South Florida Living Shorelines Spatial Database:

Restoration, Enhancement and Stabilization Projects

Version 1.0

Technical Report

SUBMITTED TO:
THE NATURE CONSERVANCY

SUBMITTED BY:
Diana Mitsova, PhD
Principal Investigator
School of Urban and Regional Planning
FLORIDA ATLANTIC UNIVERSITY

This project was funded by The Nature Conservancy under Grant Agreement #FLFO-FAU-060114.

South Florida Living Shorelines Spatial Database: Restoration, Enhancement and Stabilization Projects

VERSION 1.0

Prepared by:

Diana Mitsova, PhD
Associate Professor and Principal Investigator

Stephanie Reed
Graduate Research Assistant

School of Urban and Regional Planning
FLORIDA ATLANTIC UNIVERSITY

Boca Raton, FLORIDA

December 31, 2014

Revised January 19, 2015

EXECUTIVE SUMMARY

The SE Florida Living Shoreline Spatial Database incorporates nearly 1,500 shoreline features. They include natural habitats and an array of shoreline restoration, enhancement and stabilization projects. The spatial extent of the database encompasses Broward County, Miami-Dade County, Palm Beach County, and the Blowing Rocks Preserve in Martin County. More specifically, the focus is on estuarine areas along the Intracoastal Waterway. The database and the report reflect our understanding of the importance of the nature-based shoreline stabilization options which individually or in conjunction with structural measures can improve our response to coastal hazards, contribute to the health of estuarine and marine environments, and protect economic and cultural resources. Thus, the creation of the Living Shorelines Spatial Database is intended to serve as a pilot study to support development of a spatial decision support tool for shoreline management that can enhance coastal resilience and sustainability. Since the late 1980s, several large-scale habitat restoration projects have been successfully implemented in all four counties. These projects use a range of naturally occurring features to stabilize and protect shorelines, including mangrove and hammock habitat restoration; dune restoration, beach nourishment; reefs and oyster beds. Vegetated shorelines or a combination of plant communities and stabilization can attenuate wave action, dissipate wave energy, and mitigate erosional forces. The successful implementation of such projects is particularly important in the context of sea level rise which will most likely amplify the shoreline management challenges faced by residents, planners, coastal managers, and decision-makers.

The database includes four types of shoreline features: natural shorelines, shoreline restoration projects, shoreline enhancement projects and stabilization projects. Each shoreline feature is associated with 37 attributes. These attributes were derived from (i) existing geospatial datasets, (ii) permits, reports or other available documentation, (iii) local knowledge, and (iv) algorithms to calculate attribute values using the analytical tools available in ©ArcGIS. The database was developed as a collaborative effort among multiple agencies and stakeholders. The Southeast Florida (SEFL) Compact Shoreline Resilience Working Group (SRWG) provided the impetus for this effort as well as invaluable expertise, input and feedback. The Nature Conservancy, the School of Urban and Regional Planning at Florida Atlantic University, Broward County EPD, Miami-Dade County DERM, and Palm Beach County ERM played a leading role in the development of the Southeast Florida Living Shorelines Spatial Database. Every effort was made to ensure the completeness and accuracy of the information in each spatial layer. However, some discrepancies may still persist due to the variety of sources used to compile the information.

The introduction to this report summarizes the purpose of developing a spatial database of shoreline restoration, enhancement and stabilization projects and outlines the stakeholder process. Section 2 provides an overview of the pertinent literature with a focus on alternative approaches to shoreline stabilization. Section 3 provides users with additional information, explains in detail each field included in the attribute table, and specifies domain values. A synopsis of attribute labels, attribute type, attribute definition, and attribute data source is given in Appendix I.

ACKNOWLEDGMENTS

This project was funded by a Grant Agreement #FLFO-FAU-060114 between the Nature Conservancy and the Florida Atlantic University Board of Trustees.

We gratefully acknowledge the contribution of many individuals and organizations. First and foremost, we would like to thank the members of the Southeast Florida Shoreline Resilience Working Group who provided invaluable support in all phases of the project. We are sincerely thankful to Chris Bergh, Michael Renda, Andrea Graves, James Byrnes, and Caitlin Lustic from The Nature Conservancy who continually assisted us with the development of the geodatabase. We also greatly appreciate the assistance of David Stout, Katie Lelis, Josh Mahoney, Paul Davis, Julie Mitchel, Eric Anderson, Brandon Justice, Ryan St. George, and Linda Sunderland who provided data, reviewed and critically assessed the database, and assisted with a number of other tasks associated with the project. We also thank Prof. Leonard Berry, Prof. Marguerite Koch-Rose and Prof. Ann-Margaret Esnard who were involved in the initial stages of this project through the FAU Seed Grant Program.

DISCLAIMER

This application includes data derived from available information and expert knowledge. The application is not intended to create or constitute any legally binding obligation and no party shall have any liability or obligation to another with respect to using the data as is. All users should carefully consider scale, purpose and intended uses and consult the best available data sources as certain datasets may not be suitable for all proposed tasks and/or planned objectives.

Data included in the spatial database are subject to some limitations. Data for shoreline restoration, enhancement and stabilization projects were not generally available through public data sources. The data were obtained through direct communication and data requests, or derived from historical documents. Data for several parameters included in the attribute tables of the geodatabase feature classes were available only in permits and reports. Every effort was made to ensure the completeness and accuracy of the information in each spatial layer. However, some discrepancies may still persist due to the variety of sources used to compile the information. Some spatial layers may not be as comprehensive as others because such data were not produced by the owner of the data source.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

South Florida coastal resources are under increasing pressure from extensive urban development. Palm Beach County, Broward County, and Miami-Dade County are part of the state largest metropolitan region (FWS 1999). The region has the 8th highest absolute growth in the U.S. (U.S. Census 2010) which exerts ever-increasing pressure on Florida's unique ecosystems which host diverse plant and animal communities. In addition to its low-lying topography, South Florida combines unique physical and socio-economic vulnerabilities, and has some of the highest population to shoreline length ratios: 64,760 persons per mile in Broward County and 40,510 persons per mile in Miami-Dade. The Florida Beach and Shore Preservation Act of 1965 regulated construction in Florida coastal zone and was strengthened in 1985 to include the prohibition of development seaward of the thirty-year erosion projection line. While the Act was progressive and comprehensive for its time, it did not account for the effects of climate change and an increasing rate of sea level rise (Rupert 2008). Increasing urban development in the shore zone has resulted in substantial shoreline armoring, water quality impairment due to sedimentation and pollution, and loss of habitat and intertidal ecological functions (FDEP 2011).

Since the late 1980s, several large-scale habitat restoration projects have been successfully implemented in Palm Beach, Martin, Miami-Dade and Broward counties. In Palm Beach County, extensive work on habitat restoration and shoreline stabilization and enhancement has been underway for several decades. Award-wining restoration projects were developed in the Lake Worth Lagoon and other locations throughout the county. Broward and Miami-Dade counties, which are more developed, have also undertaken steps to protect marine and estuarine habitats and reduce shoreline erosion. Under the provisions of Chapter 24.58 of the Code of Metropolitan Dade County, the Miami-Dade Department for Environmental Resource Management has applied the "concept and/or use of natural vegetation communities on the majority of public owned shorelines in Biscayne Bay and on Miami-Dade's barrier beaches for more than 3 decades" (MDC, personal communication, 2011). More specifically, Miami-Dade County has developed large shoreline restoration projects including spoil islands, wetlands and dune restoration, maritime hammock and coastal strand restoration, and applied and maintained riprap revetments/planters in some inshore and barrier island shores as an alternative to new or replacement seawalls (MDC, personal communication, 2011).

In addition, the Blowing Rocks Preserve, a 73-acre sanctuary owned by The Nature Conservancy, is widely considered a model for coastal habitat restoration (The Nature Conservancy, 2012). Located on Jupiter Island in Martin County between the Atlantic seaboard and the Indian River Lagoon, the Blowing Rocks Preserve, where restoration activities began in 1985, provides over 20 years of valuable lessons in best management practices, as the restoration is now complete and mangrove wetlands and natural dunes and native vegetation (Figure 1) have been re-introduced and stabilized (The Nature Conservancy, 2012). Further north in Martin County, restoration activities are under way in the Indian River Lagoon as part of the Comprehensive Everglades Restoration Plan (CERP). A collaborative effort involving Martin County, NOAA, the South Florida Water Management District, and the Loxahatchee River District, these activities encompass 200 acres of restored oyster beds and mangrove plantings in the Indian River Lagoon that serve to protect the shore from erosion, improve water quality, and enhance biotic diversity.

In the context of sea level rise, shoreline restoration projects and natural defenses are considered in several recommendations addressing the designation and implementation of Adaptation Action Areas (SEFL-CCC 2012b). More specifically, the Southeast Florida Regional Climate Change Compact Action Plan suggests that adaptation actions with respect to natural systems be based on "monitoring, management, and conservation programs designed to protect natural systems and improve their capacity for climate adaptation" (SEFL-CCC, 2012b, p. 32). Recommended actions under policies NS-2, NS-5, NS-6, and NS-7 of the Compact Climate Change Action Plan include protection of natural areas, restoration of coastal wetlands, and use of "living shorelines" and other types of natural infrastructure to "create and maintain resilience and adaptive capacity" (SEFL-CCC, 2012b, p. 33).

Figure 1. Mangrove planting and dune vegetation at the Blowing Rocks Preserve, The Nature Conservancy (*Photo credit*: Diana Mitsova)

Overview and Purpose of the Spatial Database

The SE Florida Living Shoreline Spatial Database incorporates nearly 1,500 shoreline features. They include natural habitats and a variety of shoreline restoration, enhancement and stabilization projects. The spatial extent of the database encompasses Broward County, Miami-Dade County, Palm Beach County, and the Blowing Rocks Preserve in Martin County. More specifically, the focus is on estuarine areas along the Intracoastal Waterway. The counties supplied the initial datasets in a native ESRI format (i.e., shapefiles). The original shapefile attributes were further expanded to include parameters based on literature review and review of existing living shoreline projects. As a result, each shoreline feature included in the database is associated with 37 attributes derived from (i) existing geospatial datasets, (ii) permits, reports or other available documentation, (iii) local knowledge, and (iv) algorithms that calculate attribute values using the analytical tools in ©ArcGIS.

The creation of the Living Shorelines Spatial Database is intended to serve as a pilot study to support development of a spatial decision support tool for shoreline management that can enhance coastal resilience and sustainability. The proposed project is a continuation of a shoreline inventory study which was supported by a seed grant from the FAU Climate Change Initiative in 2012-2013.

Stakeholder Process

The database was developed as a collaborative effort among multiple agencies and stakeholders. The Southeast Florida (SEFL) Regional Climate Change Compact Shoreline Resilience Working Group (SRWG) provided the impetus for this effort as well as invaluable expertise, input and feedback. The Nature Conservancy, the School of Urban and Regional Planning at Florida Atlantic University, Broward County EPD, Miami-Dade County DERM, and Palm Beach County ERM played a leading role in the development of the Southeast Florida Living Shorelines Spatial Database. Starting in the summer of 2013, SRWG conducted regular monthly conference calls. The first face-to-face meeting was held in June 2014 when SRWG members had the opportunity to visit completed or ongoing restoration projects in Palm Beach County. A second meeting is to be held in February 2015 in Miami-Dade County. These meetings provided forums for discussions, ongoing feedback, review and expert consensus on several issues with regard to the spatial database development. The following scientists and other technical experts have been involved in various aspects of the project development:

Chris Bergh, The Nature Conservancy, SRWG
Michael Renda, The Nature Conservancy, SRWG
Andrea Graves, The Nature Conservancy, SRWG
James Byrnes, The Nature Conservancy, SRWG
Caitlin Lustic The Nature Conservancy, SRWG
David Stout, Broward County, SRWG
Katie Lelis, Broward County, SRWG
Linda Sunderland, Broward County
Ryan St. George, Broward County
Josh Mahoney, Miami-Dade County, SRWG
Paul Davis, SRWG

Julie Mitchel, Palm Beach County, SRWG
Eric Anderson, Palm Beach County, SRWG
Brandon Justice, Palm Beach County
Leonard Berry, Department of Geosciences, Florida Atlantic University
Marguerite Koch-Rose, Department of Biological Sciences, Florida Atlantic University
Ann-Margaret Esnard, Andrew Young School of Public Policy, Georgia State University

LITERATURE REVIEW

Erosion is a serious problem in a majority of coastal areas globally, and accelerated rates of sea level rise will further exacerbate erosion problems and destabilize coastlines. In response to receding shorelines, as well as more intense storm damage and flooding as a result of sea level rise and climate change, armoring of shorelines is likely to increase using traditional engineered approaches and structures. This hard-armoring approach is known to reduce sediment sources by interrupting natural sediment transport, affect water quality and reduce habitat viability in adjacent water bodies, and fundamentally disrupt the connection between coastal and offshore ecosystems. Shoreline restoration and enhancement techniques have been shown to provide comparable protection under suitable landscape and environmental conditions (Berman et al. 2007; Burke and Hardaway 2007; Swann 2008). An emerging alternative is to sustain "living shorelines" in which natural habitats are incorporated into the shoreline stabilization design (Berman and Rudnicky 2008; Currin et al. 2010; McGuire 2011). This approach allows for the long-term protection, restoration and/or enhancement of vegetated shoreline habitats, even during tropical storms. For example, McGuire (2011) showed that living shorelines controlled erosion along Indian River Lagoon (Florida) following the 2004 hurricane season. Similarly, Swann (2008) showed precast breakwaters with oyster colonization withstood the impact of Hurricane Katrina without any damaging effects at Fort Gaines Harbor located on Dauphin Island (Alabama). Creating living shorelines is also a major effort in Chesapeake Bay to restore fisheries habitats. Mitsova and Esnard (2012) documented alternative and viable approaches to shoreline stabilization techniques and land use practices that minimize structural and environmental problems associated with hard-armored shorelines. Applying soft armoring techniques, including living shorelines, are consistent with NOAA shoreline management planning policies that support shoreline protection with a "no net loss" of the shoreline ecological functions (NOAA, 2012).

Shoreline Processes

The coastal zone is a fundamentally dynamic and shifting system influenced by wind, wave action, upland disturbances, and underlying morphology and geology. The coastal zone is defined by the National Oceanic and Atmospheric Administration (NOAA) as "the coastal waters and lands immediately adjacent to and strongly influenced by the shoreline, including "islands, transitional and intertidal areas, salt marshes, wetlands, and beaches" (NOAA 1999: 3). The shoreline is the land-water line which in tidally influenced environments is most commonly defined by the mean high water line (NOAA 1999). Landward of the shoreline is the upper beach, a high-energy zone often characterized by beach dune and coastal strand communities (FWS- South Florida MSRP 1999).

Shore erosion is a natural phenomenon involving "detachment and transportation of sediment particles from the shore, resulting in the landward retreat of the land-water boundary" (Byrne and Anderson 1979). Erosion can occur gradually over time as a result of sea level rise and continuous wave action or suddenly as in the case of a storm event. Littoral drift is the movement of sand both perpendicularly to the shore or parallel to it due to wave dynamics. The forces affecting littoral drift are complex and human activities can often disturb the sand transfer equilibrium along the shore which can result in sand accretion or sand loss. Sand accretion forms shoreline features like berms, spits, beaches, barrier islands, and sand bars (Burke and Hardaway, 2007). In addition to littoral drift, shoreline dynamics are influenced by the wave climate which is determined by prevailing winds, frequency and magnitude of storms, and bathymetry (WMO 1998). Waves are limited by wind duration and fetch distance (FDOT-FHA 2011). Fetch is the distance over which wind can blow over open water seaward from a shoreline to the next landmass (Burke and Hardaway 2007). Shorelines can be generally categorized by their fetch exposure as low-energy, medium energy or high-energy depending on fetch distance (Byrne and Hardaway 1999).

Traditional Approaches to Shoreline Stabilization

The shore zone, an attractive place to live and recreate, is affected by multiple stressors both natural and anthropogenic. Natural shorelines such as mangrove swamps and sandy beaches provide numerous ecosystem services including wave dissipation, shallow intertidal habitat, fringing marshes, nursery and nesting areas, and natural sediment build-up. These services are oftentimes degraded as a result activities associated with urban development including dredging and filling, vegetation removal, shoreline armoring, and discharges of stormwater containing nutrients and contaminants (Bilkovic at al. 2007). With the anticipated effects of more intense storm damage and flooding as a result of sea level rise and climate change, armoring of shorelines is likely to increase (Defeo et al. 2009).

Engineering approaches including structural shoreline armoring have been widely used to protect development on the coastline (Berman et al. 2007). Hardening control measures include rip rap revetments, breakwater systems, seawalls and spurs. While often very effective especially in high wave energy systems, a review of the scientific literature suggests that bulkhead erosion control methods can lead to accelerated erosion, toe scouring, habitat degradation, and inability to adapt to changing stressors in the natural environment (Currin et al. 2010). These structures are also associated with decreasing wetland ecosystem services (Berman et al. 2007) as the resulting high energy environment around the bulkheads creates a poor quality habitats for fish and other species (Peterson and Lowe 2009). Seawalls in California, for instance, have been shown to reduce habitat quality by narrowing the upper intertidal and mid-intertidal zones in front of armoring structures with accompanying losses in intertidal invertebrate and avian biodiversity (Komar 2000, Dugan and Hubbard 2010).

Shoreline Restoration and Alternative Erosion Control Options

Recognition of the pitfalls of traditional coastline management approaches has led to a shift toward more holistic practices (Currin et al. 2010). A recent report by the National Wildlife Federation emphasizes the benefits of preserving and restoring natural infrastructure for reducing the vulnerability of local communities to flood and hurricane risks, in addition to numerous ecological and economic benefits (Glick et al. 2014). The report highlights the important role that healthy natural ecosystems can play in building resilient communities and provides several examples of successful implementation of nature-based strategies to counteract the damaging effects of extreme events. In Jamaican Bay, New York, for example, 150 acres of restored wetlands helped mitigate the destructive backwash waves brought about by super-storm Sandy (Glick et al. 2014). Following the 2012 Executive Order regarding statewide construction in the face of climate change and, the State of Maryland issued "Coast Smart" siting and design guidelines which require a range of natural infrastructure options to be included in flood management plans (Glick et al. 2014). The report estimates that over $20 billion worth of storm mitigation services are provided annually by coastal wetlands in the United States (Glick et al. 2014). In 2014, USACE issued "A Design Manual for Engineering with Nature Using Native Plant Communities" which describes specific tools and techniques for native plants use in design elements for engineered water resource projects (Bailey 2014).

A novel approach to nature-based shoreline stabilization is the "living shoreline" (Berman et al. 2007, FDEP 2008, Reay and Lerberg 2008). Living shoreline practices use a range of naturally occurring features to stabilize and protect shorelines, including vegetated buffers; beach nourishment; reefs, oyster beds, and mangrove habitat restoration. Dense vegetation (e.g., seagrasses and mangroves) can attenuate wave action, dissipate wave energy, and mitigate the erosion of the underlying substrate. Studies of living shorelines efficiency show measurably improved erosion rates compared to nearby upstream and downstream reaches, giving evidence of living shorelines viability as an erosion control measure (Berman et al. 2007). In 2011, Virginia state law incorporated living shoreline techniques as the preferred method of shore stabilization. Whalen et al. (2012) reviews the provisions for living shoreline implementation adopted by multiple states in planning and coastal resource management. Living shorelines and habitat restoration are just some of the cadre of strategies planners, coastal resource managers, and legislators can use to protect property values, mitigate hazards, and enhance habitats and ecosystems. Decisions regarding shoreline management must be based on sound information regarding the existing geomorphologic, ecologic, and hydrologic conditions. Site-specific design must incorporate variables such as sediment supply, wave exposure, and sediment type to insure that the living shoreline environment is both appropriate and viable (Currin and et al. 2010).

While living shoreline techniques can be highly effective in most coastal conditions, high wave energy conditions or risk from flooding can make hardened structures necessary (Mitsova and Esnard 2012). Living shorelines are also part of hybrid shoreline stabilization solutions which combine vegetation with a stabilizing structure, such as marsh-sills, and while these may be more appropriate in higher energy systems (Currin et al. 2010), there are possible tradeoffs in biodiversity and habitat services that must be considered when choosing hybrid over purely natural stabilization technique (Bilkovic and Mitchell 2013). Hybrid living shoreline techniques include the use of native vegetation and traditional hard structures. For example, in higher energy shorelines (those with fetches exceeding 1 nautical mile) marsh fringes can be combined with breakwaters (Burke and Hardaway 2007). Hardaway et al. (2010) provides general design requirements for nonstructural and hybrid living shoreline techniques. Wave energy was found to be a deciding factor in shoreline management. Other important criteria in determining the applicability of nonstructural and hybrid options include slope/elevation, substrate, salinity regime, vegetation, surrounding uses, bank conditions, level of protection, and presence of existing protection structures. Additionally, design requirements for storm surge conditions and risk protection must be determined (Burke and Hardaway 2007). Using biogenic breakwater reefs constructed of oyster beds can prevent erosion and are superior at providing environmental function and habitat for commercially and ecologically important fish and macro-invertebrates (Swann 2008, Scyphers et al. 2011). However their buffering properties are not as predictable as hard bulkheads and seawalls and may require longer and more careful design to be effective (Scyphers et al. 2011).

Due to the range of living shoreline options and variability of pre-existing conditions, management must go beyond an understanding of general techniques and tailor projects to site-specific conditions. In many places, practitioners have attempted to coalesce knowledge of environmental conditions and share living shoreline best management practices to guide future projects. An overview of the literature suggests that lack of published guidance can impede the adoption of alternative solutions by regulatory agencies (Walker et al. 2011). Lamont et al. (2014) presented the results of collaborative research commissioned by the Stewardship Centre for British Columbia and Climate Change Impacts and Adaptation Division of Natural Resources Canada to evaluate the effectiveness of soft armoring approaches with regard to comparable structural options or "hard" armoring. The study found that both natural and engineered approaches provided acceptable levels of flood control. Soft armoring outperformed hard armoring in terms of ecological functions and services and in most cases was also more cost-effective (Lamont et al. 2014). The importance is such studies and comparisons cannot be overstated as participation from property owners and contractors requires design guidance literature, relevant methods of systematically evaluating the effectiveness and appropriateness of techniques, and understanding of performance and protection levels that each technique can offer (Gerstel and Brown 2006; Subramanian et al. 2006, Lamont et al. 2014).

Figure 2. Rip-rap with mangroves – Lake Worth Lagoon, Palm Beach County (*Photo credit*: Diana Mitsova)

Shoreline Management and Sea Level Rise

The Florida Coastal Management Program legally defines the entire state of Florida as a coastal zone due to its low-lying topography, shallow aquifers, and extensive flood control infrastructure (Chapter 380, F.S., Part II). Sea level rise will most likely amplify the shoreline management challenges faced by residents, planners, coastal managers, and decision-makers. Probabilistic models of sea-level change scenarios for Florida predict shift in return period for major storms wherein 1-in-50-year storm events may become as frequent as 1-in-5-year storms (Park et al. 2011). Increased storm activity and higher tides will present a major challenge for the complex water management infrastructure and flood control systems in South Florida (Park et al. 2011, Landry 2002). The system aimed at creating farmland and protecting residents from flood risks by redirecting the Everglades wetland system freshwater flows into an extensive canal system intrinsically links developed land to the ocean and fresh water hydrologic systems and, as a result, all South Florida residents are essentially coastal dwellers. A national study of coastal vulnerability ranked Florida the second most topographically vulnerable region in the U.S. (Strauss et al. 2012). The study took into account low-lying coastal land, housing and population relative to local mean high tide levels and established that Florida has some of the highest amounts of land area within elevations of less than 3 feet above the local Mean High Water (MHW) line (Strauss et al. 2012). The same study ranked Florida first by far in vulnerable populations and housing units with over 1.6 million people living in areas that are less than 3 feet above the local MHW line (Strauss et al. 2012). The Southeast Florida Regional Climate Change Compact Inundation Mapping and Vulnerability Assessment (SEFL-CCC 2012a) indicates the magnitude of the anticipated sea level rise impacts. The study is based on high resolution LiDAR data, infrastructure and tidal gauge data and identifies locations where priority action is needed.

Restoration and shoreline enhancement projects provide both ecosystem services and potential for shoreline protection against the threats of sea level rise. A meta-analysis of living shoreline research showed overwhelmingly that marsh and mangrove vegetation can effectively attenuate wave action and protect people, property and infrastructure (Gedan et al. 2011, Click et al. 2014). Mangroves fringe swamps are key habitat for the survival of many species and provide natural defense against hurricanes and erosion (FDEP 2011). These resilient, pioneer tree communities can buffer wave action generated by high winds and are particularly adept at accreting sediment at rates likely to keep pace with average sea level rise (Alongi 2008. Kirwan and Magonigal 2013).

Broward, Miami-Dade and Palm Beach counties lost a great deal of coastal wetland and mangrove habitat over the last 100 years of development. Restoring these native communities to historical ecological functions levels became a primary goal of the coastal wetlands restoration initiatives in the region (Milano 1999; Josh Mahoney, MDC, David Stout, BC, Julie Mitchell, PBC, personal communication, 2014). *Nature-Based Coastal Defenses in Southeast Florida* (TNC 2014) is a compilation of seven case studies that showcase shoreline restoration and enhancement efforts in southeast Florida. The report is a collaborative publication of The Nature Conservancy and the Southeast Florida Regional Climate Change Compact Shoreline Resilience Working Group (TNC 2014). Building shoreline resilience using natural infrastructure provides immediate ecological benefits. (Jancaitis 2008, Glick et al. 2014). Soft armoring and living shoreline techniques can provide site-specific solutions. Achievement of regional sustainability and resilience requires an integrated approach to shoreline management and understanding of policy and planning processes at regional scales (Leafe 1998).

Figure 3. Vegetated dunes in Palm Beach County (*Photo credit*: Diana Mitsova)

Applications of Geospatial Tools and Technologies

In the last two decades, geospatial tools and technology light detection and ranging (LiDAR), and satellite imaging have provided a powerful aid for improving erosion, inundation, and shoreline change information (Leatherman 2003; Evans 2004). Geographic Information Systems (GIS) technology, in particular, has proven to be a powerful tool in bringing together large amounts of geospatial data to improve coastal decision-making. Marine spatial planning is an ecosystem-based approach that has the potential to vastly improve marine and coastal resource management (GEF 2012, Sale et al. 2014). Advancements in geospatial technologies have created the potential to combine anthropogenic stressor data with site-specific terrestrial and marine environmental data on a regional scale (Sale et al. 2014). This knowledge in turn can help coastal resource managers to systematically determine areas to prioritize for coastal resource protection or commercial services, potentially avoiding or alleviating conflict from competing uses and facilitating a flexible, pro-active, and sustainable governance structure (Sale et al. 2014).

Examples include the Coasts, Oceans, Ports and Rivers Institute (COPRI) Living Shoreline Database (COPRI 2014), and the living shorelines toolkit developed by the Virginia Institute of Marine Science (Hardaway et al. 2010). VIMS-CCRM has compiled a series of indexed, coded shoreline maps for the Chesapeake Bay Foundation showing where and which types of shoreline stabilization techniques were used. The maps also indicate proposed treatments for candidate locations and provide helpful suggestions to landowners who may be considering living shoreline treatments (Burke and Hardaway 2007). In addition, the Virginia Institute of Marine Sciences (VIMS) was contracted by the Virginia Marine Resources Commission to create a GIS-based Living Shoreline

Suitability Model which brings together information on ecosystem-based approaches and site conditions to guide coastal managers (VIMS-CCRM 2012). The model works with a Decision Tree questionnaire to aid decision-makers in identifying the best living shoreline options for a site (VIMS-CCRM 2012). For additional information regarding these tools see Appendix II.

As part of the climate adaptation planning, the Partnership for the Delaware Estuary (PDE) conducted research on living shoreline projects in the Delaware Estuary and used GIS to narrow potential sites for a living shoreline pilot project using physical and chemical parameters to characterize suitability according to wave energy (Whalen et al. 2012). PDE created a standardized framework for resource managers based on lessons learned from completed projects. The framework allows for selection of appropriate metrics, methods, and design (Kreeger and Moody 2014). Due to the complexity of locating specific sediment resources, the Louisiana Sand Resource Database was developed as a central repository of georeferenced sediment data. As part of a comprehensive sediment management plan, the database will be a tool to assist all stakeholders in the coordination of coastal protection and restoration projects (Khalil et al. 2010).

These are only a few examples of spatial databases and models to guide restoration efforts in the coastal zone. NatureServe (2014) recently published a guide of over one hundred geospatial tools and databases for use in conservation planning and evaluation in the face of climate change. The wide variety of geospatial technology tools currently available can serve ecosystem modeling and habitat restoration efforts, guide assessments and scenario evaluation, or provide background information for setting priorities and manage alternative solutions (NatureServe 2014).

SPATIAL DATABASE PARAMETERS AND METHODS

Data and Data Processing

The initial datasets for this project were provided by Broward, Miami-Dade and Palm Beach counties. The initial datasets were further processed and updated. The attribute table of each feature class was expanded to include the parameters specified in section "Attribute Definitions and Domain Values" and Appendix I. Expert knowledge, permits and publicly available data were used track and delineate completed shoreline restoration, enhancement and stabilization projects in SE Florida. For earlier projects completed in the 1980s and 1990s we sought the expertise of county staff involved in the completion of these projects, as well as publicly available permits and reports. In several occasions, drawings from the permit documentation were transferred to AutoCAD and then converted to a shaperfile for use in ©ArcGIS. Additionally, publicly available data were used to derive the information for several fields in the attribute tables. Several parameters were calculated using the ArcToolbox in ©ArcGIS. A *File Geodatabase* was used as a central repository to store the spatial data layers.

Users of the Southeast Florida Living Shoreline Database have to be aware that the data included in the geodatabase are subject to some limitations. Data for shoreline restoration, enhancement and stabilization projects were not generally available through public data sources. The data were obtained through direct communication and data requests, or derived from historical documents. The counties have supported this project with data and staff time thus facilitating the acquisition of all necessary information. Data for several parameters included in the attribute tables of the geodatabase feature classes were available only in permits and reports. Every effort was made to ensure the completeness and accuracy of the information in each the spatial layer. However, some discrepancies may still be found due to the variety of sources that were used to compile the information. Some spatial layers may not be as comprehensive as others because such data were not produced by the owner of the data source.

Southeast Florida Coastal Ecosystems Restoration

South Florida coastal ecosystems are highly susceptible to erosion/sedimentation, fragmentation, and habitat degradation due to dredging/ fill and land conversion to urban and housing development (FFFWCC 2005). Due to Florida history of disturbance and urbanization, many restoration sites require clearance of exotic vegetation and re-grading by scraping back soils to elevations appropriate for native plants to recruit (FWS 1999). Elevation is an important factor in species distribution of mangroves and marsh plants and must be considered when replanting restoration sites. Another aspect of the restoration efforts in SE Florida is the removal of exotic vegetation. A commonly seen invasive species in South Florida is the Australian pine (*Casuarina equisetifolia*), which can invade and outcompete native species (FWS 1999). Other invasive plants include Brazilian pepper (*Schinus terebinthifolius*), Burma reed (*Neyraudia reynaudiana*), seaside-mahoe (*Thespesia populnea*), and beach naupaka (*Scaevola taccada*) (Milano 2000).

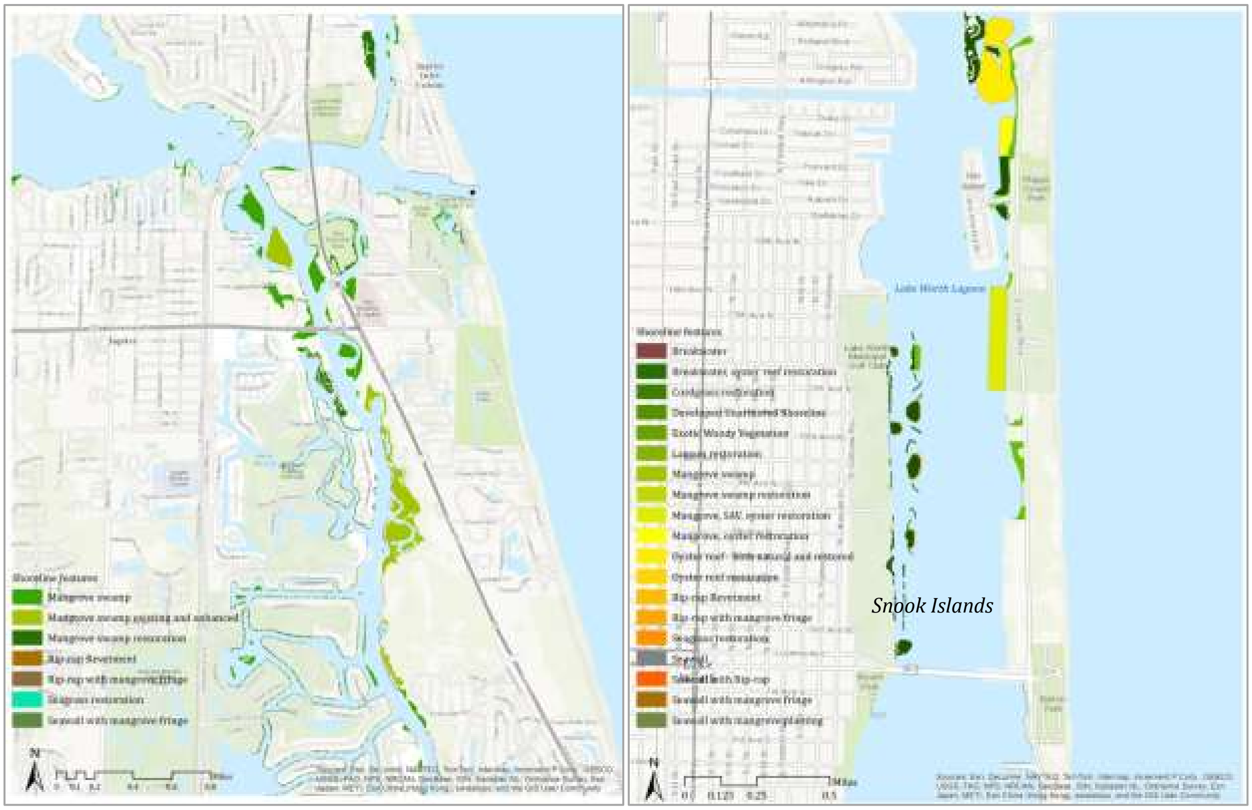

Figure 4. Mangroves swamps (both existing and restored) and shoreline restoration projects: (a) south of Jupiter Inlet (left), and (b) in the Lake Worth Lagoon (right), Palm Beach County

Figure 5. Snook Islands restoration in the Lake Worth Lagoon, Palm Beach County (*Photo credit*: Diana Mitsova)

Mangrove swamps are essential for the health of estuarine and marine environments in South Florida (FWS 1999). They provide habitat for over one thousand species of intertidal, sub-tidal, and arboreal animals (FWS 1999). They also serve as nesting sites; nurseries for fish, shellfish, and crustaceans; and are a major source of detritus which provides the basis of the marine food system (FWS 1999). Their root systems stabilize shorelines; buffer wind action; reduce turbidity and increase clarity; and cause accretion by catching sediment and debris (Kirwan and Megonigal

2013). Red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), black needlerush (*Juncus roemerianus*), and smooth cordgrass (*Spartina spartinae*) are commonly used in wetlands and mangrove restoration projects (FWS 1999). Using the National Geodetic Vertical Datum (NGVD), red mangroves are planted in the elevation range 1.0'-1.2', black mangrove 1.25'-1.5', white mangrove 1.5'-2.0', and gulf cordgrass in the range 2.1'-2.5'. Habitat may also be created by reconstruction of a more natural hydrology, such as re-establishing inter-tidal flushing creek connections. Figure 4 shows both existing and restored mangrove areas in the northern part of the Lake Worth Creek in Palm Beach County.

Starting in the 1990s, Miami-Dade DERM has successfully managed a number of spoil island restoration projects (Milano 1999, 2000). Dredged material disposal during the construction of the Atlantic Intracoastal Waterway which began in the early 1900s resulted in the creation of spoil islands (Milano 2000). They have been dominated for decades by exotic invasive species and have been known as a source of sedimentation and water quality degradation (Milano 2000). Spoil island restoration involves fill removal, clearance of exotic species, creation of flushing channels, planting mangroves and native uplands species, and shoreline stabilization (Milano 2000). Rip-raps are commonly used as "a riprap revetment can be part of a "living shoreline", as a substrate for aquatic plants and animals or as part of a "planter" for vegetation" (MDC - personal communication, 2011, 2014). Figure 6 indicates the sites of spoil island and saltwater marsh restoration in Miami-Dade County.

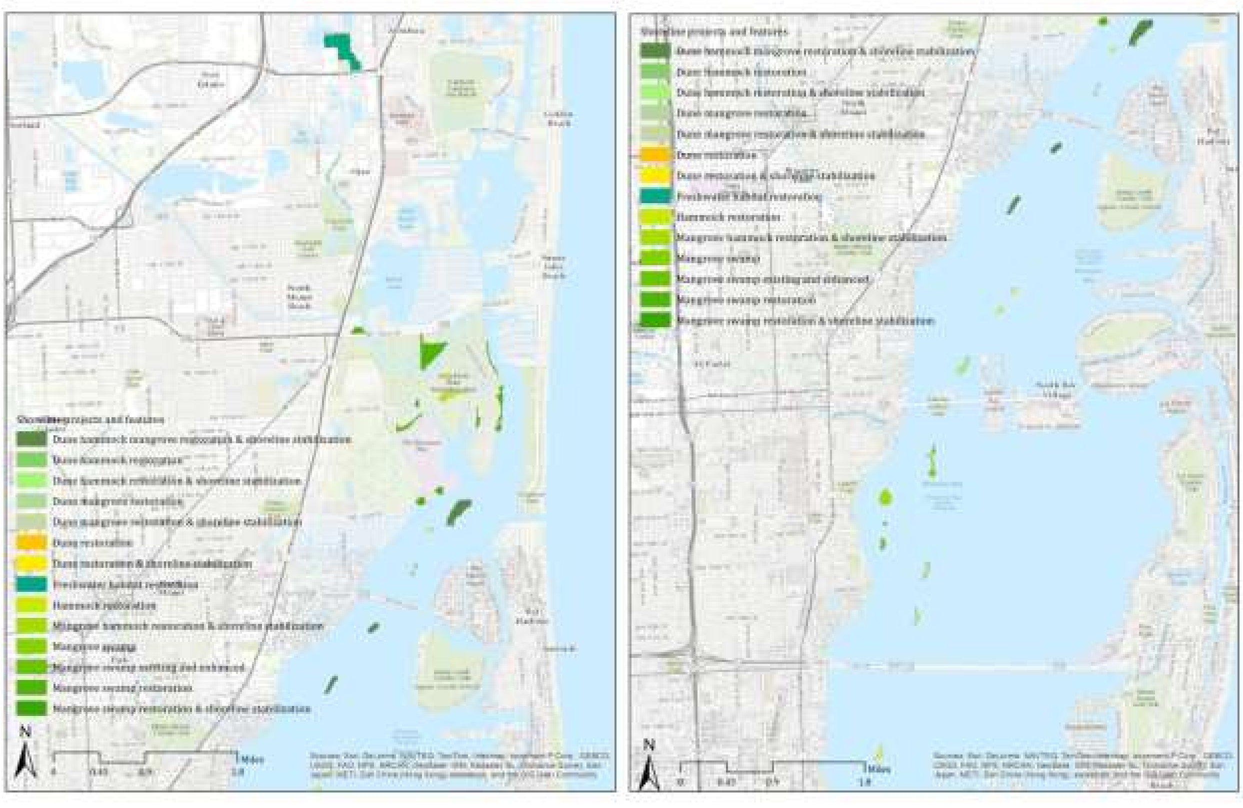

Figure 6. Restoration projects in Miami-Dade County: (a) Oleta River State Park (left) and (b) spoil islands in Biscayne Bay (right)

The Atlantic coast of Florida has a continuous habitat of beach dune from the Sebastian Inlet south to Cape Florida in Miami-Dade County (FWS 1999). South of this extent beaches become discontinuous and beach dunes may be absent, replaced by barren coastal lime-rock communities (FWS 1999). The South Florida bare sand beaches are critical habitat for the southeastern beach mouse and four federally listed species of sea turtles including loggerhead, green, hawksbill, and leatherback. Coastal strand is a broad term encompassing several habitats within the upper beach. It is found along both of Florida coasts, but is especially prevalent along the east coast from Indian River County to the edge of Biscay Bay in Miami-Dade County.

Figure 7. Wetland restoration in John U Lloyd State Beach Park, Broward County (*Photo credit*: Stephanie Reed)

Figure 8. Restored dune grasses and flushing tidal creeks in Oleta River State Park, Miami-Dade County (*Photo credit*: Stephanie Reed)

Coastal strand is found in a high-energy zone regularly affected by salt spray and sand burial between maritime hammock tree communities and beach dune herbaceous communities (FWS 1999). The most common plant species used in dune/coastal strand restoration in Florida are sea oats (*Uniola paniculata*), beach cordgrass (*Spartina patens*), sea lavender (*Tournefortia gnaphalodes*), bay cedar (*Suriana maritime*), and sea oxeye (*Borrichia frutescens*), followed further upland by saw palmetto (*Serenoa repens*) and coco plum (*Chrysobalanus icaco*) (FWS 1999).

Development of barrier islands in South Florida negatively affected many of the maritime hammock communities. In South Florida, maritime hammock is characterized by tropical, broadleaved hardwoods such as live oak, cabbage palmetto, red bay, silver palm, and black bead (FWS 1999). Species of concern which inhabit this habitat include the Florida panther, peregrine falcon, Florida prairie warbler, and several species of prickly apple (FWS 1999). South Florida hammock restoration projects are generally not planted as a monoculture, but rather as a mix. The most common species used in restoration are gumbo limbo (*Bursera simaruba*), buttonwood mangrove (*Conocarpus erectus*), strangler fig (*Ficus aurea*), false mastic (*Sideroxylon foetidissimum*) and Jamaican dogwood (*Piscidia piscipula*) (FWS 1999, MDC, personal communication, 2014). Freshwater wetlands are also part of ongoing restoration efforts in South Florida. These marshes consist mostly of herbaceous plants and grass of which saw grass, pickerelweed, arrowhead, and spikerush are the most abundant (MDC 2013). Many of these important ecosystems have been degraded or lost due to alteration of hydrologic conditions (MDC 2013).

Figure 9. Virginia Key ecosystem restoration, Miami-Dade County (*Photo credit*: Stephanie Reed)

This section provided a brief overview of several conservation and restoration projects in Southeast Florida. The overview is also intended to help users understand the rationale of selecting the set of attributes included in the geospatial database. It is useful in understanding the categorization and description of various types of shorelines included in the database. It also seeks to provide an insight regarding the importance of various shoreline characteristics (e.g., why elevation matters in shoreline enhancement and restoration efforts). The ongoing restoration activities also provided the basis of the list of plant communities incorporated as domain values in attribute fields PlantType1 through PlantType4, and the explanations included under Notes_1 and Notes_2. The subsequent section provides a full description of the attribute fields, including definitions, definition sources, and data sources where applicable.

Attribute Definitions and Domain Values

The Southeast Florida Living Shorelines Spatial Database contains three types of fields (attributes): (1) identifiers, (2) attributes derived from an existing spatial dataset, and (3) calculated attribute values. The description of each field contains specific information about the origin of the data (derived or calculated), and definitions of domain values used as attributes. Domain values were determined using the following approaches:

- existing classification schemes in which case attributes in the database were classified using an external table (e.g., *Florida Land Use Classification Code*, *Florida Ecological Restoration Inventory*),
- values in an existing geodatabase (e.g., USDA-NRCS SSURGO soil database 2013)
- expert knowledge
- computational methods as suggested by the relevant literature (e.g., *USACE Shore Protection Manual*, 1984)
- mapping products (e.g., 2013 MrSID aerial photography, Google Earth, World Imagery)

FID or OBJECTID

Attribute:
Attribute Label: OBJECTID
Attribute Alias: OBJECTID
Attribute Type: OID
Attribute Width: 4
Attribute Precision: 10
Attribute Scale: 0
Attribute Definition: Internal feature number
Attribute Definition Source: ESRI
Attribute Domain Values: Sequential unique whole numbers that are automatically generated

FID or OBJECTID is a unique identifier created automatically by ©ArcGIS when a table is added or registered with a geodatabase (ArcGIS Resources 2014). It is "an integer field used to uniquely identify rows in tables in a geodatabase" (ArcGIS Resources 2014).

AREANAME

Attribute:
Attribute Label: AREANAME
Attribute Alias: AREANAME
Attribute Type: String
Attribute Width: 70
Attribute Precision: 6

Attribute Scale: 0
Attribute Definition: Unique area name
Attribute Definition Source: Broward, Miami-Dade and Palm Beach counties, Florida, SFWMD
Attribute Domain Values: names of geographic features

The area name field is a string (textual) identifier indicating where the mapped feature is located. The area name field contains the natural terrain feature names – existing upland or coastal natural areas, and parks. In locations where no geographic name was available the name of the waterbody was used to indicate the location of the shoreline feature.

FLUCCS

Attribute:
Attribute Label: FLUCCS
Attribute Alias: FLUCCS
Attribute Type: String
Attribute Width: 70
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: FLUCCS classification description
Attribute Definition Source: FDOT, SFWMD, Palm Beach County
Attribute Domain Values: descriptors based on Florida Land Use, Cover and Forms Classification System

Florida Land Use, Cover and Forms Classification System (FLUCCS) (FDOT 1999) and its modification for the South Florida Water Management District (SFWMD 2002) were used as a basis to determine the FLUCCS codes used in his study. Table 1 provides an overview of the FLUCCS codes used in the database.

Table 1. FLUCCS codes used to describe shoreline features

FLUCCS code	Description
432	*Maritime Hammock*
612	*Mangrove Swamp*
619	*Exotic Wetland Hardwoods*
641	*Freshwater Marsh*
642	*Saltwater Marsh*
652	*Shoreline*
654	*Oyster Bar*
720	*Beach Dune*
730	*Non-vegetated*

The mangrove and shoreline characterization layers provided by Palm Beach County already contained applicable FLUCCS codes. These codes were retained with the descriptions provided by the County. *Exotic Woody Vegetation* was used to describe *Exotic Wetland Hardwoods* and this description was retained. In the same dataset, shoreline unaltered by human activities was characterized as *Developed Unarmored Shoreline* and this description was also retained. In addition, a shoreline armored with a seawall was characterized as *Developed Armored Shoreline*. Rip -raps and other areas where exposed rock was present were characterized as *Non-vegetated Exposed Rock*.

CATEGORY

Attribute:
Attribute Label: Category
Attribute Alias: Category
Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: Category refers to the type of shoreline feature
Attribute Definition Source: Broward, Miami-Dade and Palm Beach counties, Florida; expert knowledge
Attribute Domain Values: natural shoreline, shoreline stabilization, shoreline enhancement, shoreline restoration

The field CATEGORY is intended to allow users to query the data based on five domain attributes. It contains specific information to assist users with queries regarding the type of shoreline (natural or altered), and what type of alterations have occurred (armoring, enhancement, or restoration). The categories are consistent with the *Florida Ecological Restoration Inventory* (FERI) (FDEP 2011). The field includes the following domain values:

- *Shoreline restoration* involves fill removal or scraping, clearance of exotic vegetation, slope re-grading, creation of flushing channels, and re-vegetating with native plants.
- *Shoreline enhancement* refers to vegetation planting and replanting, and may involve some removal of exotic species. It may also include any aesthetic or recreational improvements (e.g., walking trails, oyster nesting platforms, etc.).
- *Shoreline stabilization* refers to hard armoring or the construction of seawalls, rip-raps, rip-rap revetments, and other hard structures.
- *Natural shoreline* refers to a shoreline unaltered by human activities. It is consistent with FLUCCS classification classes of mangrove swamp, freshwater marsh, saltwater marsh, exotic wetland hardwood, maritime hammock, beach dune, and developed unarmored shoreline.
- A combination of these four domain values was used to describe hybrid approaches (e.g., restoration/ stabilization).

DESCRIPT

Attribute:
Attribute Label: Descript
Attribute Alias: Descript
Attribute Type: String
Attribute Width: 70
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: Description of the dominant shoreline feature
Attribute Definition Source: FDOT; SFWMD; Broward, Miami-Dade and Palm Beach counties, Florida; expert knowledge
Attribute Domain Values: descriptors based on Florida Land Use, Cover and Forms Classification System

The field DESCRIPT is intended to provide additional information related to the categorization indicated in the CATEGORY field. The attribute field DESCRIPT contains detailed descriptions of the type of activities and features present. Using the DESCRIPT field users can select features contained within each domain value defined under CATEGORY.

Specific examples of *Natural Shoreline* include:

- Mangrove swamp
- Freshwater marsh
- Saltwater marsh
- Maritime hammock
- Beach dune

Specific examples of *Shoreline restoration* include:

- Mangrove planter restoration
- Mangrove swamp existing and restored
- Mangrove swamp restoration
- Hammock restoration
- Dune hammock restoration
- Dune restoration
- Wetlands hammock & dune restoration
- Wetlands restoration
- Cordgrass restoration
- Lagoon restoration
- Spoil island restoration
- Breakwater, oyster reef restoration
- Oyster reef restoration
- Mangrove, oyster restoration
- Mangrove, seagrass, oyster reef restoration
- Seagrass restoration
- Freshwater habitat restoration

Shoreline Enhancement projects are represented by:

Mangrove planting
Cordgrass planting
Rip-rap with mangrove fringe
Seawall with mangrove fringe
Seawall with mangrove planting

Shoreline Stabilization includes the following features:
Breakwater
Rip-rap revetment
Seawall with rip-rap
Seawall

Hybrid approaches can be represented by:
Mangrove Replanting & Shoreline Stabilization
Dune Hammock Mangrove Restoration & Shoreline Stabilization
Dune Hammock Restoration & Shoreline Stabilization
Dune Mangrove Restoration & Shoreline Stabilization
Hammock Mangrove Restoration & Shoreline Stabilization

The **PBC_shorelines** feature class contains two descriptive fields. DESCRIPT13 contains the current shoreline feature description. DESCRIPT01 contains the 2001 description of the shoreline when the feature class was initially created. The values of the initial description were preserved in the database to help track the changes that have occurred over the past 15 years.

VEGETATED

Attribute:
Attribute Label: Vegetated
Attribute Alias: Vegetated
Attribute Type: String
Attribute Width: 10
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: A binary variable to indicate presence/ absence of vegetation
Attribute Definition Source: Derived from 2013 MrSID aerial photography for Broward, Miami-Dade and Palm Beach counties, Florida
Attribute Domain Values: Yes/ No

The field VEGETATED is a binary field intended to allow users to quickly select vegetated vs. non-vegetated shoreline features. As a binary field, it has a response measure of only two possible outcomes (Yes/ No), where "Yes" indicates presence of vegetation while "No" indicates absence of shoreline vegetation. Vegetated shorelines provide greater protection to erosion, enhance habitat, reduce sedimentation and water quality impairment, and have higher recreational value.

PLANTTYPE1

Attribute:
Attribute Label: PlantType1
Attribute Alias: PlantType1
Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: Description of plant communities
Attribute Definition Source: SFWMD, county data layers, expert knowledge
Attribute Domain Values: Bay Bean, Bay Cedar, Beach Creeper, Beach Elder, Beach Morninglory, Biscayne Prickly Ash, Blackbead, Blacktorch, Black Needlerush, Cabbage Palm, Coconut Palm, Cocoplum, Coral Bean, Darling Plum, Dune Sunflower, False Mastic, Fiddlewood, Green Buttonwood, Gulfcoast Spikerush, Gulf Cordgrass, Gumbo Limbo, Florida Privet, Inkberry, Jacquemontia, Jamaican Caper, Jamaican Dogwood, Lantana, Mangrove Spiderlily, Pigeon Plum, Red Maple, Sand Cordgarss, Saw Palmetto, Sawgrass, Saltmeadow Cordgrass, Sea Lavender, Sea Oats, Sea Ox-eye Daisy, Sea Purslane, Seagrape, Seashore Paspalum, Silver Buttonwood, Spanish Stopper, Wax Mirtle, White Stopper

PLANTTYPE2

Attribute:
Attribute Label: PlantType2
Attribute Alias: PlantType2
Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: Description of plant communities
Attribute Definition Source: SFWMD, county data layers, expert knowledge
Attribute Domain Values: Bay Bean, Bay Cedar, Beach Creeper, Beach Elder, Beach Morninglory, Biscayne Prickly Ash, Blackbead, Blacktorch, Black Needlerush, Cabbage Palm, Coconut Palm, Cocoplum, Coral Bean, Darling Plum, Dune Sunflower, False Mastic, Fiddlewood, Green Buttonwood, Gulfcoast Spikerush, Gulf Cordgrass, Gumbo Limbo, Florida Privet, Inkberry, Jacquemontia, Jamaican Caper, Jamaican Dogwood, Lantana, Mangrove Spiderlily, Pigeon Plum, Red Maple, Sand Cordgarss, Saw Palmetto, Sawgrass, Saltmeadow Cordgrass, Sea Lavender, Sea Oats, Sea Ox-eye Daisy, Sea Purslane, Seagrape, Seashore Paspalum, Silver Buttonwood, Spanish Stopper, Wax Mirtle, White Stopper

PLANTTYPE3

Attribute:
Attribute Label: PlantType3
Attribute Alias: PlantType3
Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: Description of plant communities
Attribute Definition Source: SFWMD, county data layers, expert knowledge
Attribute Domain Values: Bay Bean, Bay Cedar, Beach Creeper, Beach Elder, Beach Morninglory, Biscayne Prickly Ash, Blackbead, Blacktorch, Black Needlerush, Cabbage Palm, Coconut Palm, Cocoplum, Coral Bean, Darling Plum, Dune Sunflower, False Mastic, Fiddlewood, Green Buttonwood, Gulfcoast Spikerush, Gulf Cordgrass, Gumbo Limbo, Florida Privet, Inkberry, Jacquemontia, Jamaican Caper, Jamaican Dogwood, Lantana, Mangrove Spiderlily, Pigeon Plum, Red Maple, Sand Cordgarss, Saw Palmetto, Sawgrass, Saltmeadow Cordgrass, Sea Lavender, Sea Oats, Sea Ox-eye Daisy, Sea Purslane, Seagrape, Seashore Paspalum, Silver Buttonwood, Spanish Stopper, Wax Mirtle, White Stopper

PLANTTYPE4

Attribute:
Attribute Label: PlantType4
Attribute Alias: PlantType4
Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: Description of plant communities
Attribute Definition Source: SFWMD, county data layers, expert knowledge
Attribute Domain Values: Bay Bean, Bay Cedar, Beach Creeper, Beach Elder, Beach Morninglory, Biscayne Prickly Ash, Blackbead, Blacktorch, Black Needlerush, Cabbage Palm, Coconut Palm, Cocoplum, Coral Bean, Darling Plum, Dune Sunflower, False Mastic, Fiddlewood, Green Buttonwood, Gulfcoast Spikerush, Gulf Cordgrass, Gumbo Limbo, Florida Privet, Inkberry, Jacquemontia, Jamaican Caper, Jamaican Dogwood, Lantana, Mangrove Spiderlily, Pigeon Plum, Red Maple, Sand Cordgarss, Saw Palmetto, Sawgrass, Saltmeadow Cordgrass, Sea Lavender, Sea Oats, Sea Ox-eye Daisy, Sea Purslane, Seagrape, Seashore Paspalum, Silver Buttonwood, Spanish Stopper, Wax Mirtle, White Stopper

LANDUSE

Attribute:
Attribute Label: Landuse
Attribute Alias: Landuse
Attribute Type: String
Attribute Width: 70
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: Adjacent land use category
Attribute Definition Source:

Layer Name: BPC.BCFutureLandUse
Originators: Broward County Planning Council
Publication date: February 21, 2008
Data type: vector digital data
Data location: Server=gisora01; Service=5152; User=bpc; Version=SDE.DEFAULT

Layer Name: EXLU
Originators: Planning and Zoning Board, Palm Beach County
Publication date: October 16, 2014
Data type: vector digital data
Data location: *http://www.pbcgov.com/iss/itoperations/cwgis/gisdatasearch/*

Layer Name: Existing Land Use Jun2011
Originators: Regulatory and Economic Resources Department, Planning Research Section
Publication date: June, 2011
Data type: vector digital data
Data location: Miami-Dade County

Attribute Domain Values: Recreation – Civic – Assembly, Commercial, Commercial – Hotel/Timeshare, Conservation, Districts, Education, Government Facilities, Government Lands, Industrial, Marina, Mixed Use, Office, Office Medical, Part of the SFWMD conservation area, Recreation – Private Golfcourse, Recreation – Public Golfcourse, Recreation - Public Park, Residential High Density, Residential Low Density, Transportation – Bridge, Utility, Vacant Commercial, Vacant Industrial, Vacant Mixed-Use, Vacant Residential Government Owned, Vacant Residential.

The LANDUSE field is intended to allow users to identify the type of land use adjacent to the shoreline feature. The land use descriptions are derived from land use datasets based on updated parcel information and future land use maps for Broward, Miami-Dade and Palm Beach County. Detailed descriptions of residential uses were grouped into two main categories – “residential high density” and “residential low density.” The Intersect tool in ©ArcGIS ArcToolbox was used to identify the proper land use category for each shoreline feature. In some occasions, where the land use category was found to be “government lands” or “boat slip” the land use designation was modified to reflect the adjacent land use as government easements and boat slips covered only a narrow strip along the shoreline and did not provide sufficient information with regard to the environmental impact of the surrounding uses. For the purposes of this application, "adjacent" indicates directly next to and/or contiguous with the shoreline feature. Information on boat docks was included in NOTES_1 attribute field.

ElevFtNAVD

Attribute:

Attribute Label: ElevFtNAVD

Attribute Alias: ElevFtNAVD

Attribute Type: Double

Attribute Width:

Attribute Precision: 0

Attribute Scale: 0

Attribute Definition: mean elevation for each shoreline feature

Attribute Definition Source:

> ***Layer Name:*** Broward_10ft (2007 Broward 10-ft DEM in NAVD 1988, Release Version 1)
> ***Originators:*** South Florida Water Management District (SFWMD)
> ***Publication date:*** November 23, 2009
> ***Data type:*** Fgdb raster digital data
> ***Data location:***
> \\ad.sfwmd.gov\dfsroot\data\elevation\lidar\2007_FDEM\DEM_Releases\Broward\ReleaseV1\merged\fgdb\Broward_Merged_10ft.gdb
>
> ***Layer Name:*** MiamiDade_10ft (2007-08 Miami-Dade 5-ft DEM in NAVD 1988, Release Version 1)
> ***Originators:*** South Florida Water Management District (SFWMD)
> ***Publication date:*** November 23, 2009
> ***Data type:*** Fgdb raster digital data
> ***Data location:*** http://www.sfwmd.gov
>
> ***Layer Name:*** PBEast_10ft Broward_10ft (2007-08 Palm Beach East 10-ft DEM in NAVD 1988, Release Version 1)
> ***Originators:*** South Florida Water Management District (SFWMD)
> ***Publication date:*** May 14, 2010
> ***Data type:*** Fgdb raster digital data
> ***Data location:***
> \\ad.sfwmd.gov\dfsroot\data\elevation\lidar\2007_FDEM\DEM_Releases\PalmBeachEast\ReleaseV1\merged\fgdb\PBEast_Merged_10ft.gdb
> ***Attribute Domain Values***:
>
> **Cell size X direction:** 10.0
> **Cell size Y direction:** 10.0
> **Cell size X units:** ft

The field Elev FtNAVD indicates the mean elevation in feet for each shoreline feature. The mean elevation was calculated from the 2007-2008 10ft LiDAR DEM for Broward and Palm Beach counties and the 2007-2008 5ft LiDAR DEM for Miami-Dade County. The Zonal Statistics tool in

©ArcGIS Spatial Analyst was used to summarize mean elevation value for each shoreline feature. The resulting floating point 32-bit unsigned raster was further processed using Raster Calculator and converted to a vector file. The shoreline feature class was then overlaid with the mean elevation feature class using the intersect tool. For restoration projects completed after 2008, the elevations derived from the LiDAR DEM were replaced with design elevations. The average elevation of a site is given in feet referenced to the North American Vertical Datum of 1988.

LENGTHFT

Attribute:
Attribute Label: LengthFt
Attribute Alias: LengthFt
Attribute Type: Double
Attribute Width:
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: length of shoreline feature at the land/water interface
Attribute Definition Source: calculated
Attribute Domain Values: a numeric value

The field LENGTHFT indicates the length of the land/water interface in feet. The field was calculated using the aerial photography and the measure tool in ArcGIS.

AREA_AC

Attribute:
Attribute Label: Area_ac
Attribute Alias: Area_ac
Attribute Type: Double
Attribute Width:
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: length of shoreline feature at the land/water interface
Attribute Definition Source: calculated
Attribute Domain Values: a numeric value

The field AREA_AC indicates the area in acres for polygon features. Area was calculated using the Calculate Geometry tool in ©ArcGIS. For some restored features the records may also include project restoration area by activities and species. Additional information can be found in NOTES_1 and NOTES_2 fields.

ORIENTED

Attribute:
Attribute Label: Oriented
Attribute Alias: Oriented
Attribute Type: String
Attribute Width: 40
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: direction faced by the shoreline
Attribute Definition Source: established from 2013 MrSID aerial photography for Broward, Miami-Dade and Palm Beach counties
Attribute Domain Values: N, S, E, W, NE, NW, SE, SW, Exposed all directions

The field ORIENTED describes the direction faced by the shoreline. The literature suggests that shoreline orientation can affect erosion rates due to prevailing wind direction and fetch exposure (Hardaway et al. 2010). Studies conducted in the Chesapeake Bay indicate that shorelines facing the prevailing wind direction with medium to high fetch are considerably more susceptible to erosion than shorelines oriented in the opposite direction (Hardaway et al. 2010). Prevailing wind direction in South Florida during the months of March through November is E–SE, while during the months of December, January and February it is N-NE (NOAA-NCDC, 2014). Higher erosion rates can, therefore, be expected for the east-southeast and north-northeast facing slopes.

STRUCTURE

Attribute:
Attribute Label: Structure
Attribute Alias: Structure
Attribute Type: String
Attribute Width: 70
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: presence of structures
Attribute Definition Source: established from 2013 MrSID aerial photography for Broward, Miami-Dade and Palm Beach counties
Attribute Domain Values: a descriptive field

The field STRUCTURE is a free text field in which general comments about existing structures can be placed. Examples of such built structures include boat docks, rip-raps, seawalls, breakwaters, culverts, turbidity barriers, etc.

FEATURES

Attribute:
Attribute Label: Features
Attribute Alias: Features
Attribute Type: String
Attribute Width: 100
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: presence of features
Attribute Definition Source: established from 2013 MrSID aerial photography for Broward, Miami-Dade and Palm Beach counties
Attribute Domain Values: a descriptive field

The field FEATURES is a free text field in which users can find general comments about existing shoreline features. In general, these features are installed either for habitat or recreational enhancement, i.e. flushing creeks, walking trails, beaches, bird nests, etc.

STATUS

Attribute:
Attribute Label: Status
Attribute Alias: Status
Attribute Type: String
Attribute Width: 20
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: indicates whether a project is completed or under construction
Attribute Definition Source: available reports, permits and other documents, expert knowledge
Attribute Domain Values: completed, under construction

The field STATUS indicates whether a project is completed or under construction.

NOTES_1

Attribute:
Attribute Label: Notes_1
Attribute Alias: Notes_1
Attribute Type: String
Attribute Width: 250
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: a free text field to place general comments

Attribute Definition Source: available reports, permits and other documents, expert knowledge
Attribute Domain Values: a descriptive field

The field NOTES_1 is a free text field to place general comments about the data spatial attributes.

NOTES_2

Attribute:
Attribute Label: Notes_2
Attribute Alias: Notes_2
Attribute Type: String
Attribute Width: 150
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: a free text field to place general comments
Attribute Definition Source: available reports, permits and other documents, expert knowledge
Attribute Domain Values: a descriptive field

The field NOTES_2 is a free text field which gives details of the project area history if information is available. Examples include clearance and removal of exotic vegetation, excavation, replanting or other activities.

BUILTBY

Attribute:
Attribute Label: BuiltBy
Attribute Alias: BuiltBy
Attribute Type: String
Attribute Width: 30
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: the institution or organization listed as the project sponsor
Attribute Definition Source: pertaining documents, comments, aerial photography, expert knowledge
Attribute Domain Values: a descriptive field

The field BUILTBY indicates the institutions or organizations listed as the project sponsors responsible for carrying out the project.

YEARBUILT

Attribute:
Attribute Label: BuiltBy
Attribute Alias: BuiltBy
Attribute Type: String
Attribute Width: 30
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: the year of completion of a restoration or enhancement project
Attribute Definition Source: pertaining documents, comments, aerial photography
Attribute Domain Values: a descriptive field

The field YEARBUILT indicates the year of completion of a restoration or enhancement project.

PERMITNO

Attribute:
Attribute Label: PermitNo
Attribute Alias: PermitNo
Attribute Type: String
Attribute Width: 50
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: permit/ license number
Attribute Definition Source: Permits available through the counties (Broward, Miami-Dade and Palm Beach) or the E-permitting database of the South Florida Water Management District, URL: http://www.sfwmd.gov/ePermitting/MainPage.do;jsessionid=3C9C87818ADAC9C1DA0B0A5DCF22169E
Attribute Domain Values: a descriptive field

The field PERMITNO refers to permits issued for projects by the South Florida Water Management District (SFWMD), Florida Department of Environmental Resources and Management (DERM), or the Army Corps of Engineers (USACE).

COUNTY

Attribute:
Attribute Label: County
Attribute Alias: County
Attribute Type: String
Attribute Width: 30
Attribute Precision: 0

Attribute Scale: 0
Attribute Definition: county where the shoreline feature is located
Attribute Definition Source: County
Attribute Domain Values: Broward, Miami-Dade, Palm Beach

The field COUNTY refers to the county where the shoreline feature is located.

WATERBODY

Attribute:
Attribute Label: County
Attribute Alias: County
Attribute Type: String
Attribute Width: 50
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: name of waterbody
Attribute Definition Source: SFWMD, expert knowledge
Layer name: AHED.BASIN v2.4.20130228
Originators: SFWMD
Publication date: February 28, 2913
Data type: vector digital data
Data location: Server=ghydssde; Service=5159; User=ahed; Version=SDE.DEFAULT
Attribute Domain Values: a descriptive field

The field WATERBODY indicates any major waterbody to which a site is adjacent, connected to, or within. Waterbodies geographic names are consistent with the waterbody names included in the feature class. The feature class Waterbody is part of the Hydrography feature dataset of the Arc Hydro Enhanced Database (AHED) maintained by the South Florida Water Management District (SFWMD 2013).

NAVCHANNEL

Attribute:
Attribute Label: NavChannel
Attribute Alias: NavChannel
Attribute Type: String
Attribute Width: 20
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: a binary field (Yes/No) to indicate whether a shoreline feature is located on a navigational channel or not

Attribute Definition Source: expert knowledge
Attribute Domain Values: Yes/ No

The field NAVCHANNEL (i.e., navigational channel) is a binary (Yes/ No) field intended to allow users to quickly select features located on navigational channels. For the purposes of this dataset, navigational channel refers to any stream of a suitable depth for motorized navigation, while creeks and streams which are only navigable by non-motorized vessels are not considered navigational channels. In addition to wind-driven waves, shoreline features located on navigational channels are more likely to experience the effect of boat wakes which occasionally can create severe wave climate (Hardaway et al. 2010).

INLETDISMI

Attribute:
Attribute Label: InletDisMi
Attribute Alias: InletDisMi
Attribute Type: Double
Attribute Width:
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: distance to inlet in miles
Attribute Definition Source: calculated
Attribute Domain Values: a numeric value

The field INLETDISMI indicates distance to inlet in miles. The distance was calculated using the Near function in the Proximity Analysis toolset in the ©ArcGIS. Shoreline features in close proximity to inlets are more likely to experience higher volume of boat wakes and therefore will be subject to more severe wave climate than shoreline features further way. Values of [-99] indicate No Value.

FETCHCAT

Attribute:
Attribute Label: FetchCat
Attribute Alias: FetchCat
Attribute Type: String
Attribute Width:
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: fetch category based on average fetch distance
Attribute Definition Source: classification based on calculated values

Attribute Domain Values: Very low < 0.25 mi; Low 0.25 to 0.5mi; Medium 0.5 to 1.0 mi; High 1.0 to 10.0 mi; Unbounded > 10.0 mi

The field FETCHCAT denotes fetch category determined from calculated average fetch (FETCHAVEMI) for each shoreline feature and expert knowledge.

FETCHAVEMI

Attribute:
Attribute Label: FetchAveMi
Attribute Alias: FetchAveMi
Attribute Type: Double
Attribute Width:
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: average fetch distance
Attribute Definition Source: calculated
Attribute Domain Values: a numeric value

The field FETCHAVEMI (average fetch in miles) was calculated using the *Application of Wind Fetch and Wave Models for Habitat Rehabilitation and Enhancement Projects* (Rohweder et al. 2012). The application *Waves2012.tbx* is a toolbox for ©ArcGIS 10.0/10.1 based on the methodology described in the *USACE Shore Protection Manual* (USACE 1984). The application calculates effective fetch using as inputs a land-water raster and a text file with compass directions and respective wind direction weights in percent. Table 2 below shows wind direction and respective weights in percent for the Miami International Airport.

The effective fetch is calculated as the arithmetic mean of nine radial distances spread at three-degree increments in the prevailing wind direction (Rohweder et al. 2012). The wind direction weights were calculated as percentage of time the wind blows from a specific direction during the months of June, July, and August over a 5-year time period 2009-2013. The summer months were selected for the analysis as they coincide with the hurricane season in South Florida when tropical cyclones associated with higher wind speed are often observed. Values of [-99] indicate No Value.

Table 2. Wind direction and wind direction weights in percent for the Miami International Airport (MIA) (*Data source*: NOAA- National Climatic Data Center)

Wind Direction	Compass Degrees	Dec Jan Feb	Mar Apr May	Jun Jul Aug	Sep Oct Nov
N	360	12.2	5.1	5.3	10.2
NNE	20	2.5	1.2	2.6	5.1
NE	40	3.8	3.1	3.5	9.2
ENE	70	5.8	8.2	7.5	11.3
E	90	12.7	17.6	17.9	17.7
ESE	110	9.1	14.5	15.9	9.5
SE	130	8.7	12.2	13.5	7.5
SSE	160	6.5	9.3	7.5	4.1
S	180	5.3	5.6	6.5	4.2
SSW	200	2.4	2.1	2.5	2.5
SW	220	2.5	2.2	2.7	2.3
WSW	250	2.6	2.3	2.6	2.8
W	270	3.5	3.4	3.5	3.3
WNW	290	4.8	4.8	2.3	3.4
NW	310	4.3	3.3	2.7	3.7
NNW	340	13.3	5.1	3.5	3.2

FETCHMAXMI

Attribute:
Attribute Label: FetchMaxMi
Attribute Alias: FetchMaxMi
Attribute Type: Double
Attribute Width:
Attribute Precision: 0
Attribute Scale: 0
Attribute Definition: maximum fetch distance
Attribute Definition Source: calculated
Attribute Domain Values: a numeric value

The field FETCHMAXMI indicates maximum fetch distance. The fetch toolbox application (Rohweder et al. 2012) calculates fetch distances for each wind direction. The longest fetch for the prevailing wind direction was used as the maximum fetch distance. Values of [-99] indicate No Value.

The fields SUBSTRATE, GEOMORPHOL, RUNOFF, DRAINAGE, HYDROGRP, TAXCLNAME, AND TAXORDER were populated using information from the Soil Survey Geographic (SSURGO) Database of the Natural Resources Conservation Service (USDA-NRCS2014).

SUBSTRATE

Attribute:
Attribute Label: Substrate
Attribute Alias: Substrate
Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: component name
Attribute Definition Source: USDA-NRCS SSURGO Database, URL:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Attribute Domain Values: component name
The field SUBSTRATE indicates the dominant soil component for each shoreline feature. Substrate/ component name are consistent with the definitions of the Soil Survey Geographic (SSURGO) Database (USDA-NRCS 2014).

GEOMORPHOL

Attribute:
Attribute Label: Geomorphol
Attribute Alias: Geomorphol
Attribute Type: String
Attribute Width: 150
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: geomorphic setting
Attribute Definition Source: USDA-NRCS SSURGO Database, URL:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Attribute Domain Values: a descriptive field providing details on the geomorphic setting of a component (USDA-NRCS 2014)

RUNOFF

Attribute:
Attribute Label: Runoff
Attribute Alias: Runoff

Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: runoff potential category
Attribute Definition Source: USDA-NRCS SSURGO Database, URL: ,
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Attribute Domain Values: runoff potential class for the soil component: Negligible, Low, High, Very High (USDA-NRCS 2014).

DRAINAGE

Attribute:
Attribute Label: Drainage
Attribute Alias: Drainage
Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: natural soil drainage conditions
Attribute Definition Source: USDA-NRCS SSURGO Database, URL:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Attribute Domain Values: a drainage class description based on the natural drainage conditions of the soil and referring to the frequency and duration of ponding periods. The class descriptions include: Very poorly drained, Poorly drained, Somewhat poorly drained, Moderately well drained, Well drained, Excessively drained (USDA-NRCS 2014).

HYDROGRP

Attribute:
Attribute Label: HYDROGRP
Attribute Alias: HYDROGRP
Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: hydrologic soil group as defined in the National Soil Survey Handbook (NSSH 2014)
Attribute Definition Source: USDA-NRCS SSURGO Database, URL:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631

Attribute Domain Values: The hydrologic soil group (HYDROGRP) as defined by the National Soil Survey Handbook (NSSH 2014). HYDROGRP consists of groups of soils that exhibit similar runoff characteristics under similar storm and cover conditions NSSH 2014). Categories include A, A/B, A/D, B, C and D. For details refer to NSSH (2014).

TAXCLNAME

Attribute:
Attribute Label: Taxclname
Attribute Alias: Taxclname
Attribute Type: String
Attribute Width: 150
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: soil taxonomy subgroup and soil family
Attribute Definition Source: USDA-NRCS SSURGO Database, URL:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Attribute Domain Values: a description integrating the Soil Taxonomy subgroup and soil class name (USDA-NRCS 2014)

TAXORDER

Attribute:
Attribute Label: HYDROGRP
Attribute Alias: HYDROGRP
Attribute Type: String
Attribute Width: 50
Attribute Precision: 6
Attribute Scale: 0
Attribute Definition: highest taxonomy soil level
Attribute Definition Source: USDA-NRCS SSURGO Database, URL:
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Attribute Domain Values: soil taxonomy level (USDA-NRCS 2014)

REFERENCES

Alongi, Daniel M. 2008. Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science* 76:1-13.

ArcGIS Resources. 2014. What is an OBJECTID? URL: http://resources.arcgis.com/en/help/main/10.1/index.html#//006z00000009000000, accessed 12/05/2014).

Ariza, Eduard, Kenyan C. Lindeman, Pallab Mozumber, and Daniel O. Suman. 2014. Beach management in Florida: Assessing stakeholder perceptions on governance. *Ocean & Coastal Management* 96:82-93.

Bailey, P. 2014. A Design Manual for Engineering with Nature Using Native Plant Communities, U.S. Army Engineer Research & Development Center, U.S. Army Corps of Engineers, Vicksburg, MS, URL: http://el.erdc.usace.army.mil/ewn/pdfs/EWN%20Design%20Manual.pdf, (accessed 12/18/2014).

Berman, Marcia and Harry Berquist, Julie Herman, and Karinna Nunez. 2007. *The Stability of Living Shorelines – An Evaluation*. Final Report Submitted to National Oceanic and Atmospheric Administration. Annapolis, Maryland: Chesapeake Bay Program Office.

Bilkovic, D.M., D. Stanhope and K. Angstadt. 2007. Shallow Water Fish Communities and Coastal Development Stressors in the Lynnhaven River, Final Report to U.S. Army Corps of Engineers, Virginia Institute of Marine Science, Center for Coastal Resources Management, Gloucester Point, Virginia, URL: http://ccrm.vims.edu/research/coastal_stressors/lynnhaven_fish_06/lynnhaven_habitat.pdf, (accessed 12/27/2014).

Bilkovic, D.M. and M.M. Mitchell. 2013. Ecological tradeoffs of stabilized salt marshes as a shoreline protection strategy: Effects of artificial structures on macrobenthic assemblages. *Ecological Engineering* 61:469-481.

Bradbury, H., Jennifer Corrin, Alasdair J. Edwards, David O. Obura, Yvonne J. Sadovy de Mitcheson, Melita A. Samoilys, and Charles R.C. Sheppard. 2014. Transforming management of tropical coastal seas to cope with challenges of the 21st century. *Marine Pollution Bulletin* 85:8-23.

Burke, D.G. and C.S. Hardaway. 2007. South River Shore Erosion Management and Living Shoreline Guidelines, A report prepared by the Virginia Institute of Marine Science & Burke Environmental Associates. http://web.vims.edu/physical/research/shoreline/docs/SouthRiverManagementPlan/AppendixC.pdf, (accessed 09/09/2014).

Byrne, Robert J., and Gary L. Anderson. 1979. Shoreline Erosion in Tidewater Virginia. Chesapeake Research Consortium Report No. 8.

Coasts, Oceans, Ports and Rivers Institute (COPRI). 2014. Living Shorelines Database. URL: http://mycopri.org/node/1467, (accessed 10/12/2014).

Currin, C.A., Chappell, W.S, and Deaton, A. 2010. Developing alternative shoreline armoring strategies: The living shoreline approach in North Carolina, *in* Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and Dinicola, R.S., eds., 2010, Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop, May 2009: U.S. Geological Survey Scientific Investigations Report 2010-5254, p. 91-102.

Defeo, Omar, Anton McLachlan, David S. Schoeman, Thomas A. Schlacher, Jenifer Dugan, Alan Jones, Mariano Lastra, and Felicita Scapinil. 2009. "Threats to sandy beach ecosystems: A review." *Estuarine, Coastal and Shelf Science* 81:1-12.

Dinicola, R.S., eds., 2010, *Puget Sound Shorelines and the Impacts of Armoring—Proceedings of a State of the Science Workshop*, May 2009: U.S. Geological Survey Scientific Investigations Report 2010-5254:187-194.

Dugan, J.E., and Hubbard, D.M. 2010. Ecological effects of coastal armoring: A summary of recent results for exposed sandy beaches in southern California, *in* Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., and

Evans, Rob L. 2004. Rising Sea Levels and Moving Shorelines. *Oceans* 43(1): 6-11.

Fish and Wildlife Service (FWS). 1999. *South Florida Multi-Species Recovery Plan (MSRP) - Coastal Communities*, South Florida Ecological Services Field Office, U.S. Department of the Interior. URL: http://www.fws.gov/VeroBeach/ListedSpeciesMSRP.html (accessed 10/14/2014).

Florida Department of Environmental Protection (FDEP). 2014. *Florida Coastal Management Program Guide*, Florida Coastal Management Program, URL: http://www.dep.state.fl.us/cmp/publications/FCMP_Program_Guide_2014.pdf, (accessed 10/01/2014).

Florida Department of Environmental Protection (FDEP). 2011. Florida Ecological Restoration Inventory (FERI), URL: http://www.dep.state.fl.us/water/wetlands/feri/index.htm, (accessed 12/17/2014).

Florida Department of Environmental Protection (FDEP). 2008. Living Shorelines: Natural Protection of Florida's Coasts, URL: http://www.dep.state.fl.us/coastal/news/articles/2008/0812_Shorelines.htm, (accessed 11/15/2014).

Florida Department of Transportation (FDOT). 1999. Florida Land Use, Cover and Forms Classification System (FLUCCS), third edition. Florida Department of Transportation Surveying and Mapping Office, Geographic Mapping Section, Tallahassee, Florida. URL: http://www.dot.state.fl.us/surveyingandmapping/documentsandpubs/fluccmanual1999.pdf, (accessed 12/15/2014)

Gedan, K.B., M.L. Kirwan, E. Wolanski, E.B. Barbier, and B.R. Silliman. 2011. The present and future role of coastal wetland vegetation in protection shorelines: Answering recent challenges to the paradigm. *Climatic Change* 106:7-29.

Gerstel, W.J. and J.F. Brown. 2006. *Alternative Shoreline Stabilization Evaluation Project.* Final Report Prepared for Puget Sound Action Team. URL: http://pugetsound.org/science/puget-sound-science/reports/shoreline, (accessed 09/10/2014).

Glick, P., J. Kostyack, J. Pittman, T. Briceno, and N. Wahlund. 2014. Natural Defenses from Hurricanes and Floods: Protecting America's Communities and Ecosystems in an Era of Extreme Weather, National Wildlife Federation & Earth Economics, URL http://www.nwf.org/news-and-magazines/media-center/news-by-topic/global-warming/2014/10-20-14-new-report-action-needed-now-to-fix-climate-change.aspx,, (accessed 11/28/2014).

Global Environmental Facility (GEF). 2012. Marine Spatial Planning in the Context of the Convention on Biological Diversity, GEF/STAP/C.43/Inf.05, URL: http://www.unep.org/dgef/Portals/43/news/GEFSTAP_C43Inf_05_MarineSPContextConvention_on_BiologicalDiversity.pdf (accessed 12/30/2014)

Hardaway, Jr., C.S. and R. J. Byrne. 1999. Shoreline Management in Chesapeake Bay. Special report in Applied Marine Science and Ocean Engineering Number 356. Virginia Sea Grant Publication VSG--11.

Hardaway, Jr., C.S., D.A. Milligan and K. Duhring. 2010. *Living Shoreline Design Guidelines for Shore Protection in Virginia's Estuarine Environments*, Special Report in Applied Marine Science and Ocean Engineering No. 421, Virginia Institute of Marine Science, College of William & Mary, Gloucester Point, Virginia.

Heinz Center. 2000. *Evaluation of Erosion Hazards: Summary*. Prepared for the Federal Emergency Management Agency (Contract EMW-97-CO-0375). Washington, DC: Heinz Center for Science, Economics, and the Environment.

Jancaitis, K.M. 2008. Florida on the Coast of Climate Change: Responding to Rising Seas. UC Davis Law School. *Environs Environmental Law and Policy Journal* 31(2):157-194.

Khalil, S.M., C.W. Finkl, H.H. Roberts, and R.C. Raynie. 2010. New Approaches to Sediment Management on the Inner Continental Shelf Offshore Coastal Louisiana. *Journal of Coastal Research* 26(4):591-64.

Kirwan, M.L. and J.P. Magonigal. 2013. Tidal wetland stability in the face of human impacts and sea-level rise, *Nature*, 503, 53-60.

Komar, P.D. 2000. Shore Leave. *The Sciences,* January/February, p. 20-24.

Kreeger, D. and J. Moody. 2014. A Framework for Standardized Monitoring of Living Shorelines in the Delaware Estuary and Beyond. *Partnership for the Delaware Estuary Shoreline Monitoring Framework*. Accessed September 27, 2014. https://s3.amazonaws.com/delawareestuary/sites/default/files/PDE%20Living%20Shoreline%20Monitoring%20Framework%204-23-14%20DRAFT.pdf.

Lamont, G., Readshow, J., Robinson, C., St-Germain, P. 2014. Greening Shorelines to Enhance Resilience: An Evaluation of Approaches for Adaptation to Sea Level Rise. Guide prepared by SNC-Lavalin Inc. for the Stewardship Centre for British Columbia and submitted to Natural Resources of Canada (AP040), 46 p. URL: http://www.stewardshipcentrebc.ca/PDF_docs/reports/Greening_Shorelines_to_Enhance_Resilience.pdf, (accessed 11/05/2014).

Landry, C.J. 2002. Who Drained the Everglades? *PERC Reports* 20(5):3-6.

Leafe, R., J. Pethick, and I. Townend. 1998. Realising the benefits of shoreline management. *The Geographic Journal* 164:282-290.

Leatherman, S.P. 2003. Shoreline Change Mapping and Management along the U.S. East Coast. *Journal of Coastal Research* 38:5–13.

Miami-Dade County (MDC). 2013. Freshwater wetlands, Regulatory Economic Resources, Ecosystem Protection, URL: http://www.miamidade.gov/environment/wetlands-freshwater.asp, (accessed 12/27/2014).

Milano, G.R. 1999. Restoration of coastal wetlands in southeastern Florida. *Wetland Journal* 11(2):15-24.

Milano, G.R. 2000. Island restoration and enhancement in Biscayne Bay, Florida, 1-17. In P.J. Cannizarro (ed.). Proceedings of the 26th Annual Conference on Ecosystem Restoration and Creation, Hillsborough Community College, Tampa, Fl.

Mitsova, D. and A.M. Esnard. 2012. Holding Back the Sea: An Overview of Shore Zone Planning and Management. *Journal of Planning Literature* 27(4): 446-459.

NatureServe. 2014. Tools for Landscape-Level Assessment and Planning: A Guide for the North Pacific Landscape Conservation Cooperative, Ecosystems-Based Management Tools Network, Arlington, VA.

National Oceanic and Atmospheric Administration (NOAA). 2000. *Tide and Current Glossary*, U.S. Department of Commerce. URL: http://co-ops.nos.noaa.gov/publications/glossary2.pdf, (accessed 09/30/2014).

Park, J., J. Obeysekera, M. Irizarry, J. Barnes, P. Trimble, and W. Park-Said. 2011. Storm surge projections and implications for water management in South Florida. *Climatic Change* 107:109-128. DOI 10.1007/s10584-011-0079-8.

Peterson, M.S. & M. R. Lowe. 2009. Implications of Cumulative Impacts to Estuarine and Marine Habitat Quality for Fish and Invertebrate Resources. *Reviews in Fisheries Science* 17(4):505-523. http://dx.doi.org/10.1080/10641260903171803.

Reay, W.G. and S. Lerberg. 2008. Living Shorelines: Restoring multi-function buffers on coastal shorelines. *Water Resources IMPACT* 10(3):9-11.

Rohweder, J., J. T Rogala, B. L Johnson, D. Anderson, S. Clark, F. Chamberlin, D. Potter, and K. Runyon. 2012. Application of Wind Fetch and Wave Models for Habitat Rehabilitation and Enhancement Projects – 2012 Update. Contract report prepared for U.S. Army Corps of Engineers Upper Mississippi River Restoration – Environmental Management Program. 52 p.

Ruppert, T.K. 2008. Eroding Long-Term Prospects for Florida Beaches: Florida's Coastal Construction Control Line Program. Sea Grant Law and Policy 1(1): 65–98, http://nsglc.olemiss.edu/SGLPJ/Vol1No1/4Ruppert.pdf, (accessed 09/10/2014).

Sale, P.F., T. Agardy, C.H. Ainsworth, B.E. Feist, J.D. Bell, P. Christie, O. Hoegh-Guldberg, P.J. Mumby, D.A. Feary, M.I. Saunders, T.M. Daw, S.J. Foale, P.S. Levin, K.C. Lindeman, K. Lorenzen, R.S. Pomeroy, E.H. Allison, R. H. Bradbury, J. Corrin, A.J. Edwards, D.O. Obura, Y.J. Sadovy de Mitcheson, M.A. Samoilys, and C.R. Sheppard. 2014. Transforming management of tropical coastal seas to cope with challenges of the 21st century. *Marine Pollution Bulletin* 85:8-23.

Scyphers, S.B., Powers S.P., Heck K.L. Jr., Byron D. 2011. Oyster Reefs as Natural Breakwaters Mitigate Shoreline Loss and Facilitate Fisheries. *PLoS ONE* 6(8):e22396. DOI:10.1371/journal.pone.0022396.

Southeast Florida Regional Climate Change Compact (SEFL-CCC). 2012a. Inundation Mapping and Vulnerability Assessment Work Group. Analysis of the Vulnerability of Southeast Florida to Sea Level Rise. p. 103, URL: http://www.southeastfloridaclimatecompact.org//wp-content/uploads/2014/09/vulnerability-assessment.pdf, (accessed 11/25/2014).

Southeast Florida Regional Climate Change Compact (SEFL-CCC). 2012b. A Region Responds to a Changing Climate: Regional Climate Action Plan, URL: http://www.southeastfloridaclimatecompact.org//wp-content/uploads/2014/09/regional-climate-action-plan-final-ada-compliant.pdf, (accessed 01/19/2015).

South Florida Water Management District (SFWMD). 2002. FLUCCS Codes Modified for SFWMD, URL: http://www.evergladesplan.org/pm/projects/project_docs/pdp_08_eaa_store/111303_docs_08_socio_fluccs.pdf, (accessed 12/10/2014).

South Florida Water Management District (SFWMD). 2013. Basin Metadata, URL:
http://www.sfwmd.gov/gisapps/sfwmdxwebdc/openxml.asp?file=metadata/meta_xml1963.xml&xsl=FGDCESRI.xsl, (accessed 12/07/2014).

Stauble, Donald K. 2003. The Use of Shoreline Change Mapping in Coastal Engineering Project Assessment. *Journal of Coastal Research* 38:178-206.

Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) [Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535, DOI:10.1017/CBO9781107415324.

Strauss, B.H, R. Ziemlinski, J.L Weiss and J.T Overpeck. 2012. Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States, *Environmental Research Letters*, 7(1), 1-12.

Subramanian, Bhaskaran, Gene Slear, Kevin M. Smith, and Karen A. Duhring. 2006. Current Understanding of the Effectiveness of Nonstructural and Marsh Sill Approaches. Paper presented at *The Living Shorelines Summit: Evaluation of Living Shoreline Techniques*, William and Mary Virginia Institute of Marine Science, Williamsburg, Virginia, p.35-40.
http://www.vims.edu/cbnerr/coastal_training/recent_workshops/ls_summit.php, (accessed 09/10/2014).

Swann, LaDon. 2008. The Use of Living Shorelines to Mitigate the Effects of Storm Events on Dauphin Island, Alabama, USA. *American Fisheries Society Symposium* 64:47–57.

U.S. Army Corps of Engineers (USACE). 1971. *Report of the National Shoreline Study*. Washington, DC: U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers (USACE). 1984. *Shore Protection Manual*, *Volume 1 and Volume 2*. Department. of the Army, Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, Mississippi; Washington, DC.

U.S. Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS).2014. Soil Survey Geographic (SSURGO) Database. USDA-NRCS Soil Survey Staff, Available online at
http://sdmdataaccess.nrcs.usda.gov/, (accessed 10/25/2014).

U.S. Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS). 2014. National Soil Survey Handbook, USDA-NRCS Soil Survey Staff, Available online at
http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_054242, (accessed 12/15/2014).

U.S. Department of Transportation -Federal Highway Administration (FDOT-FHA). 2011. Highways in the Coastal Environment, Second Edition, Chapter 4 – Waves (4.4 Wave Generation), URL:
http://www.fhwa.dot.gov/engineering/hydraulics/pubs/07096/4.cfm, (accessed 12/05/2014).

Virginia Institute of Marine Science – Center for Coastal Resources Management (VIMS-CCRM). 2012. Living Shorelines Policy: The Integration of Shoreline Management and Planning, *Rivers and Coasts*, 7 (1), 1-8, URL:
http://ccrm.vims.edu/publications/pubs/rivers&coast/vol7_no1LSPolicy.pdf, (accessed 10/23/2014).

Walker, R., B. Bendell, and L. Wallendorf. 2011. Defining Engineering Guidelines for Living Shoreline Projects. *Coastal Engineering Practice* ASCE 1064-1077.

Whalen, L., D. Kreeger, D. Bushek, and J. Moody. 2012. Strategic Planning for Living Shorelines in the Delaware Estuary. *National Wetlands Newsletter* 34(6):14-19. Washington, DC: Environmental Law Institute.

Whalen, L., D. Kreeger, D. Bushek, J. Moody, and A. Padeletti. 2011. Practitioner's Guide: Shellfish-Based Living Shorelines for Salt Marsh Erosion Control and Environmental Enhancement in the Mid-Atlantic. *Partnership for the Delaware Estuary Report* 11-04, URL: https://s3.amazonaws.com/delawareestuary/pdf/Living%20Shorelines/DELSI%20Practitioners%20Guide%20v9.7.11.pdf, (accessed 09/28/2014).

The Nature Conservancy (TNC). 2014. Nature-based Coastal Defenses in Southeast Florida. A collaborative publication of The Nature Conservancy and the Southeast Florida Regional Climate Change Compact Shoreline Resilience Working Group, URL: http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/florida/explore/nature-based-coastal-defenses-in-southeast-florida.xml, (accessed 12/29/2014).

The White House, Office of the Press Secretary. 2014. FACT SHEET: What Climate Change Means for Florida and the Southeast and Caribbean [Press Release]. http://www.whitehouse.gov/sites/default/files/docs/state-reports/FLORIDA_NCA_2014.pdf, (accessed 09/28/2014).

World Meteorological Organization (WMO). 1998. *Guide to Wave Analysis and Forecasting*, 2nd edition, WMO-No. 702, URL: http://www.wmo.int/pages/prog/amp/mmop/documents/WMO%20No%20702/WMO702.pdf, (accessed 12/15/2014).

Appendix I

Table 3. Attribute label, attribute type, attribute definition and attribute definition source

Attribute Label	Attribute Type	Attribute Definition	Attribute Definition Source
OBJECTID	OID	Internal feature number	ESRI
AREANAME	String	Unique area name	SFWMD, county data layers, expert knowledge
FLUCCS	String	FLUCCS classification description	FDOT, SFWMD, Palm Beach County
Category	String	Category refers to the type of shoreline with regard to restoration activities	FDEP-FERI**,** county data layers, expert knowledge
Descript	String	Description of the dominant shoreline feature	County data layers, expert knowledge
Vegetated	String	A binary variable to indicate presence/ absence of vegetation	Established from 2013 MrSID aerial photography for Broward, Miami-Dade and Palm Beach Counties
PlantType1	String	Description of plant communities	SFWMD, county data layers, expert knowledge
PlantType2	String	Description of plant communities	SFWMD, county data layers, expert knowledge
PlantType3	String	Description of plant communities	SFWMD, county data layers, expert knowledge
PlantType4	String	Description of plant communities	SFWMD, county data layers, expert knowledge
LandUse	String	Adjacent land use category	***Layer Name:*** BPC.BCFutureLandUse ***Originators:*** Broward County Planning Council ***Publication date:*** February 21, 2008 ***Data type:*** vector digital data ***Data location:*** Server=gisora01; Service=5152; User=bpc; Version=SDE.DEFAULT ***Layer Name:*** EXLU ***Originators:*** Planning and Zoning Board, Palm Beach County ***Publication date:*** October 16, 2014 ***Data type:*** vector digital data ***Data location:*** *http://www.pbcgov.com/iss/itoperations/cwgis/gisdatasearch/* ***Layer Name:*** Existing Land Use Jun2011 ***Originators:*** Regulatory and Economic Resources Department, Planning Research Section ***Publication date:*** June, 2011 ***Data type:*** vector digital data ***Data location:*** Miami-Dade County
ElevFtNAVD	Double	Mean elevation for each shoreline feature	***Layer Name:*** Broward_10ft (2007 Broward 10-ft DEM in NAVD 1988, Release Version 1) ***Originators:*** South Florida Water Management District (SFWMD) ***Publication date:*** November 23, 2009 ***Data type:*** Fgdb raster digital data ***Data location:***

			\\ad.sfwmd.gov\dfsroot\data\elevation\lidar\2007_FDEM\DEM_Releases\Broward\ReleaseV1\merged\fgdb\Broward_Merged_10ft.gdb ***Layer Name:*** MiamiDade_10ft (2007-08 Miami-Dade 5-ft DEM in NAVD 1988, Release Version 1) ***Originators:*** South Florida Water Management District (SFWMD) ***Publication date:*** November 23, 2009 ***Data type:*** Fgdb raster digital data ***Data location:*** http://www.sfwmd.gov ***Layer Name:*** PBEast_10ft Broward_10ft (2007-08 Palm Beach East 10-ft DEM in NAVD 1988, Release Version 1) ***Originators:*** South Florida Water Management District (SFWMD) ***Publication date:*** May 14, 2010 ***Data type:*** Fgdb raster digital data ***Data location:*** \\ad.sfwmd.gov\dfsroot\data\elevation\lidar\2007_FDEM\DEM_Releases\PalmBeachEast\ReleaseV1\merged\fgdb\PBEast_Merged_10ft.gdb
LengthFt	Double	Length of shoreline feature at the land/water interface	Calculated in ©ArcGIS using MrSID aerial photography and the measure tool
Area_ac	Double		Calculated or provided in publicly available reports
Oriented	String	Direction faced by the shoreline	Established from 2013 MrSID aerial photography for Broward, Miami-Dade and Palm Beach counties
Structure	String	Presence of structures	Established from 2013 MrSID aerial photography for Broward, Miami-Dade and Palm Beach counties
Features	String	Presence of features	Established from 2013 MrSID aerial photography for Broward, Miami-Dade and Palm Beach counties
Status	String	The field indicates whether a project is completed or under construction	Available reports, permits and other documents, expert knowledge
Notes_1	String	A free text field to place general comments	Available reports, permits and other documents, expert knowledge
Notes_2	String	A free text field to place general comments	Available reports, permits and other documents, expert knowledge
BuiltBy	String	The institutions or organizations listed as the project sponsors	Available reports, permits and other documents, expert knowledge
YearBuilt	String	The year of completion of a restoration or enhancement project	Available reports, permits and other documents, expert knowledge
PermitNo	String	Permit/ License number	Permits available through the counties (Broward, Miami-Dade and Palm Beach) or the E-permitting database of the South Florida Water Management District, URL: http://www.sfwmd.gov/ePermitting/MainPage.do;jsessionid=3C9C87818ADAC9C1DA0B0A5DCF22169E
County	String	County where the shoreline feature is located	County

Waterbody	String	Waterbody name	SFWMD Hydrography Dataset ***Layer name***: AHED.BASIN v2.4.20130228 ***Originators***: SFWMD ***Publication date***: February 28, 2913 **Data type:** vector digital data **Data location:** Server=ghydssde; Service=5159; User=ahed; Version=SDE.DEFAULT
NavChannel	String	A binary field (Yes/No) to indicate if a shoreline feature is located on a navigational channel or not	Expert knowledge, SFWMD Hydrography Dataset ***Layer name***: AHED.BASIN v2.4.20130228 ***Originators***: SFWMD ***Publication date***: February 28, 2913 **Data type:** vector digital data **Data location:** Server=ghydssde; Service=5159; User=ahed; Version=SDE.DEFAULT
InletDisMi	String		Calculated using the Near tool in ©ArcGIS
FetchCat	String	Fetch category based on average fetch distance	Expert knowledge
FetchAveMi	Double	Average fetch distance in miles	Calculated using the *Application of Wind Fetch and Wave Models for Habitat Rehabilitation and Enhancement Projects* (Rohweder et al. 2012). The application ***Waves2012.tbx*** is a toolbox for ©ArcGIS 10.0/10.1 based on the methodology described in the *USACE Shore Protection Manual* (USACE 1984).
FetchMaxMi	Double	Maximum fetch distance in miles	Calculated using the *Application of Wind Fetch and Wave Models for Habitat Rehabilitation and Enhancement Projects* (Rohweder et al. 2012). The application ***Waves2012.tbx*** is a toolbox for ©ArcGIS 10.0/10.1 based on the methodology described in the *USACE Shore Protection Manual* (USACE 1984).
Substrate	String	Component name	2014 USDA-NRCS SSURGO Database, URL: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Geomorphol	String	Geomorphic setting	2014 USDA-NRCS SSURGO Database, URL: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Runoff	String	Runoff potential category	2014 USDA-NRCS SSURGO Database, URL: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Drainage	String	Natural soil drainage conditions	2014 USDA-NRCS SSURGO Database, URL: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Hydrogrp	String	Hydrologic soil group	2014 USDA-NRCS SSURGO Database, URL: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Taxclname	String	Soil taxonomy subgroup and soil family	2014 USDA-NRCS SSURGO Database, URL: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631
Taxorder	String	Highest taxonomy soil level	2014 USDA-NRCS SSURGO Database, URL: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053631

APPENDIX II

Table 4. Attributes used in COPRI Living Shoreline Database, and Virginia Institute of Marine Science (VIMS) toolbox

Living Shorelines Database (COPRI) (Institute of the American Society of Civil Engineers) (http://mycopri.org/)		Additional Considerations		
Pre-project conditions:	Submerged aquatic vegetation	Shore morphology	pocket, straight, irregular	Hardaway & Duhring 2010
	Pre-project erosion	Intertidal range	Spring tide	Hardaway & Duhring 2010
	Existing vegetation	Erosion trends		Hardaway & Duhring 2010
	Existing structures/ debris	Upland land use		
		Depth offshore	wave attenuation	
Environmental considerations	Name of waterbody			
	Bank elevation / slope	Bank condition	erosional, stable, undercut	Hardaway & Duhring 2010
	Max exposed fetch distance	Bank substrate		
	Shoreline orientation relative to max fetch distance	Average fetch (wave energy potential)	very low <0.5 mi, very high > 15 mi	Hardaway & Duhring 2010
	Adjacent to navigation channel	Boat speed limit		
	Boat wake exposure	No-wake zone		
	Salinity	Historic conditions		
	Adjacent structures			
Design	Fill brought in			
	Presence of structure			
	Construction material			
	Length			
	Width			
	Structure side slope			
Additional	Pictures			