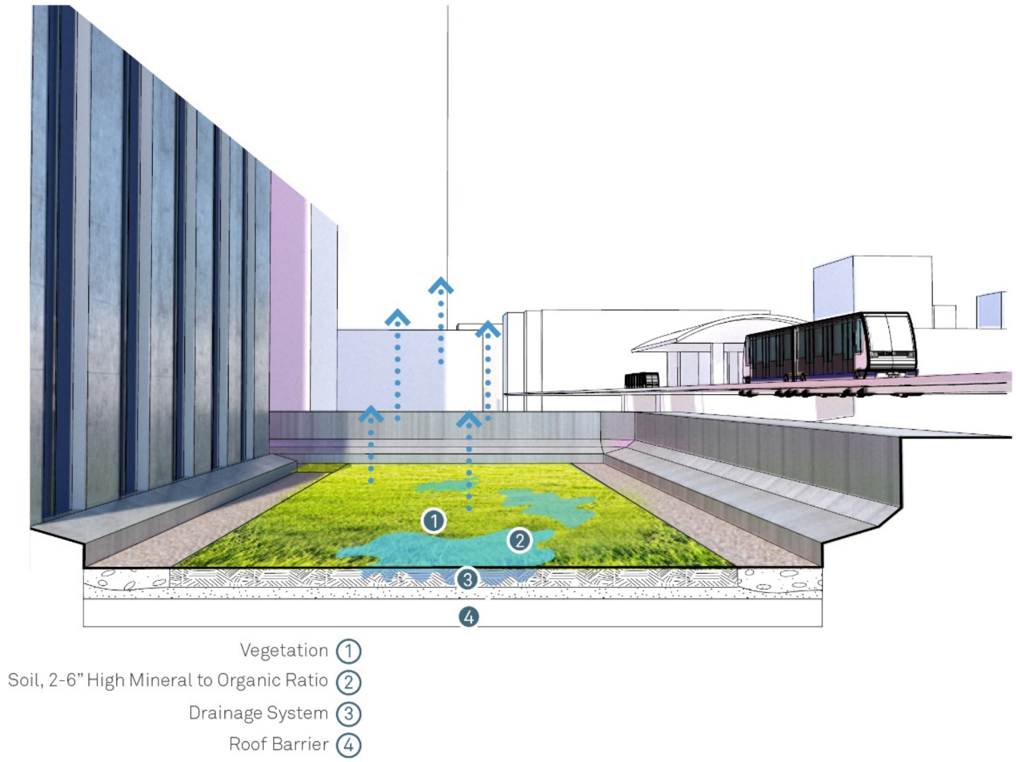
Figure 56. Schematic cross section of a green or vegetated roof

https://www.google.com/search?q=vegetated+roof&rlz=1C1CHBF_enUS698US698&sxsrf=ALeKk030ZVSkZhtJlsaoYhtiisoUDmoQmg:1593962332513&tbm=isch&source=iu&ictx=1&fir=b9NOABlK1b3sJM%252CErC6mTbiiqoVYM%252C_&vet=1&usg=AI4_-kRAr-jucyX14G6Oj_x17pvKen38Jg&sa=X&ved=2ahUKEwig5vS0tLbqAhVKZc0KHSzAC-MQ_h0wAXoECAoQBg&biw=872&bih=561#imgrc=kpU4sbxWSphd6M&imgdii=QFWgdghK4WQIDM

Successful implementation requires an ideal combination of adapted plant species, regular maintenance, irrigation and periodic upkeep. To prevent overflows, construction typically includes a perforated pipe beneath the planter that will allow excess water to be diverted to a stormwater system of some type (retention ponds are normally the discharge points). Green roofs can provide a cost-effective solution, while also providing a roof landscaping feature that is desirable for some communities. It will also help reduce urban heat island effects and increase building occupant comfort and aesthetics. LEED® credits can also be obtained by using green roofs, as was done in the FAU Engineering East Building that achieved LEED® Platinum (Figure 57).

Figure 57. Photo of a green roof installation at FAU Engineering East in Boca Raton, FL

Design considerations are summarized in Figure 58.



4. Vegetated Roof

Intended to be closed loop systems, vegetated roofs collect rainwater at its source, slow its release, and reduce its volume through evapotranspiration from plants. Vegetated roofs also regulate building temperature through additional thermal insulation, reducing heating and cooling loads. Vegetated roofs are especially effective in controlling intense, short-duration storms, and have been shown to reduce cumulative annual runoff by 50 percent in temperate climates. Vegetated roofs are desirable in flood-prone climates with regular flash storm events.

Where it can applied
retention, helps maintain the storage volume, in conjunction w other measures

Benefits
Protects Property, treats runoff, building scale

Barriers to implementation
requires irrigation and runoff is too much rainfall occurs

Cost
$30-$100/sf

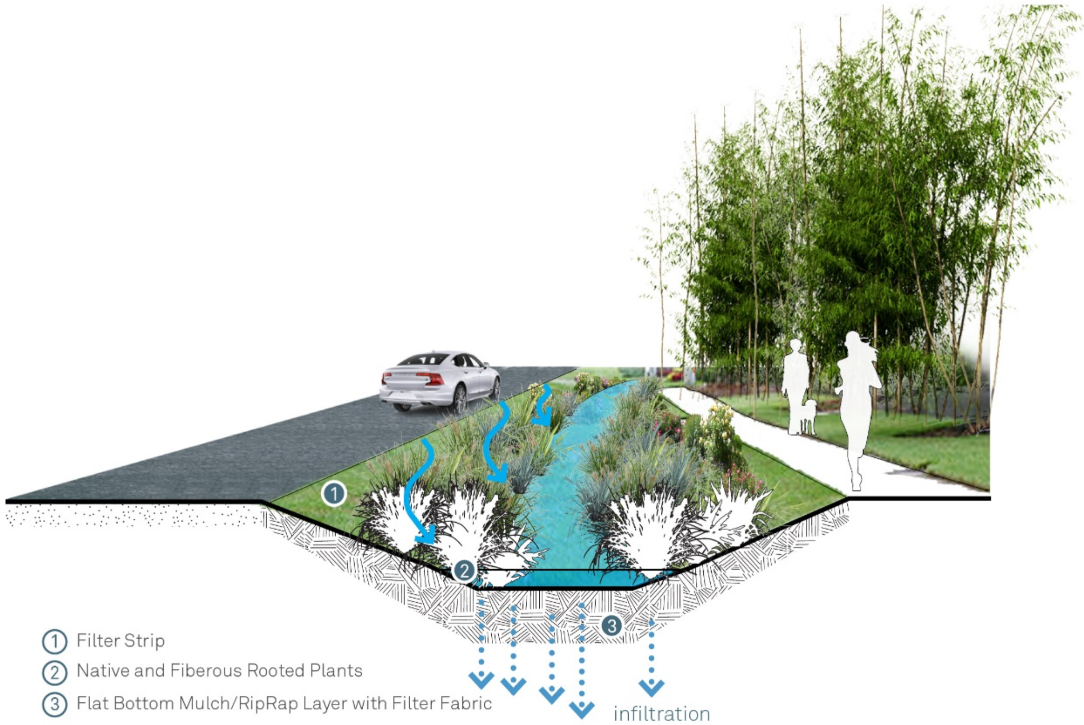
Figure 58. Design considerations, benefits, barriers and costs for a vegetated roof

5.1.5 Bioswale

Bioswales are vegetated drainage ways that function by slowing runoff as it comes off an impervious surface, such as parking areas (Figure 59). Bioswales remove sediments and other pollutants and provide infiltration into the soil during small scale rain events.

Figure 59. Photo of a bioswale pilot installation in Hallandale Beach, FL (https://www.hallandalebeachfl.gov/)

To prevent overflows, construction typically includes a perforated pipe beneath the bioswale that will allow excess water to be diverted to a stormwater system of some type (retention ponds are normally the discharge points). Design considerations are illustrated in Figure 60, and Figure 61 shows the detail for construction.



5. Bioswale

Bioswales are a bioretention device in which pollutant mitigation occurs through phytoremediation by facultative vegetation. Bioswales combine treatment and conveyance services, reducing land development costs by eliminating the need for costly conventional conveyance systems. The main function of a bioswale is to treat stormwater runoff as it is conveyed, whereas the main function of a rain garden is to treat stormwater runoff as it is infiltrated. Bioswales are usually located along roads, drives, or parking lots where the contributing acreage is less than five acres Bioswales can also be sized to improve water quality as the plants are effective at removing many contaminants, especially petroleum-based contaminants. The solution is also cost effective, while also providing a landscaping feature that is often required for new developments, helps reduce urban heat island effects, and increases aesthetics when maintained. The use of native plants that require minimal irrigation is appropriate. LEED® credits can also be gained by using bioswales.

Where it can applied
Parking lots, runoff from development - primarily treatment for discharge to another system

Benefits
Protects Property, treats runoff

Barriers to implementation
maintenance, limited volume disposed of, mostly for treatment

Cost
$20k-$200k/acre

Figure 60. Design considerations, benefits, barriers and costs for a bioswale

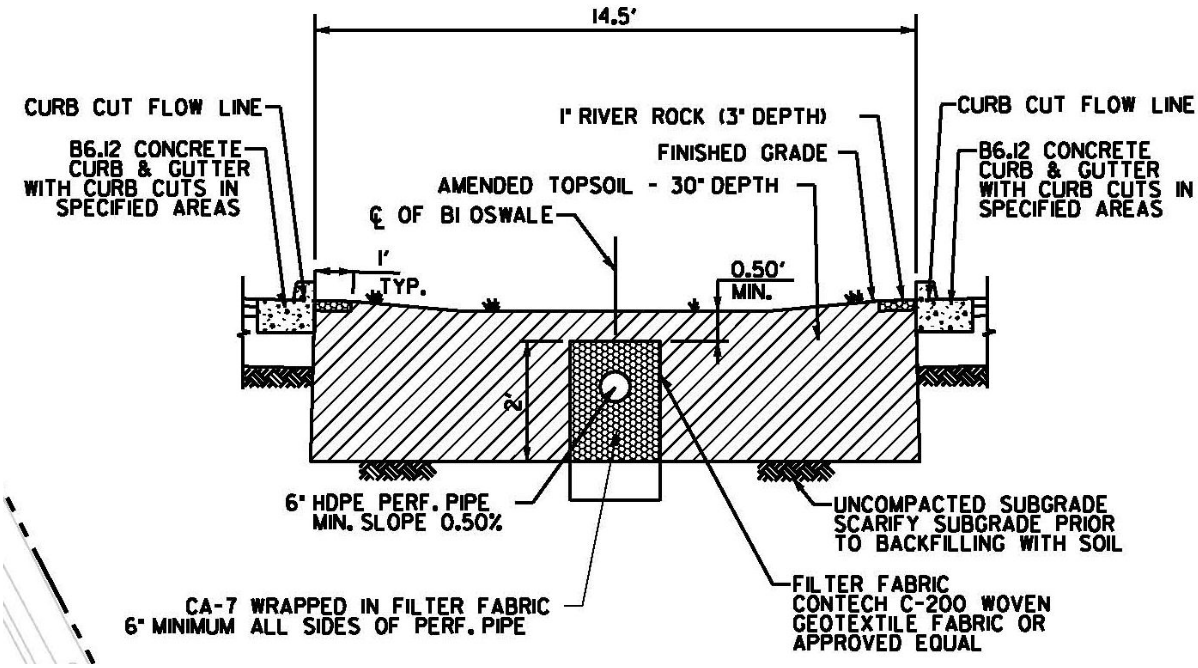


Figure 61. Construction detail of a bioswale (https://www.warrenville.il.us/456/Bioswales)

5.1.6 Pervious Paving

Transportation surfaces (roads, parking lots, and driveways) account for over 60% of impervious urban surfaces. Permeable pavement allows rainfall to infiltrate down from these surfaces rather than running off into storm sewers. Rainfall moves into a rock chamber below the pavement. Water in the pore space between the aggregate either percolates out and down through surrounding soils or moves to a perforated drainpipe installed in the rock chamber. Water is slowly released to become ground flow or enter surface waters after it has been cleaned and cooled by moving through the pavement and underground rock chamber. Since impervious pavement is the primary source of stormwater runoff, low impact development (LID) strategies recommend permeable paving for parking areas and other light duty hard surfaces. The benefits of pervious surfacing include: 1) lower surface temperature, 2) less flash flooding and standing water, 3) fewer surface pollutants entering downstream waterbodies, 4) less stormwater runoff, 5) less need for detention ponds and other stormwater management practices, and 6) more recharge to water table aquifers.

Permeable paving techniques include pavement (Figure 62) and pavers (Figure 63). All permeable paving systems consist of a durable, load bearing, pervious surface overlying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. Pervious pavements require maintenance. The holes that make the pavement pervious can become clogged with organics, plants, or sediments. Periodic removal of sediment is required, or the pavement will no longer be permeable. In Florida, because of the potential for plugging, pervious pavements are considered impervious when permitting and designing stormwater systems.

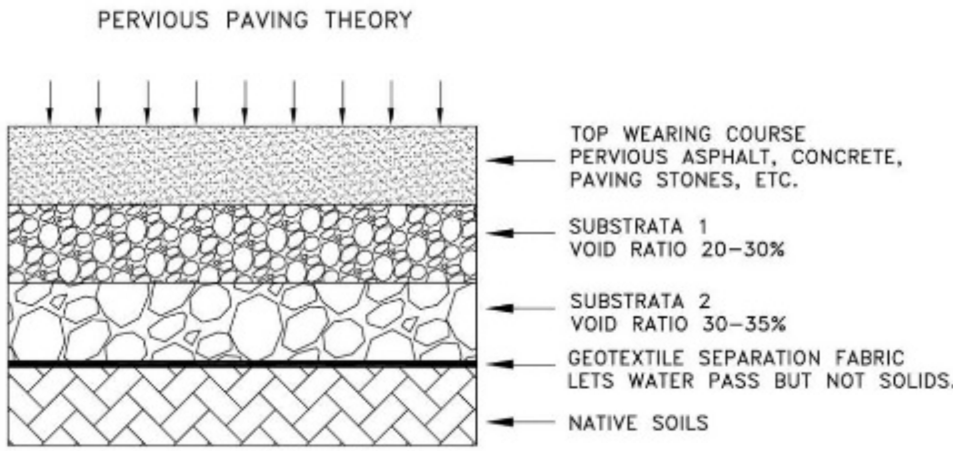
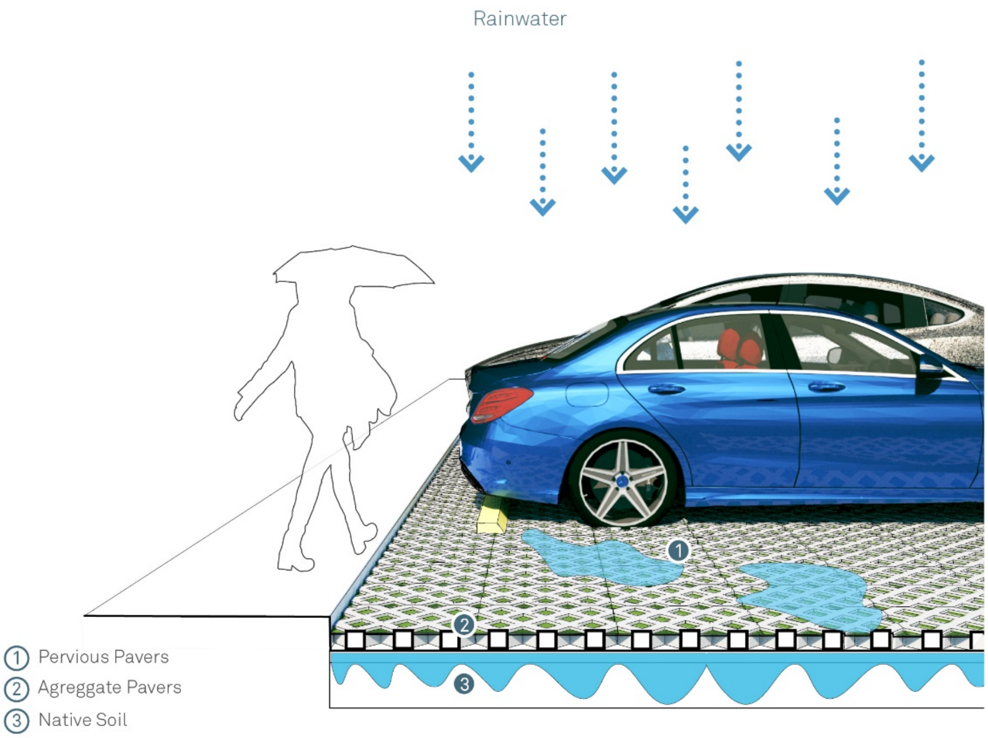


Figure 62. Pervious pavement detail (https://www.grantspassoregon.gov/280/Pervious-Pavement-Alternative)

Figure 63. Example of a pervious paver driveway

Design considerations are summarized in Figure 64.



6. Pervious Paving

A pervious paving system includes a subsurface base made of course aggregate for stormwater storage. In some designs, pervious pavement is supported by underground layers of soil, gravel and sand to increase storage and maximize infiltration rates. Pervious paving removes sediment and other pollutants. It acts to reduce and distribute stormwater volume, encouraging groundwater infiltration. Multiple types of pervious paving, including modulated precast pavers, poured in place systems, porous asphalt, porous concrete, and gravel, offer varying levels of service. Reduction of the urban heat island effect is possible when using high-albedo, lightly colored systems.

Where it can applied
parking lots, patios, anything except paved roads due to traffic loading

Benefits
reduces roadway and parking lot flooding

Barriers to implementation
must be maintained via vacuuming or the perviousness fades after 2-3 years

Cost
$10-20/sf, requires bumpers and sub-base to maintain paver integrity

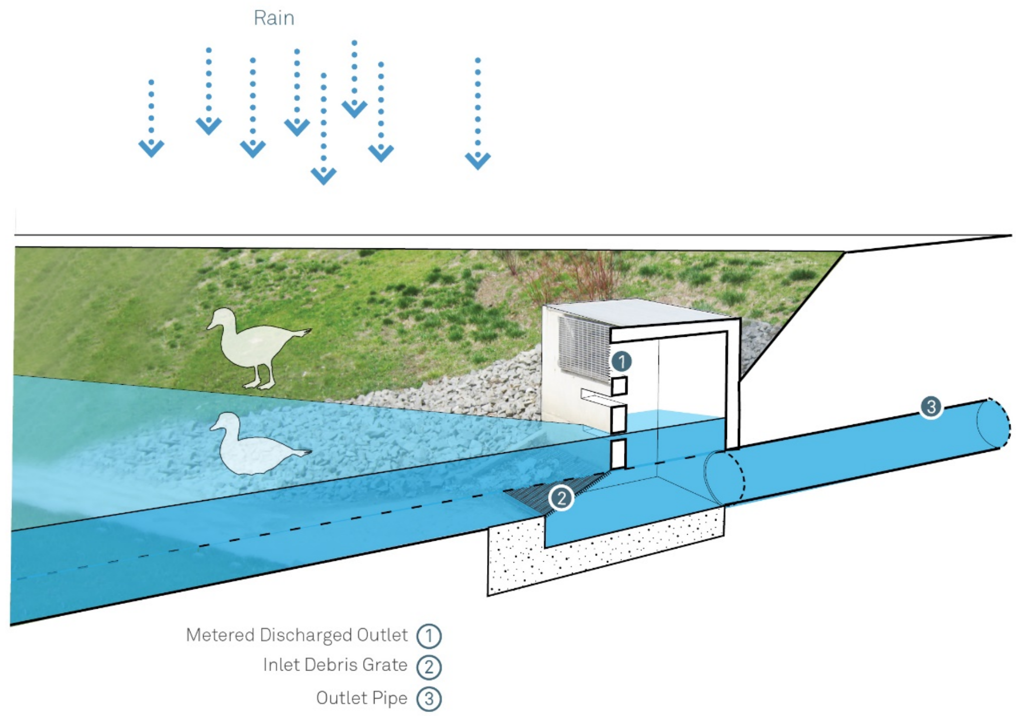
Figure 64. Design considerations, benefits, barriers and costs for pervious paving

5.1.7 Detention

Detention ponds are widely used and designed for stormwater management applications. Detention is distinctly different from retention, which keeps the water on site, while detention releases it slowly with time to mimic the natural system or has an overflow (Figure 65). Effective detention designs dramatically reduce runoff rates, prevent most increases in flooding associated with new development, reduce run-off pollutants and prevent erosion. A detention basin will have an overflow that will go to an offsite stormwater system. The concept is to hold the water for a period of time and release it slowly back into the natural system.

Figure 65. Detention basin with overflow

Detention basins are well developed from a technology perspective, widely used, well understood. They are inexpensive to construct as long as land is available. They will remove pollutants with limited added features. They do have two issues: 1) they tend to plug when not maintained, so to reduce maintenance, mowing, aeration and other maintenance needs are required 2) if the area is densely built with limited pervious available, the volume of runoff may rapidly overwhelm the amount of water the basin can handle. Design considerations are summarized in Figure 66.



7. Detention

Detention ponds are designed to completely evacuate water from storm events, usually within 24 hours. They primarily provide runoff volume control reducing peak flows that cause downstream scouring and loss of aquatic habitat. As a general rule, detention ponds should be implemented for drainage areas greater than 10 acres. On smaller sites it may be difficult to provide control since outlet diameter specifications needed to control small storm events are small and thus prone to clogging. Also, treatment costs per acre are reduced when implemented at larger scales.

Where it can applied
Common for new development, but difficult to retrofit; developer resist because it consumes land they could otherwise develop; limited to open areas

Benefits
Removes water from streets, reduces flooding

Barriers to implementation
Land availability, maintenance of pond, discharge location

Cost
$200k/acre

Figure 66. Design considerations, benefits, barriers and costs for detention

5.1.8 Vegetated Wall

Vegetated or green walls are vertical structures that have greenery attached to them. Variants can be from ivy to heavy foliage, planted in a growth medium consisting of soil, stone and water. The walls contain living plants, so nutrients and water must be provided. As a result, while vegetated walls can be used to absorb water that would normally run down a building face to the street or sidewalk, the plants will require supplemental irrigation that can come from a cistern or other storage means. They are particularly useful in wet environments. Figure 67 is an example of how vegetated walls are constructed. Maintenance and upkeep will be ongoing concerns. Design considerations are summarized in Figure 68.

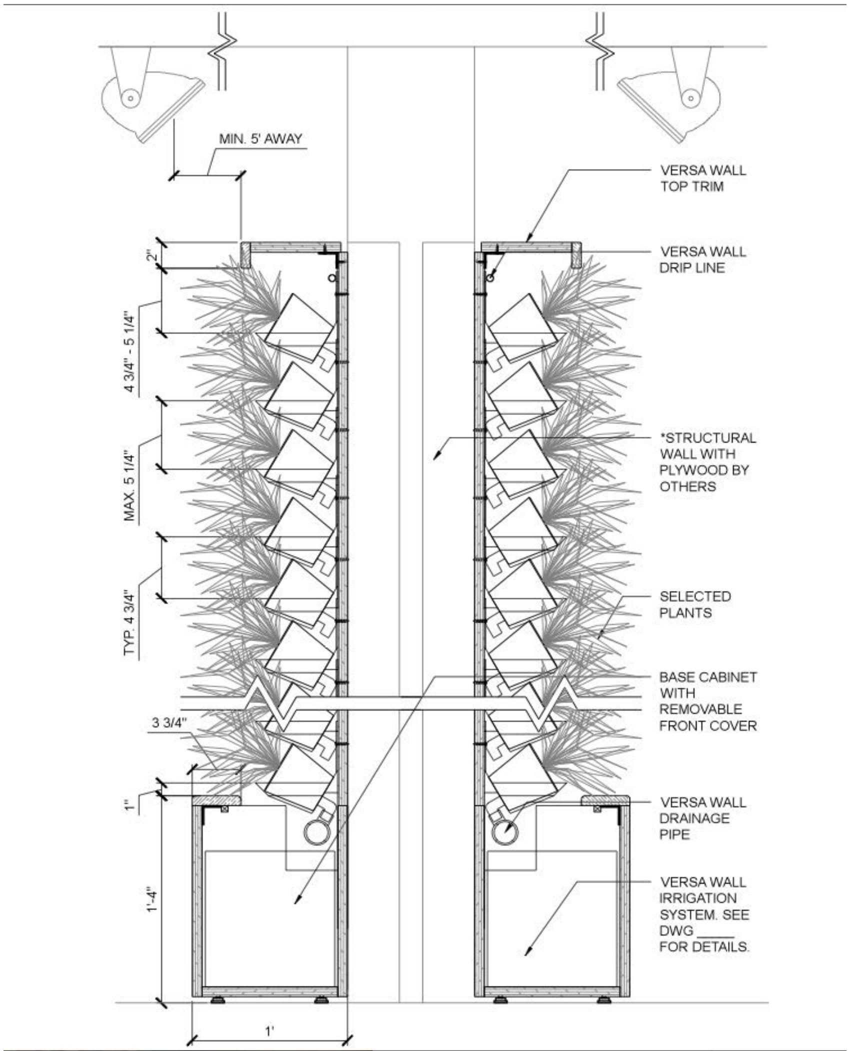
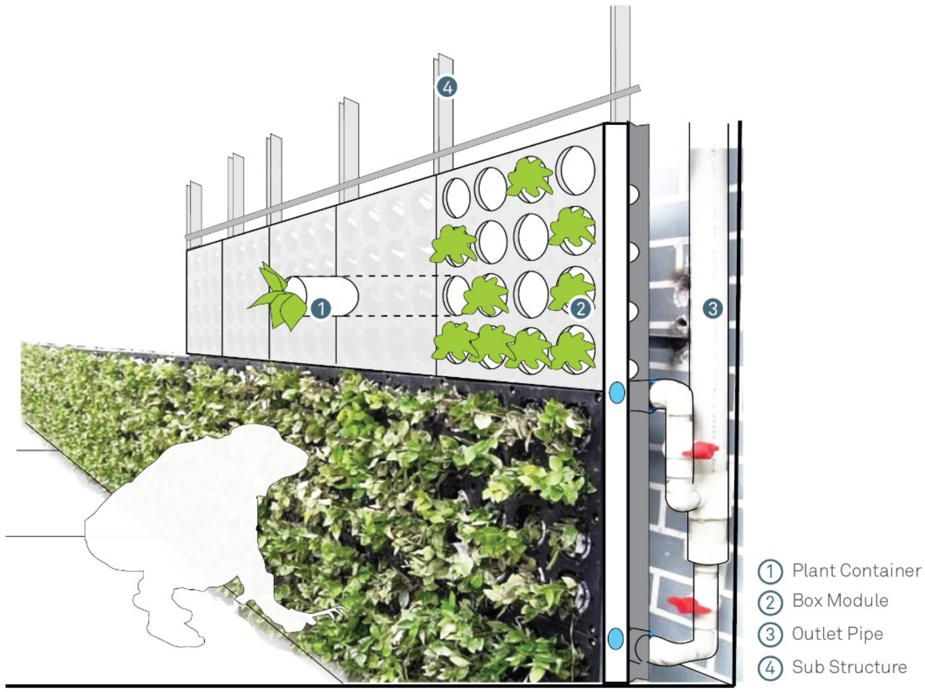


Figure 67. Vegetated wall construction
https://www.google.com/search?q=green+wall+construction&rlz=1C1CHBF_enUS698US698&sxsrf=ALeKk03yZgI6Dw8vhWWPV2KLSk_rLFVaZA:1593964316794&tbm=isch&source=iu&ictx=1&fir=uCXffXSBUBpCwM%252CDGpnlyPHgxHKKM%252C_&vet=1&usg=AI4_-kRig-wiBKLMXmw1ZZJhY0HHUV5WTQ&sa=X&ved=2ahUKEwjthYznu7bqAhVUG80KHSPBClAQ9QEwAHoECAoQKw&biw=872&bih=561#imgrc=uCXffXSBUBpCwM



8. Vegetated Wall

Vegetated walls are classified as passive or active systems. While active systems address air quality, passive systems address water quality, and thus are more applicable to LID. Similar in application to vegetated roofs, vegetated walls harvest water to reduce stormwater runoff loads. Vegetated walls also regulate building temperature through additional thermal insulation, reducing heating and cooling loads

Where it can applied
Used on walls of buildings and retaining walls

Benefits
Protects Property, treats runoff

Barriers to implementation
requires irrigation and runoff is too much rainfall occurs.

Cost
$30-$300/sf

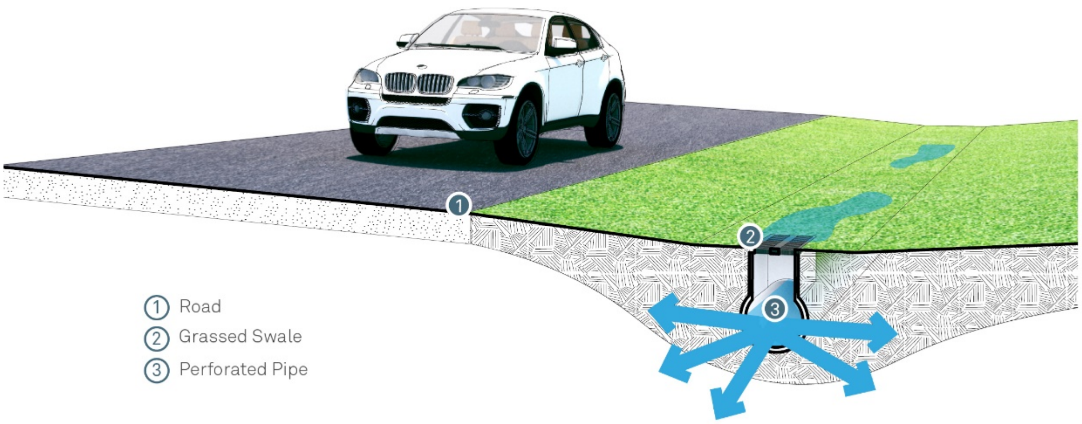
Figure 68. Design considerations, benefits, barriers and costs for a vegetated wall

5.1.9 Exfiltration Trench

The Florida Department of Transportation (FDOT) and most municipalities rely heavily on exfiltration trenches or French drains. These systems work because the perforated piping is located above the water table, thereby allowing water to leak out; however, they cease to function if they are located below the water table. As the water table rises, exfiltration systems in low-lying areas will cease to work as they become submerged. Exfiltration trenches, or French drains, are commonly used in Florida. Exfiltration is a preferred strategy behind retention areas by SFWMD. The concept is simple: install a perforated pipe beneath the surface of a road, parking area or swale, and have the drainage system empty to it. The difference in head between the surface of the drainage system and the water table, combined with the hydraulic conductivity of the soil, provides an indication of the amount of water that can be disposed of. The assumption is typically a 24-inch perforated pipe placed in a 4 ft gravel trench, laid fully above the water table to maximize the potential for water to exit the pipe and filter into the soil. The results of engineering calculations generally are characterized by the length of trench required to dispose of a given volume of water.

Benefits of exfiltration trenches include that they are well developed from a technology perspective, widely used, well understood and generally can dispose of large volumes of water, especially when large parts of the drainage system on-site are exfiltration trenches. They do have two issues – they tend to plug when not maintained, so to reduce maintenance, baffling is needed to prevent leaves and fines from entering the trench pipe. Unfortunately, this is only partially successful, so regular vacuum service is needed, which is difficult to implement. Second, if the area is densely built with limited pervious area, the volume of runoff may overwhelm the amount of water the soil can take. Recent rainfall and heightened water tables complicates exfiltration trench operation because the higher water tables cause them to work least efficiently when you need them most – rainfall at the end of the wet season. But they have value and function well.

The cost to install exfiltration trenches vary depending on pipe trench width and depth. Typical costs are $150 per linear foot. Developers routinely install them to reduce the amount of land required for retention ponds. They also will pull contaminants into the trench as opposed to allowing them to runoff to surface water bodies. That can also be an issue unless additional treatment is otherwise provided. Trenches do not work if not well maintained, in muck soils and when the groundwater level inundates the trenches. In these circumstances, a better option is required. Design considerations are summarized in Figure 69.



9. Exfiltration Trench

Exfiltration trenches are particularly useful for sites with poorly-drained soils. Runoff gradually percolates through an engineered trench with amended soil over a period of days. Exfiltration trenches filter particulates as stormwater runoff moves through the media. Exfiltration trenches require less maintenance if upstream pre-treatment facilities like filter strips are used. Trees should not be planted near exfiltration trenches. These two actions reduce the potential for clogging the trench. Annual inspection is recommended to remove large debris and/or trash.

Where it can applied
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

Benefits
Excess water drains to aquifer, some treatment provided

Barriers to implementation
Significant damage to roadways for installation, maintenance needed, clogging issues reduce benefits

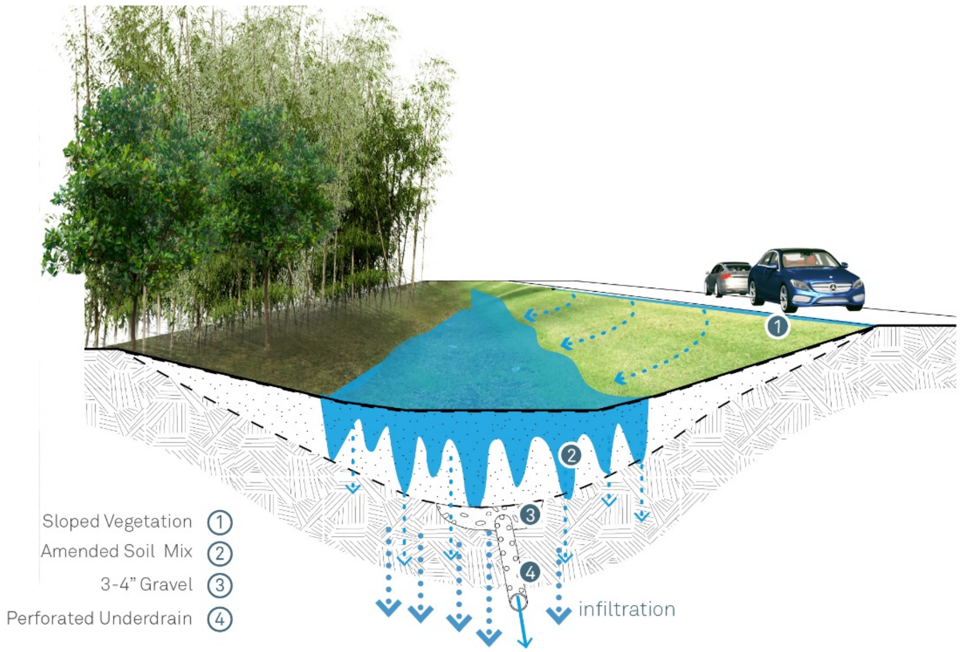
Cost
$250/lf

Figure 69. Design considerations, benefits, barriers and costs for an exfiltration trench

5.1.10 Dry Swale

A dry swale is similar to a bioswale except that there is no planted vegetation. The most common place to find them is adjacent to roads (Figure 70) or parking lots where the buried pipe will be in place to prevent overflows. Design considerations are summarized in Figure 71. In all cases, the dry swale has both quantity and water quality benefits.

Figure 70. Roadway dry swale



10. Dry Swale

In place of hard-engineered concrete channels, dry swales offer services beyond peak flow reduction that include runoff detention and sedimentation. Dry swales, when combined with check dams and underdrains, detain stormwater, and increase infiltration. Often located in drainage easements, they are a cost effective way to convey water between buildings, land uses, and along roadsides. Water quality is optimized when the channel profile is two to eight foot maximum in bottom width, holding a four inch water volume depth. During the establishment newly seeded banks should be stabilized with erosion control devices.

Where it can applied
Parking lots, runoff from development - primarily treatment for discharge to another system

Benefits
Protects Property, treats runoff

Barriers to implementation
maintenance, limited volume disposed of, mostly for treatment

Cost
$200k/mile

Figure 71. Design considerations, benefits, barriers and costs for a dry swale

5.1.11 Retention Pond

Development causes the ground surface to become more impervious, which results in greater runoff of rainfall and a loss of infiltration. The heightened runoff patterns increase the likelihood that older infrastructure (piping) will be insufficient to move water from developed areas, resulting in increased funding. The loss of wetlands, mangroves and other coastal ecosystems diminishes the ability to store water or to provide areas to direct excess precipitation to avoid flooding. Storage areas to delay movement of water until a lower tide and increased infiltration capacity are priorities. Prevention of the conversion of land over areas where stormwater may collect, in floodplains and low areas to development should also be a land use priority. For redevelopment areas, reduced development and the migration of development in these areas should be a priority in local communities. The use of low impact development (LID) techniques to delay peak and reduce stormwater runoff can be a cost-effective option to consider from a land use perspective. Costs for changes in development patterns and protection of low-lying areas will be costly and highly controversial.

Benefits of retention ponds include that they are well developed from a technology perspective, widely used, well understood. Retention keeps the water on a site, as opposed to detention ponds, which releases the water slowly with time to mimic the natural system. Retention ponds (Figure 72) are inexpensive to construct as long as land is available (something developers prefer not to do). They will remove pollutants with limited added features. They do tend to have issues with maintenance, mowing, aeration and other requirements. Second, if the area is densely built with limited pervious area, the volume of runoff may overwhelm the amount of water the basin can take. Recent rain can cause the pond to be full, and unavailable when you need them for the next rain event. Ponds do not work if not well maintained, in muck soils and when the groundwater levels are high. Another issue might be eutrophication from overfertilization and nutrient runoff. In these circumstances, a better option is required.

Figure 72. Aerated retention pond

Figure 73 shows the typical design parameters or retention ponds.

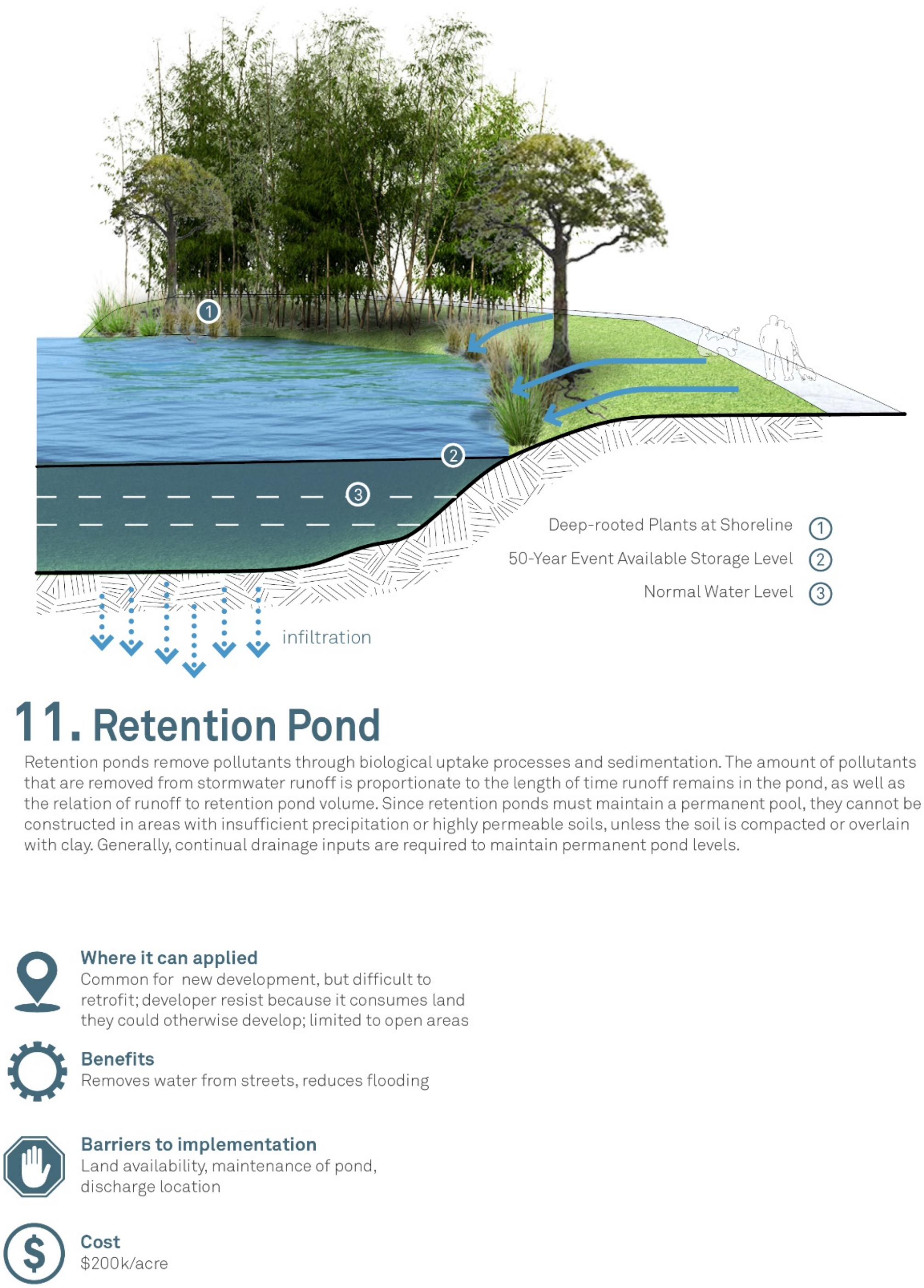


Figure 73. Design considerations, benefits, barriers and costs for a retention pond

5.1.12 Rain Garden

Rain gardens (Figure 74), like bioswales are vegetated drainage ways that function by slowing runoff as it comes off an impervious surface, such as parking areas. Sediments and other constituents are removed. Rain gardens improve the environment by:

- Allowing the soil to naturally filter and remove some pollutants from rainwater before it goes into groundwater aquifers
- Preventing/reducing flooding by decreasing the amount of rain pouring over impermeable surfaces into storm sewers, which then flow into rivers and streams
- Providing habitat for birds, beneficial insects, and butterflies
- Conserving water by reducing the need for irrigation of land near a rain garden

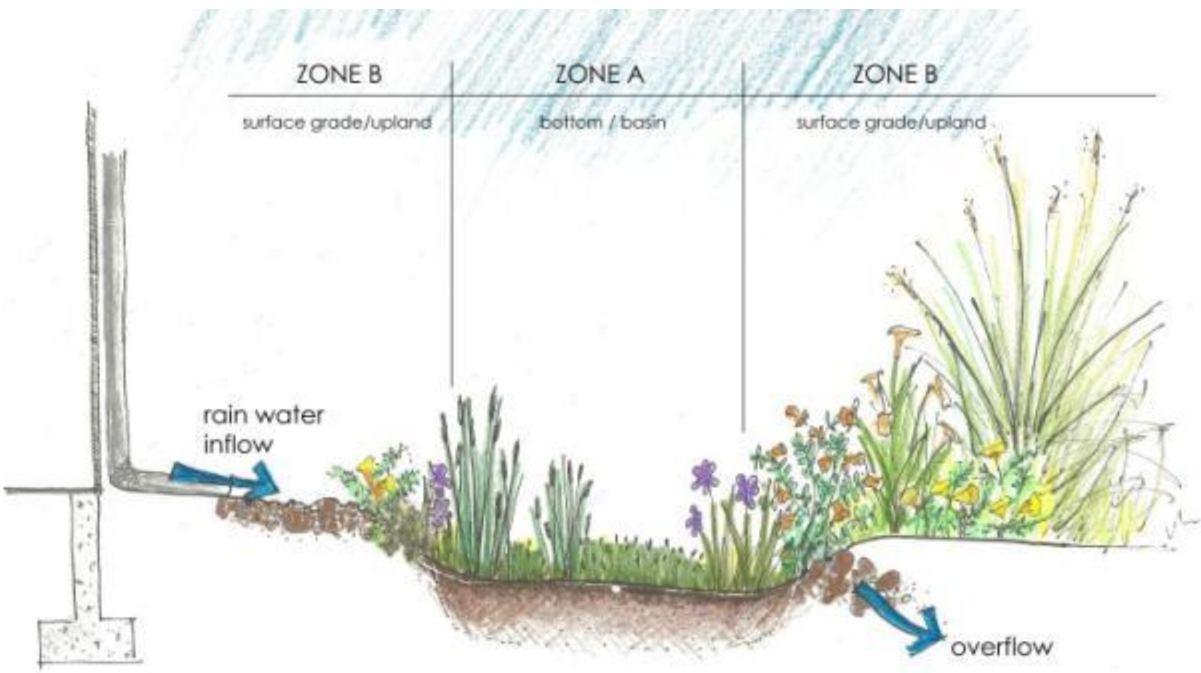
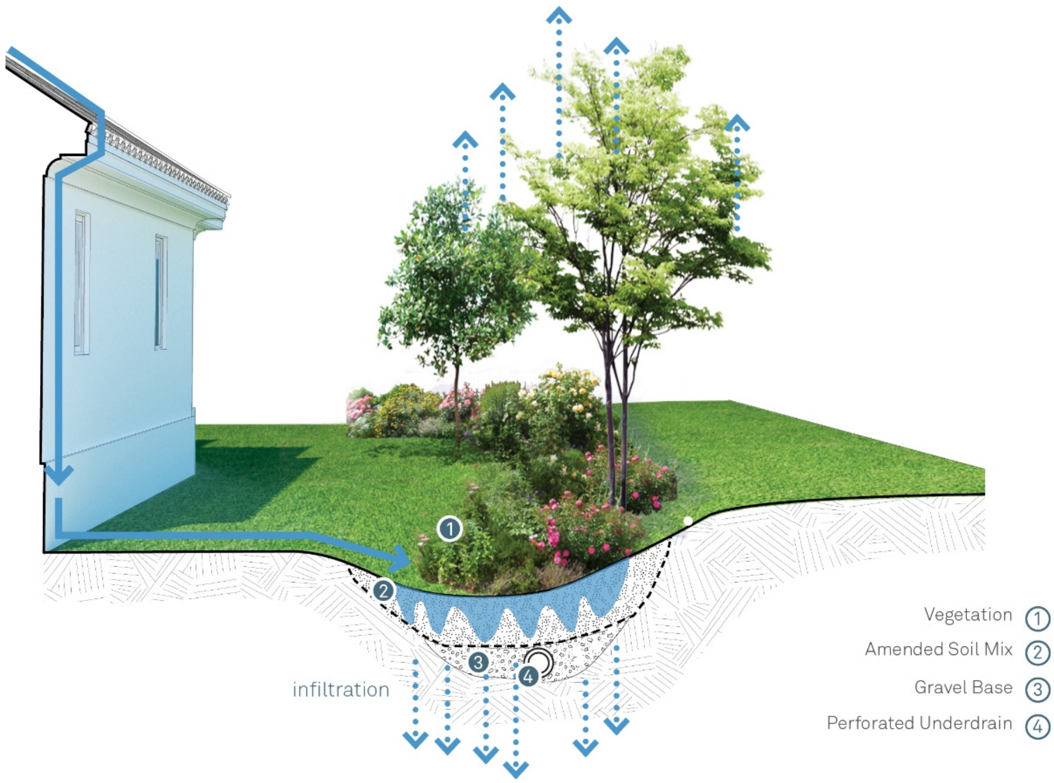


Figure 74. Rain garden conceptual schematic
https://www.google.com/search?q=rain+garden+design&rlz=1C1CHBF_enUS698US698&sxsrf=ALeKk01CEJX_Xa0fuSYXjEL3eeGTrvMUIg:1593966911998&source=lnms&tbm=isch&sa=X&ved=2ahUKEwic18q8xbbqAhUCWa0KHdZMDrYQ_AUoAXoECA8QAw&biw=1280&bih=529#imgrc=p7zvU7iEZV-UNM

The solution is also cost effective, while also providing a landscaping feature which is often required for new developments, helps reduce urban heat island effects, and increases aesthetics when maintained. The use of native plants that require minimal irrigation is appropriate. LEED® credits can be gained. The main disadvantage of a rain garden is if it is not built correctly, it can accumulate standing water and increase erosion. To prevent overflows, the construction typically includes a perforated pipe beneath the bioswale that will allow excess water to be diverted to a stormwater system of some type (retention ponds are normally the discharge points). Design considerations are summarized in Figure 75.



12. Rain Garden

A rain garden is commonly known as a bioretention facility. Stormwater pollutant mitigation is accomplished through phytoremediation processes as runoff passes through the plant and soil community. Rain gardens combine layers of organic sandy soil for infiltration, and mulch to promote microbial activity. Native plants are recommended based upon their intrinsic synergies with local climate, soil, and moisture conditions without the use of fertilizers and chemicals. Rain gardens are best applied on a relatively small scale. They work well along driveways and in low lying areas of a property.

Where it can applied
Local, small scale, easily implemented in developed areas

Benefits
Protects Property, treats runoff

Barriers to implementation
limited volume disposed of so many are needed, maintenance

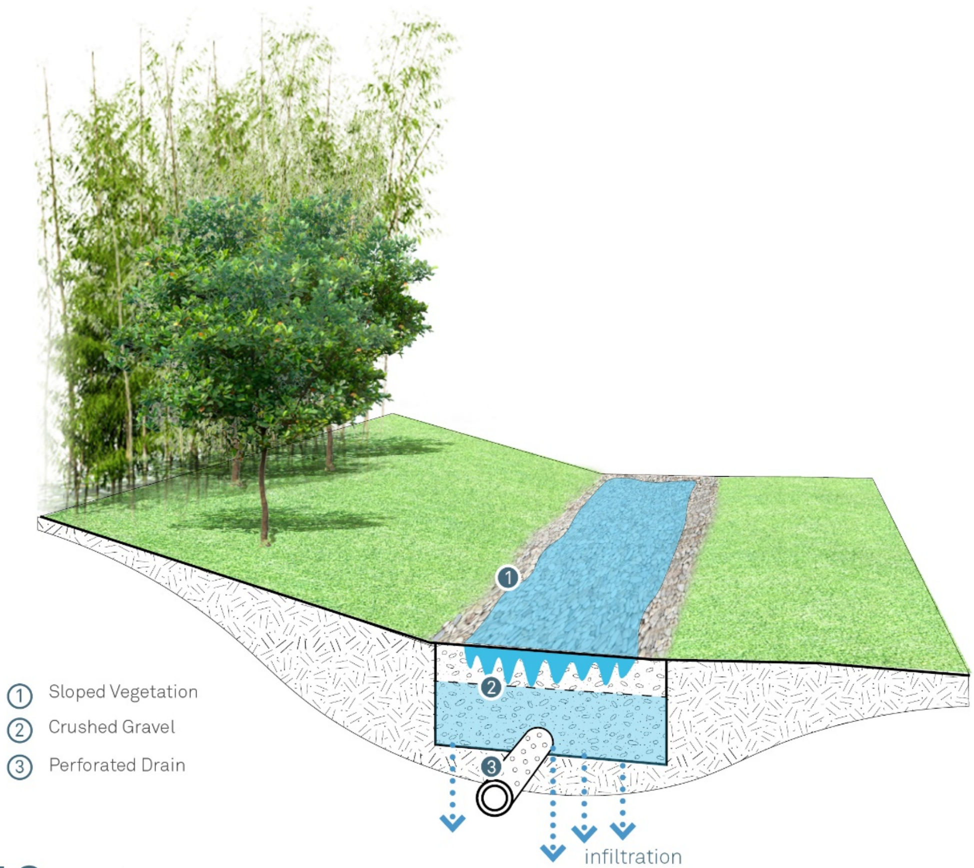
Cost
$20k/acre

Figure 75. Design considerations, benefits, barriers and costs for a rain garden

5.1.13 Infiltration Trench

Once exfiltration trenches cease to work, there may be an alternative, one that can be spread along vulnerable infrastructure – horizontal wells. These work like exfiltration trenches, only backwards – water flows in and is guided to a pump station where it is pumped to another location. The benefit is that some treatment occurs, and the installation has minimal surface footprint. However, the rate at which the water can infiltrate to a horizontal well is not the same as the pumping rate to a vertical well. Most modeling software is also not capable of modeling the seepage rate, which complicates design.

Vertical well modeling is related to the thickness, head and transmissivity of the aquifer. The thickness is not relevant to a horizontal well and the head is constant over the entire well screen. Horizontal wells must be screened but can be much shallower than vertical wells. Larger contact with the aquifer is also provided with a horizontal well that pulls equally from the entire canal, and as a result, the pumpage/capture can be matched to the seepage rate. No preferential flow paths result. The cost of such systems is on the order of $200/ft, plus the pumping stations. The inflow would likely be 1 MGD/mile of trench and would operate more or less constantly to keep groundwater levels down and create soil storage capacity for rain events. Design considerations are summarized in Figure 76.



13. Infiltration Trench

Infiltration trenches are particularly useful for sites with poorly-drained soils. Runoff gradually percolates through an engineered trench with amended soil over a period of days. Infiltration trenches filter particulates as stormwater runoff moves through the media. These facilities promote algae growth that serves as pollutant digesters. Since the maximum catchment area for infiltration trenches is two acres, it may be necessary to incorporate supporting LID facilities into the stormwater management plan.

Where it can applied
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

Benefits
Excess water gathered from soil and drained to pump stations, creating storage capacity of soil to store runoff, soil treatment

Barriers to implementation
Significant damage to roadways for installation, maintenance needed, clogging issues - must discharge somewhere(pump station, detention pond)

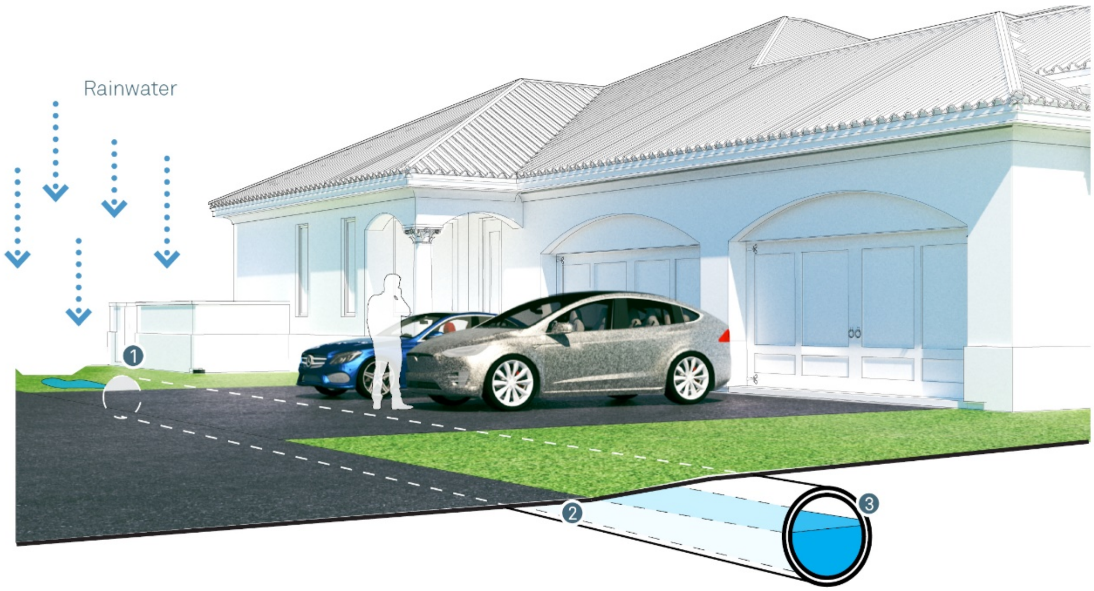
Cost
$250/lf plus pump station

Figure 76. Design considerations, benefits, barriers and costs for an infiltration trench

5.1.14 Oversized Pipes

Piping is a grey infrastructure solution that has worked for thousands of years. In urban areas, current stormwater collection and management systems may need to be redesigned to increase capacity since current capacity is not likely to address future peaking factors associated with more intense storms. Development causes the ground surface to become more impervious, which results in greater runoff and a loss of infiltration capacity. The heightened runoff patterns increase the likelihood that older infrastructure (piping) will be insufficient to move water from developed areas, resulting in increased funding. Installing more piping, and larger piping is an option.

In areas without storm sewers, that rely on ditches (rural areas) or have systems that lack central design, the first step is a stormwater planning effort to determine the appropriate piping for a community (Figure 77). Then the question of larger piping can be ascertained more easily and the disruption likely less, but the costs may be higher on a per resident basis due to lower density in such communities.



① Swale
② Underground Water Current
③ Oversized Pipe

14. Oversized Pipe

While oversized pipes are more costly, they eliminate larger pressure drops and high velocities associated with undersized, or even correctly sized pipes during larger storm events. Lower velocities reduce outlet erosion and scouring. Larger volume pipes allow water to be detained, without creating problematic backwater effects..

Where it can applied
Local solution - not watershed level, holds water to reduce flooding

Benefits
Protects Property, treats runoff

Barriers to implementation
Sediments, maintenance needs, lack of means to flush, cost

Cost
$350/lf of more

Figure 77. Design considerations, benefits, barriers and costs for oversized pipes

The downside to this option is that there is more/larger diameter stormwater piping to maintain and given that the velocities will be smaller, more need to remove silt and debris from the pipes. The cost and disruptions may be significant. Very large diameter tunnels used by large communities to address excess storm (or combined) wastewater may cost billions of dollars. This concept is less useful in Florida where the groundwater is near the surface.

5.1.15 Central Sewer Installation

Central sewers are regulated, and programs are in place to monitor them for breaks, leaks and at the end of the pipe, treatment. The concept is to use gravity lines to collect sewage from households and convey it to a central treatment facility. Disposal can include many options including reuse for irrigation.

Installation of central sanitary sewers has been a standard practice for over 100 years, but many older developments in remote areas are still on septic tanks. In Florida, there are about 2.8 million septic tanks (FDoH, 2020). The challenge is that on-site treatment and disposal systems such as septic tanks may only work when the drainfield is above water, thereby permitting soil treatment of the discharged water in the vadose zone. These systems do not function properly when the water table is high, and the discharge is essentially injected into the near surface aquifer without treatment and often finds its way into local surface water bodies. Results from observing septic and sewered areas by FAU in south Florida and Taylor County, demonstrate that there is an ongoing release of contaminants during the seasonal high water table elevation event (Meeroff and Morin, 2005; Meeroff, Morin and Bloetscher, 2007; Bocca, Meeroff and Bloetscher, 2007; Meeroff, Bloetscher, Bocca and Morin, 2008; Meeroff, Bloetscher, Long and Bocca, 2014). As a result, septic systems have the potential to contaminate certain stormwater infrastructure (exfiltration, infiltration pipelines), thereby making water quality permitting options more difficult.

Replacement of septic tanks with central sewer is problematic given that it costs $10,000-$15,000 per residential connection to install sewers and remove the old septic tank (not including sewer connection charges), which creates a challenge for residents and a difficult decision for public officials. Design considerations are summarized in Figure 78.

15. Central Sewer Installation

On site treatment and disposal systems such as septic tanks may only work when the drainfield is above water, thereby permitting soil treatment of the discharged water in the vadose zone. These systems do not function properly when the water table is high and the discharge is essentially injected into the near surface aquifer without treatment and often finds its way into local surface water bodies.

Where it can applied
All areas where there are septic tanks. Mostly a water quality issue

Benefits
Public health benefit of reducing discharges to lawns, canals and groundwater from septic tanks

Barriers to implementation
Cost, assessments against property owners, property rights issues

Cost
$15,000 per household

Figure 78. Design considerations, benefits, barriers and costs for central sewer installation

5.1.16 Filter Strips

A filter strip is similar to a bioswale, except that the filter strip is at the base of a hill to prevent runoff from reaching natural water bodies of the property of others. There is normally some form of planted vegetation. The most common place to find them is behind buildings or downstream of parking areas before water bodies (Figure 79). Filter strips can contain water, but major flooding must be planned for as a filter strip is normally only focused on water quality.

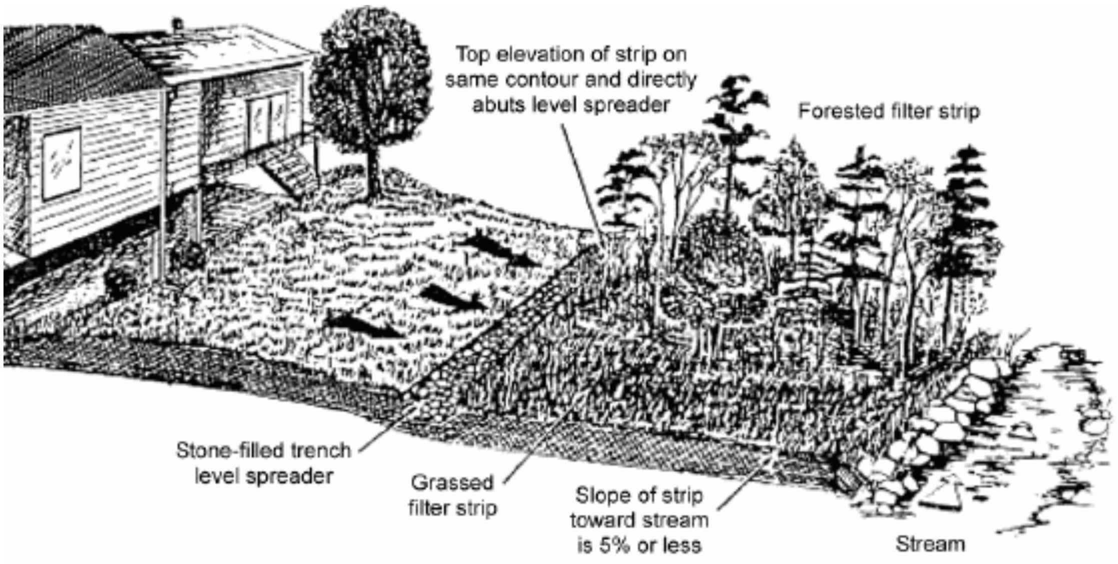
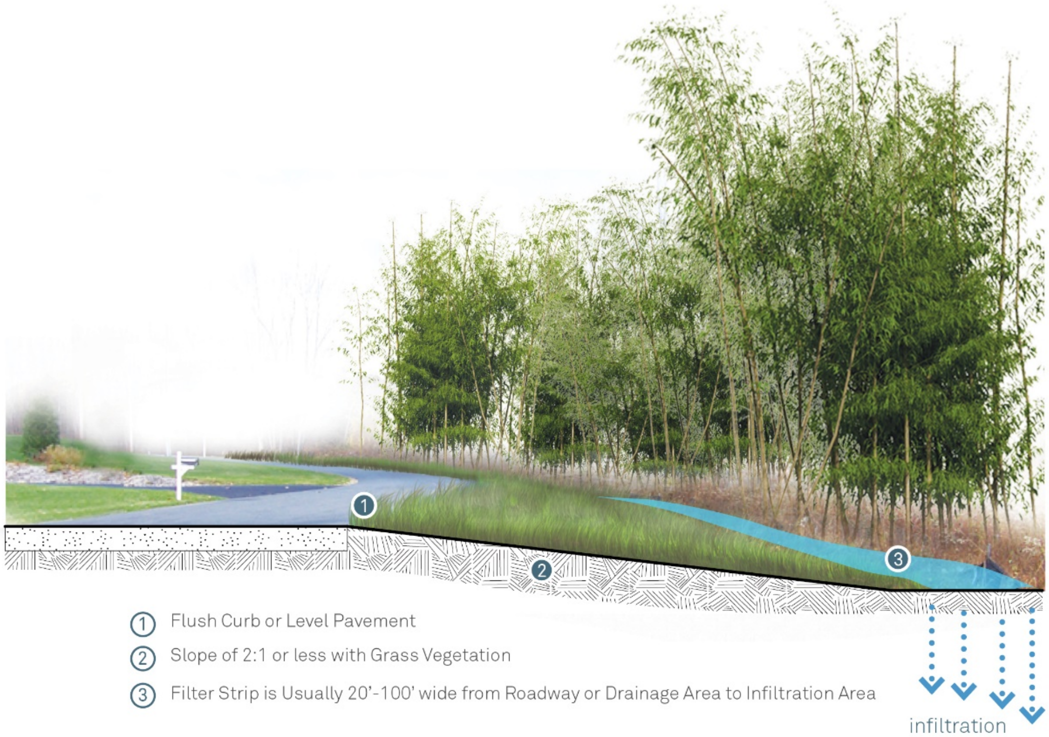


Figure 79. Example of design for a filter strip
https://www.google.com/search?q=stormwater+filter+strip+design&rlz=1C1CHBF_enUS698US698&sxsrf=ALeKk03msJ1LtPwb8K8yFqZKL3puwUVRaA:1593967037050&tbm=isch&source=iu&ictx=1&fir=6sQUNnP4IWqtYM%252CeQ3sCGig-GkEzM%252C_&vet=1&usg=AI4_-kTxxa10Bl_4TRxfWxvIyMCqvKprbA&sa=X&ved=2ahUKEwjXqZv4xbbqAhULMawKHflWDhoQ9QEwAXoECAoQHg&biw=1280&bih=529&dpr=1.5#imgrc=6sQUNnP4IWqtYM

Design considerations are summarized in Figure 80.



16. Filter Strip

Filter strips use vegetation to slow runoff, allowing suspended sediment and debris loads to drop out of runoff flow. This prevents clogging of stormwater drainage systems or receiving waterbodies. Stormwater runoff should be uniformly distributed along the top of the entire filter strip using a flow control facility such as a level spreader. Other treatment facilities, such as a swale, should be used for channelized flows. The drainage area should not exceed 150 linear feet to ensure proper functioning of the filter strip. The lateral slope of the filter strip should be one to two percent. A series of stepped level spreaders could compensate for slightly steeper slopes.

Where it can applied
Localized along shorelines and roadways

Benefits
Protects Property, treats runoff

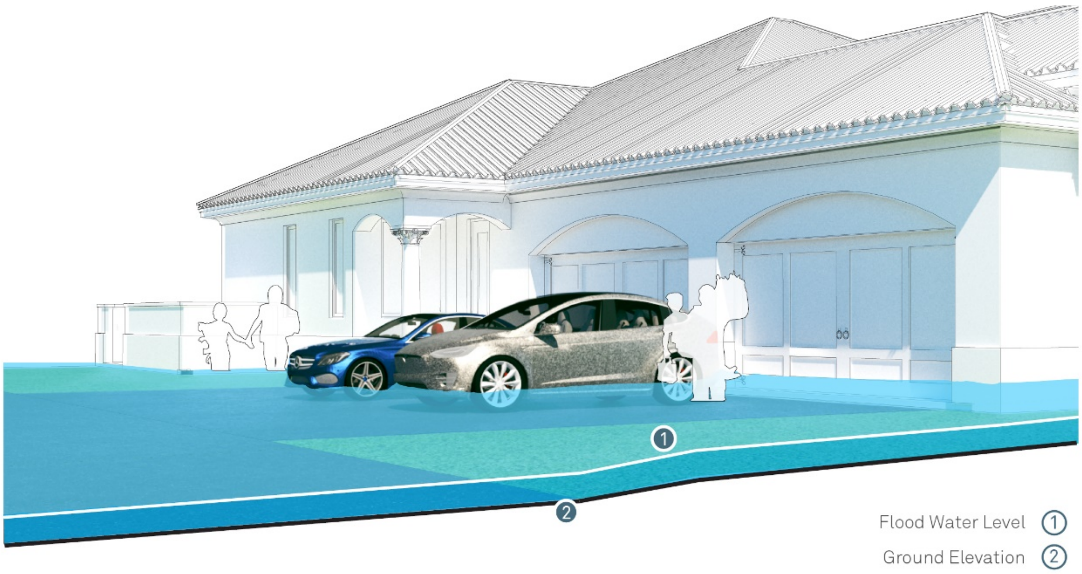
Barriers to implementation
No address flooding, treatment/water quality measure

Cost
$50k/mile

Figure 80. Design considerations, benefits, barriers and costs for a filter strip

5.1.17 Flood Prone Property Acquisition

The loss of wetlands, mangroves and other coastal ecosystems diminishes the ability to store water or to provide areas to direct excess precipitation to avoid flooding. Conservation of land to prevent development over areas where stormwater may collect, in floodplains and low areas should be a land use priority. While the NFIP and FEMA will not prohibit development in a flood zone, local officials have the capacity to enhance restrictions on land development and to acquire properties that are repetitive losses. The goal is to remove land that is subject to flooding from development pressures. Landowners may willingly sell property, may be compensated for losses incurred and zoning that prevents redevelopment and a host of other options. These are costly options, as acquisition of developed property can be a major cost. However, the benefits of not having to protect such properties may prove to have a positive long-term outcome. A summary of considerations is shown in Figure 81.



17. Flood Prone Acquisition

The loss of wetlands, mangroves and other coastal ecosystems diminishes the ability to store water or to provide areas to direct excess precipitation to avoid flooding. Conservation of land to prevent development over areas where stormwater may collect, in floodplains and low areas should be a land use priority. While the NFIP and FEMA will not prohibit development in a flood zone, local officials have the capacity to enhance restrictions on land development and to acquire properties that are repetitive losses. The goal is to remove land that is subject to flooding from development pressures. Landowners may willingly sell property, may be compensated for losses incurred and zoning that prevents redevelopment and a host of other options. These are costly options, as acquisition of developed property can be a major cost. However, the benefits of not having to protect such properties may prove to have a positive long-term outcome.

Where it can applied
Regional agency - could be any low lying areas

Benefits
removes flood prone areas from risk areas

Barriers to implementation
difficult to implement if occupied, issues with willing sellers, cost, lack of funds for acquisition

Cost
$200k-$1 million/acre depending on where it

Figure 81. Design considerations, benefits, barriers and costs for flood prone acquisition

5.1.18 Class I Injection Wells

40 CFR 146 is the federal regulation for underground injection control (UIC). The rules set forth standards for underground injection control programs which are mirrored in many states. The regulations include an extensive set of definitions concerning injection wells. Class I injection wells are identified as wells used by generators of hazardous waste or owners and operators of hazardous

waste management facilities to inject those hazardous waste beneath the surface. The requirement is that the waste be injected beneath the lower-most formation within 1/4 mile of a well bore for an underground drinking water source. Other industrial and municipal disposal wells that inject fluids beneath the lower-most formation containing potable drinking water supplies are also included.

The regulations establish a set of formulas to be utilized to calculate well spacing and design, and establish corrective actions for well failures and requirements for mechanical integrity tests to determine that there are no leaks in the casing, tubing, or packer (when used), and that is there is no significant fluid movement into an underground source of drinking water through vertical channels adjacent to the well are also established. The testing methods to achieve these results are included. Under sub parts B, C, D and F, the criteria and standards applicable to construction requirements, operating, monitoring and reporting requirements, and information that is to be considered in permitting wells. This would include information on the proposed operation of the well (such as maximum daily rate of flow and volume of fluids to be injected in the average injection pressure), the source of the water, the analysis of the characteristics of the injected fluids, the appropriate geological data and the construction details of the well. As a part of the revisions to the Safe Drinking Water Act in 1986, the federal government permitted the States to apply for primacy over the UIC program. 34 states have full delegation, while 6 more, including Florida, have partial delegation. Each of the 40 states have rules that mimic or are more stringent than the federal rules. Florida regulates injection wells under section 62.528 of the Florida Administrative Code.

If pumping is added, there is the potential for an injection zone in the surficial aquifers. If FDEP would permit such a well, like an aquifer storage and recovery well, this might be useful for stormwater applications. A 1 MGD well (700 gpm) would cost up to $500,000 and may not drain precipitation fast enough without providing millions of gallons of storage. Plugging would be a potential problem much like the exfiltration trench discussed previously. A more expensive, but also higher capacity option are Class I wells (Figure 82), which have never been used for stormwater.

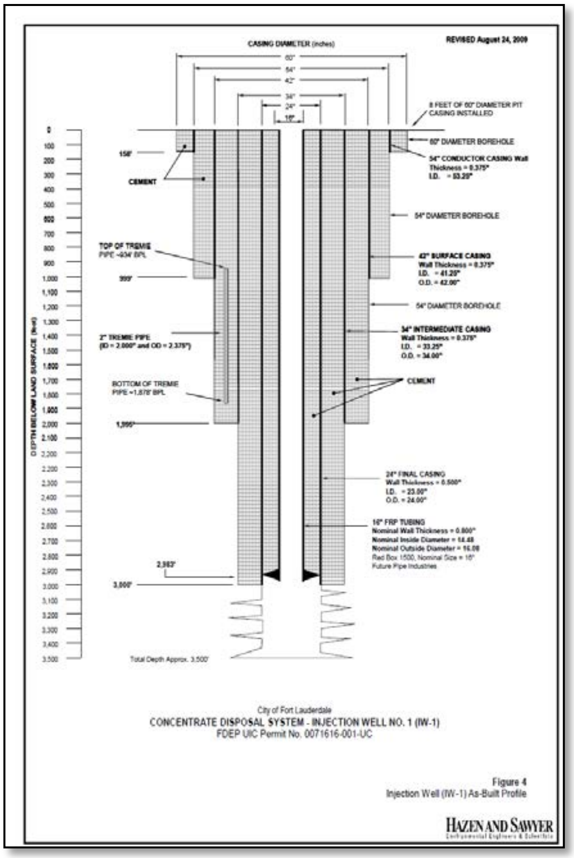
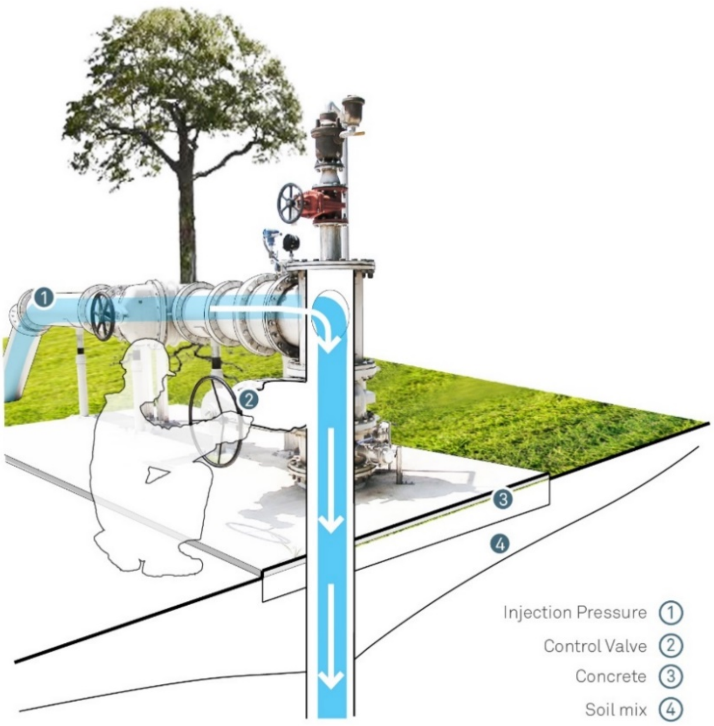


Figure 82. Typical class 1 injection well design (left) and wellhead (right) for a typical injection well

Class I injection wells are not applicable everywhere. There needs to be a receiving zone. The Boulder zone in south Florida is the appropriate formation. It is not available north of Lake Okeechobee. That means there are limitations to placement.

The cost is also an issue ($6 million each), so only places with dense development and little open space, plus a large tax base, will find this solution to be viable. There are also disbenefits, including, ongoing maintenance, the need for treatment and the loss of a potential water resource, are disbenefits. They will work as long as they are needed and are a robust solution if the appropriate geology is present, which is the case in much of Florida. Design considerations are summarized in Figure 83.



18. Class I Injection Well

Class I injection wells are identified as wells used by generators of hazardous waste or owners and operators of hazardous waste management facilities to inject those hazardous waste beneath the surface. The requirement is that the waste be injected beneath the lower-most formation within 1/4 mile of a well bore for an underground drinking water source. Other industrial and municipal disposal wells that inject fluids beneath the lower-most formation containing potable drinking water supplies are also included.

Where it can applied
Any low-lying area where stormwater collects, and there is sufficient land to permit, install and operate a Class I well - limited

Benefits
Means to drain neighborhoods - potentially large volumes

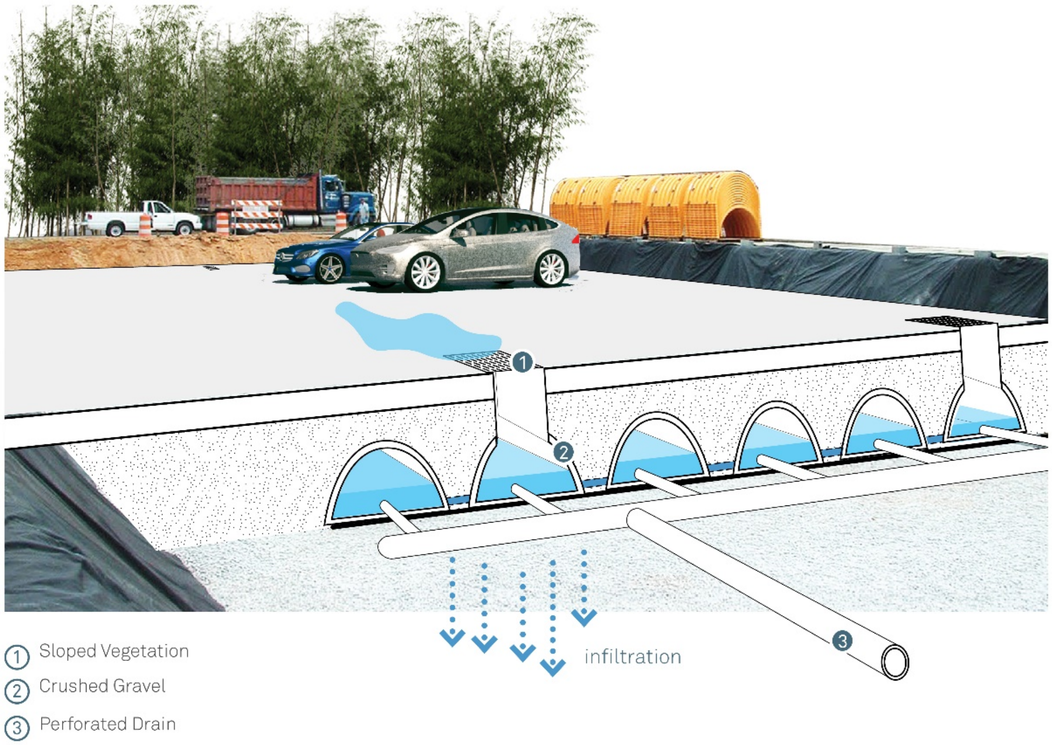
Barriers to implementation
Needs baffle box, injection zone may not be available required permit, may compete with water users

Cost
$3-6 million depending on size/depth

Figure 83. Design considerations, benefits, barriers and costs for a class I injection well

5.1.19 Underground Storage

Underground systems are used for the collection and storage of rainwater in addition to the storage of water for irrigation, air conditioning condensate, and cooling tower make-up. Note because the cistern will only hold a certain amount of water, a means to address overflows is needed. The costs for these systems are low, but ballast to prevent floatation of a dry tank is required. Maintenance is limited to periodic cleaning to remove runoff debris. See prior discussion about cisterns in Section 5.1.3. Design considerations are summarized in Figure 84.



19. Underground Storage

Underground storage systems store and slowly release runoff into the LID network. Some systems can infiltrate stormwater if the soil beneath is permeable. Underground storage is employed in places where available surface area for on-grade storage is limited.

Where it can applied
Parking lots, runoff from development - primarily treatment for discharge to another system

Benefits
Protects Property, treats runoff

Barriers to implementation
maintenance, limited volume disposed of, mostly for treatment

Cost
$20k-$50k/acre

Figure 84. Design considerations, benefits, barriers and costs for underground storage detention

5.1.20 Constructed Wetlands

Development has created significant losses of wetlands in the state. Wetlands serve multiple purposes. They store water, filter nutrients, recharge aquifers, moderate temperatures, and provide habitat. Constructed wetlands are treatment systems that use natural processes involving wetland vegetation, soils, and their associated microbial assemblages to improve water quality. Constructing an artificial wetland requires knowledge of water quality, runoff patterns, storage elevation, and plants. Wetlands are some of the most biologically diverse and productive natural ecosystems in the world. While not all constructed wetlands replicate natural ones, it makes sense to build wetlands that improve water quality and support wildlife habitat. Constructed wetlands can also be a cost-effective and technically feasible approach to managing stormwater. Figure 85 shows an example of a constructed wetlands, but many options are available.

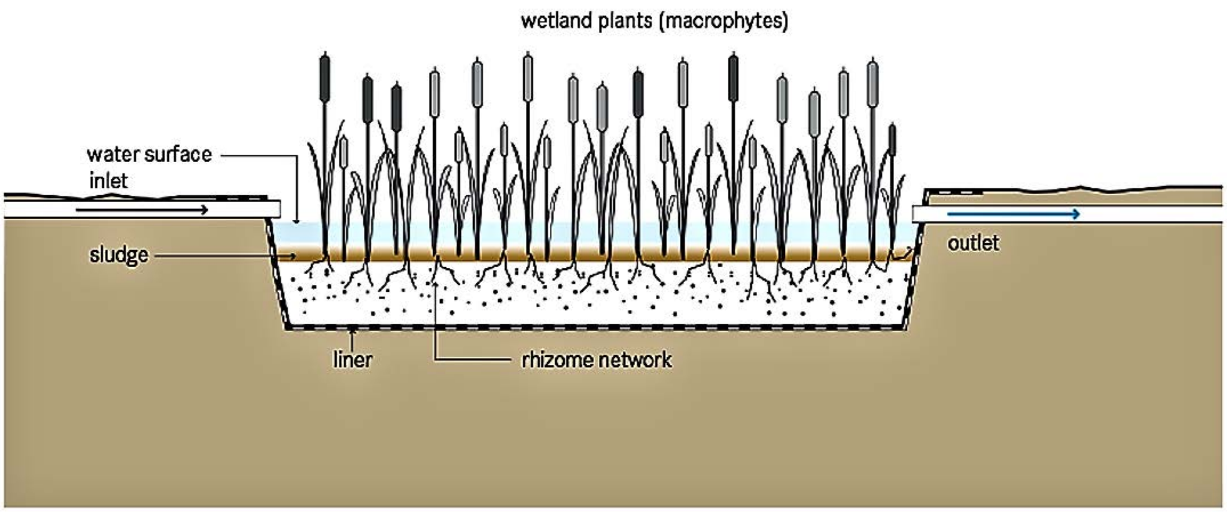
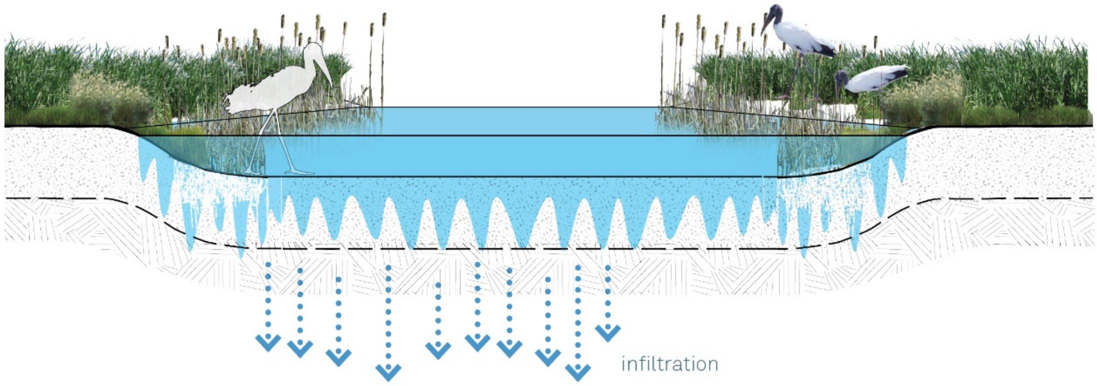


Figure 85. Constructed wetlands
https://www.google.com/search?q=constructed+wetlands&rlz=1C1CHBF_enUS698US698&sxsrf=ALeKk02kBU5RFBQbWYybH0VEYRVO-a76NQ:1593975717365&source=lnms&tbm=isch&sa=X&ved=2ahUKEwjI06ej5rbqAhVtmK0KHYz-D2UQ_AUoAXoECBMQAw&biw=1280&bih=578&dpr=1.5#imgrc=Cw--1lduG3z4yM

Design considerations are summarized in Figure 86.



20. Constructed Wetland

Considered to be a comprehensive treatment system, constructed wetlands, like infiltration basins, require intrinsic hydrogeologic properties to reproduce natural watershed functioning. As with other infiltration systems, pre-treatment systems upstream help to remove sediment that may clog a wetland system, resulting in eutrophication or an oxygen deprived system.

Where it can applied
Where there is low-lying flood prone land that can be developed into wetlands

Benefits
Reduces flooding by providing low-lying place for water to go to.

Barriers to implementation
Water quality, permitting, monitoring costs, maintenance

Cost
$200k-$1million/acre

Figure 86. Design considerations, benefits, barriers and costs for constructed wetlands

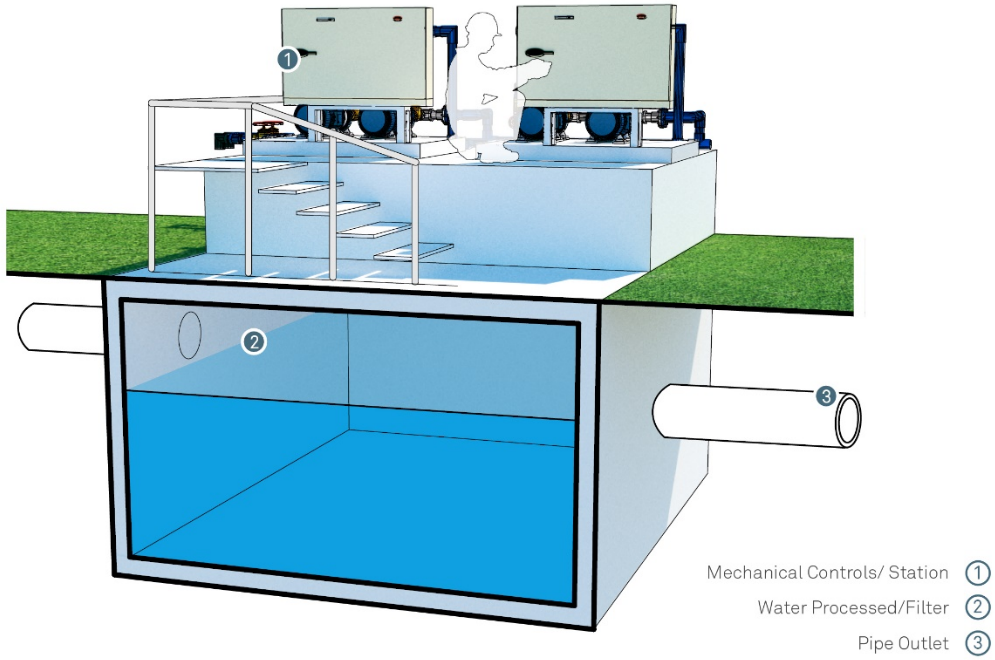
5.1.21 Pump Stations

In urban areas, stormwater collection and management systems may need to be redesigned and expanded to increase capacity since current capacity is not likely to address new peaking factors associated with climate change. In low lying areas, exfiltration trenches and other pipes are already inundated. As a result, a more consistent solution is required, which usually involves pumping. The concept is simple: drain the stormwater to a central area, install a pump, and move the water to another place (or waterbody). Pump stations are commonly used, are reliable, and can protect property. Emergency generators are often required to insure operation during electrical power disruptions.

Pumping is a preferred strategy when retention areas and exfiltration are not feasible. The difference in head between the surface of the drainage system and the water table are not relevant as the only issue is that the receiving waterbody is lower than the pump to prevent backflow. The amount of pumping is proportional to the area served and the design storm of concern. The pump station demand will increase with time as groundwater levels rise, precipitation becomes more intense, or water crosses the sea walls. Hence pumping stations must be designed to be expanded or they will have to be replaced.

The cost of pump stations starts at $250,000 and increase with demands and area served. Very large ones may cost upwards of $100 million. Developers routinely install them when retention ponds cannot be constructed. Pump stations do not remove contaminants in and of themselves. Treatment can be added at the station with increased cost and maintenance. A bigger issue is water quality impacts to the receiving waterbody. It should be noted that water quality is sensitive to increased water temperatures, changes in patterns of precipitation, and changes in pollutant loadings. If a waterbody, such as the Intracoastal Waterway, receives more water from the land, nutrients, carbon and other contaminants will increase, while salinity will be reduced. All have poor impacts on native biota in the estuary. Temperatures increase due to runoff, so there will be both direct and indirect effects on aquatic ecosystems, especially during low flow periods. Water quality impacts to surface waters are currently difficult to quantify. There are no current hydrologic observing systems for purposes of detecting effects on water resources, and limited studies of hydrologic trends in the southeast or Florida have been completed. Lower flows in streams during the summer and fall could substantially reduce available dilution in those streams, thereby concentrating salts and other pollutants. Temperature and nutrients will reduce dissolved oxygen (by increasing temperature and increasing metabolism). As a result, it may become more difficult to meet or maintain current surface water quality standards for receiving water bodies.

Pumping is one of the more robust solutions for dealing with runoff and sea level rise. Larger stations will be needed, employing more power and requiring more maintenance. Studies for individual neighborhoods will be required to identify such needs. At some point, pump stations will cease to work when an area is completely inundated by coastal water bodies. Design considerations are summarized in Figure 87.



21. Pumping Station

In urban areas, stormwater collection and management systems may need to be redesigned and expanded to increase capacity since current capacity is not likely to address new peaking factors associated with climate change. In low lying areas, exfiltration trenches and other pipes are already inundated. As a result, a more consistent solution is required, which usually involves pumping. The concept is simple: drain the stormwater to a central area, install a pump, and move the water to another place (or water body). Pump stations are commonly used, are reliable, and can protect property. Emergency generators are often required to insure operation during electrical power disruptions.

Where it can applied
Regional (WMD) or Local Responsibility

Benefits
Creates regional system to use coastal ridge to protect inland property, keeps saltwater out

Barriers to implementation
SFWMD, western residents, private property rights arguments

Cost
$200 million ea

Figure 87. Design considerations, benefits, barriers and costs for pump stations

5.1.22 Armored Sewer Systems

Increased infiltration/inflow (I/I) due to saturated soil conditions and infrastructure structural issues (e.g., broken pipes, deteriorating pipes) will need to be addressed. Infiltration (Figure 88) is a direct result of groundwater that migrates into the pipes due the pipes being under water, which is the normal situation for most of coastal Florida. Most utilities have peaks, which are likely to become larger if climate change results in increased rainfall volume. Peaks are caused by inflow during rain events – generally surface connections. Reducing infiltration and inflow reduces the demands on wastewater plants, frees capacity, and limits chlorides, which can make reuse disposal options a challenge. It will also reduce the pump run times on lift stations due to lower flows.

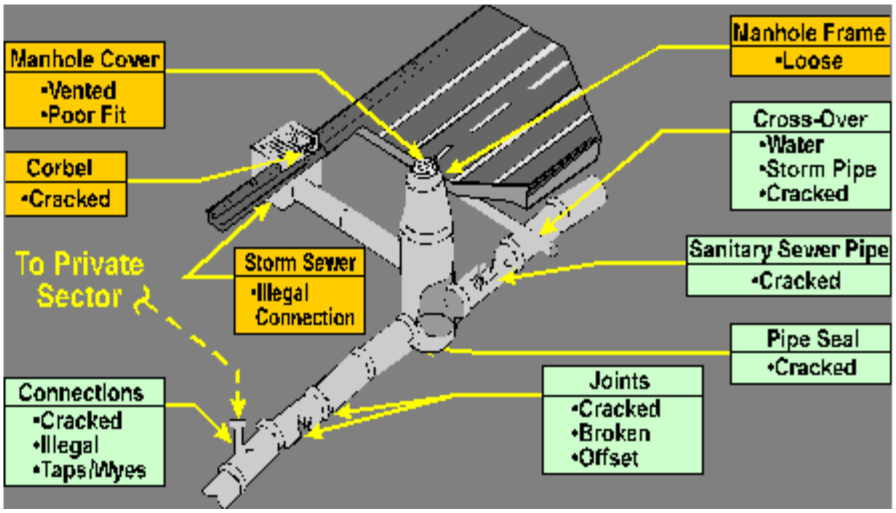


Figure 88. Potential infiltration and inflow areas (Bloetscher, 2008)

It is estimated that there are over 1 million manholes in Florida, nearly all of which are located in areas vulnerable to flooding. New sanitary sewer systems will need to be designed and installed to meet predicted future conditions that could include increased infiltration potential resulting from either changes in rainfall patterns or sea level rise. New and existing systems will need to adapt to these different hydrologic conditions.

Over 10% of sewer service lines are believed to be damaged based on south Florida experience causing about half of the infiltration issues that will be found in a low flow inspection. There are no limits to implementation other than costs. The cost to seal manholes is estimated at $100/manhole with other improvements such as chimney seals (Figure 89), LDL plugs (Figure 90), rain dishes (Figure 91), and ancillary corrections to service lines on both public and private property. A full inflow removal program is on the order of $500/ manhole, which will reduce costs associated with infiltration and generally pays for itself. The improvements will function until the area is fully inundated, and development moves elsewhere. It is a robust improvement that will last for years but does require ongoing upkeep as the system deteriorates with time.

Figure 89. Chimney seal installed (Courtesy USSI)

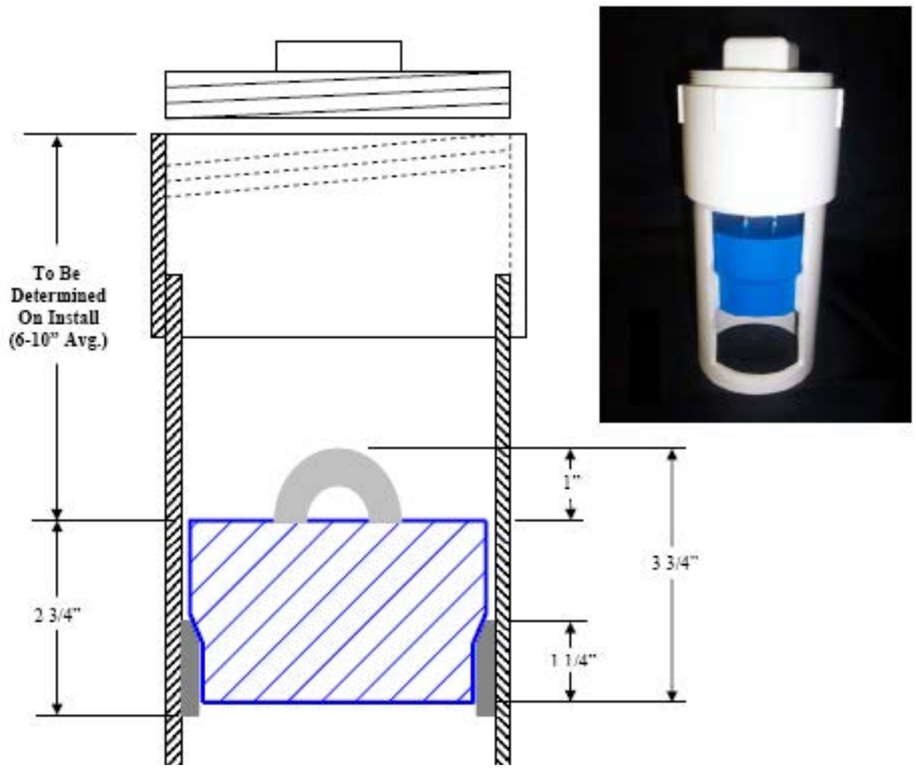
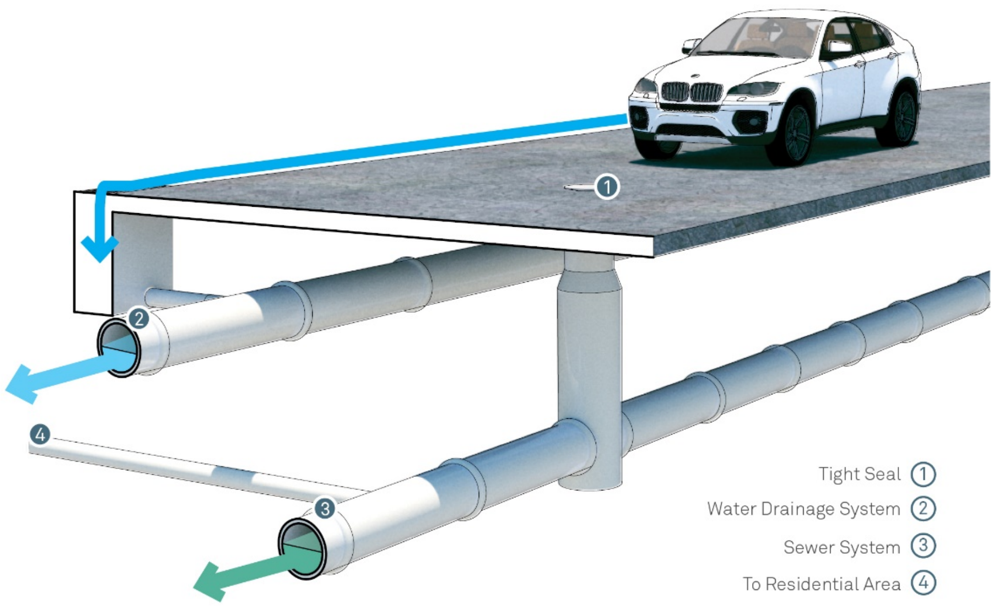


Figure 90. LDL plug design (Courtesy USSI)

Figure 91. Inflow defender manhole rain dish (Courtesy USSI)

Design considerations are summarized in Figure 92.



22. Armoring Sewer System

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Where it can applied
Any area where gravity sanitary sewers are installed, which is most of the City

Benefits
Keeps stormwater out of sanitary sewer system and reduces potential for disease spread from sewage overflows. Major public health solution

Barriers to implementation
limited expense beyond capital cost

Cost
$500/manhole

Figure 92. Design considerations, benefits, barriers and costs for armoring sewer systems

The protocol for identifying breaches in the system that lead to infiltration/inflow include:

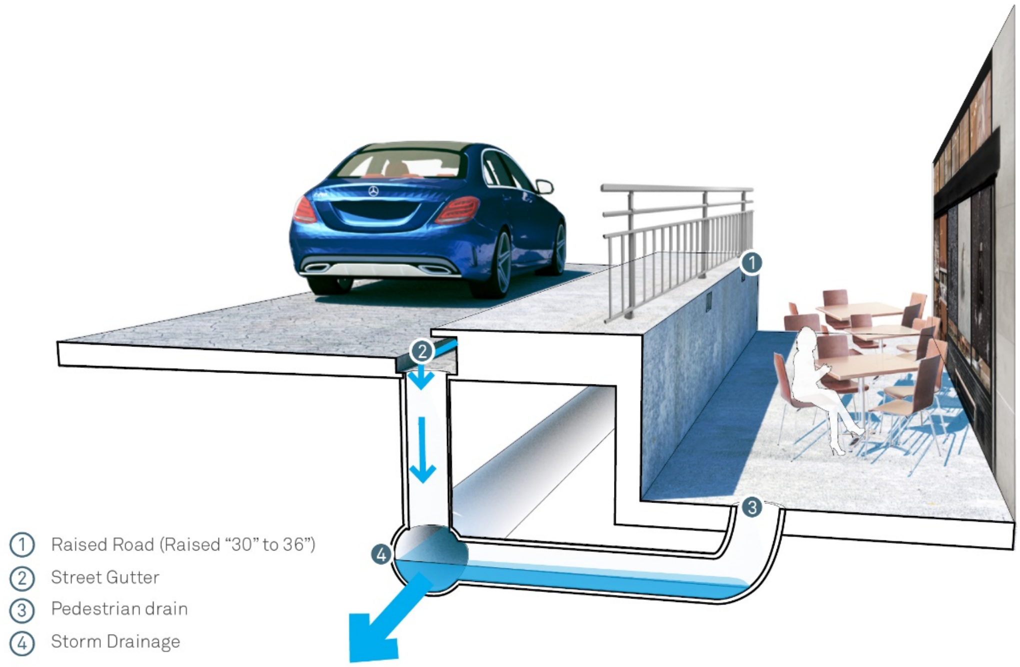
- Inspection of all sanitary sewer manholes for damage, leakage or other problems all documented in a report that identifies problem type, location and recommended repair
- Repair the flow path in the bottom of the manhole (bench) in poor condition or exhibiting substantial leakage
- Repair manhole walls in poor condition or exhibiting substantial leakage

- Repair/seal chimneys in all manholes to reduce infiltration from the street during flooding events
- Install dishes in all manholes to prevent infiltration
- Install LDL™ plugs where manholes in the public right-of-way or other portion of the utility's system is damaged (Figure 90)
- Identify sewer system leaks, including those on private property (via location of smoke on private property)
- Perform a low flow inspection

5.1.23 Raised Roadways

FDOT and most municipalities rely heavily on exfiltration trenches or French drains for managing stormwater. These systems work because the perforated piping is located above the water table. They cease to function if they are located below the water table. Exfiltration systems in low-lying areas will cease to work as they become submerged. Future storm water systems should be designed similar to sanitary sewers with tight piping, minimal allowances for infiltration and adequately sized pumping stations with permitted discharge points and means for associated treatment, as needed.

For low-lying areas, elevating roads may be an option. However, this option comes with two significant issues: 1) roadway elevations and 2) impacts on adjacent properties. Insurance companies define any floor that is less than 18 inches above the crown of the adjacent roadway to be a basement, and basements are excluded from flood insurance coverage throughout the state. Roadways are designed for 50 to 100-years of service life. As a result, transportation agencies should design roadway bases to be above the mean high water table (at the end of the design life if possible). Under these criteria, roads located in coastal areas would likely have surface elevations at or above 8 ft NGVD, which well above many of today's low-lying roads and in many cases above the finished floors of adjacent properties. They will also act as dams unless provisions, such as culverts or pumps, are made for horizontal movement of water, creating a potential stormwater runoff concern. Raising roadways is expected to exceed the cost of new roads; it will cost on the order of $1 million per lane-mile, plus the additional right-of-way costs. Furthermore, sanitary sewers, water mains and other utilities are typically located underneath these pavements. Elevating the roads would require manholes to be reconstructed, water lines replaced and most of the other underground utilities replaced or upgraded. The costs for these improvements are estimated at roughly $4 million per mile of roadway. Design considerations are summarized in Figure 93.



23. Raised Roadways

Roadways are designed for 50 to 100-years of service life. As a result, transportation agencies should design roadway bases to be above the mean high water table (at the end of the design life if possible). Under these criteria, roads located in coastal areas would likely have surface elevations at or above 8 ft NGVD, which well above many of today's low lying roads and in many cases above the finished floors of adjacent properties. They will also act as dams unless provisions, such as culverts or pumps, are made for horizontal movement of water, creating a potential stormwater runoff concern.

Where it can applied
Limited to areas where redevelopment is occurring areawide due to ancillary impacts on adjacent properties

Benefits
Keeps traffic above floodwaters, access for emergency vehicles, commerce impacted

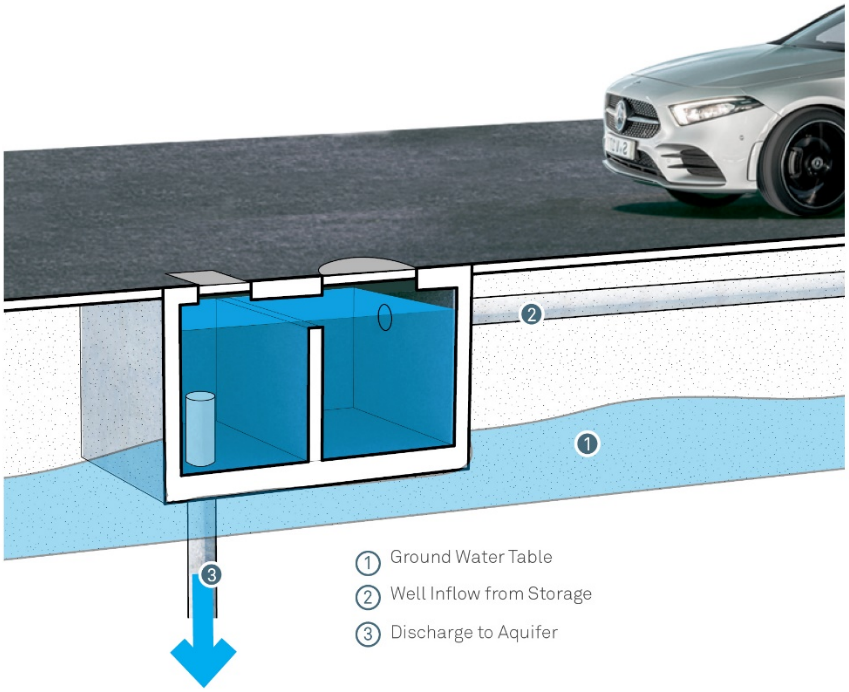
Barriers to implementation
Runoff, cost, utility relocation

Cost
$2 - 4 million/lane mile

Figure 93. Design considerations, benefits, barriers and costs for raised roadways

5.1.24 Class V Gravity Wells

Drainage wells could be an essential component to improving drainage systems. Class V gravity wells have been used for years in coastal areas where saltwater has intruded beneath the surficial aquifer. These wells require splitter boxes and filters to remove solids, regular inspections, and regular maintenance, which would need to be included in budget considerations. They are primarily used in coastal areas where saltwater has intruded below the surface. They do not function if saltwater is not present in the subsurface (0-150 ft below land surface). To work, the Ghyben-Hertzberg principle allows freshwater head to depress the saltwater head, thereby allowing freshwater to flow into the deeper saltwater zone. If there is no saltwater, the freshwater cannot "float." The head of the surficial system must be above that of the saltwater, otherwise the wells will flow backwards, an ever-increasing phenomenon. FDEP permits these wells. Baffle boxes are required, and the well boxes must be maintained and cleaned regularly. The wells can handle up to 1 MGD (assuming 24-inch diameters, 150 ft deep). Local conditions vary, so a test well is usually required. Gravity wells will not work is saltwater does not underly the area selected for the gravity well. Design considerations are summarized in Figure 94.



24. Class V Gravity Well

Drainage wells could be an essential component to improving drainage systems. These wells require splitter boxes and filters to remove solids, regular inspections, and regular maintenance, which would need to be included in budget considerations. They are primarily used in coastal areas where saltwater has intruded below the surface. They do not function if saltwater is not available.

Where it can applied
Any low lying areas where stormwater collects and is located where saltwater has intruded the surficial aquifer beneathe the site (generally east of Dixie Highway)

Benefits
Means to drain neighborhoods, limited volume

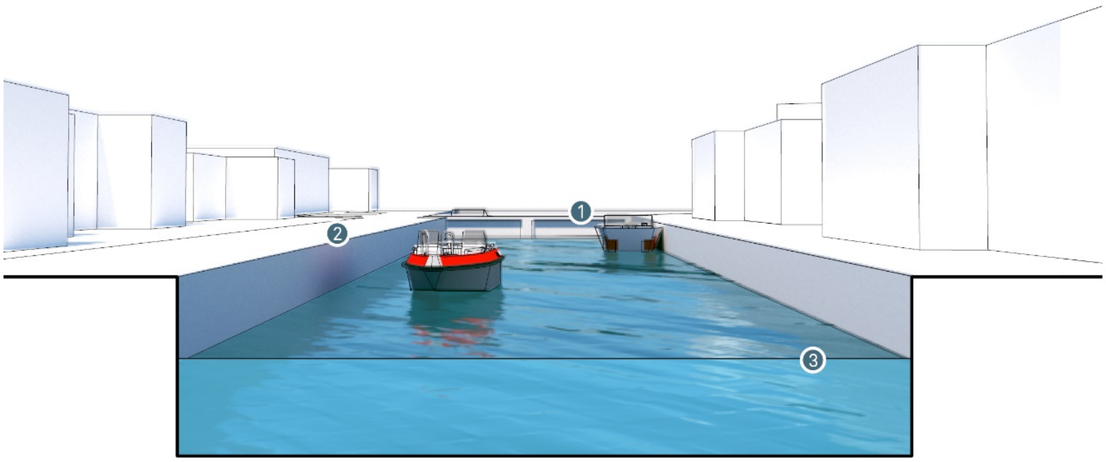
Barriers to implementation
Needs baffle box, limited flow volume (1 MGD), zone for discharge may not be avaialble, permits, water supply wells

Cost
$250K ea

Figure 94. Design considerations, benefits, barriers and costs for class V gravity wells

5.1.25 Canals

Water managers in Southeast Florida use the extensive system of drainage canals to control water table levels. Canals and control structures are built to control flooding through discharge of storm water to tide in coastal areas. Properly placed control structures can also prevent the inland migration of seawater in the canals and substantially define the location of the saltwater intrusion front. Canal structures, localized and regional pumping stations, and piping may be needed. With the start of development in the state of Florida in the early 1900s, there were demands made to control the water and open south Florida for agriculture and development. Today, water supply for nearly half the state is managed through a canal network, consisting of 1,800 miles of canals and levees, 200 water control structures and 16 major pump stations, that controls the movement of water to the coasts. Design considerations are summarized in Figure 95.



1. Canal Operational Wall
2. Sea wall
3. Canal

25. Drainage Canal

Water managers in Southeast Florida use the extensive system of drainage canals to control water table levels. Canals and control structures are built to control flooding through discharge of storm water to tide in coastal areas. Properly placed control structures can also prevent the inland migration of seawater in the canals and substantially define the location of the saltwater intrusion front. Canal structures, localized and regional pumping stations, and piping may be needed. With the start of development in the state of Florida in the early 1900s, there were demands made to control the water and open south Florida for agriculture and development.

Where it can applied
Limited to areas where redevelopment is occurring areawide due to ancillary imapcts on adjacent properties

Benefits
Keeps traffic above floodwaters, access for emergency vehciles, commerceout

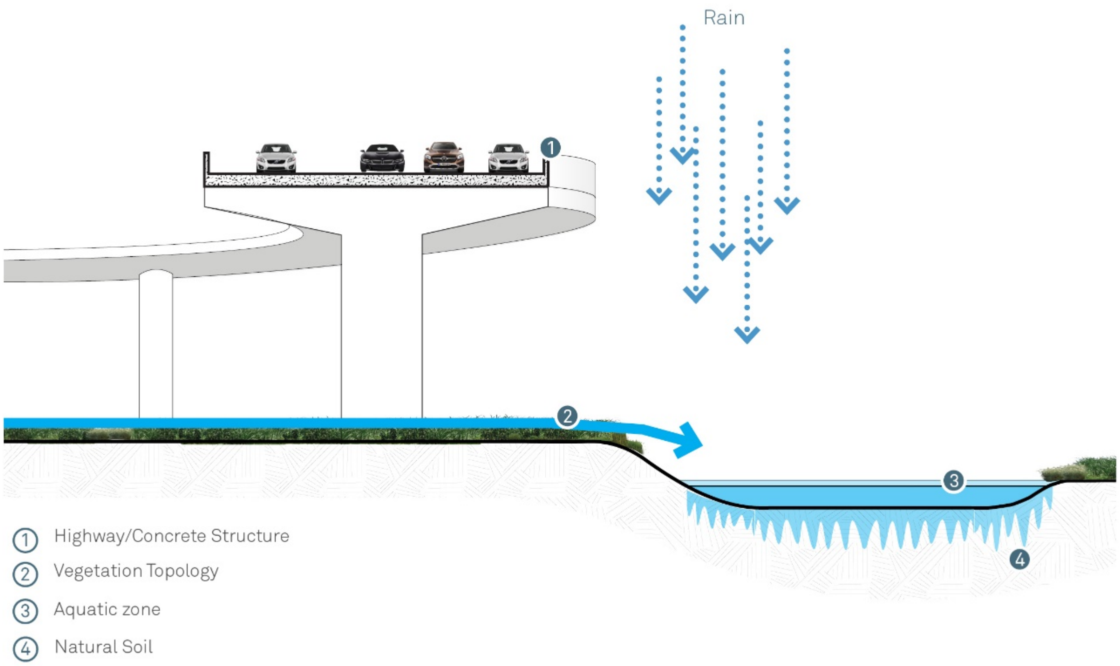
Barriers to implementation
Runoff, cost, utility relocation

Cost
$2 - 4 million/lane mile

Figure 95. Design considerations, benefits, barriers and costs for drainage canals

5.1.26 Aquatic Zones

Aquatic zones include any low-lying or flood-prone area that is undeveloped and can store large volumes of water. These zones may be natural or engineered and can act as important natural biofilters, protecting aquatic environments from excessive sedimentation, polluted surface runoff, erosion, and retention of stormwater. They can also provide habitat for aquatic species and shade if vegetated. In addition, depending on the size and location, these aquatic zones can contribute to nearby property values by providing water sports amenities (footpaths, bicycle greenways, fishing, watercraft sports, etc.) and views. Design considerations are shown in Figure 96.



26. Aquatic Zones

Aquatic zones include any low-lying or flood prone area that is undeveloped and can store large volumes of water. Like land acquisition, retention/detention basins, and polders, they must be maintained, cost, impact on property owners.

Where it can applied
any low-lying or flood prone area that is undeveloped and can store large volumes fo water

Benefits
place to store large volumes of water

Barriers to implementation
Must be maintained, cost, impact on property owenrs

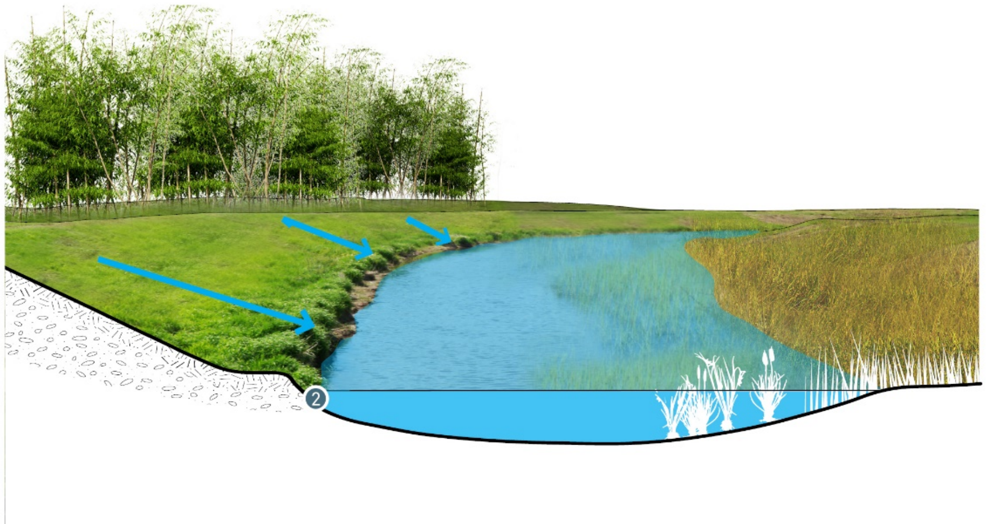
Cost
$200k/ac

Figure 96. Design considerations, benefits, barriers and costs for aquatic zones

5.1.27 Levees

A levee is an artificially constructed berm that has gates and pumps to regulate water levels. Levees are also used to divert water away from civilization. Examples of levee systems include the New Orleans levees that are designed to keep the Mississippi River out of New Orleans (which exists at an elevation below the river) and the Hooke Dike around Lake Okeechobee. Levees exist throughout Florida along canals. They are normally earthen and often parallel to the course of the waterbody in its floodplain or along low-lying coastlines.

Levees are an expensive option to construct and must be maintained so they do not fail as happened after Hurricane Katrina in New Orleans. Levees are not popular if river/lake/ocean views are disrupted, or ocean access diminished. Levees will have lock structures and pump stations to operate. In Davie, FL, SFWMD recently constructed a large pumping station ($100 million) to discharge from the C-11 canal. Pumping stations could cost on the order of $100 million each. Models for this scenario and more advance solutions exist in Venice, Italy and the Netherlands. Design considerations are summarized in Figure 97.



27. Levee

A levee is an artificially constructed berm that has gates and pumps to regulate water levels. Levees are also used to divert water away from civilization. Examples of levee systems include the New Orleans levees that are designed to keep the Mississippi River out of New Orleans (which exists at an elevation below the river) and the Hoover Dike around Lake Okeechobee. Levees exist throughout Florida along canals. They are normally earthen and often parallel to the course of the waterbody in its floodplain or along low-lying coastlines.

Where it can applied
Regional issue- along rivers, lakes, impoundments

Benefits
protects widescale property

Barriers to implementation
maintenance, limited volume disposed of, mostly for treatment

Cost
$ millions

Figure 97. Design considerations, benefits, barriers and costs for levees

5.1.28 Lock Structures

With the extensive canals in southeast Florida, exists a secondary problem. There are many areas of the state where there are no structures to prevent the migration of seawater inland, including much of Miami-Dade County and southern Broward County where the salinity control structures may be 8 miles inland. The problem is that this is west of the coastal ridge, breaching the dike that separates the east from the remnant Everglades west of I-95. Compounding the problem is that the SFWMD acknowledges that about 30% of the drainage system capacity has been lost due to sea level rise. With increasing development and more runoff, the system is failing. Locks are a solution that could be employed to both protect open ocean access and stem the impact of storm surge. However, ten years ago, SFWMD was approached by at least one eastern utility about the possibility of installing coastal lock structures closer to the coast than the current systems. The District did not pursue this because of concerns regarding inverse condemnation suits from homeowners who no longer would have open ocean access, thus claiming a loss of property values. A lock structure would cost $20 to 30 million, and dozens are potentially needed to protect the aquifer from saltwater intrusion. Design considerations are summarized in Figure 98.

① Highway/Concrete Structure
② Vegetation Topology
③ Aquatic Zone
④ Natural Soil

28. Lock Structure

With the extensive canals in southeast Florida, exists a secondary problem. There are many areas of the state where there are no structures to prevent the migration of seawater inland, including much of Miami-Dade County and southern Broward County where the salinity control structures may be 8 miles inland. The problem is that this is west of the coastal ridge, breaching the "dike" that separates the east from the remnant Everglades west of I-95. Compounding the problem is that the SFWMD acknowledges that about 30% of the drainage system capacity has been lost due to sea level rise. With increasing development and more runoff, the system is failing. Locks are a solution that could be employed to both protect open ocean access and stem the impact of storm surge.

Where it can applied
Regional (WMD) Responsibility

Benefits
Keeps sea out, reduces slatwater instrusion

Barriers to implementation
SFWMD, western residents, private property rights

Cost
Up to $100 million, may require ancillary stormwater pumping stations at $2-5 million each

Figure 98. Design considerations, benefits, barriers and costs for lock structures

5.1.29 Sea Walls

Sea walls have been successfully used as a means to protect areas of human habitation, conservation and leisure activities from the action of tides, waves, or tsunamis. Historically they have been made of many different materials, from monolithic concrete barriers, brick or block walls, rubble mound structures, or steel sheet pile walls. They are naturally, heavily engineered, permanent structures that are costly to design but are a common site along the Florida coastline. The physical design of sea walls is highly variable; they can either be sloping or vertical and made from a wide range of materials. The design and the texture of the walls also have a significant impact on its performance. For example, while a smooth surface reflects wave energy better, irregular surfaces, on the other hand, disperse the direction of the waves better. Typically, the seawalls must have a deep foundation to enhance its stability. Also, earthen anchors are mostly buried deep into the land and connected by rods to the wall to help it overcome pressure from the landward side. Design considerations are summarized in Figure 99.

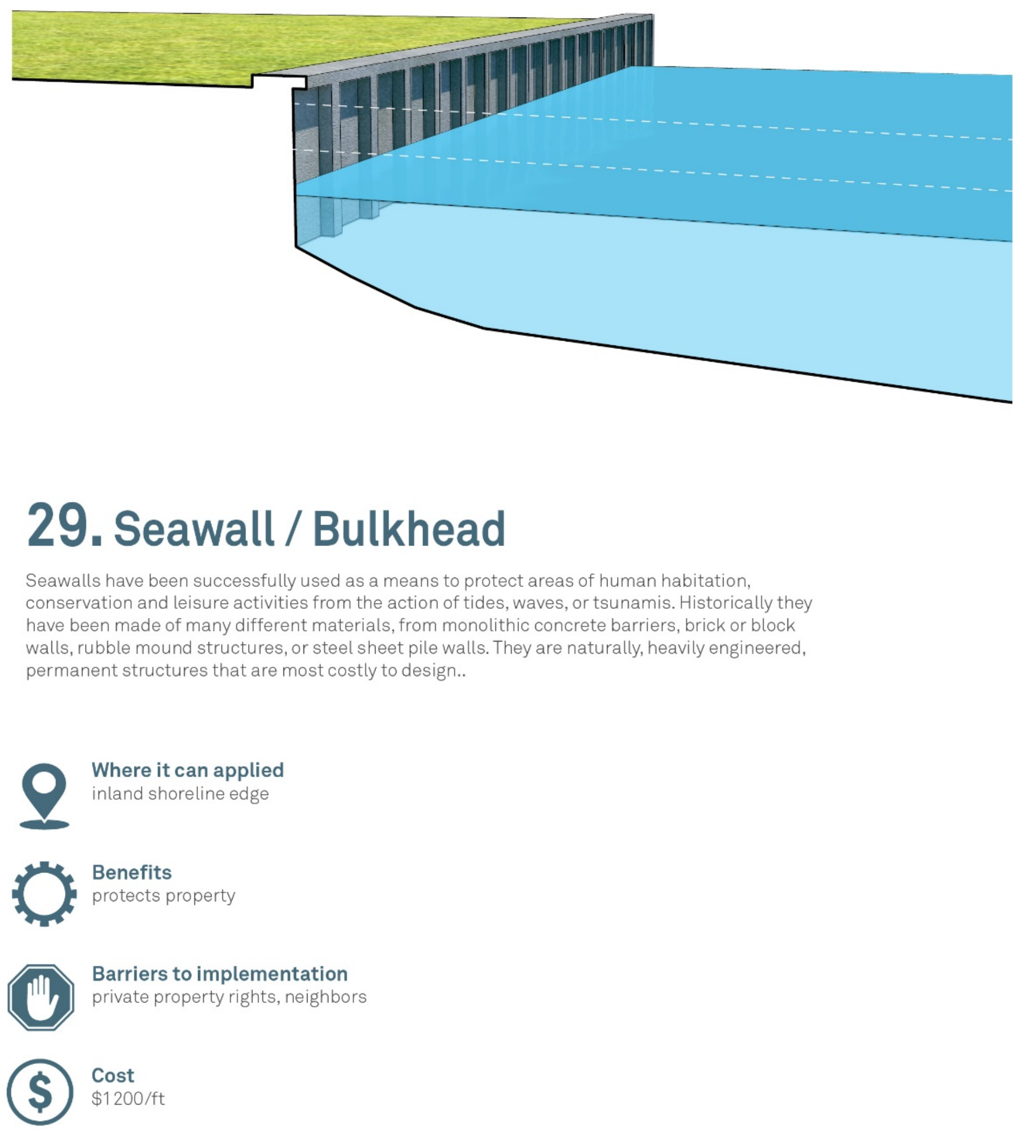
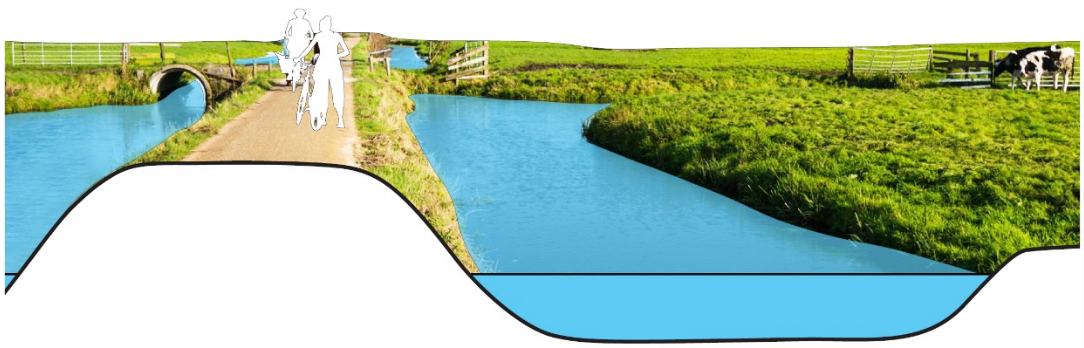


Figure 99. Design considerations, benefits, barriers and costs for seawalls

5.1.30 Polders

A polder is a low-lying tract of land that forms an artificial hydrological entity, enclosed by dikes. This is a place that can store stormwater/saltwater during periods of need. This is a coastal solution only but is not commonplace in Florida. Design considerations are summarized in Figure 100.



30. Polder

A polder is a low-lying tract of land that forms an artificial hydrological entity, enclosed by dikes. This is a place that can store stormwater/saltwater during periods of need. This is a coastal solution only.

Where it can applied
end-of-line facility, upstream of overflow basins or receiving waterbodies

Benefits
retention/filtration/infiltration/treatment

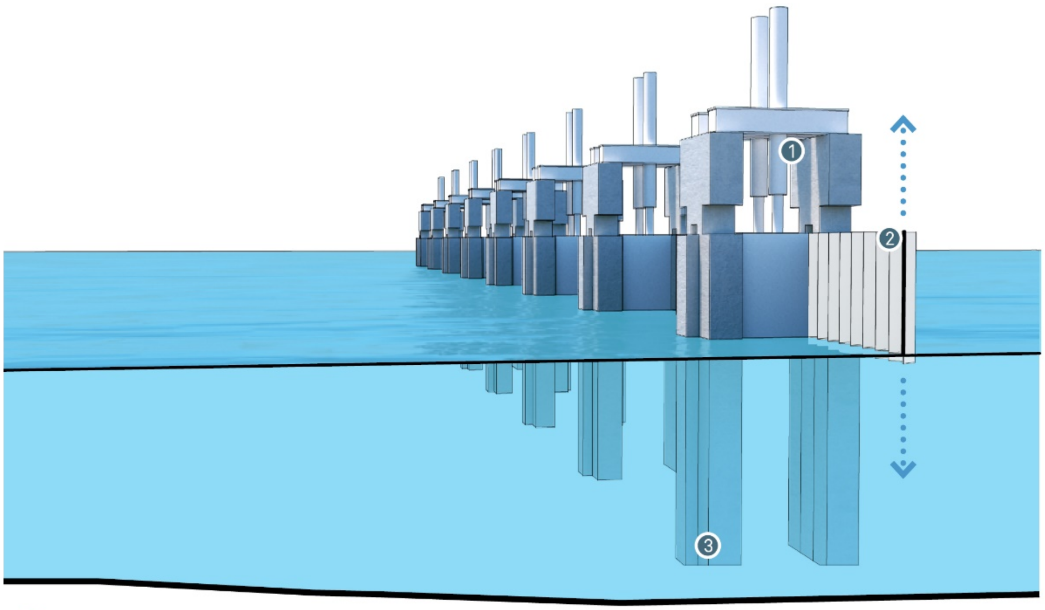
Barriers to implementation
system requires removal of trash and sediment between two and ten years, and semiannually during first three years

Cost
Varies

Figure 100. Design considerations, benefits, barriers and costs for polders

5.1.31 Surge Barriers

A surge barrier is a structure, like a lock that protects coastal property. Surge barriers, like lock structures, can be employed to both protect open ocean access and stem the impact of storm surge. Like a lock, a surge barrier is often a movable structure that is signaled to close prior to a storm and reopen to facilitate transport of goods and boat traffic or to allow natural movement of tides. As a significant physical barrier, it requires advanced civil engineering and substantial construction costs. They provide a physical barrier and are used to protect coastal communities, tidal inlets, rivers and estuaries from extreme weather events. This is a coastal solution only. Design considerations are summarized in Figure 101.



① Hydraulic Pump
② Wall
③ Structure Of Surge Wall

31. Surge Barrier

A surge barrier is a structure, like a lock that protects coastal property. Surge barriers, like lock structures, can be employed to both protect open ocean access and stem the impact of storm surge. Like a lock, a surge barrier is often a movable structure that is signaled to close prior to a storm and reopen to facilitate transport of goods and boat traffic or to allow natural movement of tides.

Where it can applied
islands, bays, harbors and rivers

Benefits
place to store large volumes of water

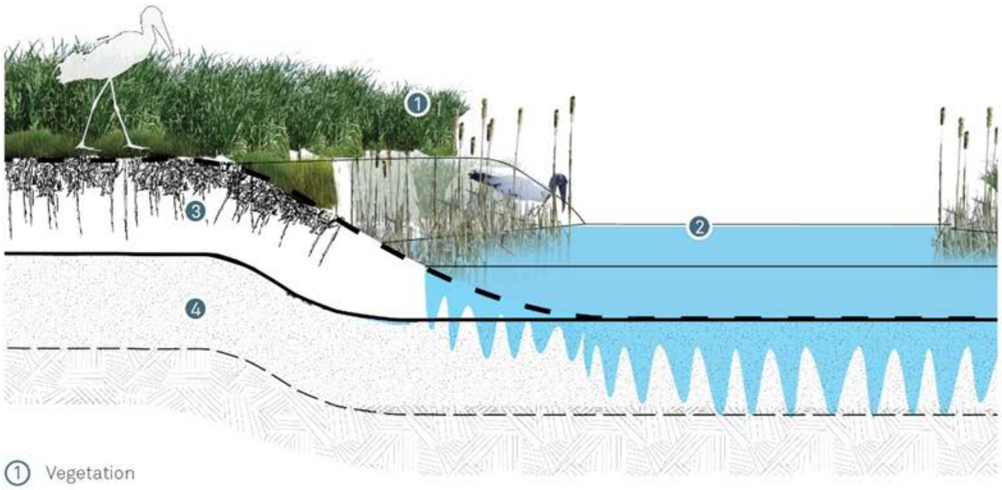
Barriers to implementation
sediment between two and ten years, and semiannually during first three years

Cost
Varies, but very costly

Figure 101. Design considerations, benefits, barriers and costs for a surge barrier

5.1.32 Enhanced Wetlands

Wetland enhancement has benefits for watershed management. The concept is to enlarge and augment existing wetlands with added waters from stormwater runoff. Coastal wetlands are an added enhancement for coastal communities as the data from Hurricane Katrina indicated that coastal wetlands and mangroves may reduce storm surge and dampen the impacts of wave action. However, enhancing wetlands requires site-specific knowledge of water quality, runoff patterns, storage elevation and plants. The concepts are otherwise similar to constructed wetlands. Design considerations are summarized in Figure 102.



32. Enhanced Wetland

Wetland enhancement has benefits for watershed management. The concept is to enhance existing wetlands with added waters from stormwater runoff, and diversion from are treatment systems that use natural processes involving flood-prone properties. However, enhancing wetlands is an entire science that requires knowledge of water quality, runoff patterns, storage elevation and plants. The concepts are otherwise similar to constructed wetlands. Coastal wetlands are an added enhancement for coastal communities as the data from Hurricane Katrina indicated that coastal wetlands and mangroves may reduce storm surge.

Where it can applied
where there is an existign wetland that can be augmented

Benefits
Reduces flooding by providing lowlying place for water to go to.

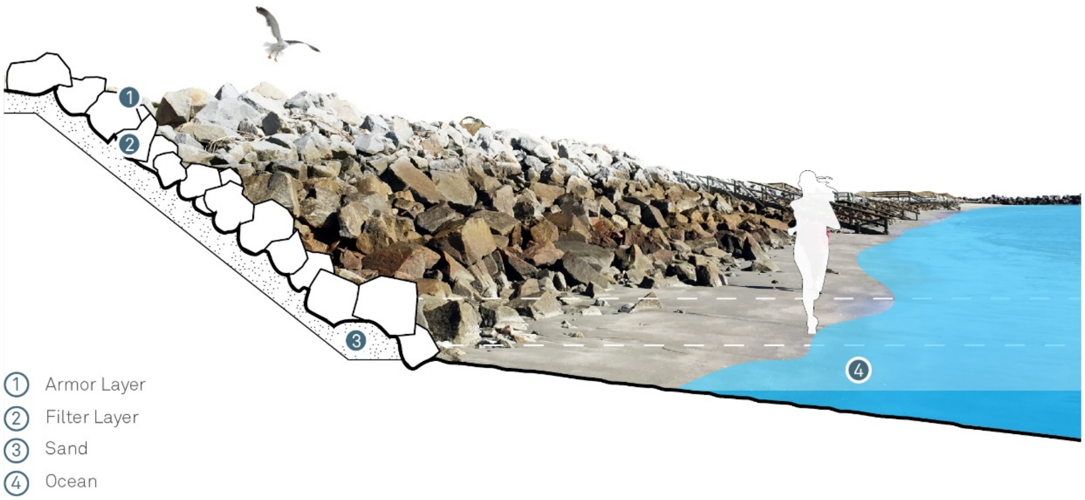
Barriers to implementation
Water quality, permitting, monitoring costs, maintenance, ecosystem impacts

Cost
$200k -$1 million/acre

Figure 102. Design considerations, benefits, barriers and costs for enhanced wetlands

5.1.33 Revetments

Like sea walls, surge barriers and levees, revetments (also known as riprap) are designed as sloping structures placed on banks in such a manner that they absorb the energy of incoming water. They reduce the potential for erosion of the coast and are common sites along the Florida coastline. Revetments are a coastal armoring tool, applicable in ocean environments primarily. Design considerations are summarized in Figure 103.



33. Revetment

Like sea walls, surge barriers and levees, revetments are designed as sloping structures placed on banks in such a manner that they absorb the energy of incoming water. They reduce the potential for erosion of the coast. They are a coastal armoring tool, applicable in ocean environments primarily.

Where it can applied
retnetion, helps maintain the storage volume, in conjunction w other measures

Benefits
improves walls of retainage

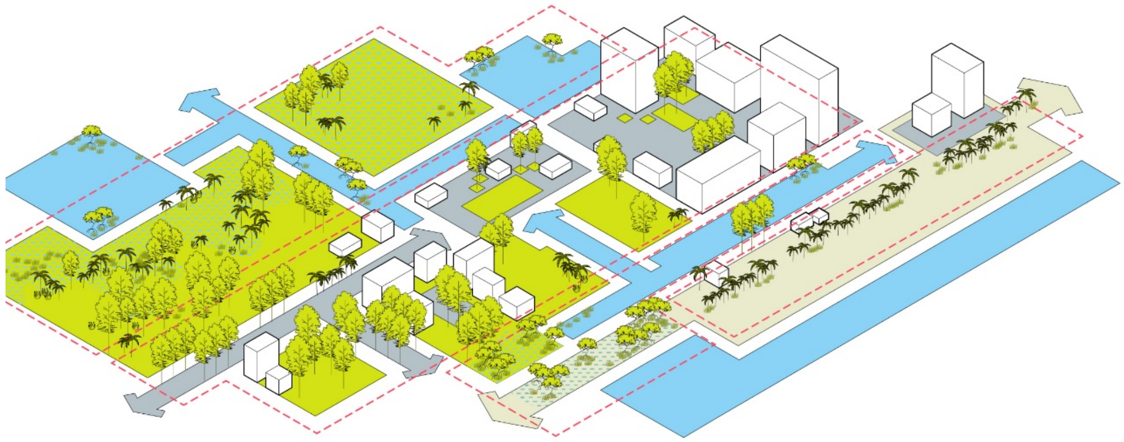
Barriers to implementation
land area, maintenance

Cost
Varies based on material, depth, and any substructural elements

Figure 103. Design considerations, benefits, barriers and costs for revetments

5.1.34 Changes in Land Use Practices

Reduced development and the migration of development in these areas should be a priority in local communities. The use of low impact development (LID) techniques to delay peak and reduce stormwater runoff can be a cost-effective option to consider from a land use perspective. Longer term, development policies will need to include the 50- and 100-year vision of development and require developers to include hardening within ordinances. This policy highlights a potential conflict point where the long-term the tax base will depend on securing future protection, yet taking property out of service reduces the tax base. Additional development in flood prone areas should not be permitted without local solutions. State and local agencies have been averse to such regulations due to private property rights arguments. However, certain properties may have value to local governments for various purposes (storage of stormwater for example or mangrove forests to counter waves). However, this is a policy decision that is likely years out. Design considerations are summarized in Figure 104.



34. Changes in Land-Use Practices

Reduced development and the migration of development in these areas should be a priority in local communities. The use of low impact development (LID) techniques to delay peak and reduce stormwater runoff can be a cost-effective option to consider from a land use perspective. Longer term, development policies will need to include the 50- and 100-year vision of development and require developers to include hardening within ordinances. Additional development in flood prone areas should not be permitted without local solutions. With time, at-risk property values will diminish due to the lack of ability to secure insurance and financing. The property may have value to local governments for various purposes (storage of stormwater for example or mangrove forests to counter waves). However, this is a policy decision that is likely years out.

Where it can applied
all low-lying and upland areas that are prone to flooding

Benefits
retention/filtration/infiltration/treatment

Barriers to implementation
conventional practices create obduracy

Cost
Varies

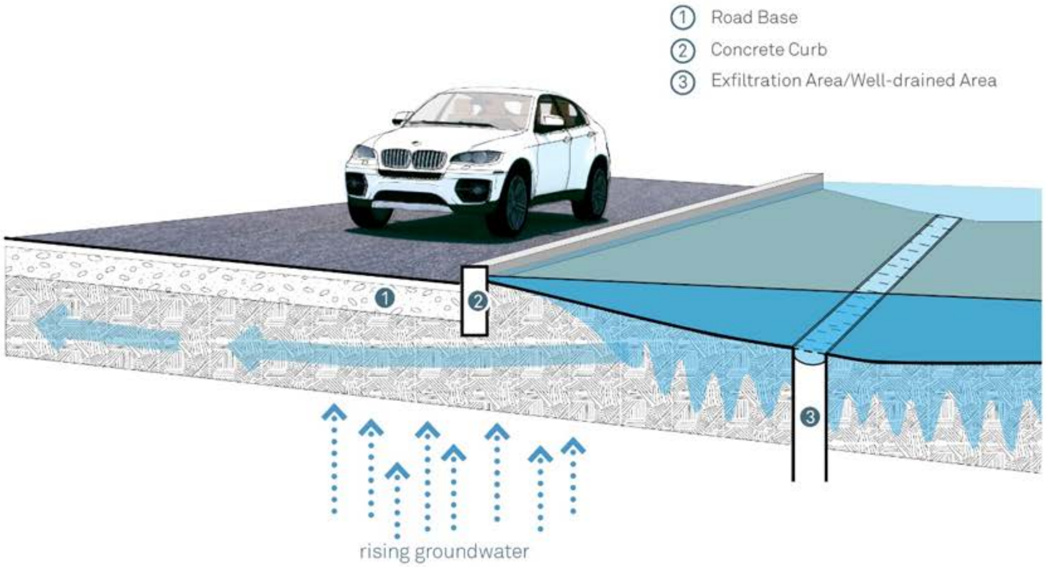
Figure 104. Design considerations, benefits, barriers and costs for changes in land use practices

5.1.35 Roadway Base Protections

A major reason is that many wastewater treatment plants originated as small developer-owned systems designed to serve their development, and later were deeded to local governments. Conventional disposal methods (e.g., stream discharges or ocean outfalls) are not easily permitted or have proven to not be sustainable in this part of the state. The costs of injection wells for small systems cannot be justified either, so the reuse (usually by percolation ponds) of small quantities of wastewater was the chosen alternative for disposal. Because it is critical to protect the roadway base, all efforts should begin with providing the base with adequate drainage systems to meet future conditions. At present, most base courses are installed above the water table. As long as the base stays dry, the roadway surface will remain stable. As soon as the base is saturated, the roadway can deteriorate. As water levels rise, well point systems (Figure 105) may need to be installed for more permanent drainage. However, well point water is usually turbid--containing sand, other particles, and contaminants from runoff, which requires an offsite discharge zone. Treatment areas for removal of particulates and sand will also be required, requiring additional area for discharge purposes. Wellpoint pump stations need to be regularly spaced along the affected roadway. As a result, a series of pump stations might be needed for every mile of roadway since typical dewatering systems are generally confined to areas less than 500 feet in length. Since well point stations do not function in flood conditions, additional drainage measures must be taken to address well point failure during heavy rainfall events.

Figure 105. Well point system installation to help drain a roadway construction project in Town of Davie, FL

The costs for roadway base protection systems could exceed $1 million per lane mile. Design considerations are summarized in Figure 106.



35. Roadway Base Protections

Because it is critical to protect the roadway base, all efforts should begin with providing the base with adequate drainage systems to meet future conditions. At present, most base courses are installed above the water table. As long as the base stays dry, the roadway surface will remain stable. As soon as the base is saturated, the roadway can deteriorate. As water levels rise, well point systems may need to be installed for more permanent drainage. However, well point water is usually turbid--containing sand, other particles, and contaminants from runoff, which requires an offsite discharge zone. The costs for such systems could exceed $1 million per lane mile.

Where it can applied
all roadways should consider protections, especially in low-lying areas

Benefits
reduced maintenance and longivity of roadway

Barriers to implementation
cost considerations

Cost
$1 million/mile

Figure 106. Design considerations, benefits, barriers and costs for roadway base protections

5.1.36 Summary of toolbox options

Table 9 outlines each of these options, their benefits and limitations.

Table 9. 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 ea	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 ea	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/ac	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

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
Green	Detention	Common for new development, but difficult to retrofit; limited to open areas	Removes water from streets, reduces flooding	$200K/ac	Land availability, maintenance of pond, discharge location Uses up land that could otherwise be developed
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/mi	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/ac	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/ac	Limited volume disposed of, so many are needed, maintenance

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
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)
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/mi	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/ac depending on whether it is already developed	Difficult to implement if occupied, issues with willing sellers, cost, lack of funds for acquisition

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
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/gal	If the tank is full, there is no storage
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/ac	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

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
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
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/ac	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)

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
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/ac	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/ac	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
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

Strategy Class	Implementation Strategy	Applications	Benefits	Cost	Barriers to Implementation
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

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 services 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 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 watershed and flood protection agencies.

Drilling down into the community of Clewiston, FL, the eastern portion of the City is identified by the screening tool as flood-prone (refer to Figure 108 left). As a result, the efforts of the City are focused on those eastern properties. One solution would be a pump station to resolve the flooding (Figure 107).

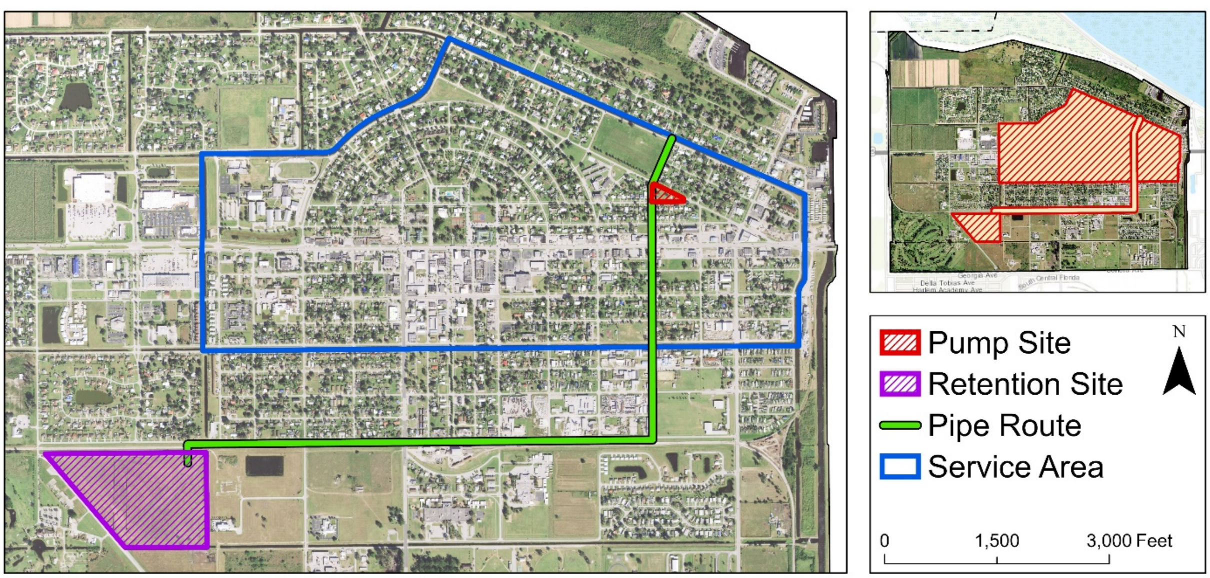


Figure 107. Proposed site layout of flood control pump station for eastern Clewiston, FL

A simulation of the impact of installing the pumping station shows a substantial difference to the expected flooding (Figure 108). The areas shaded in blue correspond to those properties that are flooded during the 3-day, 25-year storm event with and without infrastructure improvements.

Figure 108. Results of screening tool flood modeling before (left) and after (right) simulating installation of the pumping station (areas shaded in blue correspond to those properties that are flooded during the 3-day, 25-year storm event)

5.3 Prioritization of Risk

Section 4.2 outlined the process for identifying the priority projects. The next step is to establish a scoring system, which consists of a *risk factor* and a *probability factor* for each project. The risk factor should be associated with the potential consequences or losses associated with the project and other factors. The probability factor relates to how frequently or likely the event that would put the community at risk will occur. Although weighting is not necessary, if some of the selection criteria have more priority than the others, then a weighting factor can be applied. The weighting factor can be related to the level of importance assigned to each criterion. For example, Scott and Smith (2019) assigned a weighted composite score using stakeholder input based on flood probability factor (65%) and consequence of risk factor (35%) assessments.

A matrix is a visual representation of the analysis. The goal is to have the lowest composite risk items at the bottom and the highest at the top. The exact decision of the various projects will vary from watershed to watershed but should help identify those projects that should be prioritized. Table 10 is an example of the projects and the composite risk factor calculation based on a 50-50 split of probability and risk factors. There is the potential for tie scores. In this case, the projects with the higher consequence factor have been assigned higher priority. For example, in Table 10, the Route 10 bridge is assigned a higher consequence of failure than the condo pump station but lower than the Route 66 pump station replacement, and therefore is considered as the fourth highest composite risk project in the priority list.

Table 10. Composite risk matrix showing probability factors and risk factors

Project	Flood Probability Factor (50%)	Consequence of Risk Factor (50%)	Composite Risk Factor (100%)	Cost ($M)
Route 95 culvert replacement	4	5	4.5	$10.90
Downtown drainage renovations	4	4	4.0	$0.25
Route 66 pump station replacement	2	5	3.5	$1.20
Route 10 bridge replacement	3	4	3.5	$11.10
Condo association pump station installation	4	3	3.5	$0.45
Levee reinforcement	2	4	3.0	$12.50
Highway exfiltration trench	4	2	3.0	$0.05
Neighborhood J stormwater pond	5	1	3.0	$0.05
Route 16 culvert replacement	1	4	2.5	$1.10
Beach resort pump station installation	3	2	2.5	$0.35
Farm berm repair	4	1	2.5	$0.07
Route 20 culvert replacement	1	3	2.0	$1.30
County ballpark exfiltration trench	3	1	2.0	$0.15
Neighborhood X pipe replacement	2	1	1.5	$0.15
TOTAL				**$39.62**

The example has identified and objectively prioritized the topmost impactful implementation projects such as (in order of importance): Route 95 culvert replacements, downtown drainage renovations, Route 66 pump station replacement, etc. This process is systematic and objective rather than subjective. However, 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, so that the process meets the needs of the community. Using a matrix table and including costs, allows for rapid prioritization to assign the proper resources to make the most impact with limited funds. The next step is to develop a way to finance the implementation plan.

5.4 Capital Improvement and Financing 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 in order to allow the organization to pay its own way, which will also make it easier to evaluate the operational aspects of an infrastructure system.

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

1. "Inventory existing management efforts in the watershed, considering local priorities and institutional drivers
2. Quantify the effectiveness of current management measures
3. Identify new management opportunities
4. Identify critical areas in the watershed where additional management efforts are needed
5. Identify possible management practices
6. Identify relative pollutant reduction efficiencies
7. Develop screening criteria to identify opportunities and constraints
8. Rank alternatives and develop candidate management opportunities"

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 financial forecasts and financial plans are common tools in business and are worthy of consideration by elected officials.

6.0 ACTION PLAN

The previous sections have described the process of developing the initial plan, but the plan is the starting point not the end. To ensure communities are resilient in the future, the management recommendations prescribed in the plan must be implemented. First, it may be necessary to put together an implementation team. This group is likely different from the stakeholder partners assembled for the planning stage. Consider creating a watershed implementation team made up of key stakeholder partners rom 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. Also consider hiring an administrator that can act as the watershed plan implementation coordinator to lead the effort. In summary, the key components of the implementation phase are: a) the implementation team, b) information/education, c) capital improvement projects, d) maintenance, e) monitoring, and f) evaluation and adjustments.

6.1 Information Education Component

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

For more information on planning and implementing outreach campaigns, refer to USEPA's Getting in Step: A Guide for Conducting Watershed Outreach Campaigns. 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

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.

USEPA has developed a "Nonpoint Source Outreach Digital Toolbox," that provides information, tools, and outreach materials that state and local agencies and organizations can use to launch their own nonpoint source pollution outreach campaign. The toolbox is available at www.epa.gov/nps/toolbox/, and it focuses on six nonpoint source categories: stormwater, household hazardous waste, septic systems, lawn care, pet care, and automotive care, with messages geared to urban and suburban residents. Outreach products include mass-media materials, such as print ads, radio and television public service announcements, and a variety of materials for billboards, signage, kiosks, posters, movie theater slides, brochures, factsheets, and everyday object giveaways that help to raise awareness and promote non-polluting behaviors. Permission-to-use information is included for outreach products, which makes it easy to tailor them to local priorities. Evaluations of several outreach campaigns also offer real-world examples of what works best in terms of messages, communication styles, formats, and delivery methods.

6.2 Maintenance Plan

The goal of a stormwater management system 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 initial goal of a stormwater management system is always to remove excess water in a timely manner, to a place where it will not adversely impact the public. 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 stormwater organization – typically a special district, stormwater utility or a division of a local government. A community's stormwater system consists of pipes, catch basins, curb inlets, culverts, canals, swales, pump stations, ditches and manholes inlets, and other structures that help channel the stormwater to rivers, lakes, retention basins or canals, but may also direct it into basins that help resupply groundwater. Typical tasks are 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

- 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
- Stabilize banks on wet and dry retention areas
- Nutrient/pesticide management
- Clean bottom debris

Every five (5) years

- Scrape bottom or retention areas and swales
- Re-sod banks of wet and dry retention areas as needed
- Inspect all retention ponds

In additions the local governments should develop, maintain and conform to Standard Operating Procedure in accordance with stormwater permits. Finally, maintenance requires good records so the local communities should:

- Develop and maintain accurate mapping of the drainage system
- Track areas with ongoing stormwater issues and develop programs to alleviate same

All of these stormwater solutions require consistent, ongoing maintenance in order to work properly and some form of work order tracking system that will allow operators and managers to identify problem areas and track work performed. Like water and sewer, the failure to maintain these structures, creates the potential for flooding, which may put the organization at risk for responsibility of damage on public or private property. Lawsuits can be lost due to negligence of ongoing maintenance of a stormwater system. As is apparent, the majority of the stormwater system costs have traditionally been associated with maintenance activities (70% are often estimated to be operations costs) to insure the existing facilities channel water as anticipated.

6.3 Monitoring and Evaluation Plan

Finally, the watershed master plan needs a monitoring and evaluate plan to assess progress toward achieving the goals and provide a scientific basis for appropriately modifying the approach to better achieve the goals if insufficient progress is demonstrated. There are two reasons to monitor and evaluate the watershed master plan implementation. First, it is necessary to demonstrate that the management measures implemented are achieving the project goals. Second, it is critical to continuously improve the planned implementation strategies in terms of effectiveness and performance. Collecting data alone is not sufficient, if it is not used to improve the watershed master plan implementation on an ongoing basis. It is preferred to select appropriate indicators that inform quantitatively on the extent of progress. Examples of quantitative indicators are shown in Table 11.

Table 11. Examples of quantitative indicators for watershed master planning implementation

Activity Type	Example Indicators
Informational	Number of downloads, number of events conducted, number of residents at each event, etc.
Regulatory	Number of permit applications, change in property values, etc.
Property protection	Property values increase, total valuation increases, flood claims lower
Flood insurance premiums	Percent decrease in premiums year over year
Repetitive loss properties	Decrease in growth of repetitive loss properties
Infrastructure	Number of management practices installed, load reductions, numbers of inspections, dollars spent, etc.

For more information on developing monitoring programs, visit the National NPS Monitoring Program at www.bae.ncsu.edu/programs/extension/wqg/319index.htm. Because stormwater protection is often is 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 water bodies through neighboring jurisdictions. Monitoring programs are primarily administrative feature of watershed management. An effective monitoring program (EMP) will assess implementation and provide necessary information to prevent failures or property damage, or at least reduce the risk of same. 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 FAC
- Strengthen local Comp plans and submit same to 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 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

Environmental/watershed monitoring programs should verify ongoing demonstration of maintenance through the use of logs, work orders, photographic documentation and in the best of worlds, 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 that monies are available to properly execute the program to ensure 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.

If the monitoring plan determines that the project goal is not on track to meeting interim targets or milestones, then it is time to rethink the strategy. There are several possible explanations for why this might have occurred. Sometimes it takes longer than anticipated to demonstrate tangible results. Sometimes management practices have been installed but are not being maintained properly. Sometimes insufficient funds were available and impacted the effectiveness of the implementation strategy. Sometimes unanticipated events adversely impact the implementation (i.e. pandemics, natural disasters, political changes, industrial accidents, etc.). Whatever the reason, if the targets are not being met, it is time to reevaluate the target values and timelines as well as the indicator being used.

Periodically revisiting the plan and reexamining prior assessments is recommended. The watershed master planning team can change the priorities, schedule of activities, monitoring measures, and shift resources or responsible parties to better achieve the original goals of the plan or to identify new or improved goals.

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APPENDIX A: FLORIDA MODEL ORDINANCE

Model Code-Companion Floodplain Management Ordinance For Communities with Inland (Zone A) and Coastal High Hazard Areas (Zone V). April 3, 2017.

Note: This FINAL version includes inland flood hazard areas (zones shown on FIRMs that start with the "A") and coastal high hazard areas (zones that start with letter" V"). It does not include any "higher standards." Contact Technical Support mailto:for assistance with higher standards.

Please download the Instructions and Notes that go with this model, also dated April 3, 2017.

Please make any and all changes using <track changes> to facilitate DEM's review. We recommend resolving all text changes and obtaining review by Technical Support before renumbering to be consistent with your community's Code of Ordinances.

*Technical Support: Email for help and submit drafts to **flood.ordinance@em.myflorida.com**. Please allow plenty of time for at least two reviews (longer if you make many changes) – at a minimum provide the first draft at least 6 weeks before your first reading. At any given time we have many draft ordinances under review and cannot guarantee turn-around.*

NOTE: This model ordinance is specifically written as a companion to the FBC, which has requirements for buildings in flood hazard areas. DO NOT copy from your existing regulations and paste into this ordinance any requirements for buildings. For "higher standards" that affect the design of buildings (such as freeboard), see the instructions on DEM's webpage and contact Technical Support for assistance.

ORDINANCE NO. XX-XX

AN ORDINANCE BY THE {community's governing body} AMENDING THE {name of community} CODE OF ORDINANCES TO REPEAL {insert appropriate chapter/section numbers}; TO ADOPT A NEW {insert appropriate chapter/section numbers}; TO ADOPT FLOOD HAZARD MAPS, TO DESIGNATE A FLOODPLAIN ADMINISTRATOR, TO ADOPT PROCEDURES AND CRITERIA FOR DEVELOPMENT IN FLOOD HAZARD AREAS, AND FOR OTHER PURPOSES; PROVIDING FOR APPLICABILITY; SEVERABILITY; AND AN EFFECTIVE DATE.

WHEREAS, the Legislature of the State of Florida has, in {Chapter 125 – County Government or Chapter 166 – Municipalities}, Florida Statutes, conferred upon local governments the authority to adopt regulations designed to promote the public health, safety, and general welfare of its citizenry; and

WHEREAS, the Federal Emergency Management Agency has identified special flood hazard areas within the boundaries of {name of community} and such areas may be subject to periodic inundation which may result in loss of life and property, health and safety hazards, disruption of commerce and governmental services, extraordinary public expenditures for flood protection and relief, and impairment of the tax base, all of which adversely affect the public health, safety and general welfare, and

WHEREAS, the {name of community} was accepted for participation in the National Flood Insurance Program on {date of regular program entry} and the {community's governing body} desires to continue to meet the requirements of Title 44 Code of Federal Regulations, Sections 59 and 60, necessary for such participation; and

WHEREAS, Chapter 553, Florida Statutes, was adopted by the Florida Legislature to provide a mechanism for the uniform adoption, updating, amendment, interpretation and enforcement of a state building code, called the *Florida Building Code*; and

WHEREAS, the {community's governing body} has determined that it is in the public interest to adopt the proposed floodplain management regulations that are coordinated with the *Florida Building Code.*

NOW, THEREFORE, BE IT ORDAINED by the {community's governing body} of {name of community} that the following floodplain management regulations are hereby adopted.

SECTION 1. RECITALS.

The foregoing whereas clauses are incorporated herein by reference and made a part hereof.

SECTION 2. This ordinance specifically repeals and replaces the following ordinance(s) and regulation(s): {insert citation to existing flood damage reduction regulations that will be replaced by these regulations and citation(s) to other ordinances that have flood provisions, such as subdivision regulations that also will be replaced by these regulations}.

ARTICLE I ADMINISTRATION

SECTION 101 GENERAL

101.1 Title. These regulations shall be known as the *Floodplain Management Ordinance* of {name of community}, hereinafter referred to as "this ordinance."

101.2 Scope. The provisions of this ordinance shall apply to all development that is wholly within or partially within any flood hazard area, including but not limited to the subdivision of land; filling, grading, and other site improvements and utility installations; construction, alteration, remodeling, enlargement, improvement, replacement, repair, relocation or demolition of buildings, structures, and facilities that are exempt from the *Florida Building Code*; placement, installation, or replacement of manufactured homes and manufactured buildings; installation or replacement of tanks; placement of recreational vehicles; installation of swimming pools; and any other development.

101.3 Intent. The purposes of this ordinance and the flood load and flood resistant construction requirements of the *Florida Building Code* are to establish minimum requirements to safeguard the public health, safety, and general welfare and to minimize public and private losses due to flooding through regulation of development in flood hazard areas to:

- Minimize unnecessary disruption of commerce, access and public service during times of flooding;
- Require the use of appropriate construction practices in order to prevent or minimize future flood damage;
- Manage filling, grading, dredging, mining, paving, excavation, drilling operations, storage of equipment or materials, and other development which may increase flood damage or erosion potential;
- Manage the alteration of flood hazard areas, watercourses, and shorelines to minimize the impact of development on the natural and beneficial functions of the floodplain;
- Minimize damage to public and private facilities and utilities;
- Help maintain a stable tax base by providing for the sound use and development of flood hazard areas;
- Minimize the need for future expenditure of public funds for flood control projects and response to and recovery from flood events; and
- Meet the requirements of the National Flood Insurance Program for community participation as set forth in Title 44 Code of Federal Regulations, Section 59.22.

101.4 Coordination with the *Florida Building Code*. This ordinance is intended to be administered and enforced in conjunction with the *Florida Building Code*. Where cited, ASCE 24 refers to the edition of the standard that is referenced by the *Florida Building Code.*

101.5 Warning. The degree of flood protection required by this ordinance and the *Florida Building Code*, as amended by this community, is considered the minimum reasonable for regulatory purposes and is based on scientific and engineering considerations. Larger floods can and will occur. Flood heights may be increased by man-made or natural causes. This ordinance does not imply that land outside of mapped special flood hazard areas, or that uses permitted within such flood hazard areas, will be free from flooding or flood damage. The flood hazard areas and base flood elevations contained in the Flood Insurance Study and shown on Flood Insurance Rate Maps and the requirements of Title 44 Code of Federal Regulations, Sections 59 and 60 may be revised by the Federal Emergency Management Agency, requiring this community to revise these regulations to remain eligible for participation in the National Flood Insurance Program. No guaranty of vested use, existing use, or future use is implied or expressed by compliance with this ordinance.

101.6 Disclaimer of Liability. This ordinance shall not create liability on the part of **{governing body}** of **{name of community}** or by any officer or employee thereof for any flood damage that results from reliance on this ordinance or any administrative decision lawfully made thereunder.

SECTION 102 APPLICABILITY

102.1 General. Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable.

102.2 Areas to which this ordinance applies. This ordinance shall apply to all flood hazard areas within the {name of community}, as established in Section 102.3 of this ordinance.

102.3 Basis for establishing flood hazard areas. The Flood Insurance Study for {insert title of FIS} dated {insert date of FIS}, and all subsequent amendments and revisions, and the accompanying Flood Insurance Rate Maps (FIRM), and all subsequent amendments and revisions to such maps, are adopted by reference as a part of this ordinance and shall serve as the minimum basis for establishing flood hazard areas. Studies and maps that establish flood hazard areas are on file at the {Office/agency and address}.

102.4 Submission of additional data to establish flood hazard areas. To establish flood hazard areas and base flood elevations, pursuant to Section 105 of this ordinance the Floodplain Administrator may require submission of additional data. Where field surveyed topography prepared by a Florida licensed professional surveyor or digital topography accepted by the community indicates that ground elevations:
Are below the closest applicable base flood elevation, even in areas not delineated as a special flood hazard area on a FIRM, the area shall be considered as flood hazard area and subject to the requirements of this ordinance and, as applicable, the requirements of the *Florida Building Code*.
Are above the closest applicable base flood elevation, the area shall be regulated as special flood hazard area unless the applicant obtains a Letter of Map Change that removes the area from the special flood hazard area.

102.5 Other laws. The provisions of this ordinance shall not be deemed to nullify any provisions of local, state or federal law.

102.6 Abrogation and greater restrictions. This ordinance supersedes any ordinance in effect for management of development in flood hazard areas. However, it is not intended to repeal or abrogate any existing ordinances including but not limited to land development regulations, zoning ordinances, stormwater management regulations, or the *Florida Building Code*. In the event of a conflict between this ordinance and any other ordinance, the more restrictive shall govern. This ordinance shall not impair any deed restriction, covenant or easement, but any land that is subject to such interests shall also be governed by this ordinance.

102.7 Interpretation. In the interpretation and application of this ordinance, all provisions shall be:
Considered as minimum requirements;
Liberally construed in favor of the governing body; and
Deemed neither to limit nor repeal any other powers granted under state statutes.

SECTION 103 DUTIES AND POWERS OF THE FLOODPLAIN ADMINISTRATOR

103.1 Designation. The {insert position title} is designated as the Floodplain Administrator. The Floodplain Administrator may delegate performance of certain duties to other employees.

103.2 General. The Floodplain Administrator is authorized and directed to administer and enforce the provisions of this ordinance. The Floodplain Administrator shall have the authority to render interpretations of this ordinance consistent with the intent and purpose of this ordinance and may establish policies and procedures in order to clarify the application of its provisions. Such interpretations, policies, and procedures shall not have the effect of waiving requirements specifically provided in this ordinance without the granting of a variance pursuant to Section 107 of this ordinance.

103.3 Applications and permits. The Floodplain Administrator, in coordination with other pertinent offices of the community, shall:

- Review applications and plans to determine whether proposed new development will be located in flood hazard areas;
- Review applications for modification of any existing development in flood hazard areas for compliance with the requirements of this ordinance;
- Interpret flood hazard area boundaries where such interpretation is necessary to determine the exact location of boundaries; a person contesting the determination shall have the opportunity to appeal the interpretation;
- Provide available flood elevation and flood hazard information;
- Determine whether additional flood hazard data shall be obtained from other sources or shall be developed by an applicant;
- Review applications to determine whether proposed development will be reasonably safe from flooding;
- Issue floodplain development permits or approvals for development other than buildings and structures that are subject to the *Florida Building Code*, including buildings, structures and facilities exempt from the *Florida Building Code*, when compliance with

this ordinance is demonstrated, or disapprove the same in the event of noncompliance; and

- Coordinate with and provide comments to the Building Official to assure that applications, plan reviews, and inspections for buildings and structures in flood hazard areas comply with the applicable provisions of this ordinance.

103.4 Substantial improvement and substantial damage determinations. For applications for building permits to improve buildings and structures, including alterations, movement, enlargement, replacement, repair, change of occupancy, additions, rehabilitations, renovations, substantial improvements, repairs of substantial damage, and any other improvement of or work on such buildings and structures, the Floodplain Administrator, in coordination with the Building Official, shall:

- Estimate the market value, or require the applicant to obtain an appraisal of the market value prepared by a qualified independent appraiser, of the building or structure before the start of construction of the proposed work; in the case of repair, the market value of the building or structure shall be the market value before the damage occurred and before any repairs are made;
- Compare the cost to perform the improvement, the cost to repair a damaged building to its pre-damaged condition, or the combined costs of improvements and repairs, if applicable, to the market value of the building or structure;
- Determine and document whether the proposed work constitutes substantial improvement or repair of substantial damage; and
- Notify the applicant if it is determined that the work constitutes substantial improvement or repair of substantial damage and that compliance with the flood resistant construction requirements of the *Florida Building Code* and this ordinance is required.

103.5 Modifications of the strict application of the requirements of the *Florida Building Code*. The Floodplain Administrator shall review requests submitted to the Building Official that seek approval to modify the strict application of the flood load and flood resistant construction requirements of the *Florida Building Code* to determine whether such requests require the granting of a variance pursuant to Section 107 of this ordinance.

103.6 Notices and orders. The Floodplain Administrator shall coordinate with appropriate local agencies for the issuance of all necessary notices or orders to ensure compliance with this ordinance.

103.7 Inspections. The Floodplain Administrator shall make the required inspections as specified in Section 106 of this ordinance for development that is not subject to the *Florida Building Code,* including buildings, structures and facilities exempt from the *Florida Building Code*. The Floodplain Administrator shall inspect flood hazard areas to determine if development is undertaken without issuance of a permit.

103.8 Other duties of the Floodplain Administrator. The Floodplain Administrator shall have other duties, including but not limited to:

- Establish, in coordination with the Building Official, procedures for administering and documenting determinations of substantial improvement and substantial damage made pursuant to Section 103.4 of this ordinance;
- Require that applicants proposing alteration of a watercourse notify adjacent communities and the Florida Division of Emergency Management, State Floodplain Management Office, and submit copies of such notifications to the Federal Emergency Management Agency (FEMA);
- Require applicants who submit hydrologic and hydraulic engineering analyses to support permit applications to submit to FEMA the data and information necessary to maintain the Flood Insurance Rate Maps if the analyses propose to change base flood elevations, flood hazard area boundaries, or floodway designations; such submissions shall be made within 6 months of such data becoming available;
- Review required design certifications and documentation of elevations specified by this ordinance and the *Florida Building Code* to determine that such certifications and documentations are complete;
- Notify the Federal Emergency Management Agency when the corporate boundaries of {name of community} are modified; and
- Advise applicants for new buildings and structures, including substantial improvements, that are located in any unit of the Coastal Barrier Resources System established by the Coastal Barrier Resources Act (Pub. L. 97-348) and the Coastal Barrier Improvement Act of 1990 (Pub. L. 101-591) that federal flood insurance is not available on such construction; areas subject to this limitation are identified on Flood Insurance Rate Maps as “Coastal Barrier Resource System Areas” and “Otherwise Protected Areas.”

103.9 Floodplain management records. Regardless of any limitation on the period required for retention of public records, the Floodplain Administrator shall maintain and permanently keep and make available for public inspection all records that are necessary for the administration of this ordinance and the flood resistant construction requirements of the *Florida Building Code*, including Flood Insurance Rate Maps; Letters of Map Change; records of issuance of permits and denial of permits; determinations of whether proposed work constitutes substantial improvement or repair of substantial damage; required design certifications and documentation of elevations specified by the *Florida Building Code* and this ordinance; notifications to adjacent communities, FEMA, and the state related to alterations of watercourses; assurances that the flood carrying capacity of altered watercourses will be maintained; documentation related to appeals and variances, including justification for issuance or denial; and records of enforcement actions taken pursuant to this ordinance and the flood resistant construction requirements of the *Florida Building Code*. These records shall be available for public inspection at {location and instructions to request access, if applicable}.

SECTION 104 PERMITS

104.1 Permits required. Any owner or owner's authorized agent (hereinafter "applicant") who intends to undertake any development activity within the scope of this ordinance, including buildings, structures and facilities exempt from the *Florida Building Code*, which is wholly within or partially within any flood hazard area shall first make application to the Floodplain Administrator, and the Building Official if applicable, and shall obtain the required permit(s) and approval(s). No such permit or approval shall be issued until compliance with the requirements of this ordinance and all other applicable codes and regulations has been satisfied.

104.2 Floodplain development permits or approvals. Floodplain development permits or approvals shall be issued pursuant to this ordinance for any development activities not subject to the requirements of the *Florida Building Code,* including buildings, structures and facilities exempt from the *Florida Building Code*. Depending on the nature and extent of proposed development that includes a building or structure, the Floodplain Administrator may determine that a floodplain development permit or approval is required in addition to a building permit.

104.3 Buildings, structures and facilities exempt from the *Florida Building Code*. Pursuant to the requirements of federal regulation for participation in the National Flood Insurance Program (44 C.F.R. Sections 59 and 60), floodplain development permits or approvals shall be required for the following buildings, structures and facilities that are exempt from the *Florida Building Code* and any further exemptions provided by law, which are subject to the requirements of this ordinance:

- Railroads and ancillary facilities associated with the railroad.
- Nonresidential farm buildings on farms, as provided in section 604.50, F.S.
- Temporary buildings or sheds used exclusively for construction purposes.
- Mobile or modular structures used as temporary offices.
- Those structures or facilities of electric utilities, as defined in section 366.02, F.S., which are directly involved in the generation, transmission, or distribution of electricity.
- Chickees constructed by the Miccosukee Tribe of Indians of Florida or the Seminole Tribe of Florida. As used in this paragraph, the term "chickee" means an open-sided wooden hut that has a thatched roof of palm or palmetto or other traditional materials, and that does not incorporate any electrical, plumbing, or other non-wood features.
- Family mausoleums not exceeding 250 square feet in area which are prefabricated and assembled on site or preassembled and delivered on site and have walls, roofs, and a floor constructed of granite, marble, or reinforced concrete.
- Temporary housing provided by the Department of Corrections to any prisoner in the state correctional system.
- Structures identified in section 553.73(10)(k), F.S., are not exempt from the *Florida Building Code* if such structures are located in flood hazard areas established on Flood Insurance Rate Maps

104.4 Application for a permit or approval. To obtain a floodplain development permit or approval the applicant shall first file an application in writing on a form furnished by the community. The information provided shall:

- Identify and describe the development to be covered by the permit or approval.
- Describe the land on which the proposed development is to be conducted by legal description, street address or similar description that will readily identify and definitively locate the site.
- Indicate the use and occupancy for which the proposed development is intended.
- Be accompanied by a site plan or construction documents as specified in Section 105 of this ordinance.
- State the valuation of the proposed work.
- Be signed by the applicant or the applicant's authorized agent.
- Give such other data and information as required by the Floodplain Administrator.

104.5 Validity of permit or approval. The issuance of a floodplain development permit or approval pursuant to this ordinance shall not be construed to be a permit for, or approval of, any violation of this ordinance, the *Florida Building Codes*, or any other ordinance of this community. The issuance of permits based on submitted applications, construction documents, and information shall not prevent the Floodplain Administrator from requiring the correction of errors and omissions.

104.6 Expiration. A floodplain development permit or approval shall become invalid unless the work authorized by such permit is commenced within 180 days after its issuance, or if the work authorized is suspended or abandoned for a period of 180 days after the work commences. Extensions for periods of not more than 180 days each shall be requested in writing and justifiable cause shall be demonstrated.

104.7 Suspension or revocation. The Floodplain Administrator is authorized to suspend or revoke a floodplain development permit or approval if the permit was issued in error, on the basis of incorrect, inaccurate or incomplete information, or in violation of this ordinance or any other ordinance, regulation or requirement of this community.

104.8 Other permits required. Floodplain development permits and building permits shall include a condition that all other applicable state or federal permits be obtained before commencement of the permitted development, including but not limited to the following:

- The {insert name} Water Management District; section 373.036, F.S.
- Florida Department of Health for onsite sewage treatment and disposal systems; section 381.0065, F.S. and Chapter 64E-6, F.A.C.
- Florida Department of Environmental Protection for construction, reconstruction, changes, or physical activities for shore protection or other activities seaward of the coastal construction control line; section 161.141, F.S.

- Florida Department of Environmental Protection for activities subject to the Joint Coastal Permit; section 161.055, F.S.
- Florida Department of Environmental Protection for activities that affect wetlands and alter surface water flows, in conjunction with the U.S. Army Corps of Engineers; Section 404 of the Clean Water Act.
- Federal permits and approvals.

SECTION 105 SITE PLANS AND CONSTRUCTION DOCUMENTS

105.1 Information for development in flood hazard areas. The site plan or construction documents for any development subject to the requirements of this ordinance shall be drawn to scale and shall include, as applicable to the proposed development:

- Delineation of flood hazard areas, floodway boundaries and flood zone(s), base flood elevation(s), and ground elevations if necessary for review of the proposed development.
- Where base flood elevations or floodway data are not included on the FIRM or in the Flood Insurance Study, they shall be established in accordance with Section 105.2(2) or (3) of this ordinance.
- Where the parcel on which the proposed development will take place will have more than 50 lots or is larger than 5 acres and the base flood elevations are not included on the FIRM or in the Flood Insurance Study, such elevations shall be established in accordance with Section 105.2(1) of this ordinance.
- Location of the proposed activity and proposed structures, and locations of existing buildings and structures; in coastal high hazard areas, new buildings shall be located landward of the reach of mean high tide.
- Location, extent, amount, and proposed final grades of any filling, grading, or excavation.
- Where the placement of fill is proposed, the amount, type, and source of fill material; compaction specifications; a description of the intended purpose of the fill areas; and evidence that the proposed fill areas are the minimum necessary to achieve the intended purpose.
- Delineation of the Coastal Construction Control Line or notation that the site is seaward of the coastal construction control line, if applicable.
- Extent of any proposed alteration of sand dunes or mangrove stands, provided such alteration is approved by the Florida Department of Environmental Protection.
- Existing and proposed alignment of any proposed alteration of a watercourse.

The Floodplain Administrator is authorized to waive the submission of site plans, construction documents, and other data that are required by this ordinance but that are not required to be prepared by a registered design professional if it is found that the nature of the proposed development is such that the review of such submissions is not necessary to ascertain compliance with this ordinance.

105.2 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:

- Require the applicant to include base flood elevation data prepared in accordance with currently accepted engineering practices.
- 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.
- 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:
- Require the applicant to include base flood elevation data prepared in accordance with currently accepted engineering practices; or
- Specify that the base flood elevation is two (2) 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 two (2) feet.
- 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.

105.3 Additional analyses and certifications. As applicable to the location and nature of the proposed development activity, and in addition to the requirements of this section, the applicant shall have the following analyses signed and sealed by a Florida licensed engineer for submission with the site plan and construction documents:

- For development activities proposed to be located in a regulatory floodway, a floodway encroachment analysis that demonstrates that the encroachment of the proposed development will not cause any increase in base flood elevations; where the applicant proposes to undertake development activities that do increase base flood elevations, the applicant shall submit such analysis to FEMA as specified in Section 105.4 of this ordinance and shall submit the Conditional Letter of Map Revision, if issued by FEMA, with the site plan and construction documents.
- For development activities proposed to be located in a riverine flood hazard area for which base flood elevations are included in the Flood Insurance Study or on the FIRM and floodways have not been designated, hydrologic and hydraulic analyses that demonstrate that the cumulative effect of the proposed development, when combined with all other existing and anticipated flood hazard area encroachments, will not increase the base flood elevation more than one (1) foot at any point within the community. This requirement does not apply in isolated flood hazard areas not

connected to a riverine flood hazard area or in flood hazard areas identified as Zone AO or Zone AH.

- For alteration of a watercourse, an engineering analysis prepared in accordance with standard engineering practices which demonstrates that the flood-carrying capacity of the altered or relocated portion of the watercourse will not be decreased, and certification that the altered watercourse shall be maintained in a manner which preserves the channel's flood-carrying capacity; the applicant shall submit the analysis to FEMA as specified in Section 105.4 of this ordinance.
- For activities that propose to alter sand dunes or mangrove stands in coastal high hazard areas (Zone V), an engineering analysis that demonstrates that the proposed alteration will not increase the potential for flood damage.

105.4 Submission of additional data. When additional hydrologic, hydraulic or other engineering data, studies, and additional analyses are submitted to support an application, the applicant has the right to seek a Letter of Map Change from FEMA to change the base flood elevations, change floodway boundaries, or change boundaries of flood hazard areas shown on FIRMs, and to submit such data to FEMA for such purposes. The analyses shall be prepared by a Florida licensed engineer in a format required by FEMA. Submittal requirements and processing fees shall be the responsibility of the applicant.

SECTION 106 INSPECTIONS

106.1 General. Development for which a floodplain development permit or approval is required shall be subject to inspection.

106.2 Development other than buildings and structures. The Floodplain Administrator shall inspect all development to determine compliance with the requirements of this ordinance and the conditions of issued floodplain development permits or approvals.

106.3 Buildings, structures and facilities exempt from the *Florida Building Code*. The Floodplain Administrator shall inspect buildings, structures and facilities exempt from the *Florida Building Code* to determine compliance with the requirements of this ordinance and the conditions of issued floodplain development permits or approvals.

106.4 Buildings, structures and facilities exempt from the *Florida Building Code*, lowest floor inspection. Upon placement of the lowest floor, including basement, and prior to further vertical construction, the owner of a building, structure or facility exempt from the *Florida Building Code*, or the owner's authorized agent, shall submit to the Floodplain Administrator:
If a design flood elevation was used to determine the required elevation of the lowest floor, the certification of elevation of the lowest floor prepared and sealed by a Florida licensed professional surveyor; or

If the elevation used to determine the required elevation of the lowest floor was determined in accordance with Section 105.2(3)(b) of this ordinance, the documentation of height of the lowest floor above highest adjacent grade, prepared by the owner or the owner's authorized agent.

106.5 Buildings, structures and facilities exempt from the *Florida Building Code*, final inspection. As part of the final inspection, the owner or owner's authorized agent shall submit to the Floodplain Administrator a final certification of elevation of the lowest floor or final documentation of the height of the lowest floor above the highest adjacent grade; such certifications and documentations shall be prepared as specified in Section 106.4 of this ordinance.

106.6 Manufactured homes. The Floodplain Administrator shall inspect manufactured homes that are installed or replaced in flood hazard areas to determine compliance with the requirements of this ordinance and the conditions of the issued permit. Upon placement of a manufactured home, certification of the elevation of the lowest floor shall be submitted to the Floodplain Administrator.

SECTION 107 VARIANCES AND APPEALS

107.1 General. The {body designated to hear variances} shall hear and decide on requests for appeals and requests for variances from the strict application of this ordinance. Pursuant to section 553.73(5), F.S., the {body designated to hear variances} shall hear and decide on requests for appeals and requests for variances from the strict application of the flood resistant construction requirements of the *Florida Building Code*. This section does not apply to Section 3109 of the *Florida Building Code, Building.*

107.2 Appeals. The {body designated to hear variances} shall hear and decide appeals when it is alleged there is an error in any requirement, decision, or determination made by the Floodplain Administrator in the administration and enforcement of this ordinance. Any person aggrieved by the decision may appeal such decision to the Circuit Court, as provided by Florida Statutes.

107.3 Limitations on authority to grant variances. The {body designated to hear variances} shall base its decisions on variances on technical justifications submitted by applicants, the considerations for issuance in Section 107.7 of this ordinance, the conditions of issuance set forth in Section 107.8 of this ordinance, and the comments and recommendations of the Floodplain Administrator and the Building Official. The {body designated to hear variances} has the right to attach such conditions as it deems necessary to further the purposes and objectives of this ordinance.

107.4 Restrictions in floodways. A variance shall not be issued for any proposed development in a floodway if any increase in base flood elevations would result, as evidenced by the applicable analyses and certifications required in Section 105.3 of this ordinance.

107.5 Historic buildings. A variance is authorized to be issued for the repair, improvement, or rehabilitation of a historic building that is determined eligible for the exception to the flood resistant construction requirements of the *Florida Building Code, Existing Building*, Chapter 12 Historic Buildings, upon a determination that the proposed repair, improvement, or rehabilitation will not preclude the building's continued designation as a historic building and the variance is the minimum necessary to preserve the historic character and design of the building. If the proposed work precludes the building's continued designation as a historic building, a variance shall not be granted and the building and any repair, improvement, and rehabilitation shall be subject to the requirements of the *Florida Building Code*.

107.6 Functionally dependent uses. A variance is authorized to be issued for the construction or substantial improvement necessary for the conduct of a functionally dependent use, as defined in this ordinance, provided the variance meets the requirements of Section 107.4, is the minimum necessary considering the flood hazard, and all due consideration has been given to use of methods and materials that minimize flood damage during occurrence of the base flood.

107.7 Considerations for issuance of variances. In reviewing requests for variances, the {body designated to hear variances} shall consider all technical evaluations, all relevant factors, all other applicable provisions of the *Florida Building Code*, this ordinance, and the following:

- The danger that materials and debris may be swept onto other lands resulting in further injury or damage;
- The danger to life and property due to flooding or erosion damage;
- The susceptibility of the proposed development, including contents, to flood damage and the effect of such damage on current and future owners;
- The importance of the services provided by the proposed development to the community;
- The availability of alternate locations for the proposed development that are subject to lower risk of flooding or erosion;
- The compatibility of the proposed development with existing and anticipated development;
- The relationship of the proposed development to the comprehensive plan and floodplain management program for the area;
- The safety of access to the property in times of flooding for ordinary and emergency vehicles;
- The expected heights, velocity, duration, rate of rise and debris and sediment transport of the floodwaters and the effects of wave action, if applicable, expected at the site; and
- The costs of providing governmental services during and after flood conditions including maintenance and repair of public utilities and facilities such as sewer, gas, electrical and water systems, streets and bridges.

107.8 Conditions for issuance of variances. Variances shall be issued only upon:

- Submission by the applicant, of a showing of good and sufficient cause that the unique characteristics of the size, configuration, or topography of the site limit compliance with any provision of this ordinance or the required elevation standards;
- Determination by the {body designated to hear variances} that:
  - Failure to grant the variance would result in exceptional hardship due to the physical characteristics of the land that render the lot undevelopable; increased costs to satisfy the requirements or inconvenience do not constitute hardship;
  - The granting of a variance will not result in increased flood heights, additional threats to public safety, extraordinary public expense, nor create nuisances, cause fraud on or victimization of the public or conflict with existing local laws and ordinances; and
  - The variance is the minimum necessary, considering the flood hazard, to afford relief;
  - Receipt of a signed statement by the applicant that the variance, if granted, shall be recorded in the Office of the Clerk of the Court in such a manner that it appears in the chain of title of the affected parcel of land; and
  - If the request is for a variance to allow construction of the lowest floor of a new building, or substantial improvement of a building, below the required elevation, a copy in the record of a written notice from the Floodplain Administrator to the applicant for the variance, specifying the difference between the base flood elevation and the proposed elevation of the lowest floor, stating that the cost of federal flood insurance will be commensurate with the increased risk resulting from the reduced floor elevation (up to amounts as high as $25 for $100 of insurance coverage), and stating that construction below the base flood elevation increases risks to life and property.

SECTION 108 VIOLATIONS

108.1 Violations. Any development that is not within the scope of the *Florida Building Code* but that is regulated by this ordinance that is performed without an issued permit, that is in conflict with an issued permit, or that does not fully comply with this ordinance, shall be deemed a violation of this ordinance. A building or structure without the documentation of elevation of the lowest floor, other required design certifications, or other evidence of compliance required by this ordinance or the *Florida Building Code* is presumed to be a violation until such time as that documentation is provided.

108.2 Authority. For development that is not within the scope of the *Florida Building Code* but that is regulated by this ordinance and that is determined to be a violation, the Floodplain Administrator is authorized to serve notices of violation or stop work orders to owners of the property involved, to the owner's agent, or to the person or persons performing the work.

108.3 Unlawful continuance. Any person who shall continue any work after having been served with a notice of violation or a stop work order, except such work as that person is directed to perform to remove or remedy a violation or unsafe condition, shall be subject to penalties as prescribed by law {or insert specific reference to state or local law}.

ARTICLE II DEFINITIONS

SECTION 201 GENERAL

201.1 Scope. Unless otherwise expressly stated, the following words and terms shall, for the purposes of this ordinance, have the meanings shown in this section.

201.2 Terms defined in the *Florida Building Code*. Where terms are not defined in this ordinance and are defined in the *Florida Building Code*, such terms shall have the meanings ascribed to them in that code.

201.3 Terms not defined. Where terms are not defined in this ordinance or the *Florida Building Code*, such terms shall have ordinarily accepted meanings such as the context implies.

SECTION 202 DEFINITIONS

Alteration of a watercourse. A dam, impoundment, channel relocation, change in channel alignment, channelization, or change in cross-sectional area of the channel or the channel capacity, or any other form of modification which may alter, impede, retard or change the direction and/or velocity of the riverine flow of water during conditions of the base flood.

Appeal. A request for a review of the Floodplain Administrator's interpretation of any provision of this ordinance.

ASCE 24. A standard titled *Flood Resistant Design and Construction* that is referenced by the *Florida Building Code*. ASCE 24 is developed and published by the American Society of Civil Engineers, Reston, VA.

Base flood. A flood having a 1-percent chance of being equaled or exceeded in any given year. [Also defined in FBC, B, Section 202.] The base flood is commonly referred to as the "100-year flood" or the "1-percent-annual chance flood."

Base flood elevation. 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 202.]

Basement. The portion of a building having its floor subgrade (below ground level) on all sides. [Also defined in FBC, B, Section 202; see "Basement (for flood loads)".]

Coastal construction control line. The line established by the State of Florida pursuant to section 161.053, F.S., and recorded in the official records of the community, which defines that portion of the beach-dune system subject to severe fluctuations based on a 100-year storm surge, storm waves or other predictable weather conditions.

Coastal high hazard area. A special flood hazard area extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high velocity wave action from storms or seismic sources. Coastal high hazard areas are also referred to as "high hazard areas subject to high velocity wave action" or "V Zones" and are designated on Flood Insurance Rate Maps (FIRM) as Zone V1-V30, VE, or V.

Design flood. The flood associated with the greater of the following two areas: [Also defined in FBC, B, Section 202.]
Area with a floodplain subject to a 1-percent or greater chance of flooding in any year; or
Area designated as a flood hazard area on the community's flood hazard map, or otherwise legally designated.

Design flood elevation. 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 2 feet. [Also defined in FBC, B, Section 202.]

Development. Any man-made change to improved or unimproved real estate, including but not limited to, buildings or other structures, tanks, temporary structures, temporary or permanent storage of equipment or materials, mining, dredging, filling, grading, paving, excavations, drilling operations or any other land disturbing activities.

Encroachment. The placement of fill, excavation, buildings, permanent structures or other development into a flood hazard area which may impede or alter the flow capacity of riverine flood hazard areas.

Existing building and existing structure. Any buildings and structures for which the "start of construction" commenced before {date the community's first floodplain management ordinance was adopted}. [Also defined in FBC, B, Section 202.]

Existing manufactured home park or subdivision. A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including, at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed before {date the community's first floodplain management ordinance was adopted}.

Expansion to an existing manufactured home park or subdivision. The preparation of additional sites by the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads).

Federal Emergency Management Agency (FEMA). The federal agency that, in addition to carrying out other functions, administers the National Flood Insurance Program.

Flood or flooding. A general and temporary condition of partial or complete inundation of normally dry land from: [Also defined in FBC, B, Section 202.]
The overflow of inland or tidal waters.
The unusual and rapid accumulation or runoff of surface waters from any source.

Flood damage-resistant materials. Any construction material capable of withstanding direct and prolonged contact with floodwaters without sustaining any damage that requires more than cosmetic repair. [Also defined in FBC, B, Section 202.]

Flood hazard area. The greater of the following two areas: [Also defined in FBC, B, Section 202.]
The area within a floodplain subject to a 1-percent or greater chance of flooding in any year.
The area designated as a flood hazard area on the community's flood hazard map, or otherwise legally designated.

Flood Insurance Rate Map (FIRM). The official map of the community on which the Federal Emergency Management Agency has delineated both special flood hazard areas and the risk premium zones applicable to the community. [Also defined in FBC, B, Section 202.]

Flood Insurance Study (FIS). The official report provided by the Federal Emergency Management Agency that contains the Flood Insurance Rate Map, the Flood Boundary and Floodway Map (if applicable), the water surface elevations of the base flood, and supporting technical data. [Also defined in FBC, B, Section 202.]

Floodplain Administrator. The office or position designated and charged with the administration and enforcement of this ordinance (may be referred to as the Floodplain Manager).

Floodplain development permit or approval. An official document or certificate issued by the community, or other evidence of approval or concurrence, which authorizes performance of specific development activities that are located in flood hazard areas and that are determined to be compliant with this ordinance.

Floodway. The channel of a river or other riverine watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one (1) foot. [Also defined in FBC, B, Section 202.]

Floodway encroachment analysis. An engineering analysis of the impact that a proposed encroachment into a floodway is expected to have on the floodway boundaries and base flood elevations; the evaluation shall be prepared by a qualified Florida licensed engineer using standard engineering methods and models.

Florida Building Code. The family of codes adopted by the Florida Building Commission, including: *Florida Building Code, Building; Florida Building Code, Residential; Florida Building Code, Existing Building; Florida Building Code, Mechanical; Florida Building Code, Plumbing; Florida Building Code, Fuel Gas*.

Functionally dependent use. A use which cannot perform its intended purpose unless it is located or carried out in close proximity to water, including only docking facilities, port facilities that are necessary for the loading and unloading of cargo or passengers, and ship building and ship repair facilities; the term does not include long-term storage or related manufacturing facilities.

Highest adjacent grade. The highest natural elevation of the ground surface prior to construction next to the proposed walls or foundation of a structure.

Historic structure. Any structure that is determined eligible for the exception to the flood hazard area requirements of the *Florida Building Code, Existing Building*, Chapter 12 Historic Buildings.

Letter of Map Change (LOMC). An official determination issued by FEMA that amends or revises an effective Flood Insurance Rate Map or Flood Insurance Study. Letters of Map Change include:

- Letter of Map Amendment (LOMA): An amendment based on technical data showing that a property was incorrectly included in a designated special flood hazard area. A LOMA amends the current effective Flood Insurance Rate Map and establishes that a specific property, portion of a property, or structure is not located in a special flood hazard area.
- Letter of Map Revision (LOMR): A revision based on technical data that may show changes to flood zones, flood elevations, special flood hazard area boundaries and floodway delineations, and other planimetric features.

- Letter of Map Revision Based on Fill (LOMR-F): A determination that a structure or parcel of land has been elevated by fill above the base flood elevation and is, therefore, no longer located within the special flood hazard area. In order to qualify for this determination, the fill must have been permitted and placed in accordance with the community's floodplain management regulations.
- Conditional Letter of Map Revision (CLOMR): A formal review and comment as to whether a proposed flood protection project or other project complies with the minimum NFIP requirements for such projects with respect to delineation of special flood hazard areas. A CLOMR does not revise the effective Flood Insurance Rate Map or Flood Insurance Study; upon submission and approval of certified as-built documentation, a Letter of Map Revision may be issued by FEMA to revise the effective FIRM.

Light-duty truck. As defined in 40 C.F.R. 86.082-2, any motor vehicle rated at 8,500 pounds Gross Vehicular Weight Rating or less which has a vehicular curb weight of 6,000 pounds or less and which has a basic vehicle frontal area of 45 square feet or less, which is:

- Designed primarily for purposes of transportation of property or is a derivation of such a vehicle, or
- Designed primarily for transportation of persons and has a capacity of more than 12 persons; or
- Available with special features enabling off-street or off-highway operation and use.

Lowest floor. The lowest floor of the lowest enclosed area of a building or structure, including basement, but excluding any unfinished or flood-resistant enclosure, other than a basement, usable solely for vehicle parking, building access or limited storage provided that such enclosure is not built so as to render the structure in violation of the non-elevation requirements of the *Florida Building Code* or ASCE 24. [Also defined in FBC, B, Section 202.]

Manufactured home. A structure, transportable in one or more sections, which is eight (8) feet or more in width and greater than four hundred (400) square feet, and which is built on a permanent, integral chassis and is designed for use with or without a permanent foundation when attached to the required utilities. The term "manufactured home" does not include a "recreational vehicle" or "park trailer." [Also defined in 15C-1.0101, F.A.C.]

Manufactured home park or subdivision. A parcel (or contiguous parcels) of land divided into two or more manufactured home lots for rent or sale.

Market value. The price at which a property will change hands between a willing buyer and a willing seller, neither party being under compulsion to buy or sell and both having reasonable knowledge of relevant facts. As used in this ordinance, the term refers to the market value of buildings and structures, excluding the land and other improvements on the parcel. Market value may be established by a qualified independent appraiser, Actual Cash Value (replacement cost depreciated for age and quality of construction), or tax assessment value adjusted to approximate market value by a factor provided by the Property Appraiser.

New construction. For the purposes of administration of this ordinance and the flood resistant construction requirements of the *Florida Building Code*, structures for which the "start of construction" commenced on or after {date the community's first floodplain management ordinance was adopted} and includes any subsequent improvements to such structures.

New manufactured home park or subdivision. A manufactured home park or subdivision for which the construction of facilities for servicing the lots on which the manufactured homes are to be affixed (including at a minimum, the installation of utilities, the construction of streets, and either final site grading or the pouring of concrete pads) is completed on or after {date the community's first floodplain management ordinance was adopted}.

Park trailer. A transportable unit which has a body width not exceeding fourteen (14) feet and which is built on a single chassis and is designed to provide seasonal or temporary living quarters when connected to utilities necessary for operation of installed fixtures and appliances. [Defined in section 320.01, F.S.]

Recreational vehicle. A vehicle, including a park trailer, which is: [See section 320.01, F.S.)
- Built on a single chassis;
- Four hundred (400) square feet or less when measured at the largest horizontal projection;
- Designed to be self-propelled or permanently towable by a light-duty truck; and
- Designed primarily not for use as a permanent dwelling but as temporary living quarters for recreational, camping, travel, or seasonal use.

Sand dunes. Naturally occurring accumulations of sand in ridges or mounds landward of the beach.

Special flood hazard area. An area in the floodplain subject to a 1 percent or greater chance of flooding in any given year. Special flood hazard areas are shown on FIRMs as Zone A, AO, A1-A30, AE, A99, AH, V1-V30, VE or V. [Also defined in FBC, B Section 202.]

Start of construction. The date of issuance of permits for new construction and substantial improvements, provided the actual start of construction, repair, reconstruction, rehabilitation, addition, placement, or other improvement is within 180 days of the date of the issuance. The actual start of construction means either the first placement of permanent construction of a building (including a manufactured home) on a site, such as the pouring of slab or footings, the installation of piles, or the construction of columns.

Permanent construction does not include land preparation (such as clearing, grading, or filling), the installation of streets or walkways, excavation for a basement, footings, piers, or foundations, the erection of temporary forms or the installation of accessory buildings such as garages or sheds not occupied as dwelling units or not part of the main buildings. For a substantial improvement, the actual "start of construction" means the first alteration of any wall, ceiling, floor or other structural part of a building, whether or not that alteration affects the external dimensions of the building. [Also defined in FBC, B Section 202.]

Substantial damage. Damage of any origin sustained by a building or structure whereby the cost of restoring the building or structure to its before-damaged condition would equal or exceed 50 percent of the market value of the building or structure before the damage occurred. [Also defined in FBC, B Section 202.]

Substantial improvement. Any repair, reconstruction, rehabilitation, alteration, addition, or other improvement of a building or structure, the cost of which equals or exceeds 50 percent of the market value of the building or structure before the improvement or repair is started. If the structure has incurred "substantial damage," any repairs are considered substantial improvement regardless of the actual repair work performed. The term does not, however, include either: [Also defined in FBC, B, Section 202.]

- Any project for improvement of a building required to correct existing health, sanitary, or safety code violations identified by the building official and that are the minimum necessary to assure safe living conditions.
- Any alteration of a historic structure provided the alteration will not preclude the structure's continued designation as a historic structure. *[See Instructions and Notes]*

Variance. A grant of relief from the requirements of this ordinance, or the flood resistant construction requirements of the *Florida Building Code*, which permits construction in a manner that would not otherwise be permitted by this ordinance or the *Florida Building Code*.

Watercourse. A river, creek, stream, channel or other topographic feature in, on, through, or over which water flows at least periodically.

ARTICLE III FLOOD RESISTANT DEVELOPMENT

SECTION 301 BUILDINGS AND STRUCTURES

301.1 Design and construction of buildings, structures and facilities exempt from the *Florida Building Code*. Pursuant to Section 104.3 of this ordinance, buildings, structures, and facilities that are exempt from the *Florida Building Code*, including substantial improvement or repair of substantial damage of such buildings, structures and facilities, shall be designed and constructed in accordance with the flood load and flood resistant construction requirements of ASCE 24. Structures exempt from the *Florida Building Code* that are not walled and roofed buildings shall comply with the requirements of Section 307 of this ordinance.

301.2 Buildings and structures seaward of the coastal construction control line. If extending, in whole or in part, seaward of the coastal construction control line and also located, in whole or in part, in a flood hazard area:

- Buildings and structures shall be designed and constructed to comply with the more restrictive applicable requirements of the *Florida Building Code, Building* Section 3109 and Section 1612 or *Florida Building Code, Residential* Section R322.
- Minor structures and non-habitable major structures as defined in section 161.54, F.S., shall be designed and constructed to comply with the intent and applicable provisions of this ordinance and ASCE 24.

SECTION 302 SUBDIVISIONS

302.1 Minimum requirements. Subdivision proposals, including proposals for manufactured home parks and subdivisions, shall be reviewed to determine that:

- Such proposals are consistent with the need to minimize flood damage and will be reasonably safe from flooding;
- All public utilities and facilities such as sewer, gas, electric, communications, and water systems are located and constructed to minimize or eliminate flood damage; and
- Adequate drainage is provided to reduce exposure to flood hazards; in Zones AH and AO, adequate drainage paths shall be provided to guide floodwaters around and away from proposed structures.

302.2 Subdivision plats. Where any portion of proposed subdivisions, including manufactured home parks and subdivisions, lies within a flood hazard area, the following shall be required:

- Delineation of flood hazard areas, floodway boundaries and flood zones, and design flood elevations, as appropriate, shall be shown on preliminary plats;
- Where the subdivision has more than 50 lots or is larger than 5 acres and base flood elevations are not included on the FIRM, the base flood elevations determined in accordance with Section 105.2(1) of this ordinance; and
- Compliance with the site improvement and utilities requirements of Section 303 of this ordinance.

SECTION 303 SITE IMPROVEMENTS, UTILITIES AND LIMITATIONS

303.1 Minimum requirements. All proposed new development shall be reviewed to determine that:

- Such proposals are consistent with the need to minimize flood damage and will be reasonably safe from flooding;
- All public utilities and facilities such as sewer, gas, electric, communications, and water systems are located and constructed to minimize or eliminate flood damage; and

- Adequate drainage is provided to reduce exposure to flood hazards; in Zones AH and AO, adequate drainage paths shall be provided to guide floodwaters around and away from proposed structures.

303.2 Sanitary sewage facilities. All new and replacement sanitary sewage facilities, private sewage treatment plants (including all pumping stations and collector systems), and on-site waste disposal systems shall be designed in accordance with the standards for onsite sewage treatment and disposal systems in Chapter 64E-6, F.A.C. and ASCE 24 Chapter 7 to minimize or eliminate infiltration of floodwaters into the facilities and discharge from the facilities into flood waters, and impairment of the facilities and systems.

303.3 Water supply facilities. All new and replacement water supply facilities shall be designed in accordance with the water well construction standards in Chapter 62-532.500, F.A.C. and ASCE 24 Chapter 7 to minimize or eliminate infiltration of floodwaters into the systems.

303.4 Limitations on sites in regulatory floodways. No development, including but not limited to site improvements, and land disturbing activity involving fill or regrading, shall be authorized in the regulatory floodway unless the floodway encroachment analysis required in Section 105.3(1) of this ordinance demonstrates that the proposed development or land disturbing activity will not result in any increase in the base flood elevation.

303.5 Limitations on placement of fill. Subject to the limitations of this ordinance, fill shall be designed to be stable under conditions of flooding including rapid rise and rapid drawdown of floodwaters, prolonged inundation, and protection against flood-related erosion and scour. In addition to these requirements, if intended to support buildings and structures (Zone A only), fill shall comply with the requirements of the *Florida Building Code*.

303.6 Limitations on sites in coastal high hazard areas (Zone V). In coastal high hazard areas, alteration of sand dunes and mangrove stands shall be permitted only if such alteration is approved by the Florida Department of Environmental Protection and only if the engineering analysis required by Section 105.3(4) of this ordinance demonstrates that the proposed alteration will not increase the potential for flood damage. Construction or restoration of dunes under or around elevated buildings and structures shall comply with Section 307.8(3) of this ordinance.

SECTION 304 MANUFACTURED HOMES

304.1 General. All manufactured homes installed in flood hazard areas shall be installed by an installer that is licensed pursuant to section 320.8249, F.S., and shall comply with the requirements of Chapter 15C-1, F.A.C. and the requirements of this ordinance. If located seaward of the coastal construction control line, all manufactured homes shall comply with the more restrictive of the applicable requirements.

304.2 Foundations. All new manufactured homes and replacement manufactured homes installed in flood hazard areas shall be installed on permanent, reinforced foundations that:
In flood hazard areas (Zone A) other than coastal high hazard areas, are designed in accordance with the foundation requirements of the *Florida Building Code, Residential* Section R322.2 and this ordinance. Foundations for manufactured homes subject to Section 304.6 of this ordinance are permitted to be reinforced piers or other foundation elements of at least equivalent strength.
In coastal high hazard areas (Zone V), are designed in accordance with the foundation requirements of the *Florida Building Code, Residential* Section R322.3 and this ordinance.
304.3 Anchoring. All new manufactured homes and replacement manufactured homes shall be installed using methods and practices which minimize flood damage and shall be securely anchored to an adequately anchored foundation system to resist flotation, collapse or lateral movement. Methods of anchoring include, but are not limited to, use of over-the-top or frame ties to ground anchors. This anchoring requirement is in addition to applicable state and local anchoring requirements for wind resistance.

304.4 Elevation. Manufactured homes that are placed, replaced, or substantially improved shall comply with Section 304.5 or 304.6 of this ordinance, as applicable.

304.5 General elevation requirement. Unless subject to the requirements of Section 304.6 of this ordinance, all manufactured homes that are placed, replaced, or substantially improved on sites located: (a) outside of a manufactured home park or subdivision; (b) in a new manufactured home park or subdivision; (c) in an expansion to an existing manufactured home park or subdivision; or (d) in an existing manufactured home park or subdivision upon which a manufactured home has incurred "substantial damage" as the result of a flood, shall be elevated such that the bottom of the frame is at or above the elevation required, as applicable to the flood hazard area, in the *Florida Building Code, Residential* Section R322.2 (Zone A) or Section R322.3 (Zone V).

304.6 Elevation requirement for certain existing manufactured home parks and subdivisions. Manufactured homes that are not subject to Section 304.5 of this ordinance, including manufactured homes that are placed, replaced, or substantially improved on sites located in an existing manufactured home park or subdivision, unless on a site where substantial damage as result of flooding has occurred, shall be elevated such that either the:

- Bottom of the frame of the manufactured home is at or above the elevation required, as applicable to the flood hazard area, in the *Florida Building Code, Residential* Section R322.2 (Zone A) or Section R322.3 (Zone V); or
- Bottom of the frame is supported by reinforced piers or other foundation elements of at least equivalent strength that are not less than 36 inches in height above grade.

304.7 Enclosures. Enclosed areas below elevated manufactured homes shall comply with the requirements of the *Florida Building Code, Residential* Section R322.2 or R322.3 for such enclosed areas, as applicable to the flood hazard area.

304.8 Utility equipment. Utility equipment that serves manufactured homes, including electric, heating, ventilation, plumbing, and air conditioning equipment and other service facilities, shall comply with the requirements of the *Florida Building Code, Residential* Section R322, as applicable to the flood hazard area.

SECTION 305 RECREATIONAL VEHICLES AND PARK TRAILERS

305.1 Temporary placement. Recreational vehicles and park trailers placed temporarily in flood hazard areas shall:

- Be on the site for fewer than 180 consecutive days; or
- Be fully licensed and ready for highway use, which means the recreational vehicle or park model is on wheels or jacking system, is attached to the site only by quick-disconnect type utilities and security devices, and has no permanent attachments such as additions, rooms, stairs, decks and porches.

305.2 Permanent placement. Recreational vehicles and park trailers that do not meet the limitations in Section 305.1 of this ordinance for temporary placement shall meet the requirements of Section 304 of this ordinance for manufactured homes.

SECTION 306 TANKS

306.1 Underground tanks. Underground tanks in flood hazard areas shall be anchored to prevent flotation, collapse or lateral movement resulting from hydrodynamic and hydrostatic loads during conditions of the design flood, including the effects of buoyancy assuming the tank is empty.

306.2 Above-ground tanks, not elevated. Above-ground tanks that do not meet the elevation requirements of Section 306.3 of this ordinance shall:

- Be permitted in flood hazard areas (Zone A) other than coastal high hazard areas, provided the tanks are anchored or otherwise designed and constructed to prevent flotation, collapse or lateral movement resulting from hydrodynamic and hydrostatic loads during conditions of the design flood, including the effects of buoyancy assuming the tank is empty and the effects of flood-borne debris.
- Not be permitted in coastal high hazard areas (Zone V).

306.3 Above-ground tanks, elevated. Above-ground tanks in flood hazard areas shall be elevated to or above the design flood elevation and attached to a supporting structure that is designed to prevent flotation, collapse or lateral movement during conditions of the design flood. Tank-supporting structures shall meet the foundation requirements of the applicable flood hazard area.

306.4 Tank inlets and vents. Tank inlets, fill openings, outlets and vents shall be:
At or above the design flood elevation or fitted with covers designed to prevent the inflow of floodwater or outflow of the contents of the tanks during conditions of the design flood; and
Anchored to prevent lateral movement resulting from hydrodynamic and hydrostatic loads, including the effects of buoyancy, during conditions of the design flood.

SECTION 307 OTHER DEVELOPMENT

307.1 General requirements for other development. All development, including man-made changes to improved or unimproved real estate for which specific provisions are not specified in this ordinance or the *Florida Building Code*, shall:

- Be located and constructed to minimize flood damage;
- Meet the limitations of Section 303.4 of this ordinance if located in a regulated floodway;
- Be anchored to prevent flotation, collapse or lateral movement resulting from hydrostatic loads, including the effects of buoyancy, during conditions of the design flood;
- Be constructed of flood damage-resistant materials; and
- Have mechanical, plumbing, and electrical systems above the design flood elevation or meet the requirements of ASCE 24, except that minimum electric service required to address life safety and electric code requirements is permitted below the design flood elevation provided it conforms to the provisions of the electrical part of building code for wet locations.

307.2 Fences in regulated floodways. Fences in regulated floodways that have the potential to block the passage of floodwaters, such as stockade fences and wire mesh fences, shall meet the limitations of Section 303.4 of this ordinance.

307.3 Retaining walls, sidewalks and driveways in regulated floodways. Retaining walls and sidewalks and driveways that involve the placement of fill in regulated floodways shall meet the limitations of Section 303.4 of this ordinance.

307.4 Roads and watercourse crossings in regulated floodways. Roads and watercourse crossings, including roads, bridges, culverts, low-water crossings and similar means for vehicles or pedestrians to travel from one side of a watercourse to the other side, that encroach into regulated floodways shall meet the limitations of Section 303.4 of this ordinance. Alteration of a watercourse that is part of a road or watercourse crossing shall meet the requirements of Section 105.3(3) of this ordinance.

307.5 Concrete slabs used as parking pads, enclosure floors, landings, decks, walkways, patios and similar nonstructural uses in coastal high hazard areas (Zone V). In coastal high hazard areas, concrete slabs used as parking pads, enclosure floors, landings, decks, walkways, patios and similar nonstructural uses are permitted beneath or adjacent to buildings and structures provided the concrete slabs are designed and constructed to be:

- Structurally independent of the foundation system of the building or structure;
- Frangible and not reinforced, so as to minimize debris during flooding that is capable of causing significant damage to any structure; and
- Have a maximum slab thickness of not more than four (4) inches.

307.6 Decks and patios in coastal high hazard areas (Zone V). In addition to the requirements of the *Florida Building Code*, in coastal high hazard areas decks and patios shall be located, designed, and constructed in compliance with the following:

- A deck that is structurally attached to a building or structure shall have the bottom of the lowest horizontal structural member at or above the design flood elevation and any supporting members that extend below the design flood elevation shall comply with the foundation requirements that apply to the building or structure, which shall be designed to accommodate any increased loads resulting from the attached deck.
- A deck or patio that is located below the design flood elevation shall be structurally independent from buildings or structures and their foundation systems, and shall be designed and constructed either to remain intact and in place during design flood conditions or to break apart into small pieces to minimize debris during flooding that is capable of causing structural damage to the building or structure or to adjacent buildings and structures.
- A deck or patio that has a vertical thickness of more than twelve (12) inches or that is constructed with more than the minimum amount of fill necessary for site drainage shall not be approved unless an analysis prepared by a qualified registered design professional demonstrates no harmful diversion of floodwaters or wave runup and wave reflection that would increase damage to the building or structure or to adjacent buildings and structures.
- A deck or patio that has a vertical thickness of twelve (12) inches or less and that is at natural grade or on nonstructural fill material that is similar to and compatible with local soils and is the minimum amount necessary for site drainage may be approved without requiring analysis of the impact on diversion of floodwaters or wave runup and wave reflection.

307.7 Other development in coastal high hazard areas (Zone V). In coastal high hazard areas, development activities other than buildings and structures shall be permitted only if also authorized by the appropriate federal, state or local authority; if located outside the footprint of, and not structurally attached to, buildings and structures; and if analyses prepared by qualified registered design professionals demonstrate no harmful diversion of floodwaters or wave runup and wave reflection that would increase damage to adjacent buildings and structures. Such other development activities include but are not limited to:

- Bulkheads, seawalls, retaining walls, revetments, and similar erosion control structures;
- Solid fences and privacy walls, and fences prone to trapping debris, unless designed and constructed to fail under flood conditions less than the design flood or otherwise function to avoid obstruction of floodwaters; and
- On-site sewage treatment and disposal systems defined in 64E-6.002, F.A.C., as filled systems or mound systems.

307.8 Nonstructural fill in coastal high hazard areas (Zone V). In coastal high hazard areas:

- Minor grading and the placement of minor quantities of nonstructural fill shall be permitted for landscaping and for drainage purposes under and around buildings.
- Nonstructural fill with finished slopes that are steeper than one unit vertical to five units horizontal shall be permitted only if an analysis prepared by a qualified registered design professional demonstrates no harmful diversion of floodwaters or wave runup and wave reflection that would increase damage to adjacent buildings and structures.
- Where authorized by the Florida Department of Environmental Protection or applicable local approval, sand dune construction and restoration of sand dunes under or around elevated buildings are permitted without additional engineering analysis or certification of the diversion of floodwater or wave runup and wave reflection if the scale and location of the dune work is consistent with local beach-dune morphology and the vertical clearance is maintained between the top of the sand dune and the lowest horizontal structural member of the building.

{See instructions for technical amendments to FBC, if any, and insert here as a new SECTION 3; technical amendments may also be adopted by separate ordinance.}

SECTION 3. APPLICABILITY.
For the purposes of jurisdictional applicability, this ordinance shall apply in {insert name of community or all unincorporated areas of the county}. This ordinance shall apply to all applications for development, including building permit applications and subdivision proposals, submitted on or after the effective date of this ordinance.

SECTION 4. INCLUSION INTO THE CODE OF ORDINANCES.
It is the intent of the {community's governing body} that the provisions of this ordinance shall become and be made a part of the {name of community's} Code of Ordinances, and that the sections of this ordinance may be renumbered or relettered and the word "ordinance" may be changed to "section," "article," "regulation," or such other appropriate word or phrase in order to accomplish such intentions.

SECTION 5. SEVERABILITY.
If any section, subsection, sentence, clause or phrase of this ordinance is, for any reason, declared by the courts to be unconstitutional or invalid, such decision shall not affect the validity of the ordinance as a whole, or any part thereof, other than the part so declared.

SECTION 6. EFFECTIVE DATE.
This ordinance shall take effect on {insert date}.

PASSED on first reading {insert date}.

PASSED and ADOPTED in regular session, with a quorum present and voting, by the **{governing body}**, upon second and final reading this **{insert date}.**

{Governing body}

____

{Chief Elected Officer}
ATTEST:

____

{Manager/Clerk}

APPROVED AS TO FORM:

____

{Attorney}

APPENDIX B: CRS DOCUMENTS

Documents Relating to CRS: 51 / 109

Community outreach is a major part of the watershed master planning process, as it is with the CRS program locally. Since a watershed is not a legal entity, direct communication with the public normally flows through local governments. Therefore, the FAU team used the CRS Coordinator's Manual to identify those CRS activities and elements that require municipal documents for credit with the intent of securing examples. Documents, in this case, are any written materials which are not policy, infrastructure, or maps. Using this list of potential documents needed, documents were gathered from the 3 highest-scoring communities (Table) in each of those activities to serve as examples for the template the FAU team is designing (see discussion in Section 5).

Table B1. CRS documents and description list

CRS Activity	Documents		Ordinances		Description
Elements	Obtained	Required	Obtained	Required	
310					**Elevation Certificates**
312.a	2	2			Maintaining Elevation Certificates
312.b	1	1			Maintaining EC for post-FIRM buildings
312.c	1	3			Maintaining EC for pre-FIRM buildings
Subtotal	**4**	**6**			
320					**Map Information Service**
322.a	0	1			Basic FIRM information
322.b	0	1	0	1	Additional FIRM information
322.f	1	1			Historical flood information
Subtotal	**1**	**3**	**0**	**1**	
330					**Outreach Projects**
331.a	2	1			Background Activity Description
332.a	2	1			Outreach Projects
332.b	1	1			Flood response preparations
332.c	3	1			Program for public information
Subtotal	**8**	**4**			
340					**Hazard Disclosure**
342.a			1	1	Disclosure of the flood hazard
342.b			3	1	Other disclosure requirements
342.c	1	1			Real estate agents' brochure
342.d	0	1			Disclosure of other hazards
Subtotal	**1**	**2**	**4**	**2**	
350					**Flood Protection Information**
352.a	1	1			Flood protection library
352.b	1	1			Locally pertinent documents
352.c	5	1			Flood protection website
Subtotal	**7**	**3**			
360					**Flood Protection Assistance**
362.a	2	2			Property protection advise
362.b	2	1			Protection advice provided after a site visit
362.c	0	2			Financial assistance advice
362.d	0	1			Advisor training
Subtotal	**4**	**6**			
370					**Flood Insurance Promotion**
372.a	1	1			Flood insurance coverage assessment
372.b	1	1			Coverage improvement
372.c	0	1			Coverage improvement plan implementation
372.d	1	2			Technical assistance
Subtotal	**3**	**5**			

CRS Activity	Documents		Ordinances		Description
410			**1**		**Floodplain Mapping**
412.a			2	1	New Study
412.b	0	1			Leverage
412.c	0	1			State Review
412.d			3	1	Higher Study Standards
412.e			1	1	More Restrictive Floodway Standards
Subtotal	**0**	**2**	**7**	**3**	
420					**Open Space Preservation**
422.a			2	1	Open space preservation
422.b	1	1			Deed restrictions
422.c	1	1			Natural functions open space
422.d			1	1	Special flood-related hazards open space
422.e	0	1	1		Coastal erosion open space
422.f			1	1	Open space incentives
422.g			2	1	Low-density zoning
422.h			3	1	Natural shoreline protection
Subtotal	**2**	**3**	**10**	**5**	
430			2		**Higher Regulatory Standards**
432.a			3	1	Development Limitations
432.b			4	1	Freeboard
432.c			4	1	Foundation Protection
432.d	0	1	4	1	Cumulative Substantial Improvements
432.e	1	1	1	1	Lower Substantial Improvement
432.f			3	1	Protection of Critical Facilities
432.g	1	2	2		Enclosure Limits
432.h	0	1	3	1	Building Code
432.i			3	1	Local Drainage Protection
432.j			3	1	Manufactured Home Parks
432.k	1	0	3	1	Coastal A Zones
432.l			3	1	Special Flood-Related Hazard Regulations
432.m			0	1	Tsunami Hazard Regulations
432.n	0	1	2	1	Coastal Erosion Hazard Regulations
432.o			1	1	Other Higher Standard
432.q	0	1	0	1	Regulations Administration
Subtotal	**3**	**7**	**41**	**15**	
440					**Flood Data Maintenance**
442.b			1		FIRM maintenance
442.c	0	1			Benchmark maintenance
442.d	0	1			Erosion data maintenance
Subtotal	**0**	**2**	**1**	**0**	

CRS Activity	Documents		Ordinances		Description
450					**Stormwater Management**
452.a	1	1	3	1	Stormwater management regulations
452.b	1	1			Watershed master plan
452.c			2	1	Erosion and sedimentation control regulations
452.d			2	1	Water quality regulations
Subtotal	**2**	**2**	**7**	**3**	
510			**1**		**Floodplain Management Plan**
512.a	2	1			Floodplain management planning
512.b	0	2	0	1	Repetitive loss area analysis
512.c	1	2			Natural floodplain functions plan
Subtotal	**3**	**5**	**1**	**1**	
520					**Acquisition and Relocation**
522.a	1	1			Buildings acquired or relocated
522.b	1	1			Buildings on the repetitive loss list
522.c	0	1			Severe Repetitive Loss properties
Subtotal	**2**	**3**			
530					**Flood Protection**
532.a	0	1			Flood protection project technique
532.b	0	2			Flood protection improvement
532.c	0	3			Protected buildings
Subtotal	**0**	**6**			
540					**Drainage System Maintenance**
542.a	0	1			Channel debris removal
542.b	0	1			Problem site maintenance
542.c	0	2			Capital improvement program
542.d			3	1	Stream dumping regulations
542.e	0	1			Storage basin maintenance
Subtotal	**0**	**5**	**3**	**1**	
610					**Flood Warning and Response**
612.a	4	4			Flood threat recognition system
612.b	2	4			Emergency warning dissemination
612.c	0	2			Flood response operations
612.d	1	2			Critical facilities planning
612.f	0	1			Tsunami Ready community
Subtotal	**7**	**13**			
620					**Levees**
622.a	0	4			Levee maintenance
622.b	0	3			Levee failure threat recognition system
622.c	0	3			Levee failure warning
622.d	0	2			Levee failure response operations
622.e	0	4			Levee failure critical facilities planning
Subtotal	**0**	**16**			

CRS Activity	Documents		Ordinances		Description
630					**Dams**
632.a	2	2			State dam safety program
632.b	1	3			Dam failure threat recognition system
632.c	1	3			Dam failure warning
632.d	0	2			Dam failure response o perations
632.e	0	3			Dam failure critical facilities planning
Subtotal	**4**	**13**			
Total	**51**	**106**	**74**	**31**	

APPENDIX C: FLORIDA CRS EXAMPLE COMMUNITIES

As an incentive program, the CRS encourages communities to be competitive and proud about their CRS scores and to wear them as a badge of honor for the community. In a more cooperative sense, communities that do not score very high might be able to learn something from communities that did. In that spirit, we have replicated below the relative ranks of the top three highest scoring Florida CRS communities by activity from the year 2013. It is very likely that these ranks have changed since 2013 and it is also true that some of these activities were poorly scored for all communities within the state at that time. However, for most activities, the actions/policies that got a community their score in 2013 likely still maintain some relevance. By presenting these high-scoring communities by activity, one can get a sense as to why a community might have scored well. While the most accurate picture for scoring is only possible by reviewing a CRS verification letter, these are not usually publicly available and, as mentioned in Section 2, the FAU team was only able to obtain a select handful of these for disparate dates.

Table C1 Highest scoring municipalities by CRS activity. Based on the 2013 Florida spreadsheet from https://crsresources.org/files/200/state-profiles/fl-state_profile.pdf .

CRS Activity	CRS Activity Description	No. 1 Rank	No. 2 Rank	No. 3 Rank
310	Elevation Certificate collection, archiving, and dessimination	Miami-Dade County	Hernando County	Pasco County
320	FIRM and flood-related maps and information services	(Majority Tie)	(Majority Tie)	(Majority Tie)
330	Community outreach and engagment projects on flood risk and reduction	Hallandale Beach	Juno Beach	Indian Rocks Beach
340	Require disclosure of flood hazards	Bradenton Beach, Anna Maria (Tie)	Holmes Beach	Marco Island
350	Flood protection information (website, library, etc.)	North Port	Manatee county	Palm Beach County
360	Flood protection assistance, advice, training, etc.	Miami Gardens, Miami-Dade County, Bradenton, Sanibel, New Port Richey, Indian Shores, Santa Rosa County (Tie)	Palm Bay, Ft. Lauderdale (Tie)	Pinellas Park
370		Miami Beach	NA	NA
410	Floodplain mapping, higher standards, restrictive floodways, and special hazards	Clearwater	Madeira Beach	Redington Shores
420	Open space preservation	Ocala	Juno Beach	West Palm Beach
430	Higher regulatory standards on permitting, zoning, an drainage	Bay County	Ponce Inlet	Miami Lakes
440	Flood map, FIRM, benchmark, and erosion maintenance data	Anna Maria	Fort Walton Beach	Bradenton Beach
450	Stomwater management regulations, watershed master plans, erosion control and water quality regulations	Ocala	North Miami	Sunrise
510	Floodplain management planning and repetitive loss analysis	Ocala	Milton	Santa Rosa County
520	Building acquisition and relocation from severe repetitive loss or special hazard zones	Manatee County	Pinellas County	Miami-Dade County
530	Flood protection infrastructure and building improvements	Tamarac	Manatee County	Tampa
540	Drainage system maintenance, improvements program, stream dumping regulations, and basin maintenance	Bay County	**Naples**, Longboat Key, Venice, Madeira Beach, Belleair Beach, Holmes Beach, North Redington Beach, Oldsmar, Indian Shores, Largo, North Miami, Anna Maria, Cape Canaveral, Indian Rocks Beach, Destin, Lighthouse Point, Ocean Ridge, Orlando (Tie)	Okaloosa County
610	Flood warning, recognition, response, and critical facilities planning systems	Ocala	Lee County	Cape Coral
620	Levee maintenance, threat recognition and warning systems, and failure planning	-	-	-
630	Dam maintenance, threat recognition and warning systems, and failure planning	Oakland Park	(Majority Tie)	(Majority Tie)

APPENDIX D: CRS PLANNING PRE-REQUISITES

The CRS program calculates a community's score with each verification cycle and adds the respective points earned for each activity to determine which "class" the community falls in. The class level will, in turn, determine the percent reduction in insurance premiums that community qualifies for. As discussed in more depth in Section 2, the classes range from 10 to 1, with class 1 communities being the highest score possible. Class 10 communities are those that have recently failed to meet the minimum requirements of a CRS community (the requisites of class 9) and have had their status as a CRS community revoked until they can meet those base requirements again. The successful implementation of the CRS activity for Watershed Management Planning (Activity 450) is a prerequisite for class 4 communities, specifically. The language from CRS/FEMA outlining the major class prerequisites are reproduced below for quick reference.

A community must meet the prerequisites at each verification cycle to maintain or improve standing.

a. **Class 9 Prerequisites:** There are six prerequisites to become and stay a Class 9 or better community. They include being in full compliance with the minimum requirements of the National Flood Insurance Program (NFIP), receiving credit for maintaining FEMA Elevation Certificates, and meeting repetitive loss criteria.

b. **Class 6 Prerequisite:** To become a Class 6 or better community, a community must have received a classification of 5/5 or better under the Building Code Effectiveness Grading Schedule.

c. **Class 4 Prerequisites:** To become a Class 4 or better community, a community must demonstrate that it has programs that minimize flood losses, minimize increases in future flooding, protect natural floodplain functions, and protect people from the dangers of flooding.

d. **Class 1 Prerequisites:** To become a Class 1 community, a community must have had a successful Community Assistance Visit conducted by FEMA within the previous 12 months and demonstrate that it has a "no adverse impact" program by receiving a certain number of points for designated activities.

211.a. Class 9 Prerequisites

In order to become and continue to be a Class 9 or better, a community must demonstrate that it has enough points to warrant the class AND meet the following six prerequisites.

(1) The community must have been in the Regular Phase of the NFIP for at least one year.

(2) The community must be in full compliance with the minimum requirements of the NFIP. There must be correspondence from the Regional Office of the Federal Emergency Management Agency (FEMA) stating that the community is in full compliance with the NFIP. The correspondence must have been sent within six months of the initial CRS verification visit. The FEMA Regional Office or State NFIP Coordinator may need to conduct a Community Assistance Visit if neither has been in the community recently. If a community is determined at any time to be in less-than-full compliance, it will retrograde to a CRS Class 10.

(3) The community must maintain FEMA Elevation Certificates on all new buildings and substantial improvements constructed in the Special Flood Hazard Area (SFHA) after the community applies for CRS credit. This is explained in Activity 310 (Elevation Certificates).

(4) If there are one or more repetitive loss properties in the community, the community must take certain actions as specified in Sections 501–504. These include reviewing and updating the list of

repetitive loss properties, mapping repetitive loss areas, describing the causes of the losses, and sending an outreach project to those areas each year. A community with 50 or more repetitive loss properties (a "Category C" community) must also prepare a repetitive loss area analysis or floodplain management plan that addresses its repetitive flood problem.

(5) The community must maintain all flood insurance policies that it has been required to carry on properties owned by the community. The community's chief executive officer(CEO) signs the verification visit cover sheet, which includes a statement that the signer certifies that the community has all the flood insurance policies that it has been required to maintain on properties owned by the community. This is discussed further in Figure 210-1.

(6) If a coastal community receives a draft Flood Insurance Rate Map (FIRM) that delineates the Limit of Moderate Wave Action (LiMWA), the community must agree to show the LiMWA on its final published FIRM. Although showing a LiMWA on a FIRM is voluntary for non-CRS communities, it is a prerequisite for CRS participa-tion. The LiMWA delineation is for informational purposes only. There is no CRS requirement to regulate the area differently, but the series of International Codes has special construction requirements in areas subject to breaking waves of 1.5 feet or higher. Communities are encouraged to meet the criteria for Coastal A Zone credit (CAZ) in Activity 430 (Higher Regulatory Standards).

211.b. Class 6 Prerequisites

(1) The community must meet all the Class 9 prerequisites.

(2) The community must have received and continue to maintain a classification of 5/5 or better under the Building Code Effectiveness Grading Schedule (BCEGS). Both BCEGS classifications (residential/ personal and commercial) must be a class 5 or better. When communities submit a modification or undergo a cycle verification, they must meet the BCEGS prerequisite in order to achieve or remain a CRS Class 6 or better.

The BCEGS program measures a community's building code adoption and enforce-ment as they relate to natural hazards mitigation. More information on the program can be found at www.isomitigation.com/bcegs/iso-s-building-code-effectiveness-grading-schedule-bcegs.html. Credit is also provided for BCEGS classifications of 5/5 or better under the building code credit (BC) in Section 432.h.

211.c. Class 4 Prerequisites

(1) The community must meet all the Class 6 prerequisites.

(2) The community must have received and continue to maintain a classification of 4/4 or better under the BCEGS.

(3) The community must demonstrate that it has taken appropriate steps to eliminate or minimize future flood losses. To do this, a Class 4 or better community must receive credit for the following CRS activities.

    a. Activity 430 (Higher Regulatory Standards)—The community must show that it enforces higher regulatory standards to manage new development in the floodplain.

        i. The community must adopt and enforce at least a 1-foot freeboard requirement (including equipment or mechanical items) for all buildings constructed, substantially improved and/or reconstructed due to substantial damage, and buildings allowed to be floodproofed, throughout its SFHA, except those areas that receive OSP credit under Activity 420 (Open Space Preservation). In unnumbered A, AO, and V Zones, the community must first determine a base flood elevation consistent with the techniques credited under Activity 410 (Flood Hazard Mapping).

ii. The community must receive at least 700 points (after the impact adjustment) under the other elements of Activity 430 and under Sections 422.a, e, and f under Activity 420 (Open Space Preservation).

b. Activity 450 (Stormwater Management)—The community must receive the following credits for its watershed management plan(s) (WMP) under Section 451.b:

i. WMP1: 90 points (before the impact adjustment) for meeting all of the credit criteria for WMP,

ii. WMP2: 30 points (before the impact adjustment) for managing the runoff from all storms up to and including the 100-year event to ensure that flood flows downstream of new development do not increase due to the development, and

iii. An impact adjustment value of rWMP = 0.5 or more. Alternatively, the community may show that at least 50% of the watershed area where future growth is expected is covered by one or more credited watershed management plans.

c. Activity 510 (Floodplain Management Planning)—The community must have adopted and be implementing a floodplain management plan that receives at least 50% of the maximum credit under Activity 510, calculated after the impact adjustment. This 50% of the maximum credit must include at least 50% of the available points in each of planning steps 2, 5, and 8.

(4) Obtain a minimum total credit of 100 points (after the impact adjustment) from one or a combination of the following elements that credit protecting natural floodplain functions:

- 420—Natural functions open space (NFOS),
- 420—Natural shoreline protection (NSP),
- 430—Prohibition of fill (DL1),
- 440—Additional map data (AMD12) natural functions layer,
- 450—Managing the volume of stormwater runoff (SMR, DS),
- 450—Low impact development (LID),
- 450—Watershed management plan (WMP), credit point items 3, 5, 6, and 7,
- 450—Erosion and sediment control (ESC),
- 450—Water quality (WQ), and
- 510—Natural floodplain functions plan (NFP).

(5) Document the following life safety measures:

(a) Obtain some credit under Activity 610 (Flood Warning and Response).

(b) Have a map of all levees and all areas protected by levees, and an inventory of the types of buildings (residential, commercial, etc.) and the critical facilities that would be exposed to flooding should the levee(s) be overtopped or fail. This is the same as activity credit criterion (3) under Activity 620 (Levees), Section 621.b.

(c) Have a description of the dam failure threat, including a map of all areas that would be flooded by the failure of each high-hazard-potential dam that affects the community, and the types of buildings (residential, commercial, etc.) and critical facilities that would be flooded. This is the same as activity credit criteria (2) under Activity 630 (Dams), Section 631.b.

211.d. Class 1 Prerequisites

(1) Meet all the Class 4 prerequisites.
(2) Meet the minimum standards of the NFIP as determined by a Community Assistance Visit conducted by FEMA within the previous 12 months.
(3) Promote flood insurance as a vital way to protect residents and businesses from the financial impact of a flood. This is demonstrated by having at least 50% of the buildings in the community's SFHA covered by a flood insurance policy or obtaining at least 50% of the maximum points under Activity 370 (Flood Insurance Promotion).
(4) Demonstrate that it has a "no adverse impact" approach to floodplain management. A no adverse impact approach is one in which the action of one property owner or community does not adversely affect the flood risks for other properties or communities. "Adverse impact" is measured by increased flood stages, increased flood velocity, increased flows, or the increased potential for erosion and sedimentation. The "no adverse impact" concept is explained in more detail in papers published by the Association of State Floodplain Managers, which can be accessed at www.floods.org. This prerequisite is demonstrated by receiving credit under the following:
    a. For all of the floodplains in the community:
        i. The community must be enforcing regulations that discourage development in the floodplain. This is demonstrated by receiving a combined total of at least 150 points under open space incentives (OSI) in Section 422.e and development limitations (DL) in Section 432.a.
        ii. All new critical facilities must be protected to the 500-year flood level. This is demonstrated by receiving credit under protecting critical facilities (PCF) in Section 432.f in Activity 430 (Higher Regulatory Standards) and by enforcing the regulations throughout the 500-year floodplain.
        iii. The community must have mapped and be enforcing regulations appropriate for all flood-related hazards within its jurisdiction. This is demonstrated by receiving credit under Activities 410 and 430 for all special flood-related hazards that are identified in the community's floodplain management or hazard mitigation plan credited under Activity 510 (Floodplain Management Planning).
    b. In the community's riverine floodplains:
        i. The community's program must address potential increases in riverine flood elevations caused by new development. This is demonstrated by receiving the following credits:
            (i) Activity 450 (Stormwater Management)—an impact adjustment value of rWMP = 0.75 or more. As an alternative, the community may show that at least 75% of the watershed area where future growth is expected is covered by one or more credited watershed management plans; AND
            (ii) All riverine floodplains must be mapped using future conditions hydrology as credited under the higher study standard credit (HSS) in Section 412.d.
    c. In the community's coastal floodplains:
            (i) The community must receive credit for regulating new development in coastal A Zones under CAZ in Section 432.k.
            (ii) The community must receive credit for using regulatory flood elevations in the V Zones and coastal A Zones that reflect future

conditions, including sea level rise. This is demonstrated by receiving credit for future-conditions hydrology under the higher study standard credit (HSS) in Section 412.d.

(iii) The community must receive credit for regulating new development in areas subject to erosion (CER) under Activity 430 (or demonstrate that it does not have a coastal erosion problem).

(5) Have a commitment to mitigate its repetitive loss problem as well as problems caused by other natural hazards.

a. Section 501 (Repetitive Loss List): The community must demonstrate that at least 25% of the properties on its current FEMA repetitive loss list have been protected from damage from repetitive flooding through acquisition, retrofitting, or structural flood control projects.

b. Activity 510 (Floodplain Management Planning): The community must have a multi-hazard mitigation plan that has been approved by FEMA as meeting all of the requirements outlined under 44 CFR §201.6.

(6) Protect natural floodplain functions. This is demonstrated by having a total credit of at least 150 points (after the impact adjustment) from one or a combination of the elements listed under the Class 4 prerequisite in Section 211.c(4).

(7) Have a program to address the threat to life safety that flooding poses to the residents of the community. This is demonstrated by receiving the following credits:

(a) The community must obtain some credit under all the elements in Activity 620 (Levees) for all levees mapped and identified in the inventory prepared for the Class 4 prerequisite in Section 211.c(5)(b).

(b) The community must obtain some credit under all the local elements in Activity 630 (Dams) for all areas mapped and identified as subject to dam failure flooding in the inventory prepared for the Class 4 prerequisite in Section 211.c(5)(c). The credit for the state's program (SDS) is not counted toward this prerequisite.

APPENDIX E: OUTREACH TOOLS

A. Model Public Outreach

KNOW YOUR FLOOD HAZARD AND WHAT YOU CAN DO ABOUT IT

More than 20 percent of flood insurance claims come from people outside of mapped high-risk flood areas.

Protect your Family and Property from Flooding

Flooding in Hallandale Beach

Wherever it rains, it can flood! This information is offered to help protect your property and reduce potential losses due to flooding. The City of Hallandale Beach is dedicated to assisting its residents and businesses to reduce the hazardous effects of flooding in our community.

Local Flood Hazard Flooding can occur due to heavy rains over a short period of time, especially at times of high tide. The waterways are influenced by tides that contribute to drainage and flooding problems in the city. When there is a high tide and heavy rainfall, the storm drainage system will rapidly fill from both surface run-off and tidal water, increasing the likelihood of flood conditions in our streets, swale areas, and lawns.

Storm surge may affect our City. Any storm surges experienced here will most likely be as a result of a hurricane or tropical storm, typically from June 1 through November 30 each year. The City of Hallandale Beach is actively working to mitigate flooding in the city.

City Flood Services The City offers the following services to residents: Call the City at 954-457-1382 for access to the Flood Insurance Rate Maps to show if your property is: 1) in a Special Flood Hazard Area or may be affected by coastal erosion, 2) located in an area that has previously had flooding problems, 3) located near an area that should be protected because of its natural floodplain functions. The City will also provide informatoin on site specific elevations for mechanical equipment, elevation certificates, general information and brochures. **Call today to know your zone!** City Staff will offer advice and visit properties upon request to review its flood problem and explain ways to stop or prevent flood damage. Please contact the City at (954) 457-1386.

Drainage System Maintenance A serious risk to the safety of residents is the blockage of catch basins by debris which prevents proper drainage. It is a violation of our City Ordinances to dump debris of any sort, including grass clippings, into canals or storm drains. Please report violations to the Code Compliance Division at (954) 457-1390. If you live near areas where waters flow or near a catch basin, you can help by keeping storm grates and the banks clear of brush and debris. All private stormwater management facilities are required to maintain their own systems, and the City offers private property stormdrain cleaning services. For more information, call the Stormwater Division at (954) 457-1620.

Report a Concern
Visit our app My HB

Flood Safety

Do not walk through flowing water! Currents can be deceptive; six inches of moving water can knock you off your feet.

Do not drive through a flooded area! Don't drive around road barriers. Canals or ponds may not be distinguishable from roads.

Stay away from power lines and electrical wires! Electrical current can travel through water.

Look out for animals, espcially snakes! Small animals that have been floooded out of their homes may seek shelter in yours.

Look before you step! After a flood, the ground and floors are covered wtih debris including broken glass and nails and can be very slippery.

Be alert for gas leaks! Don't smoke or use candles, lanterns or open flames until the gas has been turned off and the area has been ventilated.

Flood Warning System In cases where flooding might occur during emergency situations, local radio and television stations will provide critical information as part of the Emergency Broadcast System. Hallandale Beach and Broward County depend on the National Weather Service (NWS) for flood notification. Broadcast methods of emergency notices include the City of Hallandale Beach Radio Station 1620 AM WQFQ and HB TV Channel 78 on Comcast Government Access Channel. Channel 78 will be utilized during emergencies to provide up-to-date information regarding the event including evacuation orders, shelter openings, emergency phone numbers, sandbag distribution, and more. During emergencies the City will publish the latest information on its website, www.cohb.org.

Each resident should make evacuation and sheltering plans well in advance of the emergency.

Property Protection You should know what to do to minimize flood damage to your property. "Flood proofing" means making physical alterations to your building that improve the ability of property and structures to withstand the damages caused by flooding. You should take action now to minimize losses to your property and possessions. Dry flood proofing includes sealing or waterproofing with special materials and compounds which provide a chemical or physical barrier against water intrusion during times of flooding. Construction of a small flood wall or earthen berm, or redirecting drainage to keep water away from the building is another example of property protection. Call the City at (954) 457-1386 for more information or search the Broward County Library for "Flood" information. Always obtain a permit before you make any improvements to your property. Contact the Building Division at 954-457-1390 before you alter, re-grade or perform any improvements to your property. You may also call this number to report any violations.

Flood Insurance Property losses due to flooding are not covered under standard homeowners' or renters' insurance policies. Two types of flood insurance coverage are available; building and contents coverage. Contents coverage should be purchased by renters. There are over 14,600 flood insurance policies in force in the City of Hallandale Beach. Flood insurance coverage may be mandatory for some mortgage loans. If you don't have flood insurance for your property and its contents, contact your insurance agent today. Information is also available from the www.floodsmart.gov website (or call 888-379-9531) or contact the City for flood insurance advice at 954-457-1382.

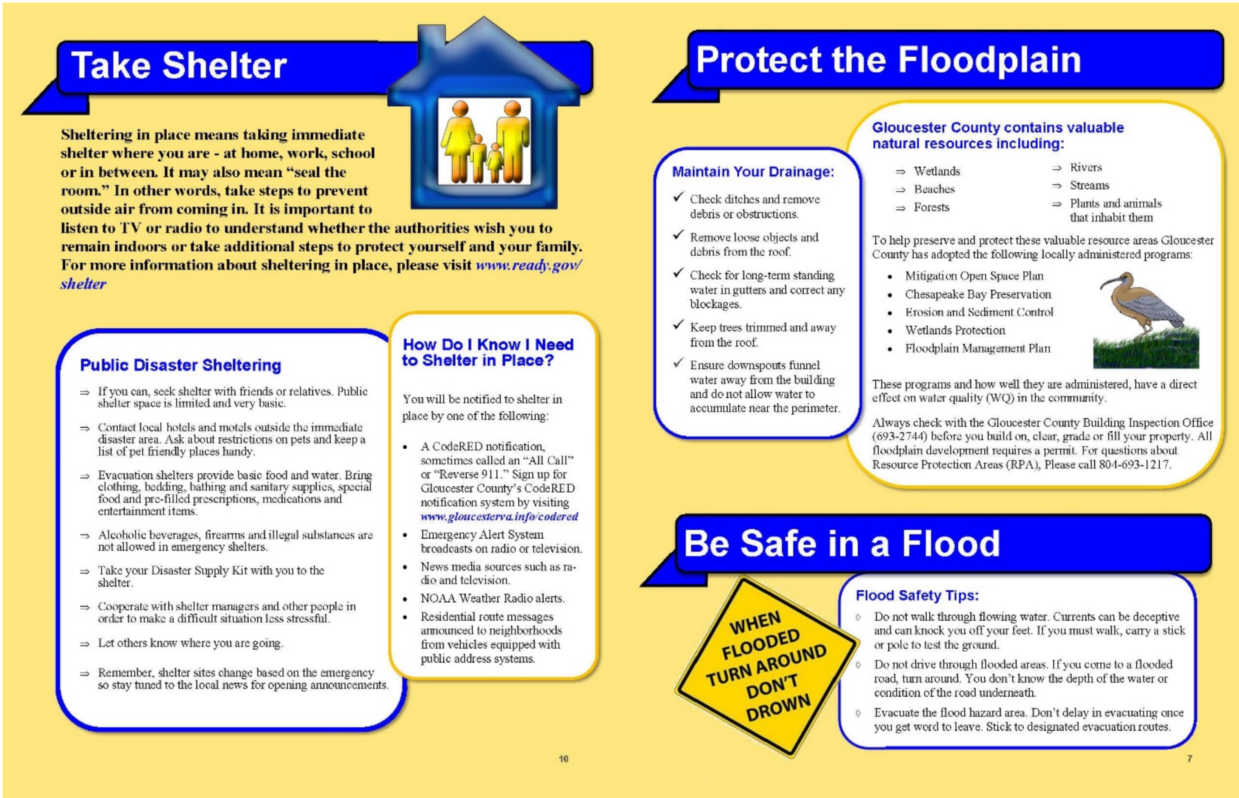
Don't wait until the next storm season to buy flood insurance as there is usually a 30-day waiting period before a flood insurance policy takes effect.

The average flood insurance policy costs about $700 per year.

Protect Natural Floodplain Functions Floodplains absorb much more rain and floodwaters than urbanized areas, reducing flood flows on downstream properties. Floodplains can also be beneficial in their ability to recharge the Biscayne Aquifer which helps to reduce some of the negative effects of drought. Plants filter stormwater runoff, making it cleaner for those downstream. One of the City's primary drainage canals, the SE 14th Avenue Canal is lined with numerous mangrove trees, which are particularly important in maintaining the ecosystem of the area. In the City of Hallandale Beach the beach and the dune system are our first line of defense against storms because they act as a buffer between the storm waves and coastal development. During hurricanes, storm waves encounter the beach and dunes before crashing into upland structures. In both Broward County and Hallandale Beach, there are many policies intended to protect coastal resources that could, in turn decrease the risk from storm surge and flooding. You can help to keep our beautiful beach in its natural condition by observing the following rules:

- Sea oats and other beach plants help stabilize our sand dunes. Enjoy them, but don't pick them – it's illegal.
- No walking off marked paths.

Report a Concern
Visit our app MyHB



Take Shelter

Sheltering in place means taking immediate shelter where you are - at home, work, school or in between. It may also mean "seal the room." In other words, take steps to prevent outside air from coming in. It is important to listen to TV or radio to understand whether the authorities wish you to remain indoors or take additional steps to protect yourself and your family. For more information about sheltering in place, please visit *www.ready.gov/shelter*

Public Disaster Sheltering

⇒ If you can, seek shelter with friends or relatives. Public shelter space is limited and very basic.

⇒ Contact local hotels and motels outside the immediate disaster area. Ask about restrictions on pets and keep a list of pet friendly places handy.

⇒ Evacuation shelters provide basic food and water. Bring clothing, bedding, bathing and sanitary supplies, special food and pre-filled prescriptions, medications and entertainment items.

⇒ Alcoholic beverages, firearms and illegal substances are not allowed in emergency shelters.

⇒ Take your Disaster Supply Kit with you to the shelter.

⇒ Cooperate with shelter managers and other people in order to make a difficult situation less stressful.

⇒ Let others know where you are going.

⇒ Remember, shelter sites change based on the emergency so stay tuned to the local news for opening announcements.

How Do I Know I Need to Shelter in Place?

You will be notified to shelter in place by one of the following:

- A CodeRED notification, sometimes called an "All Call" or "Reverse 911." Sign up for Gloucester County's CodeRED notification system by visiting *www.gloucesterva.info/codered*
- Emergency Alert System broadcasts on radio or television.
- News media sources such as radio and television.
- NOAA Weather Radio alerts.
- Residential route messages announced to neighborhoods from vehicles equipped with public address systems.

10

Protect the Floodplain

Maintain Your Drainage:

✓ Check ditches and remove debris or obstructions.

✓ Remove loose objects and debris from the roof.

✓ Check for long-term standing water in gutters and correct any blockages.

✓ Keep trees trimmed and away from the roof.

✓ Ensure downspouts funnel water away from the building and do not allow water to accumulate near the perimeter.

Gloucester County contains valuable natural resources including:

⇒ Wetlands
⇒ Beaches
⇒ Forests
⇒ Rivers
⇒ Streams
⇒ Plants and animals that inhabit them

To help preserve and protect these valuable resource areas Gloucester County has adopted the following locally administered programs:

- Mitigation Open Space Plan
- Chesapeake Bay Preservation
- Erosion and Sediment Control
- Wetlands Protection
- Floodplain Management Plan

These programs and how well they are administered, have a direct effect on water quality (WQ) in the community.

Always check with the Gloucester County Building Inspection Office (693-2744) before you build on, clear, grade or fill your property. All floodplain development requires a permit. For questions about Resource Protection Areas (RPA), Please call 804-693-1217.

Be Safe in a Flood

WHEN FLOODED TURN AROUND DON'T DROWN

Flood Safety Tips:

◊ Do not walk through flowing water. Currents can be deceptive and can knock you off your feet. If you must walk, carry a stick or pole to test the ground.

◊ Do not drive through flooded areas. If you come to a flooded road, turn around. You don't know the depth of the water or condition of the road underneath.

◊ Evacuate the flood hazard area. Don't delay in evacuating once you get word to leave. Stick to designated evacuation routes.

7

B. Suggested Public Outreach Plan for the City of Clewiston, Florida

The Community Outreach Plan (COP) for the City of Clewiston describes where the community's study and/or mapping project is in the Risk Mapping, Assessment, and Planning (Risk MAP) life cycle. It also describes other relevant, supporting initiatives that would influence and/or inform the public risk awareness process. The COP should include the following:

- A brief description of current community conditions with respect to the status of studies and/or mapping projects within the community.
- A brief description of related initiatives including such things as participation in Community Rating System (CRS), status and type of community Hazard Mitigation Plan (HMP), status of floodplain ordinance, etc.
- A brief description of community compliance issues identified in last Community Assistance Visit (CAV) or contact
- A brief description of the past, current, and future development projects (public and private) in the floodplain and/or study area

Source Information: CAV documentation (e.g., visit notes), Discovery Report, master drainage plans, community development plans, Risk MAP progress reports, Watershed/community engagement plan, HMP, and Hazard Mitigation Assistance grant activities within the community.

Plan Overview

This section of the plan describes the context and establishes the need for the community to communicate to its stakeholders about flood risk and the importance of mitigation actions.

- Describe other local communication strategies and/or initiatives that could potentially inform the COP. For example, the Federal Emergency Management Agency (FEMA) Risk MAP Regional Outreach Strategy has potentially developed a communication strategy to communicate risk within the Region, or the *Risk Communication Guidebook for Local Officials*. Coordination between the community and FEMA will help strengthen the overall risk messaging because of a greater potential to speak with one voice (message consistency). Utilize those messaging tools, such as the Region 6 web-based message tool.
- Identify and/or describe "hot button" issues that are particularly problematic for the community (e.g., expiration of Provisionally Accredited Levee (PAL) designations, outdated coastal hazard information, and unmet needs).
- Describe desired outcomes and/or issues that will be addressed or resolved as a result of implementing the plan.
- Describe the community's capacity to proactively communicate risk to constituents. Determine readily available community tools, such as websites, Twitter, or other social media.
- Identify a community "champion" who is responsible for plan development and implementation.

Goals and Objectives

Vision: FEMA has developed a vision for Risk MAP

"Through collaboration with State, local, and Tribal entities, deliver quality data that increases public awareness and leads to mitigation actions that reduce risk to life and property."

[Insert your community Vision or Resilient Community Mission Statement here.]

As an example*: "Changes to the National Flood Insurance Program (NFIP) make it imperative that [INSERT COMMUNITY] communicates with the citizens through targeted outreach to increase awareness and encourage mitigation practices and higher standards to reduce risk."*

This goals section of the plan will include a broad statement that describes what the community would like to achieve through implementing the it and not current community conditions. Characteristics of a goal statement should follow the SMART principle:

- Specific
- Measurable
- Action-Oriented
- Realistic
- Time and Resource Constrained

The following is an example goal statement for the community's consideration:

"Through targeted outreach to key stakeholders during the Risk MAP project, the community will better understand its flood risk and become a more flood resilient community. To accomplish our community goal, [INSERT COMMUNITY] will:

- Develop a community engagement and outreach strategy supported by FEMA Headquarters-approved products.
- Create a Community Outreach Toolkit in 60 days

The objectives section of the plan will describe up to five statements to which measures can be applied to evaluate whether the objective (which supports the goals) is met. In addition, all communication activities (tools/tactics) undertaken by the community need to accomplish one or more of the objectives defined in this section. It is recommended that no outreach activities are conducted that do not meet at least one of the plan objectives.

The following are example objective statements:

- Increase understanding of flood risk by 50 percent among homeowners in high-risk flood areas.
- Increase awareness of flood risk by 30 percent among insurance agents in [*INSERT COMMUNITY*].
- Ensure that all information sent to target audiences contains at least one key message about flood risk.

Schedule

Describe the schedule to develop the COP, when it should be completed, and dates for initial outreach activities. Describe suggested times for accelerated messages, and describe that your plan will be updated, as needed, to adjust in delivery, tactics, and messages.

Roles and Responsibilities

Provided in this section of the COP is a list of individuals/entities having a role in the development and implementation of the plan. Include a brief description of the position, role, and responsibility for each person, their position, and their contact information. A sample table format is below:

Name	Position	Organization	Responsibilities	Contact Information
John Smith	Plan Implementation Leader, Outreach Specialist	Public Affairs, Drafts Community Emergency Management Agency	Coordinates and tracks implementation and metrics	123-555-1212
Jane Smyth	Director of Public Affairs	Community Emergency Management Agency	Oversight and direction	Jane.Smyth@EM.com
Debbie Doer	Community Events Chair	Community Planning Agency	Update community events calendar	987-654-4321

Stakeholders

Primary Stakeholders: The plan should list the primary stakeholders (e.g., insurance agents, business owners) who will receive targeted outreach through implementing the plan. These stakeholders should include the top three to five groups that will be in a position to affect behavior change, ultimately reducing flood hazard risk in the community (high return for the investment of communication resources).

Secondary Stakeholders: The plan should also list the secondary stakeholders who also will receive targeted outreach, but at a reduced level of effort.

Key Messages

Provided in this section of the plan are the primary and secondary key messages that the community will convey in all information products about risk and the Risk MAP project. Primary messages convey broader, less-detailed information, and secondary messages include more detailed information in support of the primary message.

The following is an example of a primary message and supporting secondary messages:

The new maps that result from our Risk MAP project will help us better understand which parts of our community are at a greater risk of flooding.

- New maps were prepared using information from storms and flood events that happened since the previous flood risk maps were developed.
- High-risk flood areas on the new maps are an indication of where flooding is most likely to occur.
- Flooding can occur outside of these high-risk zones, depending on the unique characteristics of a storm or flood event.

Each Risk Communication product that a community prepares should include at least one of the key messages described below.

The following are the community's primary and secondary messages for this plan:

1. [insert key message]

1a.

1b.

1c.

2. [insert key message]

2a.

2b.

2c.

3. [insert key message]

3a.

3b.

3c.

Communication Tools and Tactics: Stakeholder Engagement Approach

This section of the plan describes the communication tools and tactics that will be implemented for each primary and secondary stakeholder group identified above, the objective that will be accomplished through the specific tool/tactic, and the means by which it will be evaluated to measure how well the tool/tactic helped to accomplish the objective. It is important to define the minimum level of effort required to accomplish the objective, which could be as simple as a checklist (e.g., send one letter/email to the targeted stakeholder group at key points along the mapping lifecycle).

Included are two formats for your Stakeholder Engagement Approach. Determine a format for the stakeholder engagement approach to describe the stakeholders, tools, and tactics that best meet the goals and objectives of the plan.

An extensive collection of tools and templates for communicating risk at the local level can be found in the FEMA Region 6 "Risk Communications Guidebook for Local Officials", available on www.fema.gov/risk-map-region-vi. For more information, contact the appropriate FEMA project monitor.

Stakeholder Group: Media [Lead: John Smith, Community Public Affairs]

Objective:

To ensure flood risk messages are included extensively in local media coverage at key project milestones throughout the community's flood risk project.

Tactics:

▪ Media kits (to include frequently asked questions, fact sheets, newsletters)

▪ Press releases

▪ Editorial board

Evaluation:

Conduct media content analysis to determine the frequency, accuracy, and timeliness of local media coverage of the key messages.

The following are the community's tools and tactics for each stakeholder group identified in this COP:

PRIMARY STAKEHOLDERS:

Stakeholder Group: [Insert stakeholder group and lead]

Objective:

Tactics:

Evaluation:

Stakeholder Group: [Insert stakeholder group and lead]

Objective:

Tactics:

Evaluation:

Stakeholder Group: [Insert stakeholder group and lead]

Objective:

Tactics:

Evaluation:

Stakeholder Group: [Insert stakeholder group and lead]

Objective:

Tactics:

Evaluation:

SECONDARY STAKEHOLDERS:

Stakeholder Group: [Insert stakeholder group and lead]

Objective:

Tactics:

Evaluation:

Stakeholder Group: [Insert stakeholder group and lead]

Objective:

Tactics:

Evaluation:

Stakeholder Group: [Insert stakeholder group and lead]

Objective:

Tactics:

Evaluation:

KEY GROUPS TACTICS KEY

MESSAGES

ACTIONS

Internal Stakeholders-

Regional Administrator. External Affairs.

Mitigation Division.

Recovery – Individual Assistance; Public Assistance.

Joint Field Office

• Briefings

• PowerPoint

• Resource links

• *Be aware of changes in the NFIP and the effects on FEMA programs and customers.*

• *Support efforts to share this information with external stakeholders and citizens.*

Media - • Media Kits (Flood Insurance Reform Toolkit)

• Social Media

See Key Messages in 7.0.

• *Share information with citizens and stakeholders on the Flood Insurance Reform.*

• *Educate public to know their risk and encourage actions to reduce that risk.*

Communication and Outreach Activities Action Plan

In addition to chronological milestones (e.g., short-, mid-, and long-term), consideration should be given to defining and implementing specific communication activities as they relate to the Risk MAP timeline. The community's outreach lead will have the responsibility for ensuring that the action plan is effectively implemented. The action plan should include "touch points" between the outreach lead and community decision makers to assess progress and determine what adjustments to the plan are needed to better meet plan goals and objectives.

Activity Deadline Responsibility Detail/Strategy/Status

Current (1 to 3 months)

3 to 6 months

6 to 9 months

9 to 12 months

Potential Stakeholders

- Congressional and State elected officials representing local jurisdictions
- Local elected officials and government agencies or department heads
- Floodplain, stormwater, emergency managers
- Public sector land use planners
- Local chapters of regional/national associations (e.g., League of Women Voters,
- Association of State Floodplain Managers)
- Local environmental organizations, civic organizations and interest groups, churches
- and faith-based groups

- Flood zone determination companies
- Insurance companies and agents
- Developers, Lenders, and banks

Potential Key Messages

Potential Target Audience

Potential Messages for All Audiences

- Our community is at risk of flooding.
- We are working at all levels (e.g., mayor's office, emergency planners, land use developers) to reduce the impact of flooding on our community.
- Our office will keep you informed about changes to our community's risks.
- There are low-cost steps you can and should take to reduce the impact of floods. To review our community's flood maps and see what steps you can take, visit [insert Region 6 mapping website link or www.msc.fema.gov].
- Share information about the flood risks in your area with your friends and neighbors.
- Know your risk.

Potential Messages to Share with Business Community

- Protect your investment by taking steps to reduce the impacts of floods on your business.
- Taking steps to protect your business from flooding can be a strategic advantage.
- Federal assistance and flood insurance will only help you to a degree. You will sustain your competitive advantage after a disaster by protecting your business from flooding.
- Encourage your community and other businesses to take steps to reduce flood risk; be sure to speak with local business owners to ensure the safety of their employees in the event of a disaster (helping with continuity of business operations).
- You play an important role in the community's preparation and mitigation before a flood and recovery after a flood.
- Acting responsibly before and after a flood will result in quicker, more sustained economic, physical, and social recovery in your community.

Potential Messages for Business Community to Share with Others

- All Businesses - We are committed to the economic viability of our community through responsible planning, which will help us recover faster after a flood.
- All Businesses - Let's work together to understand our risks, prepare, and protect ourselves from flooding impacts. Work together to make [community name] a resilient community.
- For Small Town or Community Focused Businesses - We understand our flood risks; you need to also understand this risk so we can all take precautions and act responsibly as a community.

Potential Messages for Land Use Planners

- [INSERT COMMUNITY] has some flood risk, and FEMA has new tools to help identify, assess, and mitigate that risk as part of the planning process.
- [INSERT COMMUNITY] relies on you not to build in certain areas, including sites with higher risk of flooding.

- Build smartly and balance the risk versus the economic benefit to your business and your community.
- Hazard planning is similar to traditional community planning. Build hazard mitigation into your plans to help ensure the community's sustainability.
- Flood risks change over time, based on new building, weather changes, and other factors. Visit www.fema.gov or www.fema.gov/risk-map-region-vi to get the latest information about your community's flood risks.

Potential Messages for Planners to Share with Others

- Here are the flood risks in the community and the steps we are taking through land use planning to reduce the impact of floods on our community. Our efforts are part of a larger, community-wide effort to better protect ourselves from flooding.
- Individuals should also do what they can to mitigate risk. To learn what you can do, visit www.fema.gov.

Potential Messages to Share with Floodplain/Stormwater Managers and NFIP State Coordinators

- These are your maps, this is your community, and your citizens are looking to you to better protect the community from flood risk.
- FEMA's new Risk MAP program is offering new tools based on the best science available to help you better identify and assess your community's risks and evaluate the benefits of taking steps to reduce your community's vulnerability. To learn more, visit www.fema.gov.
- There are steps you and your constituents can take to continue to reduce the impact of floods. To learn more, visit www.fema.gov/safer-stronger-protected-homes-communities.
- Flood risks change over time, based on new building, weather changes, and other factors. Visit www.fema.gov or www.fema.gov/risk-map-region-vi to get the latest information about your community's flood risks.

Potential Messages for Floodplain/Stormwater Managers and NFIP State Coordinators to Share with Others

- As part of our participation in the NFIP, we have already taken steps to reduce the impact of flooding, and we're striving to go even further to protect our community.
- The floodplain manager's office will work with other community officials to keep you informed about your flood risk and is taking proactive steps to protect our community.
- Flood insurance is only one component of flood protection. There are low-cost steps you can and should take to reduce the impact of floods. Build upon existing efforts that the community has already taken. To learn more, visit www.fema.gov or www.fema.gov/risk-map-region-vi.

Potential Messages to Share with the General Public

- Get to know and stay up-to-date with your community's risk of flooding by visiting www.fema.gov or www.fema.gov/risk-map-region-vi.
- Take steps to reduce the impact of floods on yourself and your family.
- Tell others about your community's flood risk and what steps they should take to reduce the impact of floods – like home elevation or purchasing flood insurance.
- [Community name] can flood, and even small floods can cause a lot of damage.

- Nature and development in [Community name] cause floods; FEMA's responsibility is to depict the flood risks.
- New maps have been created using the best available science. Your community's flood maps show your risk. To see your map and learn more, visit www.msc.fema.gov or www.fema.gov/risk-map-region-vi.
- Flooding cannot only take away your financial stability, but your sense of security as well.
- If you do not take steps to reduce the impacts of floods, you may be putting yourself and your family at risk.
- Flood risks change over time, based on new building, weather changes, and other factors. Visit www.fema.gov or www.fema.gov/risk-map-region-vi to get the latest information about your community's flood risk.
- Reducing risk to your home and family is a personal responsibility. Take steps to reduce the impact of floods. To learn more, visit www.fema.gov, www.ready.gov, or www.fema.gov/risk-map-region-vi.
- Disaster Assistance is limited and primarily comes in the form of loans that you would need to repay.
- Taking steps to reduce the impact of flooding and purchasing flood insurance can help you establish and maintain your independence.

Potential Messages to Economic Authority Members

- Mitigation and economic development are not mutually exclusive. Building with disaster resistant techniques will have long-term payoffs in terms of community and economic resiliency.
- Protecting your community from disasters such as floods should be a critical component of the continuity of operations plans of businesses in your community.
- There are low-cost steps businesses should take to reduce the impact of flooding. To learn more, visit www.fema.gov/safer-stronger-protected-homes-communities or www.ready.gov.

Potential Messages for Economic Authority Members to Share with Others:

- Everyone needs to know their risk. Your business may be at risk for flooding.
- Mitigation and economic development are not mutually exclusive. Building with disaster resistant techniques will have long-term payoffs in terms of community and economic resiliency.
- Becoming a resilient community is everyone's responsibility. Our community is taking action to help protect your business from flooding – just one more reason to keep doing business here (or consider doing business here).
- There are low-cost steps businesses should take to reduce the impact of flooding. To learn more, visit www.fema.gov/safer-stronger-protected-homes-communities or www.ready.gov.

Potential Messages to Emergency Managers

- New tools, such as HAZUS, the Flood Risk Report, Flood Risk Map, and Flood Risk Database, which are available from FEMA's new Risk MAP program, will help you better identify and assess your community's risks and evaluate the benefits of taking steps to reduce your community's vulnerability. To learn more, visit www.fema.gov/risk-map-region-vi
- Use Risk MAP tools and data to inform your emergency action plans and exercises.
- Be a champion for mitigation. Encourage others to better protect themselves, their businesses, and their community from flooding.

- Flood risks change over time, based on new building, weather changes, and other factors. Visit [community/state website] to get the latest information about your community's flood risks.

Potential Messages for Emergency Managers to Share with Others

- Our community is at risk for flooding (support with data provided through Risk MAP Solution).
- We have considered flooding in our emergency action plans. This is one step of many that the community should take to protect itself from flooding.
- There are low-cost steps you should take to protect yourself from flood risks. To learn more, visit www.fema.gov or www.ready.gov.

Potential Messages to Share with State Hazard Mitigation Officers (SHMOs)

- FEMA has a new program called Risk MAP, which offers new tools you can use to improve mitigation plans and better protect your State.
- To learn more, visit www.fema.gov/safer-stronger-protected-homes-communities. Messages for SHMOs to Share with Others:
- Every community in the State is at risk from flooding (support with data provided through High-Level Solution).
- You are responsible for implementing a mitigation plan to protect your community. You also are responsible for sharing information with your constituents to help them protect themselves.
- There are new tools you can use to improve your mitigation plans and better protect your community. To learn more, visit www.fema.gov/risk-map-region-vi.

Potential Messages to Real Estate Agents

- Flood waters do not stop at the lines on a flood map. Floods can happen anywhere, at any time.
- Actions taken to better protect a home (or community) from flooding add value.
- Homeowners insurance does not cover flood damage.
- Advise your clients to talk to their insurance agents about the flood risks facing a particular property.

Potential Messages for Real Estate Agents to Share with Others

- Flood waters do not stop at the lines on a flood map. Floods can happen anywhere, at any time.
- Homeowners insurance does not cover flood damage.
- Talk to your insurance agent about the flood risks facing the property you are considering.
- Actions taken to better protect a home (or community) from flooding add value.
- Safer homes are a better investment.

Potential Messages to Architects and Contractors

- It is often significantly more cost effective to build flood mitigation measures (e.g., raising a house) into a structure from the start than to retrofit the structure later. To learn more, visit www.fema.gov.
- Incorporating flood mitigation measures into structures adds value and may be a competitive advantage. Build structures that can withstand flooding and be seen as leaders in the building community.

Potential Messages to Architects and Contractors to Share with Others

- It will be much less expensive to build flood mitigation measures into your structure from the start than to retrofit it later. To learn more, visit www.fema.gov.
- Mitigation measures may help increase the structure's value.
- By implementing protective measures, you may save money on flood insurance. To learn more, visit www.FEMA.gov/NFIP.

Potential Messages to Share with Insurance Companies/Write-Your-Own (WYO) Companies:

- Flood waters do not stop at a line on a map; in fact, many flood insurance claims come from low- to moderate-risk areas
- There is a 26% chance of flooding over the life of a 30-year mortgage if you are in the high- risk area, which is significantly higher than the chance of fire.
- To help your clients protect their property, recommend that they purchase flood insurance and take protective measures, even if they are not located in a high-risk area. To learn more, visit www.FEMA.gov/NFIP.
- Training is available on flood insurance, and FEMA offers all of the resources you need to be the best at your job.

Potential Messages to Claims Adjustors

- As first point of contact with people who have experienced flood damage, you can encourage people to rebuild safer and stronger to protect against future risks.
- There are low cost steps people should take to better protect themselves from flooding. To learn more, visit www.fema.gov/safer-stronger-protected-homes-communities.

Potential Messages for Claims Adjustors to Share with Others

- You have an opportunity to build back safer and stronger to protect you and your family from future floods.
- There are low-cost steps you should take to protect your home or business from future flooding.
- Even if you have been flooded before, you can still buy flood insurance. Land developers

Potential Messages to Share with Land Developers Developers/Infrastructure Developers

- The tools and maps developed under FEMA's new Risk MAP program can help you create a better risk mitigation and land use plan.
- Be leaders in advocating for building away from the floodplain.
- Transportation and water/sewer infrastructure is critical to a community's ability to handle and bounce back after a disaster.
- Flood risks change over time, based on new building, weather changes, and other factors. Visit www.fema.gov or www.fema.gov/risk-map-region-vi to get the latest information about your community's flood risks.

Potential Messages for Land Developers/Infrastructure Developers

- We have factored flood risk into our plans.
- We have taken steps to mitigate damages from flooding to our community's infrastructure.
- We need to work together to reduce our community's vulnerability to floods.

Potential Messages to Lenders

- Flood waters do not stop at a line on a map; in fact, many flood insurance claims come from moderate- to low-risk areas.
- There is a 26% chance of flooding over the life of a 30-year mortgage if you are in the high- risk area, which is significantly higher than the chance of fire.
- The Federal Government uses the best available technology to create the most precise, up-to- date maps, which are used to set flood insurance policy rates.
- To help protect your investment, encourage your clients to purchase flood insurance and take protective measures, even if they are not located in a Special Flood Hazard Area. To learn more, visit www.fema.gov.

Potential Messages for Lenders to Share with Others

- Flood waters do not stop at a line on a map; in fact, many flood insurance claims come from moderate- to low-risk areas.
- There is a 26% chance of flooding over the life of a 30-year mortgage if you are in the high- risk area, which is significantly higher than the chance of fire.
- Purchase flood insurance to protect your new investment. There are also other low-cost measures you can take to protect your property. To learn more, visit www.fema.gov/safer- stronger-protected-homes-communities.

Potential Messages to Flood Determination Companies

- There are new mapping technologies available that use the latest data and information available to create comprehensive and precise, up-to-date flood maps.
- These maps will make your job easier by creating consistency in the determination of properties and reducing disputes by homeowners.
- In addition to flood insurance, there are many other low-cost measures homeowners can take to reduce their flood risk. Learn more by visiting www.fema.gov/safer-stronger-protected-homes-communities.

Messages for Flood Determination Companies to Share with Others

- In addition to flood insurance, there are many other low-cost steps you can take to protect your home from flooding. To learn more, visit www.fema.gov/safer-stronger-protected-homes-communities.
- Even if your home is not located in a floodplain, flood waters do not stop at a line on a map. Flood insurance and other protective measures are a good idea for all homeowners.
- In fact, many flood insurance claims come from moderate- to low-risk areas.
- There is a 26% chance of flooding over the life of a 30-year mortgage if you are in the high- risk area, which is significantly higher than the chance of fire.

Potential Tactics

Local officials can use a variety of tactics to raise flood risk awareness among the people who live and work in their community. The tactic used to communicate is important to ensuring that the correct message is received. Local officials should keep their community’s unique characteristics in mind when determining which tactic to use to reach each of its stakeholders because no one communication plan will work nationwide.

Stakeholder Advisory Group

To provide regular updates on flood risk, mitigation activities, and encourage actions to reduce risk, consider developing a stakeholder advisory group with representatives from each stakeholder organization. The group could meet quarterly or more, as required, and provide a forum to answer questions, discuss available resources and funding, and identify points of coordination. Below are additional tactics to consider by stakeholder.

Tactics by Stakeholder Group

- For Local Elected Officials, Tribal leaders and Government Entities:
  - Develop talking points and collateral materials on flood risk.
  - Present at council meetings on mapping and local outreach efforts.
  - Provide demonstration of flood risk mapping portal to staff when available.
  - Develop COP – gain support of local efforts and awareness campaign by officials.
  - Keep local officials, tribal leaders, and government entities informed of the outreach efforts and mapping status regularly through regular reporting.
- For the business community:
  - Develop talking points and collateral materials on flood risk.
  - Attend meetings of the local Chamber of Commerce, Rotary International, and other civic groups.
  - Identify local businesses predisposed to mitigation to engage, then promote their efforts to peers.
  - Deliver messages in post-disaster periods.
- For Land Use Planners:
  - Enhance and/or form partnerships through associations such as the American Planning Association.
- For Floodplain/Stormwater Managers:
  - Enhance and/or form partnerships through associations such as the Association of State Floodplain Managers, State Floodplain Management Associations, and National Association of Flood and Stormwater Management.
  - Encourage outreach as part of the CRS program.
  - Consider larger audience strategies, such as county, parish, or watershed outreach activities.
  - Identify CRS user groups to broaden outreach initiatives.
- For the General Public:
  - Consider using social media and Web 2.0 such as your community's Facebook page or Twitter account to share flood risk information.
  - Provide briefings on the nightly news or through local daily newspapers.
  - Conduct outreach about flood risk at key times as appropriate, such as the beginning of hurricane season (www.ready.gov/hurricanes), National Preparedness Month (www.ready.gov/September), and Spring flooding or snowmelt (www.ready.gov/winter-weather).
  - Mail letters directly to property owners affected by the map changes.
  - Reach out through community-focused events including Homeowner Associations, festivals, and tribal activities.
  - Promote flood awareness through community websites. Consider linking to FEMA's website (www.FEMA.gov/NFIP) or www.fema.gov/risk-map-region-vi.

    - Enlist primary, secondary, and college students as ambassadors of flood risk information.
    - Provide flood risk information through local libraries or other public buildings.
    - Theatre advertisement on flood risk information, public mapping meetings, or links to flood maps.
    - Distribute flood risk awareness materials through existing resources – utility bills, grocery bags, notes in schoolbags.
- For Economic Authorities:
    - Enhance and/or form partnerships through associations such as the Chamber of Commerce.
    - Attend appropriate conferences and meetings.
    - Conduct media outreach to appropriate trade publications.
- For Emergency Managers:
    - Encourage attendance at FEMA meetings, such as Discovery, Flood Risk Review, and Resilience.
    - Share Flood Risk Tools and products with local emergency management partners.
    - Coordinate outreach activities – preparedness activities, drills, and other local venues for communicating risk.
    - Consider developing joint outreach campaign with Emergency Management.
    - Invite Emergency Management staff to be part of the Stakeholder Advisory team for Community Outreach.
    - Invite local Emergency Managers to attend State Floodplain Management Conferences.
    - Enhance and/or form partnerships through associations such as National Emergency Managers Association.
    - Attend appropriate conferences and meetings.
    - Coordinate key messages for citizens – present "one-voice" on local flood risks.
    - Share coordination of outreach success stories with FEMA Region 6.
- For the Insurance Industry:
    - Present at the local monthly Insurance Agent meeting – share flood risk information and new tools available, such as interactive mapping portal.
    - Invite insurance agents to learn about the new flood maps prior to the Open House, then invite them to the Open House to share information with the public.
    - Direct insurance agents to www.fema.gov/risk-map-region-vi to learn more about flood risk and share the site with their customers.
    - Encourage use of new tools, such as Changes Since Last FIRM to inform customer base of flood risks.
    - Use established partnerships with Flood Insurance Producers National Committee and others to enhance understanding and awareness of risk and actions to take.
    - Conduct media outreach to appropriate trade publications especially during hurricane season, National Flood Awareness Week, National Preparedness Month, etc.
- For Mortgage Lenders:
    - Provide flood risk information for lenders to include in their letters requiring flood insurance.
    - Conduct media outreach to appropriate trade publications especially during hurricane season, National Flood Awareness Week, National Preparedness Month.
    - Conduct outreach in post-disaster periods.
- For Realtors:
    - Present at the local monthly real estate agent meetings – share flood risk information and new tools available, such as interactive mapping portal.

- Produce and distribute collateral materials that provide risk messaging and action steps.
- Enhance and/or form partnerships through associations such as the National Association of Realtors.
- Sample Brochure for Activity 340 Hazard Disclosure
- Flood Hazard: Check Before You Buy
- Most everyone knows that coastal properties are subject to flooding and wind damage from hurricanes. There are maps that show areas predicted to flood. To find out more about flood-prone area maps, check with ___________________ [office that administers the map information service credited under Activity 320]
- However, flooding and other surface drainage problems can occur well away from the coast. If you're looking at a property, it's a good idea to check out the possible flood hazard before you buy. Here's why:
- The force of moving water or waves can destroy a building.
- Slow-moving floodwaters can knock people off their feet or float a car.
- Even standing water can float a building, collapse basement walls, or buckle a concrete floor.
- Water-soaked contents, such as carpeting, clothing, upholstered furniture, and mattresses, may have to be thrown away after a flood.
- Some items, such as photographs and heirlooms, may never be restored to their original condition.
- Floodwaters are not clean: floods carry mud, farm chemicals, road oil, and other noxious
- substances that cause health hazards.
- Flooded buildings breed mold and other problems if they are not repaired quickly and properly.
- The impact of a flood—cleaning up, making repairs, and the personal losses—can cause great stress to you, your family, and your finances.

Floodplain Regulations: [INSERT COMMUNITY] regulates construction and development in the floodplain to ensure that buildings will be protected from flood damage. Filling and similar projects are prohibited in certain areas. Houses substantially damaged by fire, flood, or any other cause must be elevated to or above the regulatory flood level when they are repaired. More information can be obtained from __________________ *[name, phone number of permit office]*

Check for a Flood Hazard: Before committing to buying property, do the following:

- Ask the __________________ *[name, phone number of permit office]* if the property is in a floodplain; if it has ever been flooded; what the flood depth, velocity, and warning time are; if it is subject to any other hazards; and what building or zoning regulations are in effect.
- Ask the real estate agent if the property is in a floodplain, if it has ever been flooded, and if it is subject to any other hazards, such as sewer backup or subsidence.
- Ask the seller and the neighbors if the property is in a floodplain, how long they have lived there, if the property has ever been flooded, and if it is subject to any other hazards.

Flood Protection: A building can be protected from most flood hazards, sometimes at a relatively low cost. New buildings and additions can be elevated above flood levels. Existing buildings can be protected from shallow floodwaters by regrading, berms, or floodwalls. There are other retrofitting techniques that can protect a building from surface or subsurface water.

Flood Insurance: Homeowners insurance usually does not include coverage for a flood. One of the best protection measures for a building with a flood problem is a flood insurance policy under the National Flood Insurance Program, which can be purchased through any licensed property insurance agent. If the building is located in a floodplain, flood insurance will be required by most federally backed mortgage lenders. Ask an insurance agent how much a flood insurance policy would cost.

Sample Fact Sheet for Activity 370 Flood Insurance Promotion

TEMPLATE: FACT SHEET – WHAT INSURANCE PROFESSIONALS NEED TO KNOW

FLOOD RISKS ARE CHANGING

WHAT INSURANCE PROFESSIONALS NEED TO KNOW

Important changes to the [INSERT COMMUNIY] *flood hazard maps are underway. As floodplain boundaries change, clients will likely turn to their agents to help make decisions about insuring their properties and other assets. The changes may affect agents as well; therefore, it is essential to stay informed.*

[INSERT COMMUNITY] FLOOD MAPS ARE CHANGING

[INSERT COMMUNITY] and the Federal Emergency Management Agency (FEMA) will release new *preliminary* flood hazard maps, known as Flood Insurance Rate Maps (FIRMs), [for specific watersheds/all of Name] County. The new FIRMs will show which portions of the county are currently at risk for flooding. The remapping effort—part of FEMA's nationwide flood Risk Mapping, Assessment and Planning (Risk MAP) effort—was necessary because flood hazard and risk information shown on the flood maps need to be updated. Detailed studies in some areas are more than [years] old. Since then, drainage patterns changed, new land development occurred, and mapping and modeling technology significantly improved.

KNOW THE EFFECTS AND THE FLOOD INSURANCE OPTIONS While the FIRMs may not become effective for another [number] months or more, it is important for insurance professionals to understand the effects these map changes have on flood insurance requirements and what options are available for their clients. Properties may be newly identified to be at high risk, have changes in their Base Flood Elevations (BFEs), be newly identified to be at moderate or low risk, or remain in the same zone. Insurance professionals need to properly educate property owners about these changes, how they affect the flood insurance requirements, and the insurance options available.

NFIP RATING OPTIONS COULD SAVE CLIENTS MONEY If a building is being newly identified to be in a high-risk zone (noted on the flood maps with the letter beginning with the letter "A" or "V") and there is a federally backed mortgage on the property, flood insurance will be federally required. If a property is already in a high-risk area, its BFE may change or it may be identified to be in a higher risk zone (e.g., Zone AE to Zone VE). Any of these changes could result in higher flood insurance premiums for clients.

The National Flood Insurance Program (NFIP) provides lower-cost flood insurance rating options. For example, buildings newly identified to be in a high-risk area may be eligible for the lower-cost Preferred Risk Policy (PRP) rates for the first 12 months after the maps become effective. Premiums will then increase no more than 18 percent a year until they reach their full-risk rate. This is known as the Newly Mapped procedure.

For buildings that don't qualify for a PRP or are in a high- risk zone and there is an increase in the Base Flood Elevation (BFE) [or are being mapped into a higher risk zone (e.g., Zone AE to VE)], FEMA allows for the lower BFE [or lower risk zone] to be used for rating. This is known as "grandfathering".

Because these “grandfathered” insurance rates may be less than the rates for the zone or BFE shown on the new FIRM, it is important to compare both when discussing insurance options.

CONVERSION KEEPS CLIENTS PROTECTED Some properties’ flood risk may decrease and change from a high-risk zone to a moderate- or low-risk zone (shown on the new FIRM as an “X” or shaded “X” zone). Federal requirements for the mandatory purchase of insurance are lifted, though some lenders may continue to require coverage.

Property owners should be reminded that the risk has only been reduced, *not removed.* They can maintain coverage by converting their current policy to the lower-cost Preferred Risk Policy (PRP). This conversion is backdated to the current policy’s effective date and then the cost of the PRP is deducted from the original premium paid. Consequently, no additional funding is required from the insured, and it typically results in a refund of premium. The NFIP also allows agents to keep the commission on both policies. With premiums starting at less than $200 per year, a PRP offers significant cost savings while still providing important coverage.

If maps show high risk of flooding for the property, these requirements, options, and savings apply:

- Change from moderate or low flood risk to high risk (flood Zone B, C, or X to Zone A, AE, AH, AO, V or VE)

Flood insurance is mandatory. Flood insurance will be federally required for most mortgage holders. Insurance costs may rise to reflect the true (high) risk.

Rating Options can offer savings. The NFIP provides savings by allowing lower-cost PRP rates to be used the first 12 months after a new flood map becomes effective. Premiums will then increase no more than 18 percent each year. Affected property owners are encouraged to buy a PRP before the maps become effective for additional savings.

- Change from high-risk Zone A or AE to higher-risk Zone V or VE

An increase in risk can result in higher premiums; however, “grandfathering” can offer savings. The NFIP grandfathering rules allow policyholders who built in compliance with the flood map in effect at the time of construction to keep their previous Zone A or AE to calculate their insurance rates. This could result in significant savings.

- Change from high flood risk to moderate or low risk (e.g., flood Zone V, VE, A, AE, AH, AO, to Zone X or shaded X)

Flood insurance is optional but recommended. The risk has only been reduced, not *removed*. Flood insurance can still be obtained at lower rates. About 25 percent of all flood insurance claims and 1/3 of flood disaster claims come from moderate-to low-risk areas.

Conversion offers savings. An existing policy can be easily converted to a lower-cost PRP, if the building qualifies. Note that lenders always have the option to require flood insurance in these areas.

- Increase in the BFE

An increase in the BFE can result in higher premiums; however, “grandfathering” can offer savings. The NFIP grandfathering rules allow policyholders who built in compliance with the flood map in effect at the time of construction to keep the earlier BFE to calculate their insurance rates. This could result in significant savings.

- No change in risk level

No change in insurance rates. However, this is a good time to review coverage and ensure building and contents are adequately insured.

STAY INFORMED Knowing when and where map changes are occurring allows insurance professionals to properly educate clients about insurance options available. Prepare by staying in contact with local officials and periodically visiting the [INSERT WEBSITE IN HERE]. When released, the preliminary maps can be viewed at [community or county name web site at web link or if no website then www.fema.gov/risk-map-region-vi]. The maps will also be available for viewing at [put building location and times it is open]. Questions can be directed to the [identify where] by calling [phone number] during business hours [days and times].

For specific information about rating options including grandfathering and conversion, visit: www.fema.gov/flood-insurance-manual. To learn more about FEMA's Region 6 mapping program, visit www.fema.gov/risk-map-region-vi.

[DATE] — Preliminary flood maps released [DATE] — Open House Held; Public Review [DATE] — Start of [90-day] Public Comment Period [(for filing of appeals and comments)] [Target Date, Month or Season – e.g. fall 2018]* — New flood maps take effect; new flood insurance requirements also take effect Visit www.fema.gov/risk-map-region-vi to learn more about the mapping process and where and when meetings may be held For General Information Call The [name of local call center or contact number] at [phone #]. Open [enter hours of operation]. * *Date subject to change pending completion of review process*

APPENDIX F: DATA SOURCES USED TO COMPILE RESULTS

Table F1. 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	3.28G bytes, raster images	Native
	USGS_NED	USGS	Part of Florida, raster image in 3m	Created by USGS	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\LiDAR_DEM\DEM_3m	40.9G bytes, raster images	Native
	Miami-Dade	NOAA	Miami Dade County, raster image in 4.92ft	Created by Miami-Dade County Information Technology Department (ITD) in 2015	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\LiDAR_DEM\MD_2015_LiDAR_DEM_NOAA	14G bytes, raster images	Native
	USGS_DEM	USGS	Florida, Raster data in 10m	Created by USGS	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\USGS_DEM	22.6 G bytes, raster images	Native
	DEM_3m_merged	USGS	3m in tiff		\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\LiDAR_DEM\DEM_3m_merged	186G bytes, raster images	FAU Processed

	SRTM_30m	NASA	30m Raster		\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\LiDAR_DEM\SRTM_30m_UCF_Chang	607M bytes, raster images	Native
Groundwater	FL_GW	South FL Water Management District	Florida, Excel	Daily, 1980-2020	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_GW\South Florida District	140 M bytes, 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 G bytes, Geodatabase	Native
	FL_GW	Suwanne Water Management District	Florida, Excel	Daily, 1980-2020	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_GW\Suwanne District	64 M bytes, excel	Native
	FL_GW	NWFWD	Florida, Excel	Daily, 1980-2020	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_GW\NWFWD	216 M bytes, excel	Native
	FL_GW	St. John River Water Management District	Florida, Excel	Daily, 1980-2020	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_GW\St. Johns River District Ground Water\	103M bytes, excel	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\	74.5M bytes, in excel and dbf	Native

Soil	FL_Soil	FY2019 USDA Soil SSURGO gSSURGO) Database https://sdmdataaccess.nrcs.usda.gov/	Florida, Raster data is in 10m	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	107G bytes, both vector and raster	FAU Processed
Land Cover	USGS_LC	USGS	Conterminous United States, raster format, 30m 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	20G bytes, raster	Native
	Impervious Surface	USGS	Florida, 30m derived from satellite	Created by USGS in 2016 (Most recent)	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\Impervious\NLCD_2016_Impervious_descriptor_L48_20190405\	24.6G Bytes, Raster Image	FAU Processed
	Open Space	USGS	Florida, 30m derived from satellite	Created by USGS in 2016 (Most recent)	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_LCLU\NLCD2016_OpenSpace\	21G bytes, raster	FAU Processed
Precipitation Records	FL_NOAA14_Precipitation	NOAA Atlas 14 Database	Florida, raster in 800m	Most recent release from NOAA	\\engsynws01.eng.fau.edu\Project_mastercopy\Datasets\FL_NOAA14_Precipitation\se25y3d_inch.tif	34 M bytes, raster images	FAU Processed, 3 day-25 year and 3 day-100 year