Tampa Bay Environmental Restoration Fund Final Report: Hard Bottom Mapping and Characterization for Restoration Planning in Tampa Bay

TBERF AGREEMENT NO. 2014 REV0010

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Acknowledgements

The Southwest Florida Water Management District (District) received a 2014 Tampa Bay Environmental Restoration Fund (TBERF) grant to create a comprehensive benthic map that characterized hard bottom, oyster, and tidal flat habitats for a portion of Tampa Bay, Florida. The TBERF grant provided funding for survey and mapping of hard bottom habitats by the consultant team of SurvTech Solutions, Inc. and CSA Ocean Sciences Inc. (CSA). The Southwest Florida Water Management District funded creation of habitat map data for seagrass, oyster and tidal flats. Staff at the Tampa Bay Estuary Program provided substantial assistance in the creation of the oyster model and led the facilitation of the project's target setting exercise.

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Introduction

The Southwest Florida Water Management District (District) received a 2014 Tampa Bay Environmental Restoration Fund (TBERF) grant to create a comprehensive benthic map that characterized hard bottom, oyster, and tidal flat habitats for a portion of Tampa Bay, Florida. Using the comprehensive map products, the award also supported a restoration planning exercise seeking to set bay-wide restoration or protection targets for each habitat type. The ecological importance of each habitat is well known. Hard bottom represents a unique habitat in Tampa Bay that support sponges, soft corals, algae, and live rock. Hard bottom and oyster reefs are considered important essential fish habitat and are protected under state and federal wetland regulations. Oyster reefs provide food and habitat for numerous nekton, including recreationally-important species such as sheepshead and blue crabs. In addition, oyster reefs filter water providing local water quality improvements. Tidal flats support dense populations of benthic invertebrates (Robison 2010) and are valuable wading and feeding areas for resident and migratory birds such as egrets, roseate spoonbills, and white pelicans.

Project Objectives

The primary objectives of this project were: 1) to create a benthic habitat map of hard and live bottom for portions of the Middle and Lower Tampa Bay and, 2) to provide data support for habitat restoration target setting of three submerged habitat types.

General Project Approach

To accomplish the project's objectives, the project was implemented in two phases and multiple methods of habitat mapping were employed. Phase 1 activities expanded the District's ongoing geospatial seagrass mapping efforts to include bay-wide mapping of oysters and recently re-defined tidal flats. For the purposes of this project the term "seagrass maps" is understood to be inclusive of oyster and tidal flat maps. Phase 1 also included creation of historical seagrass, oyster, and tidal flat habitat map products for two portions of Tampa Bay.

Hard bottom substrates and their associated biological communities are not consistently visible in aerial imagery and cannot be included in the expansion of the seagrass mapping program. Therefore, hard bottom habitats were mapped using alternative methods during Phase 2. Due to the cost of the alternative mapping techniques, only hard bottom features located within a 42.5 mi^2 area of interest (AOI) in southern Tampa Bay were mapped for this grant. The combined mapping products from Phase 1 and 2 were used to support the Phase 2 restoration planning exercise.

Phase 1: Seagrass Mapping

Phase 1 efforts analyzed several District created geospatial mapping products and provided the products and analyses for Phase 2 efforts. This included the GIS-based 2014 Tampa Bay seagrass maps, with oyster and newly re-defined tidal flat classifications incorporated, and GIS-based 1970s seagrass maps for two regions of Tampa Bay.

Every two years the District maps seagrass in five Gulf coast estuaries, including Tampa Bay. The objective of the broad scale mapping program is to quantify seagrass present in the bay and track progress towards TBEP's seagrass restoration target. For the 2014 effort, the District increased the habitat types classified in seagrass maps to include oyster beds, further refining the representation of bay bottom features in the maps (Figures 1 and 2). While the District program has historically classified tidal flats in maps, the definition used previously used was thought to be insufficient for understanding the extent and ecological significance of the habitat type. A modification of this mapping class was developed with input from the Southwest Florida Seagrass Working Group for inclusion in the 2014 seagrass map.

The District was also responsible for providing historical benthic mapping products for Old Tampa Bay (Figure 3) and for the project's AOI (Figure 4). The maps delineate the extent of seagrass, oysters, and tidal flats present in 1970s era black and white geo-rectified photography for each region (1969 Pinellas County photographs, 1973 Hillsborough County photographs, and 1973 Manatee County Photographs).

Phase 1: Methods

Contemporary seagrass geospatial mapping is a multi-step process including: aerial imagery acquisition, imagery processing, photo-interpretation and digitization, and field verification. Aerial imagery is photo-interpreted and digitized manually on-screen in a GIS environment. The photo-interpretation process includes identifying habitats of a minimum size from imagery, delineating a boundary around the habitat feature, and then classifying it using a District modified version of the Florida Land Use, Cover and Forms Classification System (FLUCCS) (Table 1). Finally, field verification efforts assist in refining the line-work created from aerial images and the resulting GIS polygon map is field tested for accuracy. Historical mapping followed these standard methods when possible with the exception of field verification and accuracy testing.

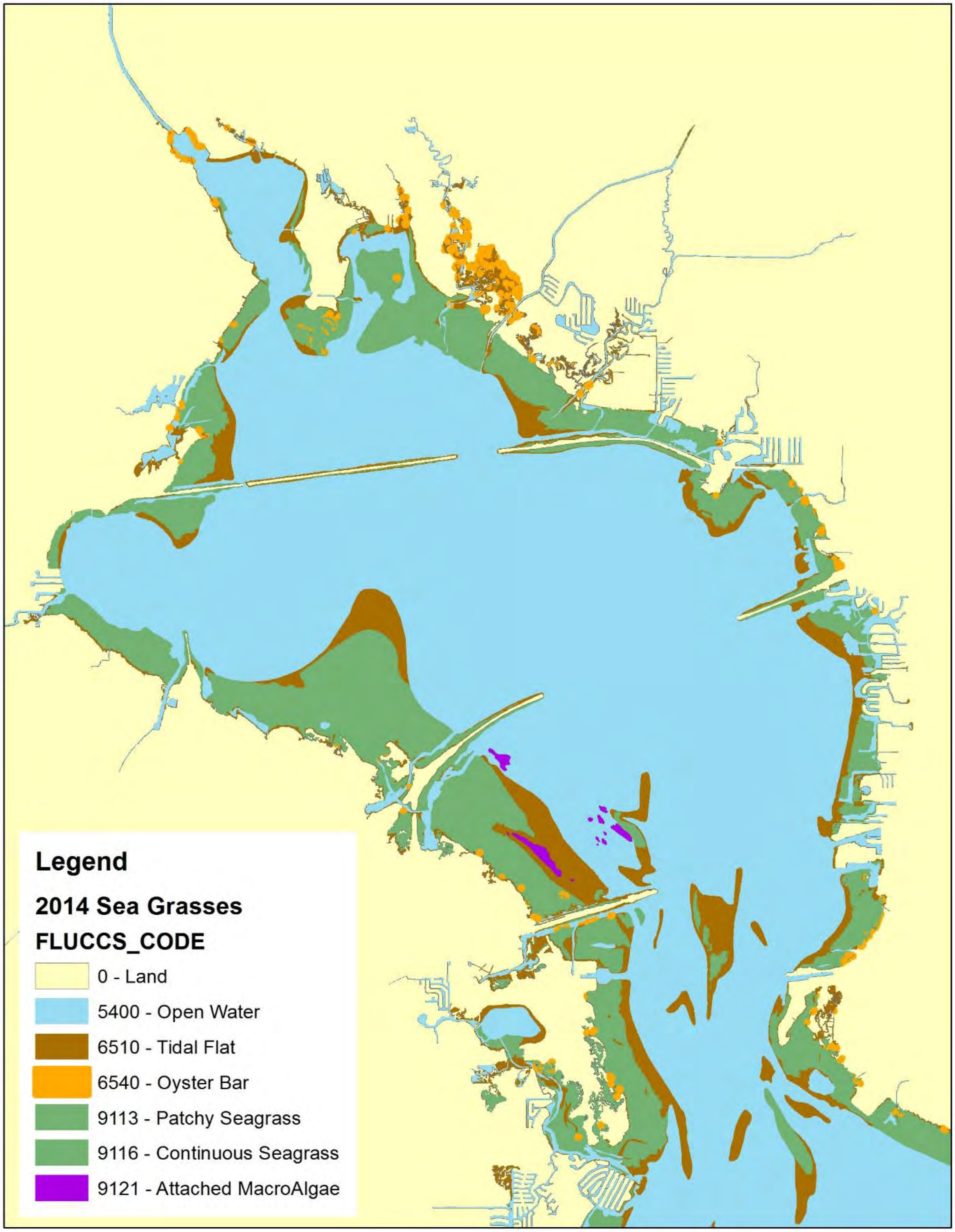

Figure 1. 2014 Seagrass Map for Old Tampa Bay.

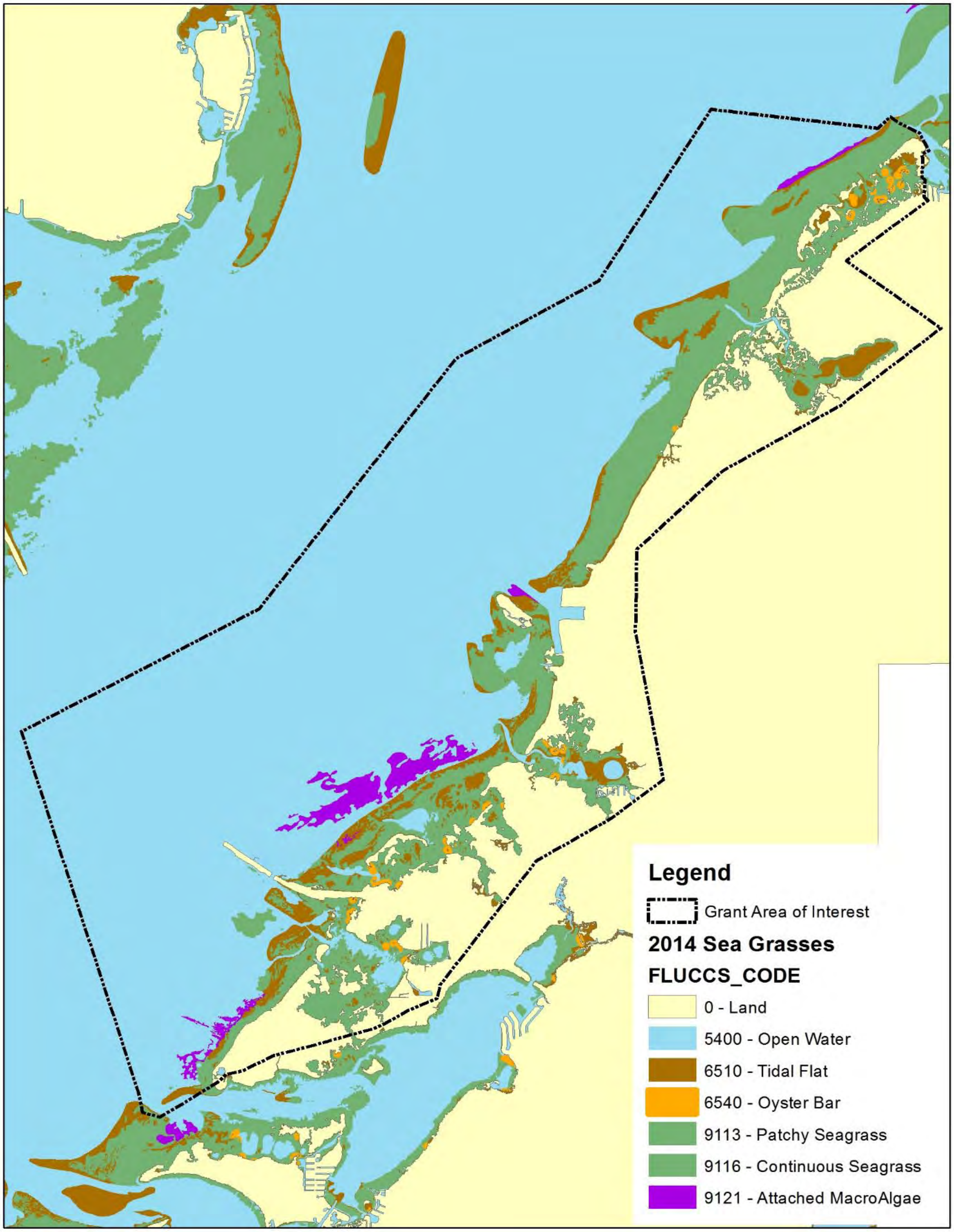

Figure 2. 2014 seagrass map for AOI.

Table 1. District modified classifications for seagrass mapping. These definitions have been used since the 1990s mapping efforts with exception: (9121) was updated in 2012 and the (6510) definition was updated in 2014.

FLUCCS Code	FDOT FLUCCS Descriptor	District Working Definition
0	Not Classified	Land
5400	Bays and Estuaries	Open Water (Non vegetated)
6510	Tidal Flats	Intertidal, non-vegetated, unconsolidated sediments located in estuarine/low energy environments, habitats capable of supporting seagrass if able to establish.
6540	Oyster Bars	Oyster Bar Intertidal, non-vegetated where oysters breed and grow naturally, outer edge of oyster bar capable of supporting seagrass if able to establish.
7100	Beaches Other Than Swimming Beach	Isolated stands of open sand, not vegetated, and not intertidal. Non-swimming beaches are delineated for isolated strands of open (non-vegetated) sand, not typically accessible (on islands and fringes).
9113	Patchy Seagrass	Isolated patches of seagrass or extensive areas of patchy seagrass coverage. Usually these areas include small round clumps of vegetation or elongated strands of seagrass coverage. Category appears as singular, isolated patches of seagrass or extensive areas of patch strands mixed with open bottom. Typically, areas appear as rounded clumps, or elongated strands mixed with sand.
9116	Continuous Seagrass	Seagrass containing areas that exhibit uniform signatures with less than 25 percent of any particular area showing up as un-vegetated bottom. Areas exhibit a continuous and uniform signature. Small, (less than 0.25 acre) sandy bottom features may be interspersed within the bed, but these areas are not dominant. Areas that appear as continuous beds, regardless of species composition, will be mapped.
9121	Attached Macroalgae	Monospecific stands of rhizophytic attached algae such as *Caulerpa spp.* or *Sargassum spp*. Where feasible, all areas should be field verified particularly areas thought to have less than 10% cover.

Phase 1: Results

At the April 16, 2014, Southwest Florida Seagrass Working Group meeting, the Tampa Bay Estuary Program facilitated a discussion about refinement of the mapping classification definition for “tidal flat.” The agenda item included discussion of the defining ecological characteristics of tidal flats: depth (subtidal and intertidal) and substrate type (mud and sand). Also discussed was the limitations of defining a habitat based on visual cues, the intended use of the data, possible regulatory implications, and management of the resource. Based on feedback from the meeting, the District's working definition of tidal flat was revised to be:

"Non-vegetated intertidal shallow-water habitats. These are unconsolidated sediments located in low energy environments and are capable of supporting seagrass if able to establish. A characteristic of this class is its alternating cycle of submergence and exposure to the atmosphere."

This newly revised definition of tidal flat was incorporated into the 2014 mapping effort, and subsequently 14,813.48 acres of that habitat was documented bay-wide. In 2014, Tampa Bay seagrass mapping effort also estimated that Tampa Bay contained 131.42 acres of oyster beds.

Old Tampa Bay

As of 2014, Old Tampa Bay supported 10,272.53 acres of seagrass (Table 2). The 1970s map documented Old Tampa Bay previously contained 7,822.15 acres of seagrass. This is a 31.3 percent increase over four decades (1969/73 – 2014). Old Tampa Bay currently maintains 45.1 percent of the bay-wide oyster population for Tampa Bay. Oyster reefs decreased from 83.83 acres in the 1970s to 59.30 acres in 2014. This is a 29.3 percent decrease in coverage. Tidal flat habitat decreased from 7,701.72 acres in the 1970s to 4,650.29 acres, a 39.6 percent decrease over the 41-year time-period.

Table 2. District Mapping Results for Old Tampa Bay

Habitat Map Classifications (FLUCCS)	1970 Historical Acres	2014 Contemporary Acres	Change in Acres (New-Old)
Land (0)	123,020.23	122,810.30	-209.94
Open Water (5400)	36,736.44	37,455.02	718.58
Tidal Flat (6510)	7,701.72	4,650.29	-3,051.43
Oyster Bar (6540)	83.83	59.30	-24.53
Patchy Seagrass (9113)	3,937.64	5,362.12	1,424.48
Continuous Seagrass (9116)	3,884.51	4,910.41	1,025.91

Grant Area of Interest

As of 2014, the AOI supported 5,574.98 acres of seagrass (Table 3). The 1970s-map documented that the AOI previously contained 4,726.28 acres of seagrass. This is an 18 percent increase over the 41-year time-period (1973 – 2014). The AOI contained 13.64 acres of oyster in 2014, 10.4 percent of the total bay-wide coverage. Oyster in the AOI decreased from 34.53 acres in 1970s to 13.64 acres in 2014. This is a 60.5 percent decrease in coverage. Tidal flat habitat increased from 1,275.02 acres in the 1970s to 1,538.43 acres, a 20.7 percent change over the four decades.

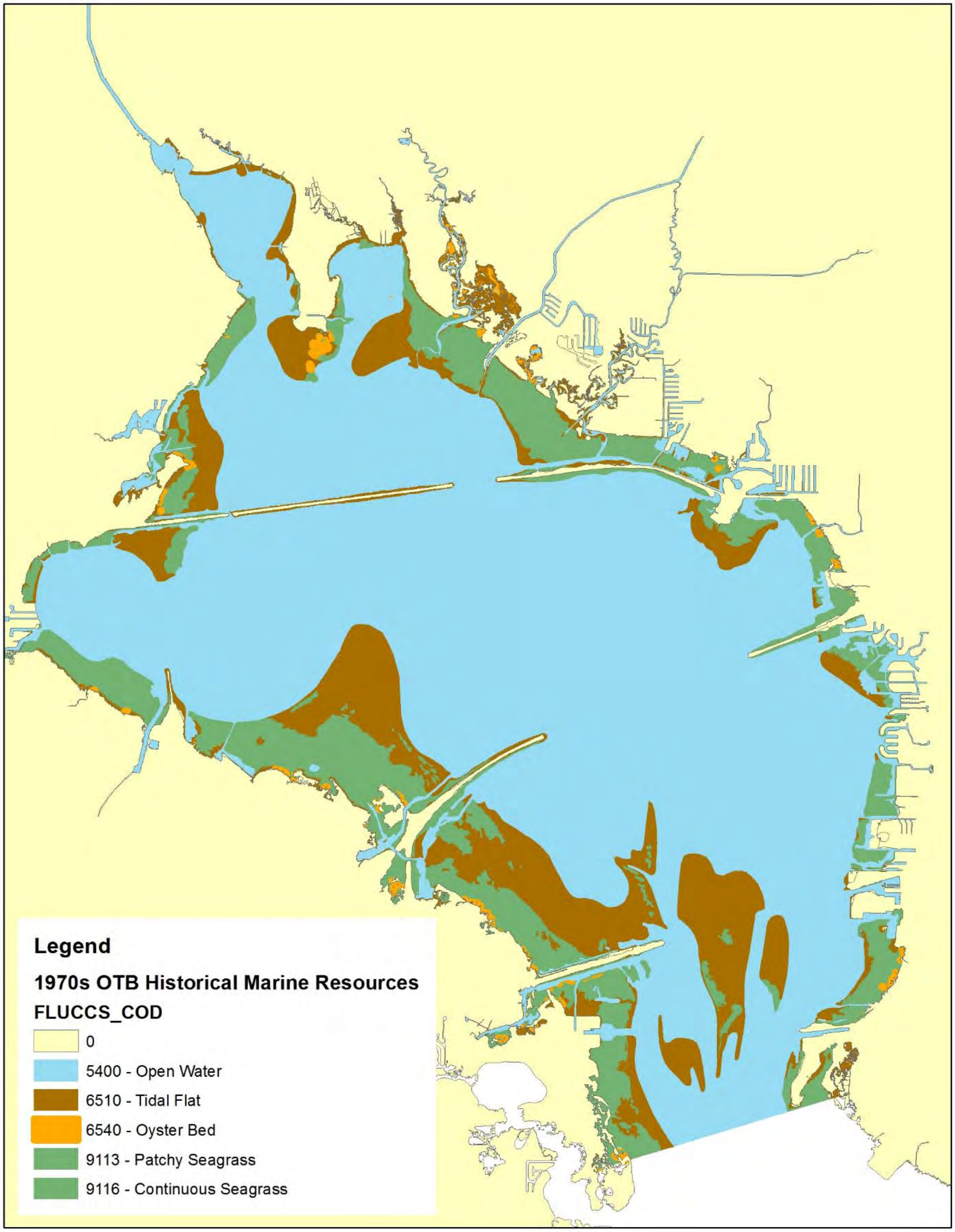

Figure 3. Old Tampa Bay ca. 1969 for Pinellas County & 1973 for Hillsborough County.

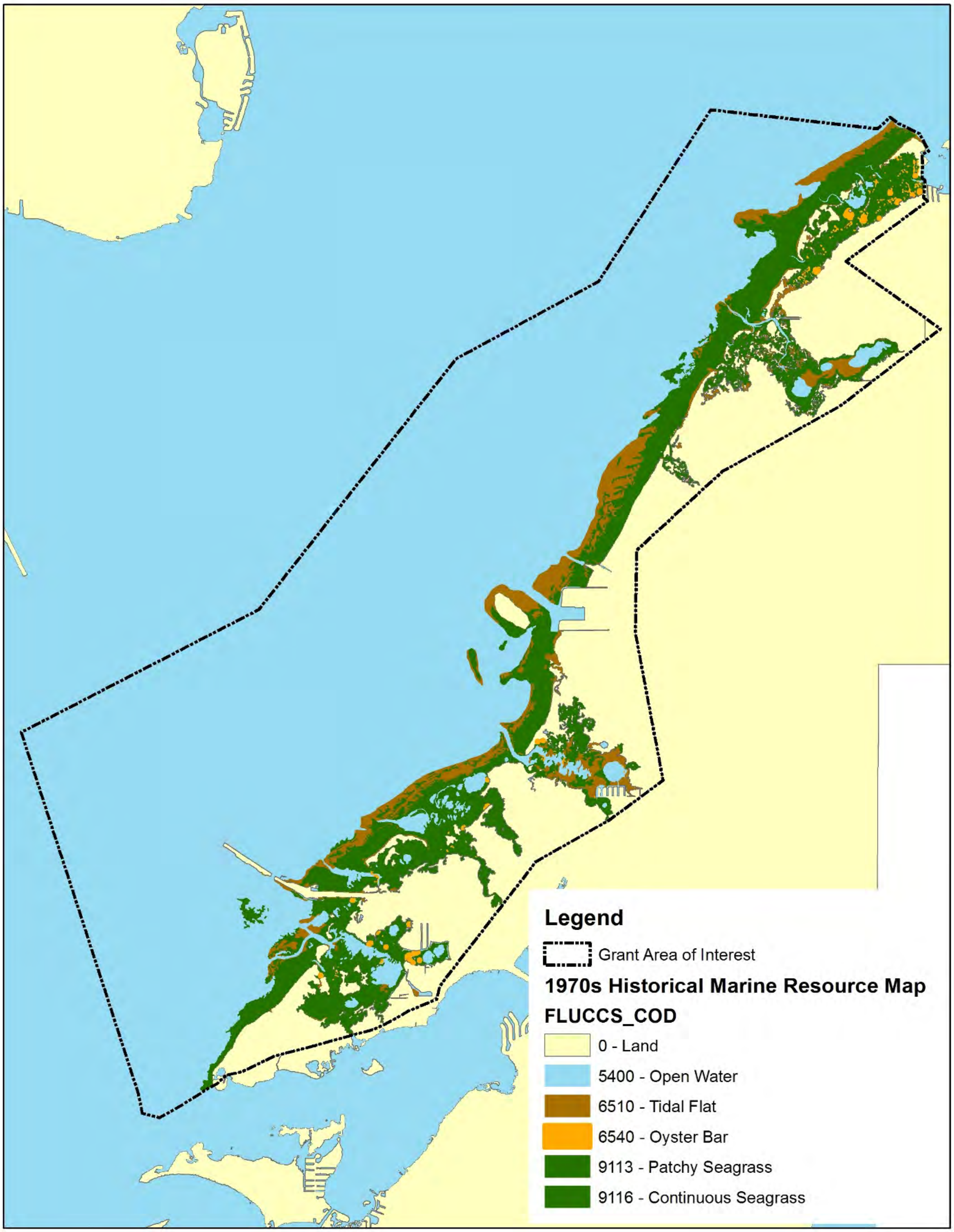

Figure 4. AO ca. 1973 for Hillsborough & Manatee County.

Table 3. District Mapping Results for AOI.

Habitat Map Classifications (FLUCCS)	1970 Historical Acres	2014 Contemporary Acres	Change Acres (New-Old)
Land (0)	7,090.80	7,345.65	254.86
Open Water (5400)	11,061.89	21,172.16	10,110.27
Tidal Flat (6510)	1,275.03	1,538.43	263.40
Oyster Bar (6540)	34.53	13.64	-20.89
Patchy Seagrass (9113)	732.43	2,213.25	1,480.82
Continuous Seagrass (9116)	3,993.85	3,361.73	-632.12

Phase 2: Hard Bottom Mapping

Phase 2: Methods

Data Collection

The project mapped 42.5 mi^2 of the almost 400 mi^2 Tampa Bay waterbody (10.6 percent) (Figure 5). The mapping data was collected using two different methods within the AOI depending on water depths. During Phase 1 of the project, the “nearshore” waters within the 42.5 mi^2 AOI were mapped aerially for seagrass, oysters, and tidal flats. The “offshore” waters that ranged in depths from approximately 4 feet to 39 feet were scanned with hydrographic equipment and mapped for hard bottom habitats. The hydrographic scans covered a total area of 34.56 mi^2. The entire AOI could not be surveyed with side-scan due to depth limitations of the vessel.

Side-scan sonar and interferometric bathymetry data was collected July and August of 2015 to serve as the source data for creation of a GIS-based hard bottom map of the AOI. An EdgeTech 6205 dual frequency (550 kHZ and 1600 kHZ) hydrographic acoustic sonar system was used for data collection. Field data collection efforts also included ground truthing via georeferenced (where feasible) underwater video. Additional information on the data collection effort is available in the Tampa Bay Hard Bottom Mapping Project Survey Report (SurvTech 2015).

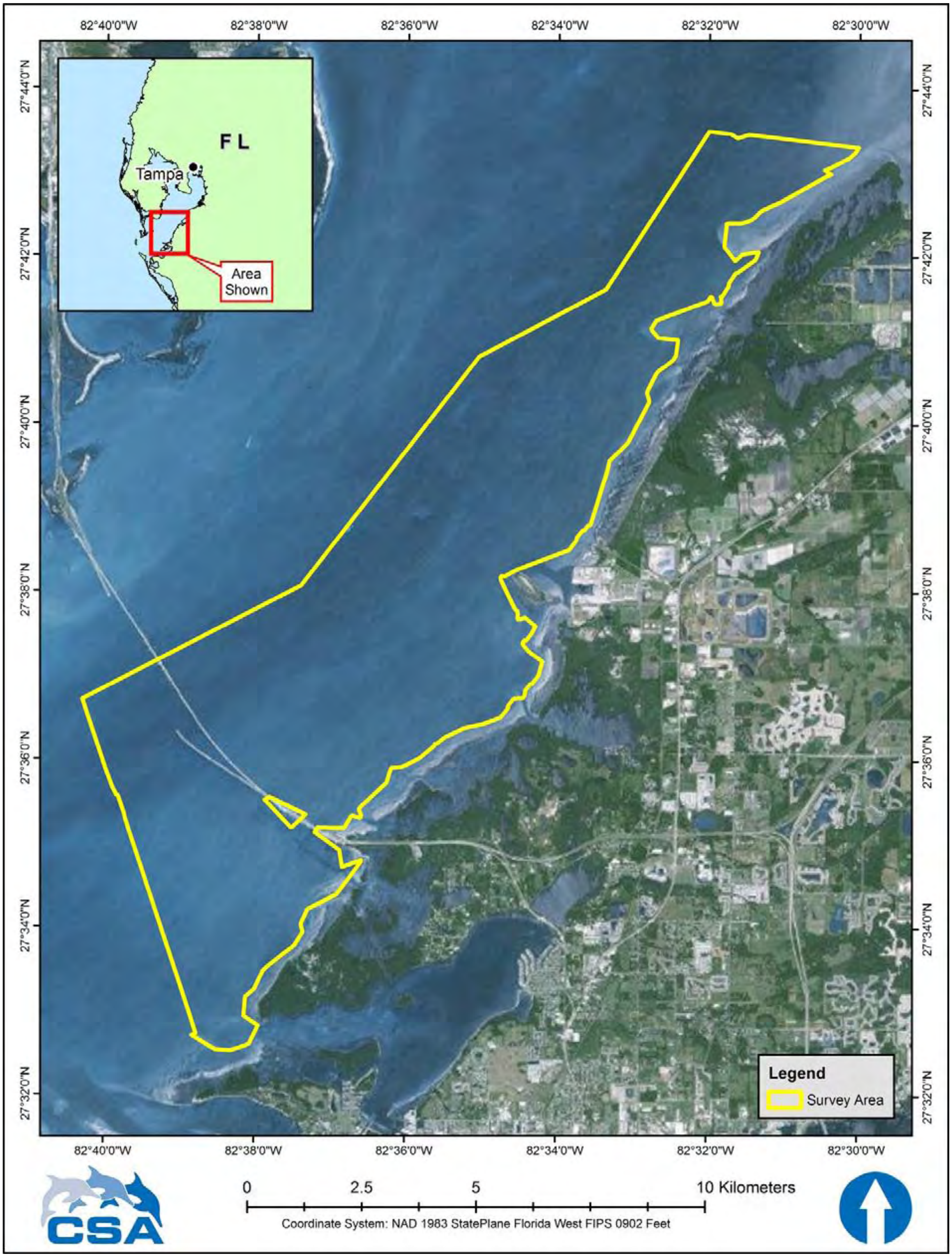

Figure 5. Extent of grant funded hydrographic survey collection for hard bottom mapping.

Habitat Mapping

A thematic map of hard bottom features was created from interpreted side-scan sonar data and corroborating underwater video. Chesapeake's SonarWiz5 software was used to process side-scan sonar data for visualization and initial feature extraction. ESRI's ArcGIS v10.3 software was used for refining feature delineations.

A multi-step process was used to conduct the mapping exercise. As a first step, acoustic returns and signatures visible in the side-scan images were initially classified into three major bottom types: hard bottom areas, potential hard bottom areas, and unconsolidated bottom. A sampling universe of locations within the three identified bottom types was created and groundtruthing data was then collected at 500 locations from a random stratified sampling of the universe. Underwater video tows provided data on substrate type, hard bottom classification, and biota. Video data of the groundtruthing locations provided the additional understanding needed to refine polygon delineations and apply habitat mapping classifications as a second step. Two ancillary datasets, the 2014 seagrass maps and associated aerial imagery as well as Hillsborough County Environmental Protection Commission's (HCEPC) Benthic Monitoring Data were reviewed to assist with final classification of bottom type. Referencing these datasets allowed for application of additional classifications such as artificial reef material, spoil areas, and seagrass.

The Florida Land Use Land Cover Classification System (FLUCCS) is the region's most widely used aerial mapping classification system; however, the scheme does not include classification codes for hard bottom. The District chose to utilize the Coastal and Marine Ecological Classification Standard (CMECS) as the classification scheme for mapping hard bottom habitat from side-scan sonar data in Tampa Bay. The National Oceanic and Atmospheric Administration created the CMECS as a national framework for organizing coastal and oceanic living systems data into ecological units for geospatial mapping purposes. The classification standard is a hierarchical structure allowing for characterization of four components of the seascape setting: water column, geoform, substrate, and biotic communities. Three types of hard bottom: rubble field, boulder field, and artificial reef are categorized as geoforms in CMECS, and along with substrate, were the basis for the interpretation of the grant side-scan returns (Table 4). Applying CMECS locally to the unique low relief Tampa Bay hard bottom communities required modification and refinement of CMECS codes. Modified classes and associated descriptions were provided by the Florida Fish and Wildlife Research Institute (FWRI) who developed a working adaptation of CMECS for independent surveys of reef fish in the Gulf of Mexico (Table 4).

The habitats delimited with map polygons were ultimately characterized using various combinations of CMECS derived codes. When marrying the signatures of habitat features from side-scan sonar with finer scale in-situ observations, it was found that the broader scale signatures could encompass more than one of the available habitat descriptors. As a rule for classification during this project, the identified substrate type was considered the dominant bottom feature. With substrate defined, other geoform(s) or biota present within a delineated polygon were added to the overall polygon classification. No minimum or range of coverage for a habitat was required for inclusion in classification of a polygon. More than one code describing distinct habitats could be applied to a single polygon if multiple habitat types were found to be present. This resulted in multi-coded polygons.

Accuracy Assessment

After completion of the GIS-based hard bottom habitat map, a thematic accuracy assessment was conducted. The tests focused on the accuracy of identifying a hard bottom community from the biological communities observed to be present at a location. The assessment entailed conducting two exercises using two different authoritative datasets.

The first test was modeled after standard protocols for thematic accuracy testing of District seagrass maps, where field in-situ bottom type observations are the authoritative data. One hundred and twenty-two assessment videos were collected in March of 2016 to identify substrate and presence of any biological communities. The georeferenced video testing data were then analyzed in a GIS environment and compared to the hard bottom map product. The second exercise was a "map to map" comparison using the 2014 District seagrass map as the authoritative dataset. This test entailed conducting a GIS analysis to determine where the maps differed in their classification of the bay bottom.

Phase 2: Results

Phase 2: Mapping Results

Hard bottom mapping results were shared at a joint meeting of the ABM and the TBEP's Habitat Restoration Sub-committee on April 21, 2016. Project methods, maps, accuracy test results, and underwater video were presented.

The habitat acreages reported by the SurvTech and CSA team (CSA 2016) were reviewed for this report. Instances in the final product where habitats were mapped on the outer extents of the sonar data and polygons were delineated adjacent to the termination of the data were reviewed for accuracy. When overlaid with aerial imagery and seagrass maps, it was observed that some polygons at the terminus of the data incorrectly extended too far into known sandy beaches, mangrove fringed shorelines, or bridge pilings. These portions of the delineated habitats were updated and removed from the map. The revised acreages are reflected in the results reported here (Tables 5 and 6).

The project used the ten distinct CMECS and FWRI modified codes to characterize bottom features in the AOI, resulting in nine combinations of codes (Figure 6). The habitat map documented the majority of the scanned 34.56 mi^2 (22,123.01 acres) to be comprised of unconsolidated bottom. An estimated 260.96 acres of natural hard bottom were documented from the side-scan sonar data. An additional 24.78 acres of artificial reef were identified for an overall total of 285.75 acres of hard bottom habitat (Table 5). Including the areas classified as Spoil Areas the total area of potential hard bottom for the AOI becomes 720.6 acres.

*Table 4. Explanation of CMECS Coding in District hard bottom map. Black text is CMEC derived, black text with * are code names that have been modified for the grant project from the original CMECS name, red text is FWRI derived, blue and green text note additional CMEC descriptions that may apply to the modified CMEC code.*

CMECS Code	Code	CMECS Component: Level	Description
Artificial Reef	AR 223	Geoform: Geoform	An artificial structure placed on the ocean floor to provide a hard substrate for sea life to colonize. Artificial reefs are constructed by sinking dense materials (such as old ships and barges, concrete-ballasted tire units, concrete and steel demolition debris, and dredge rock) on the seafloor within designated reef sites.
Boulder Field	BF 18	Geoform: Geoform	An area dominated by large, boulder-sized (256 millimeters - 4,096 millimeters) stones or pieces of rock. These can occur below cliffs or at the foot of steep slopes or canyons, where they are the result of depositional processes. These fields can also occur as the result of currents that have removed the finer sediments. An area containing stones or pieces of rock greater than 0.5-m in diameter. These can occur at the foot of steep slopes or canyons, or below cliffs or ledges. Acoustic image will show an area of no or low relief bottom with individual features that give hard returns on the nadir side followed by large shadows behind the hard return.
Coarse Sandy Bottom* (Coarse Sand) (Very Coarse Sand) (Coarse Unconsolidated Substrate)	CSB 288 287 263	Geologic Substrate: Substrate subgroup Substrate subgroup Substrate	Geologic Substrate surface layer contains no trace of Gravel and is composed of > 90% Sand, with a median grain size of 0.5 millimeters to < 1 millimeter. Geologic Substrate surface layer contains no trace of Gravel and is composed of > 90% Sand, with a median grain size of 1 millimeter to < 2 millimeters. Geologic Substrate surface layer contains > 5% Gravel (particles 2 millimeters to < 4,096 millimeters). These sediments are classified using the upper three rows of the Folk (1954) Gravel-Sand-Mud diagram.
Fragmented Bottom	FB	Not in CMEC	Areas dominated by exposed rock or coral that may be separated by narrow channels of finer sediment that has been eroded by current action leaving the rock elevated above the seafloor with relief of greater than 0.1-m. Acoustic image will be "bumpy" showing evidence of patchy hard bottom with the presence of large shadows or hard returns. The features present in this habitat type will show some connectivity whereas boulder fields will contain large, distinctly separated pieces of rock.
Rubble Field	RB 148	Geoform: Geoform	A loose mass of angular rock fragments. These can occur both on land and underwater. An area containing a loose mass of rock fragments (<0.5-m in diameter) deposited on the seafloor by natural processes. The acoustic return will show an area of bright returns

			with small shadows measuring <0.5 m.
Sandy Mud Bottom	SMB 281	Substrate: Substrate Group	Geologic Substrate surface layer contains no trace of Gravel and is composed of 10% to < 50% Sand; the remainder is composed of Mud (particles less than 0.0625 millimeters in diameter).
Spoil Area* (Dredge Deposit)	SA 238	Geoform: Geoform	A subaqueous area that is substantially shallower than the surrounding area, which resulted from the deposition of materials from dredging and dumping. An accumulation of material (rocks, shells, etc.) on the seafloor not associated with a designated reef site where spoil material from a dredging operation or other development related project is placed. These often exhibit relief and can support biological communities different than the surrounding area. They are often unconsolidated in character but can be relatively stable. An example of a dredge deposit that is evident on the west Florida shelf is along the natural gas pipeline where linear rock piles can be observed in an acoustic image.
Seagrass * (Seagrass Bed)	SG 567	Biotic: Biotic Group	Tidal aquatic vegetation beds dominated by any number of seagrass or eelgrass species, including *Cymocedea* sp., *Halodule* sp., *Thalassia* sp., *Halophilla* sp., *Vallisnera* sp., *Ruppia* sp., *Phyllospadix* sp., and *Zostera* sp. Seagrass beds (Figure 8.15) may occur in true marine salinities, and they may extend into the lower salinity zones of estuaries.
Unconsolidated Sediment* (Unconsolidated Mineral Substrate)	UC 29	Substrate: Substrate Class	Geologic Substrates with less than 50% cover of Rock Substrate. This class uses Folk (1954) terminology to describe any mix of loose mineral substrate that occurs at any range of sizes—from Boulders to Clay. This hierarchy and the associated terms are shown in Figure 7.2. These classifications may be based on percent weight (e.g., for retrieved samples); percent cover (e.g., for plan-view images); or visual percent composition (for other approaches). Units with bracketed letters, e.g., [G], [mSG], correspond to the labeled polygons in Figure 7.2, using conventions from Folk (1954).

The largest portion of hard bottom habitats at 57 percent (148.11 acres) was characterized as “CSB/RB/BF/FB.” This classification contains the largest variety of hard bottom geoforms in combination with the substrate type “coarse sandy bottom.” It should be noted identification of “coarse sandy bottom” alone was not considered a definitive identifier of hard bottom. The “CSB/RB/BF/FB” polygons were found most prominently offshore of Shell Key, Rattle Snake Key, and Mariposa Key. The second most abundant characterization of natural hard bottom was “CSB/RB” covering 75.91 acres or 29 percent of the natural hard bottom. This classification has a single geoform descriptor combined with the “coarse sandy bottom” substrate type. The “CSB/RB” classified hard bottoms along with “CSB/RB/BF/FB” were found off the mouth of the Little Manatee River and off the shores of the Terra Ceia Preserve State Park. The “CSB/RB” polygons were identified along a distinctly different portion of the AOI compared to “CSB/RB/BF/FB,” navigation channels and near Port Manatee (Figure 7). The classification distinctions may be a result of the differences in side cast material along the navigation channels compared to the sediments along the rivers and natural shorelines. Spoil areas are also identified as a prominent bottom feature and should be investigated further as potential hard bottom habitat.

Table 5. Estimated acreages of classified bottom types from hard bottom habitat map.

Bottom Type	Estimated Area (acres)
Natural Hard Bottom	260.96
Artificial Reef Area	24.78
Spoil Area	434.86
Unconsolidated Bottom	21,242.94
Total Area	22,123.01

Accuracy Assessment Results

Accuracy assessment field points were generated with the use of a priori data consisting of draft map polygons where the consultant identified “possible hard bottom” and seagrass maps. Much of the accuracy assessment field effort was directed to collected data outside of and near the draft map polygons to test for errors of omission. The bias of the testing data also benefited the effort by documenting and visualizing more of the bay bottom in the AOI. For the traditional accuracy test 21 of the 26 field points were classified correctly in the hard bottom map for an accuracy of 81 percent. The “map to map” comparison found 100 percent agreement for 49 seagrass habitats in the maps.

Table 6. Thematic coding, derived from CMECS, utilized in hard bottom mapping. Distinct codes were combined if necessary to accurately describe identifiable bottom features from side-scan data.

Map Codes	Total Area (acres)
AR	24.78
CSB	12.97
CSB/BF	0.03
CSB/RB	75.86
CSB/RB/BF	4.17
CSB/RB/BF/FB	148.11
CSB/RB/FB	27.68
CSB/RB/SG	2.98
CSB/SG	27.34
CSB/SMB/CSMB/SG	14.92
RB	0.49
SA	434.86
SMB	16.75
SMB/RB	1.65
SMB/SG	87.49
UC	21,242.94
Total	**22,123.01**

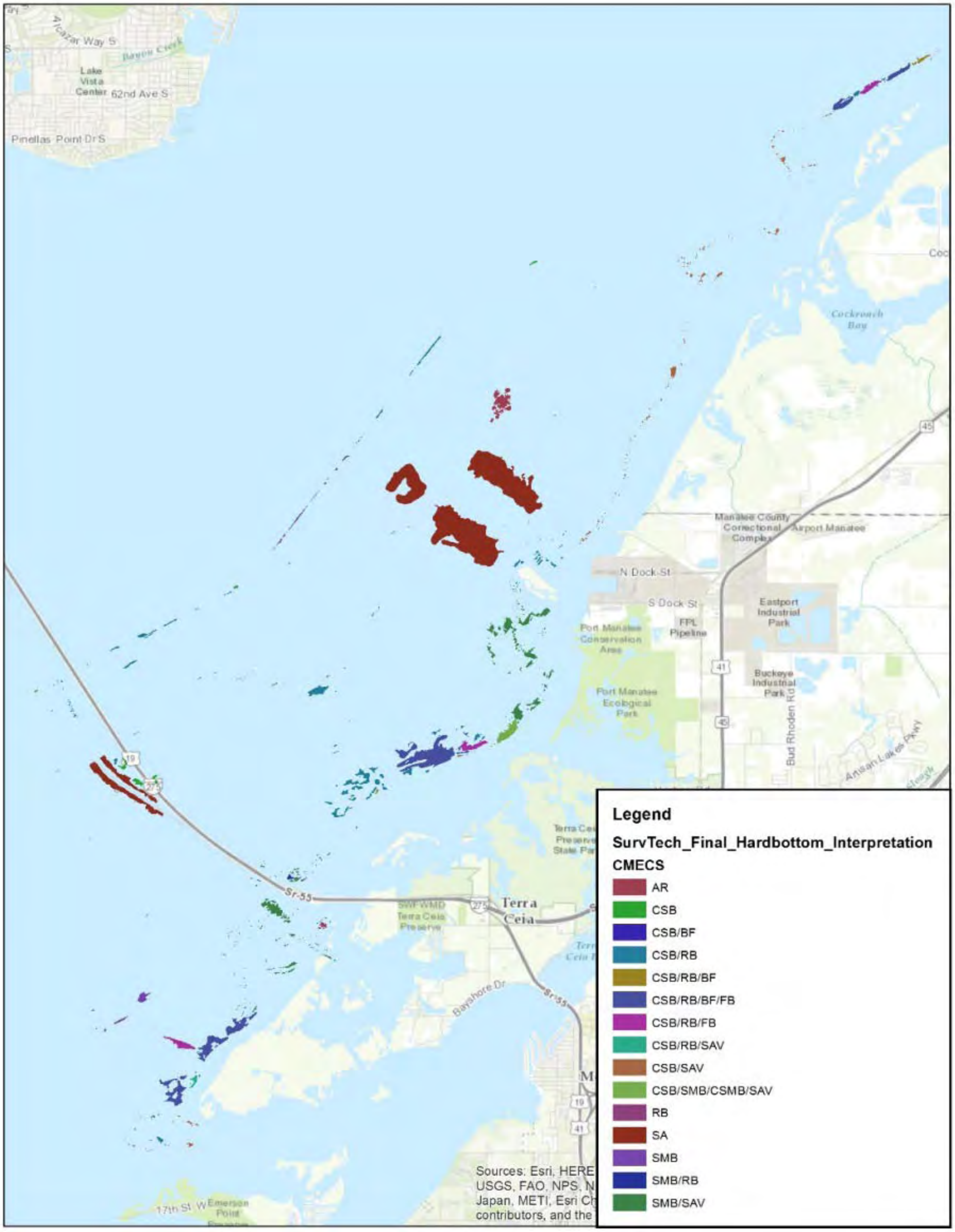

Figure 6. Map of interpreted hard bottom in southeast Tampa Bay. Map shows full extent of sonar collection within the AOI.

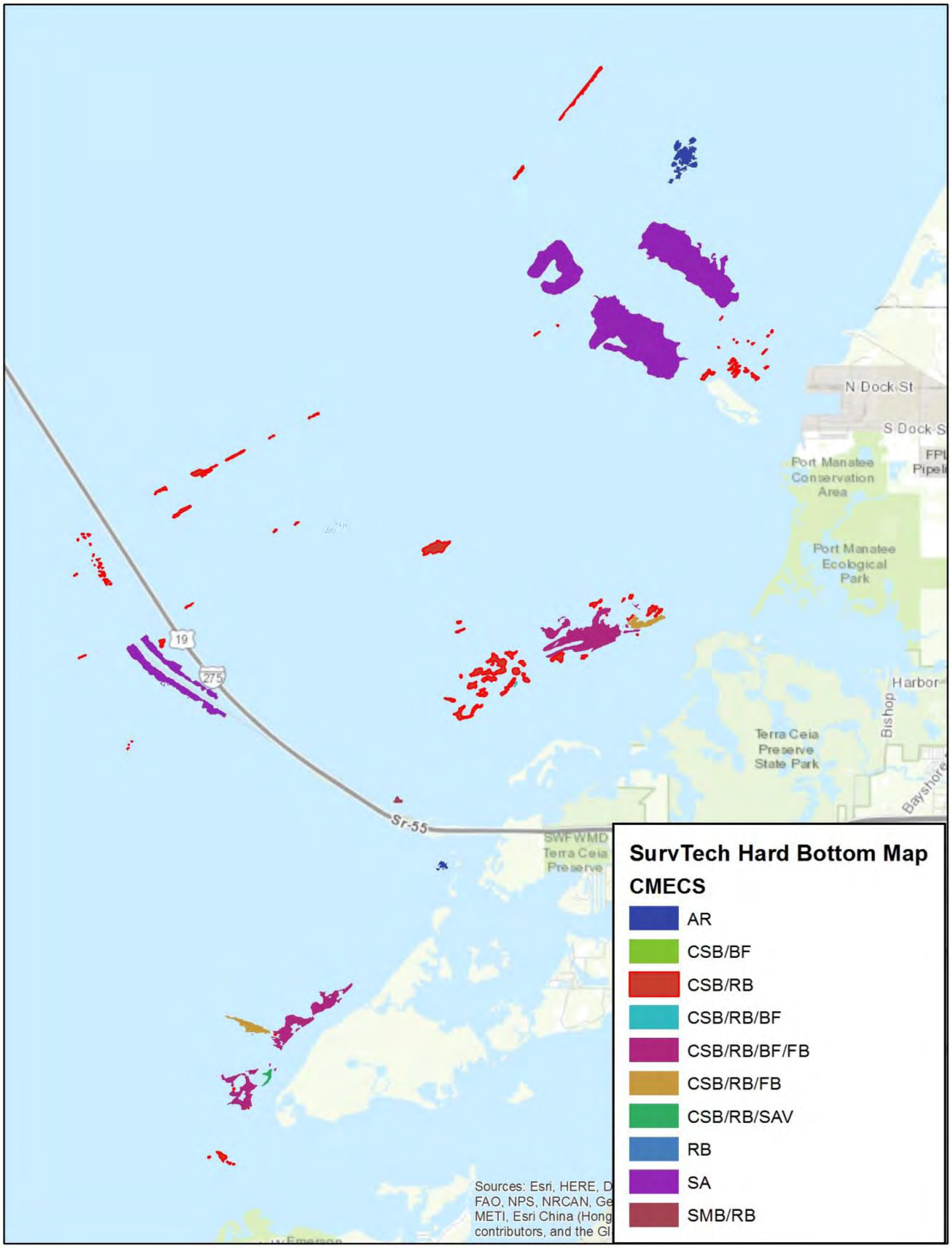

Figure 7. Zoom-in of hard bottom habitats mapped for grant. "CSB/RB", the second most common hard bottom classification, is found along navigation channels, Port Manatee, and with other hard bottom features near the Terra Ceia Preserve.

Phase 1 & 2 Map Integration

Two different classification systems describe the thematic map polygons in the 2014 seagrass and the hard bottom habitat maps. An overall objective of the project was to provide a means of integrating the two map products for ease of visualization and use. Integration of the maps was explored through several methods. Displaying the individual map layers together in GIS, creating a crosswalk to a common classification, and using geoprocessing tools to analyze the two maps for similarities and differences were all investigated.

GIS Display

The most straight forward way of integrating the two maps is to simply visualize both datasets together. Figure 8 demonstrates creating an integrated map using specific thematic features from each source map.

Habitat Classification Crosswalk

Crosswalking translates datasets by integrating them into one common classification scheme. The integration of the District 2014 seagrass map and the AOI hard bottom map required crosswalking the District seagrass map FLUCCS classification system to the CMECS standard. The exercise required identifying how the CMECS codes related to the classifications from the existing 2014 seagrass map (FLUCCS) and translated them into the CMECS coding system. As described in Appendix H of the Federal Geographic Data Committee (2012) document:

"Crosswalking can be done to compare the conceptual units from one classification to units in another classification (unit-to-unit crosswalking) or related observational data (samples, plots, or mapping polygons) that are collected using one classification to another classification (observation-to-unit crosswalking).

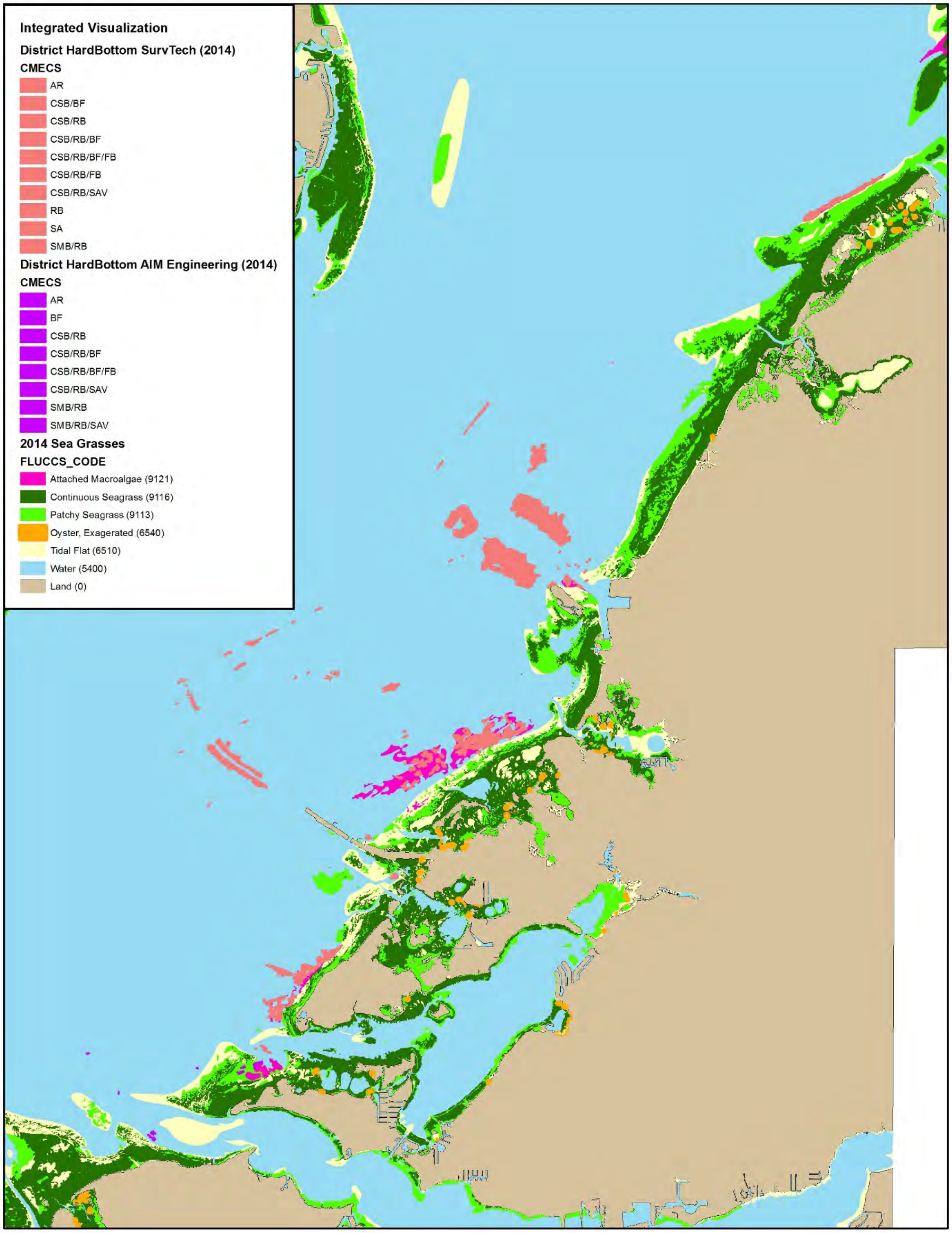

Figure 8. Integrated visualization of two map layers. Note: oysters have been exaggerated so they are visible in the map.

The Federal Geographic Data Committee (2012) manual offers guidance on completing crosswalks and a GIS-based tool is available at https://coast.noaa.gov/digitalcoast/tools/cmecs-crosswalk.html. A crosswalk between CMECS and the Florida-based System for Classification of Habitats in Estuarine and Marine Environments (SCHEME) is available for download. Madden and Goodin (2007) built the relational linkages between CMECS and SCHEME. The translation from the modified FLUCCS classification used in District seagrass maps used an intermediate crosswalking step (in this case, SCHEME) to achieve translation to CMECS. The Florida SCHEME system is easily related to the FLUCCS codes used in the District seagrass maps. Both SCHEME and FLUCCS are hierarchical systems building greater detail into classifications as tiers are added. The SCHEME structure builds to five tiers or classification categories, starting with "Class" and can add up to four subclasses for additional description (Madley et al. 2004). The FLUCCS structure is a four level hierarchy increasing in specificity as subcategories for finer detailed features are added (FLUCCS 1999).

Through best professional judgement it was determined that most biotic habitat codes had equivalencies or common descriptors at SCHEME's third subclass and at the fourth level in FLUCCS. Sediment or land based habitats could only be described to "Class" for SCHEME and related to level 1 or level 4 FLUCCS codes depending on the habitat (Table 7). A crosswalk of reasonable confidence was created from FLUCCS to SCHEME (Table 7) for the District 2014 seagrass map and the available GIS-based tool was run to translate the newly assigned SCHEME class to CMECS. The GIS crosswalk tool breaks the components into separate files or layers, compartmentalizing the data for easy visualization of information. This exercise was undertaken to demonstrate the utility of the crosswalking concept. This may be a tool needed in the future to understand and create commonalities for datasets created by different entities within the region who are mapping benthic resources with project specific modified CMECS codes.

The crosswalk translations for the map products created a new means of visualizing the data. A common classification system makes visual interpretation of the multi-layered data more digestible. Although the hard bottom map utilized CMECS classifications as a basis for the project, we consider this to be a modified use of CMECS. Some regional coding conventions and additional classes were applied during mapping, as well as a multi-coded classification approach. Therefore it is recommended that collaboration with FFWCC be initiated to create a crosswalk for development of a more sophisticated and regionally useful modified CMECS. A new online resource is available for CMECS that can be used to continue developing local application of CMECS, https://iocm.noaa.gov/index.html.

Table 7. Classification description equivalency table for FLUCCS and SCHEME.

FLUCCS Code	FLUCCS Description (FDOT 1999)	SCHEME Category	SCHEME Description (Madley et al. 2004)
0	Land	6	**Land** – Mainland, islands, causeways
6510	Tidal Flat	1	**Unconsolidated Sediments** (0 to >10% colonization)
6540	Oyster Bar	321	**Bivalve Reefs (i.e. oyster reefs)** – mollusk reefs dominated by oysters, at time partially exposed during low tide.
9113	Patchy Seagrass	212	**Discontinuous Submersed Rooted Vascular Plants** – seagrass areas with breaks in coverage that result in isolated patches
9116	Continuous Seagrass	211	**Continuous Submersed Rooted Vascular Plants** – seagrass continuous beds of any shoot density (i.e. sparse continuous, dense continuous or any combination).
9121	Attached Macroalgae	2211	**Attached Macroalgae** – 10% or more cover of mixed or monospecific macroalgae attached to the substrate with holdfasts, rhizomes, or other morphological features.

Geoprocessing Techniques for Integration

The extents of the AOI hard bottom and 2014 seagrass data sets overlapped in a portion of the AOI. This data overlap was used in the accuracy assessment exercise described earlier as well as in an analysis of the map products for integration purposes. Geoprocessing techniques were used to create the comparisons. The intersect geoprocessing tool computes the geometric intersection of the two polygon maps. Features from the polygon maps that overlap when the two files are layered are recorded in a new GIS file.

The geoprocessing exercise revealed useful information about both mapping products. The analysis identified both commonalities and differences in the datasets. These results provide a better understanding of each individual product as well as an improved characterization of the natural environment they are attempting to describe. These findings may also positively influence future data collection and mapping efforts.

The intersect analysis quantified possible errors of omission for the hard bottom map, locations where hard bottom habitats may be going undocumented. In District seagrass maps, polygons coded with the 9121 FLUCCS code document visually interpreted attached macroalgae. The attached macroalgae most commonly identified during groundtruthing in the AOI are of the genus *Sargassum* or *Caulerpa* in coarse sediments (Kaufman personal observations). Field observations of attached macroalgae beds often include identification of sponges and gorgonians or other hard bottom features. At the initiation of the project, the hypothesis was that all delineated macroalgae (FLUCCS 9121) polygons within the AOI footprint would be identified as hard bottom habitats in the grant map. The intersect analysis found of the 498.32 acres of macroalgae mapped in 2014; the hard bottom map classified 39.5 percent of that area as hard bottom (197.25 acres). The majority of the attached macroalgae habitats (301.07 acres) within the AOI were classified as unconsolidated sediment. This finding may suggest that AOI map is a conservative estimate of hard bottom and may underestimate the total footprint of the habitat in this area (Figure 9). This is further supported by video from the accuracy assessment exercise where additional hard bottom biota was noted in locations not delineated in the grant map. Revisiting the grant sonar and bathymetry data to further investigate and interpret features from the data is likely necessary.

The hard bottom map was able to provide additional habitat information for areas classified as open water in 2014 seagrass maps. The grant hard bottom map documented 30.04 acres of seagrass within areas identified as open water (FLUCCS 5400) in the 2014 seagrass map (Figures 10 and 11). In addition to seagrass, 56.40 acres of hard bottom was documented in areas classified as open water.

The intersect analysis found a 90 percent agreement in the two maps for areas classified as continuous seagrass habitats (FLUCCS 9116). Much of the continuous seagrass beds were characterized as sandy mud bottom/seagrass (SMB/SG) in the hard bottom map. This finding is contrasted with the results for District delineated patchy seagrass habitats. Only 20.88 percent of the patchy seagrass coverage from the District 2014 seagrass map (238.25 acres) was classified as seagrass in the hard bottom map (49.74 acres). The hard bottom map characterized the majority of the patchy seagrass (FLUCCS 9113) as unconsolidated sediment (184.99 acres).

There are two possible explanations for the results related to patchy seagrass. The definition of patchy seagrass allows for un-vegetated bottom to be included in delineated polygons. The extraction of fine scale information from the side-scan sonar data delineated seagrass at a finer resolution than the 2014 District seagrass map and therefore: 1) mapped individual patches/beds of seagrass; and 2) excluded portions of un-vegetated sediments from the delineations. Another possible explanation for the discrepancy between the two maps was that diffuse or sparse coverage of seagrass in these polygons may have been at insufficient densities to create a return on the side-scan data and was therefore undetectable in the side-scan data.

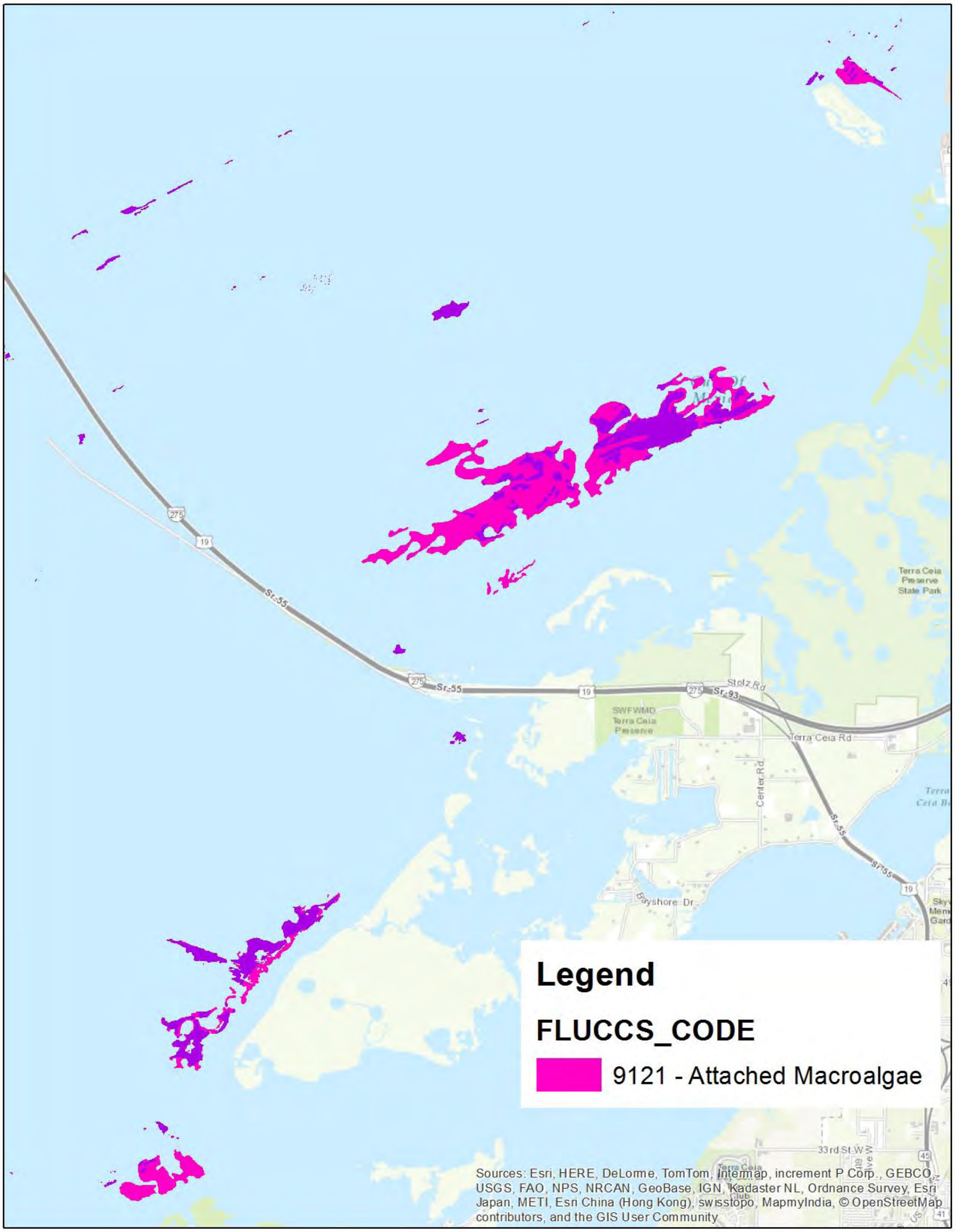

Figure 9. Comparison of map data layers. Pink represents the extent of attached macroaglae in 2014, and indicator of hard bottom. The purple extent is mapped hardbottom.

Figure 10. An example of the extent of seagrass in the grant hard bottom map that was classified as open water (FLUCCS 5400) in the 2014 seagrass map.

Figure 11. An example of the extent of seagrass in the hard bottom map classified as open water (FLUCCS 5400) in the 2014 seagrass map.

Phase 2: Habitat Resource Target Setting

Benthic inventories beyond the current mapping of Tampa Bay seagrass will expand our knowledge of other critical marine habitats that act as essential fish habitat and contribute to system-wide biodiversity (Madden and Goodin 2007). Habitat inventories and their characterizations of the biological communities are needed to develop meaningful restoration and protection targets for the marine resources. The habitat distribution maps created by the District were designed to assist in the development of habitat resource targets for oysters, tidal flats, and hard bottom in Tampa Bay. Data as well as formal goals and quantitative objectives are needed to create the foundation for management of these resources. Crafting of goal statements must incorporate biological or ecological targets as well as action items that are realistic and achievable (zu Ermgassen et al. 2016). This should produce habitat targets that can be successfully implemented to achieve restoration or protection (zu Ermgassen et al. 2016).

Following other successful TBEP efforts to set restoration targets for seagrass and coastal wetlands, the TBEP with support from the District, initiated efforts for these three habitats. The community-based process included holding a series of public meetings to disseminate grant findings and garner input on a path forward for the conservation, protection, and restoration of the three resources. Meetings were held June 23rd, August 2nd, and September 15th of 2016. Direction and feedback from the group is reflected in analyses and recommendations provided within this report. This target setting effort was intended to be an initiation of work that would be carried forward into the next TBEP Habitat Master Plan Update where goals and objectives for the target setting process could be further developed.

During the meetings three important steps for target setting were addressed:

1. *Estimate habitat historical extent* – The group provided suggestions on references and to the extent possible all available literature was compiled. Historical data and references for all three habitats were found to be extremely limited.

2. *Determine current extent and functionality* – Data for the current extent of each habitat based on District 2014 seagrass maps and the grant hard bottom map were presented. In addition, TBEP staff investigated and presented functional components of oyster habitat.

3. *Determine the most appropriate target setting approach* – The group discussed five target setting approaches and determined their utility for each habitat of interest. The well-established historical reference period approach, no net loss via resource protection, and the ecological function approach received the most attention. Additional approaches were: protection and monitoring of probable habitat locations and a derivation of "restoring the balance" dubbed "maintaining the balance" where the current proportion of each marine habitat in a bay segment would be sustained or maintained.

The body of knowledge on each item above, as described by the group and compiled during the project is provided in the next section by habitat type. Relevant to all three habitats is the dearth of information related to historical extents. Historical data for these habitats in Tampa Bay is primarily limited to descriptive and occasional quantitative information. The majority of information found referenced the habitats in terms of submerged navigation hazards or as food and fisheries related resources. The lack of a historical perspective limits the opportunities for a reference period approach. Using the available data to understand historical conditions will still assist managers in providing context for restoration needs, setting realistic restoration goals, and planning implementation of restoration activities. In addition, "…it may not be ecologically or physically possible to restore to historical baselines. An alternative objective for restoration is to focus on restoring ecosystem services, and the associated benefits that these services provide to people." (zu Ermgassen et al. 2016). This has been reflected in other resource-goal setting exercises for the TBEP, including seagrasses (Greening et al. 2014) and intertidal habitats (Robison 2010).

Key themes/concepts from the meetings that became actionable items were:

1. Target setting based on a strict reference period approach was determined to be unsuitable for these habitat types due to insufficient data, but could be used as a starting point;
2. Continue to document and map the distribution of hard bottom in the bay;
3. Create area-based restoration targets, explore habitat suitability modeling similar to Charlotte Harbor National Estuary Program's efforts for oysters; and
4. Investigate functional target setting from an ecosystem services perspective.

Oysters

Ecological Significance

Oysters are bivalve mollusks and sedentary invertebrates, with the most common species present in the Gulf Coast and Tampa Bay being the eastern oyster (*Crassostrea virginica*) (zu Ermgassen et al. 2016, Yates et al. 2011). Oyster habitat refers to substrates with a veneer of live oysters (zu Ermgassen et al. 2016). Oyster planktonic larvae ("spat") require solid substrate for attachment and development. Any firm or hard substrate can be colonized that will withstand the weight of the oysters, although they will preferentially attach to other live oysters. The raised three-dimensional bed structure created by successive generations of oysters growing on top of one another result in oyster reef habitat (zu Ermgassen et al. 2016). Oysters are essential fish habitat that provide both food and habitat for boring sponges, other mollusks, and crustaceans (Robison 2010). Oysters also offer protection for shorelines as they buffer wave energy and can improve water quality as they filter water for an estuarine ecosystem.

Historical Extent of Habitat in Tampa Bay

The exploitation of oysters and substantial degradation of environmental conditions in estuaries was underway before creation of any comprehensive baseline distribution maps for most regions of the United States. The status went undocumented until the mid to late 20th century (zu Ermgassen et al. 2012). For oysters, the Tampa Bay region saw a small surge of documentation of the resource in the 1960s and 1970s. This was a time in recent history when environmental regulation and compliance was coming to the forefront, concurrent with ongoing destructive, unpermitted, as well as managed resource extraction.

Oysters have been an integral part of daily life along the coast, with their abundance and utility documented as early as pre-colonial times. Native American middens scattered around Tampa Bay demonstrated the importance of oysters to pre-European inhabitants (Estevez 2010 and reference therein). The state of Florida began monitoring marine shell dredging in 1923. Activities from 1931 to 1974 reported extraction of 28.5 MT (62,832 lbs.) of shell material (Whitfield 1975). Estevez (2010) used accounts of shell production from leases to calculate an estimated area of bay bottom covered by an original oyster resource. Estevez (2010) estimated 1,980 acres or about 3.1 square miles of Tampa Bay submerged bottom was once occupied by oyster resources, potentially both natural reefs and submerged shell middens. This areal estimate in conjunction with a map of shell dredge areas in Tampa Bay from Whitfield (1975) provides some understanding of the historic and possible pre-historic extent of the oyster resources in this region.

Historically, oysters were reported to have been abundant in Tampa Bay, particularly northern Old Tampa Bay (Yates et al. 2011). Gasden Point, on what is now the southern end of MacDill Air Force Base, was also noted as having famous oyster reefs producing 1,500 bushels a year in the late 1800s (Ingersoll 1881). As of the 1960's the Tampa Bay system still supported a commercial production of oysters producing 5,000 to 147,487 pounds per year, with Old Tampa Bay contributing the most production (Finucane and Campbell 1968). A study conducted by the National Marine Fisheries Service during the same time frame found spat production in the Old Tampa Bay area was "continuously high" from May to June (Sykes 1966). Over 1,000 acres in Old Tampa Bay were leased oyster grounds where cultch, non-living oyster shell, was used to augment existing oyster shell for spat settlement (Finucane and Campbell 1968). It was estimated 15,000 acres of Old Tampa Bay was favorable for cultivation of oysters (Finucane and Campbell 1968). Six locations from 1961 to 1965 were documented as having shell planting activities in Old Tampa Bay and Middle Tampa Bay (off of the MacDill shoreline) for commercial fisheries (Whitfield 1975).

Based on findings from Phase 1, estimates of bay-wide oyster coverage for the 1970s can be calculated. In 2014, Old Tampa Bay contained 45.1 percent of the bay's oyster habitat. If the bay contained the same proportions of oysters during the 1970s, bay-wide oyster coverage was estimated to have been 185.88 acres. In 2014, the AOI contained 10.4 percent of Tampa Bay's oyster resources. If the bay contained the same proportions of oysters in the

1970s, oyster coverage is estimated to have been 345.3 acres. The two areas of the bay offer different possible bay-wide extents for oyster coverage in the 1970s (185.88 – 345.3 acres).

Resource Distribution

Prior to the mid-2000s, there was only limited regional knowledge of the current oyster distribution for the Tampa Bay area (O'Keefe et al. 2006 and Drexler 2011). Old Tampa Bay and McKay Bay were known to have fringe reefs, while Upper Tampa Bay Park and Cockroach Bay also host oysters (Yates et al. 2011). And remnant oyster substrates have been noted in the mouth of Manatee River, Terra Ceia Bay, Weedon Island, and Cockroach Bay (Robison 2010).

The 2014 District seagrass mapping effort documented 131.42 acres of oyster habitat bay-wide. Mapping cannot differentiate the presence of live oysters, therefore it may be more accurate to describe mapped oyster as oyster substrate. This effort also did not measure oysters within mangrove forest footprints or on seawalls, which are areas recognized as supporting significant oyster populations in Tampa Bay (Drexler 2011).

Meeting attendees requested a review of the 2014 data to identify areas that would benefit from additional oyster in-field verification. Several areas were identified that are difficult to access during groundtruthing efforts conducted by the District. Some selected areas also represent sites identified as having oyster substrate in the 2014 map but that may have additional resources in the nearby vicinity not yet delineated and quantified (Kaufman personal observation). It is believed these locations would also be appropriate candidate sites for oyster health studies or monitoring. The locations of oyster substrate, possibly accessible by shore or kayak, proposed to the group for volunteer field verification included:

1. Clam Bayou
2. Upper Tampa Bay Park
3. Double Branch Bayou
4. Cypress Point Park
5. Cooper's Point

Target Setting Objectives

Tampa Bay no longer supports commercial harvesting of oysters although designated areas are conditionally approved for recreational harvest (http://www.freshfromflorida.com/Business-Services/Aquaculture/Shellfish-Harvesting-Area-Classification/Shellfish-Harvesting-Area-Maps). The focus of restoration in Tampa Bay is specific to habitat and not oyster landings or restoration of the fisheries for harvest and consumption. The habitat provides numerous ecological benefits to an estuarine system and the focus of restoration is primarily the resulting ecosystem services provided by oyster grounds. The NOAA and Nature Conservancy Manager's Guide provides guidance on setting quantitative objectives around the return of two ecosystem services, water filtration and enhancement of non-oyster fisheries (zu Ermgassen et al. 2016).

The Charlotte Harbor National Estuary Program in cooperation with The Nature Conservancy created an Oyster Habitat Restoration Plan in 2012 (Boswell et al. 2012). They estimated that Charlotte Harbor experienced approximately 90 percent loss of oyster habitat since the 1950s. A GIS-based restoration suitability model was developed using a series of available datasets that represented components critical to oyster survival in their system. Based on their total estuarine area, the model determined 10 percent of the system to be 100 percent suitable for restoration of oysters. They have a stated current estimate of oyster coverage to be 250 acres and developed a range of acres for the system's oyster restoration goal (1,000 to 6,000 acres) (Boswell et al. 2012). The TBEP target setting meeting attendees suggested conducting a similar modeling exercise for Tampa Bay.

Habitat suitability models are created to predict the suitability of known environmental parameters for the sustainment of a specific habitat. A GIS-based oyster habitat suitability model for Tampa Bay was constructed using the existing spatial datasets for the following parameters: water depth (topobathymetry), salinity, sediment composition (percent silt/clay), and seagrass presence. Spatial data for all model parameters was used to create raster files with consistent resolution and spatial reference. A scoring system was applied to each parameter to qualify the suitability of that environmental condition for the sustainment of oysters at a particular location. All parameters were scored on a common scale of 1 to 10, with higher values denoting a higher level of suitability. Using known tolerance ranges or preferences of oysters for the above abiotic environmental conditions, data for each parameter was grouped into ranges of suboptimal, moderate, and optimal conditions. The raster data files were then reclassified to the predetermined common scale based on the selected scores for parameter values.

The USGS 2007 topobathymetry was determined to be the best available comprehensive dataset for water depth in Tampa Bay (USGS 2007). To capture the presence of oyster habitat within the system's mangrove shorelines, the range of oyster tolerances for water depth was agreed to include up to the mean high water (MHW) line. For the available dataset the MHW line was determined to be +0.37 ft. From MHW (+0.37 ft.) to -3 ft. was categorized as optimal habitat and scored 10, from -3 ft. to -6 ft. was moderate and scored 8, and deeper than 6 ft. was deemed suboptimal and was given a score of 1 (Figure 12). To reclassify the topobathy raster, the functionality required use of whole integers to input the depth ranges. Therefore, to incorporate MHW (+0.37 ft.) the optimal range was set to +1 ft. Additional post processing of model results will be required to remove the area from MHW (+0.37 ft.) to the +1 foot contour line from the dataset (Figure 13).

Water quality data from local agencies available on the Tampa Bay Water Atlas, http://www.tampabay.wateratlas.usf.edu/, was used to create an interpolated coverage of salinity. A minimum threshold condition for oysters was determined to be the probability that the 90th percentile of salinity would be greater than 3.5 ppt for any given month of data at each sampling site evaluated. The probability of occurrence for these conditions was then broken down into 10 increments and scores 1 to 10 were applied (Figure 14 and 15).

An interpolated coverage was created and reclassified for percent silt/clay data from Environmental Protection Commission of Hillsborough County's (EPCHC) long-term dataset (Figure 16). Based on knowledge of the system, the majority of exiting oysters occur at less than 23 percent silt/clay, thus values higher than 23 percent were considered suboptimal (score of 1). Percent silt/clay values greater than 17.5 percent and less than 23 percent were considered to have moderate suitability and given a score of 2. Finally, values of less than 17.5 percent silt/clay were considered optimal and given a score of 3.

The presence of seagrass was incorporated into the model as an exclusionary parameter. The footprint in the bay occupied by seagrass habitat was not under consideration for oyster restoration and is not in need of protection as oyster habitat. The number of years' seagrass was mapped (persisted) in a location from 1988 to 2014 was categorized as not suitable, moderate, or suitable and given a score on the common 1 to 10 scale (Figure 17). If seagrass was persistent for 3 to 13 years a location was considered unsuitable and given a score of 1. If seagrass was only present for 1 or 2 years during the 13 map iterations, the location was considered moderately suitable and scored a 2. Finally, if seagrass was never mapped in that location a score of 10 was applied.

The reclassified raster files for all parameters were then combined in GIS through an integration analysis. Options are available to weight parameters if their relative influence on the sustainment of oysters differs, however all parameters for this exercise were weighted equally. The model output represents the best or most preferred locations for sustaining oyster habitat based on the parameter scores included in the model (Figure 18). With the constructed scoring system, model output values could range from 4 to 33, with higher output values for a location indicating it was more favorable as oyster habitat. The final results show the lowest value applied to locations in the Tampa Bay area was 13.

Model validation testing was then conducted using the 2014 oyster map and oyster restoration spatial data provided by Tampa Bay Watch and FWRI. Model raster values that coincided with individual oyster polygons from the 2014 map and oyster restoration locations from Tampa Bay Watch were visually reviewed and compared. Key locations in the bay with a known history of oyster presence are provided in Table 8 as a sample of model results. Based on the locations sampled, Table 8 demonstrates that the current extent of oyster substrate in these locations occupy space with a minimum oyster suitability value of 22. As this data does not represent the entire universe of oyster populations in Tampa Bay, the minimum suitability value for the bay could be determined to be lower. Figure 19 shows an example from other portions of Tampa Bay where FWRI found oysters present in 2016 and their corresponding model values range from 14 to 26. This may suggest a need for refinements of seagrass model inputs to more accurately describe mangrove shorelines where seagrass and oysters co-habitat.

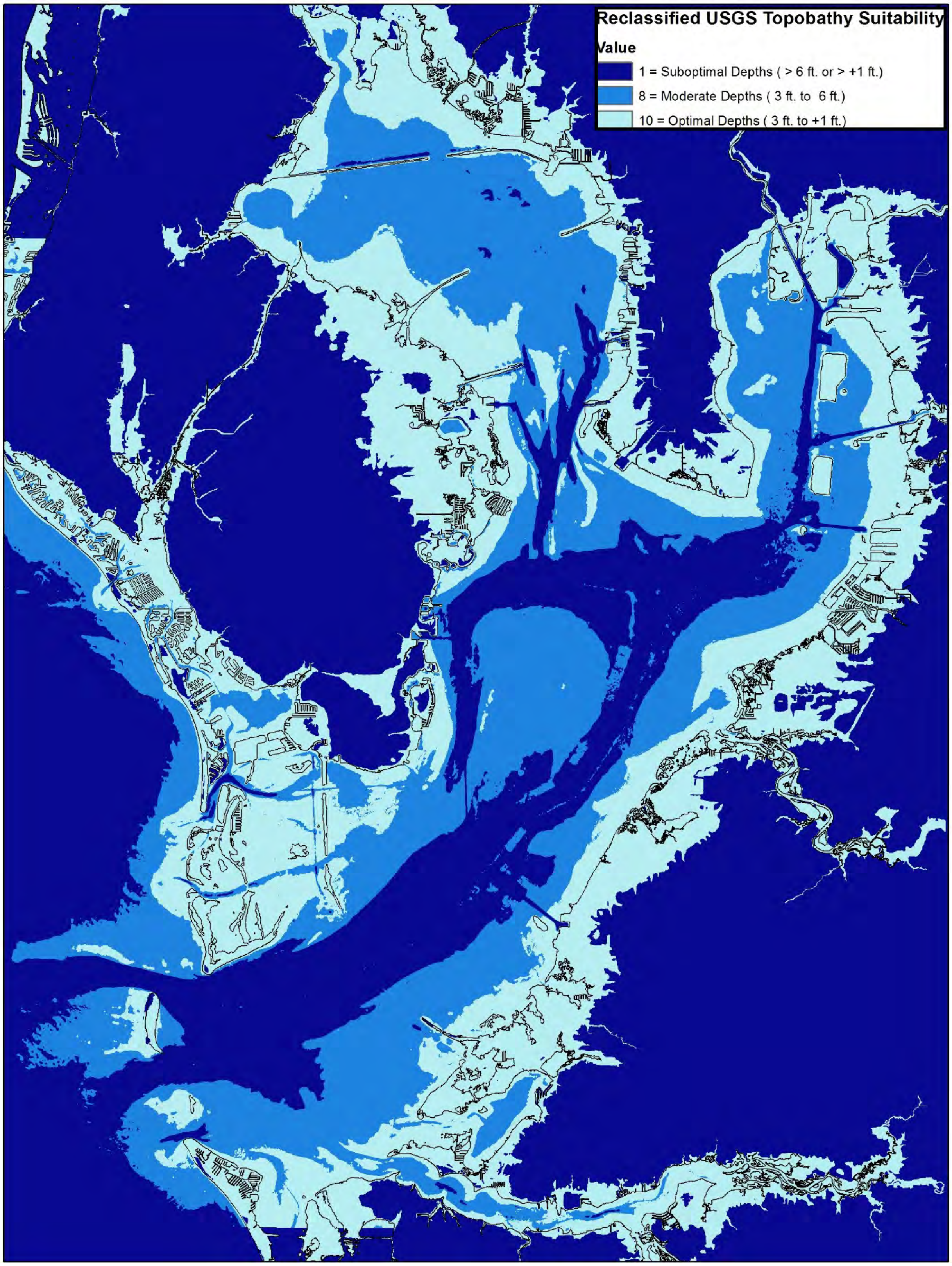

Figure 12. Oyster suitability based on specified water depths.

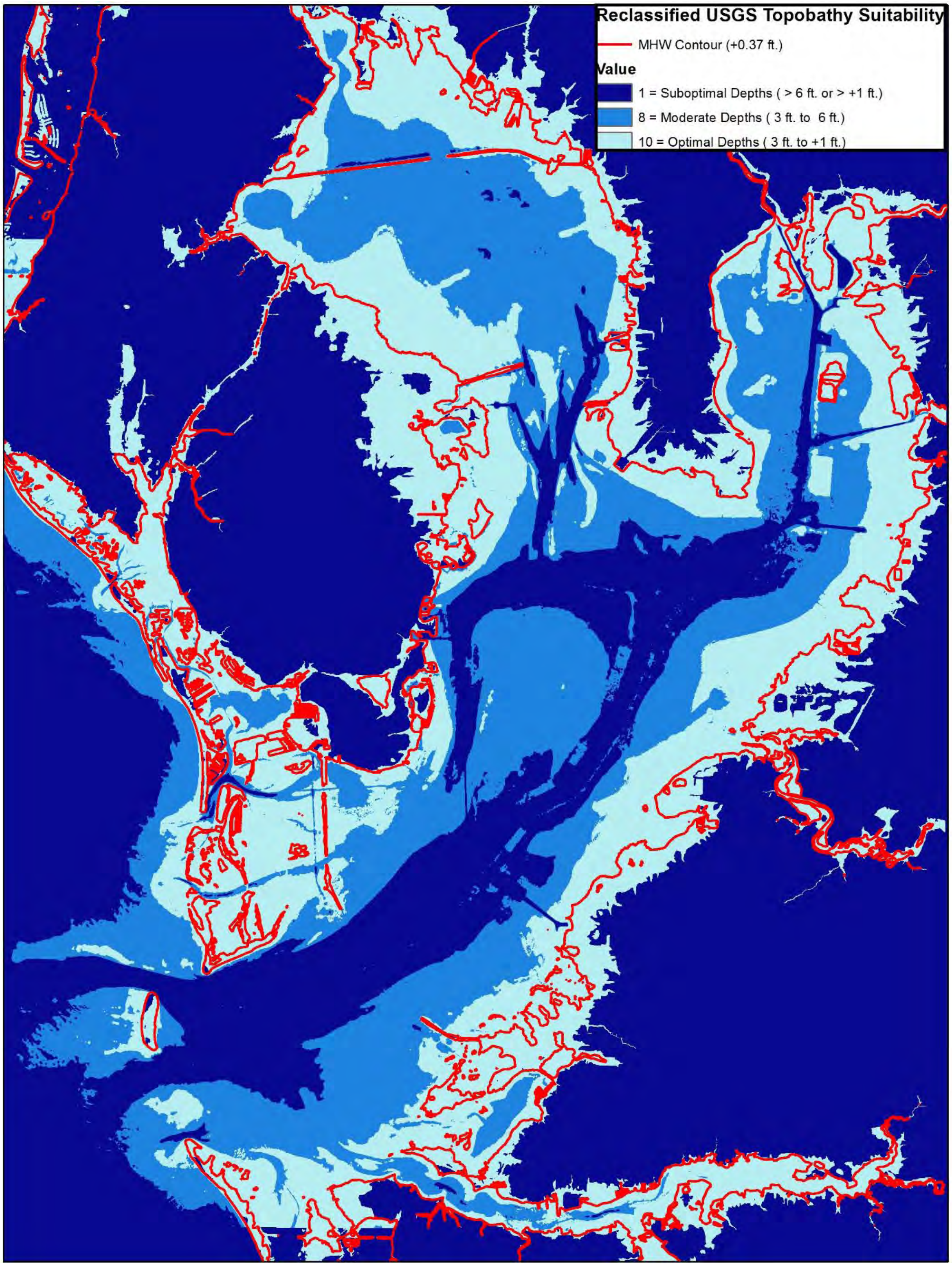

Figure 13. Results of Tampa Bay bathymetry and topography reclassified for oyster suitability. Results identified as "optimal" landward of the MHW contour are to3 be excluded from future analyses of the model results.

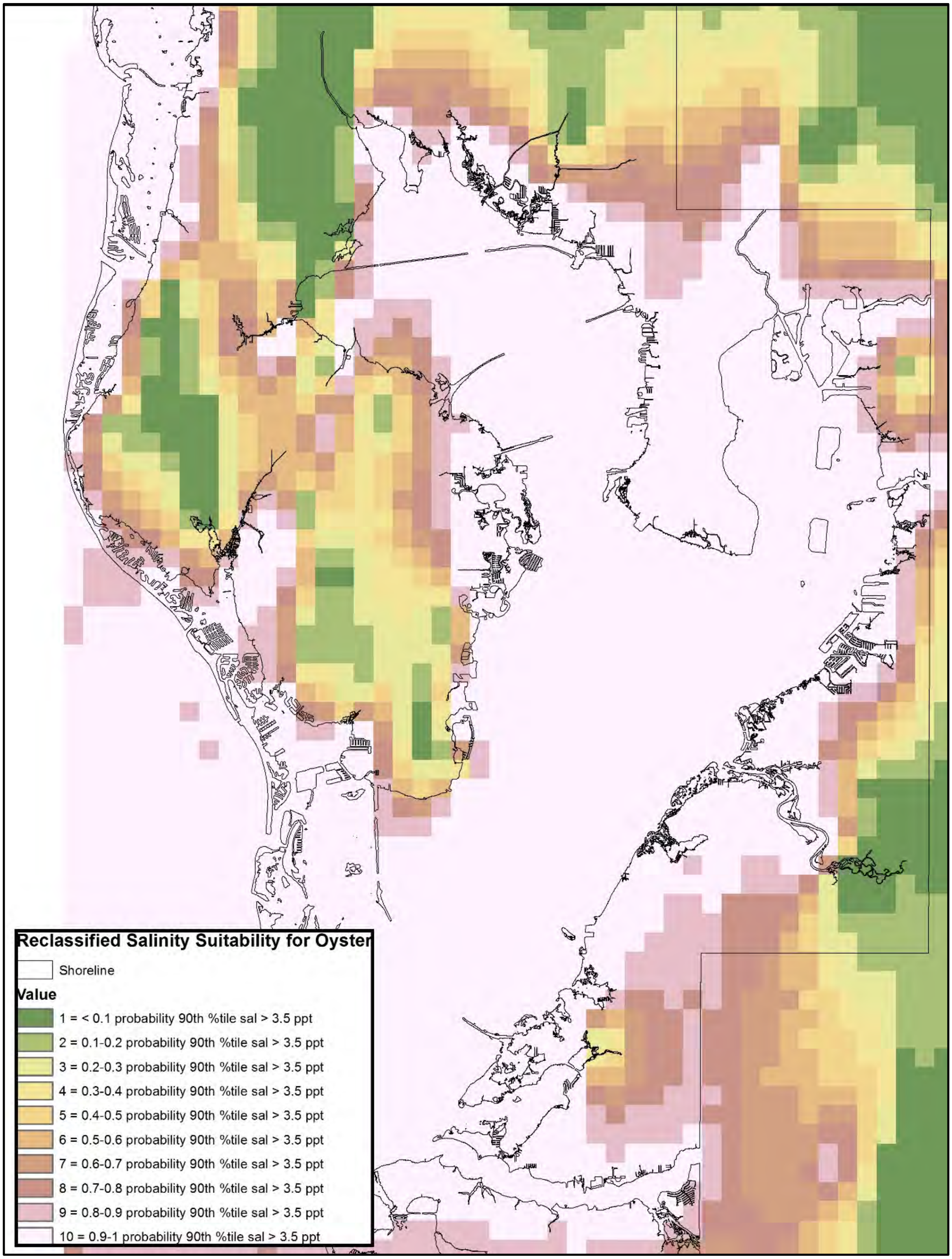

Figure 14. Oyster suitability based on salinity tolerance > 3.5 ppt.

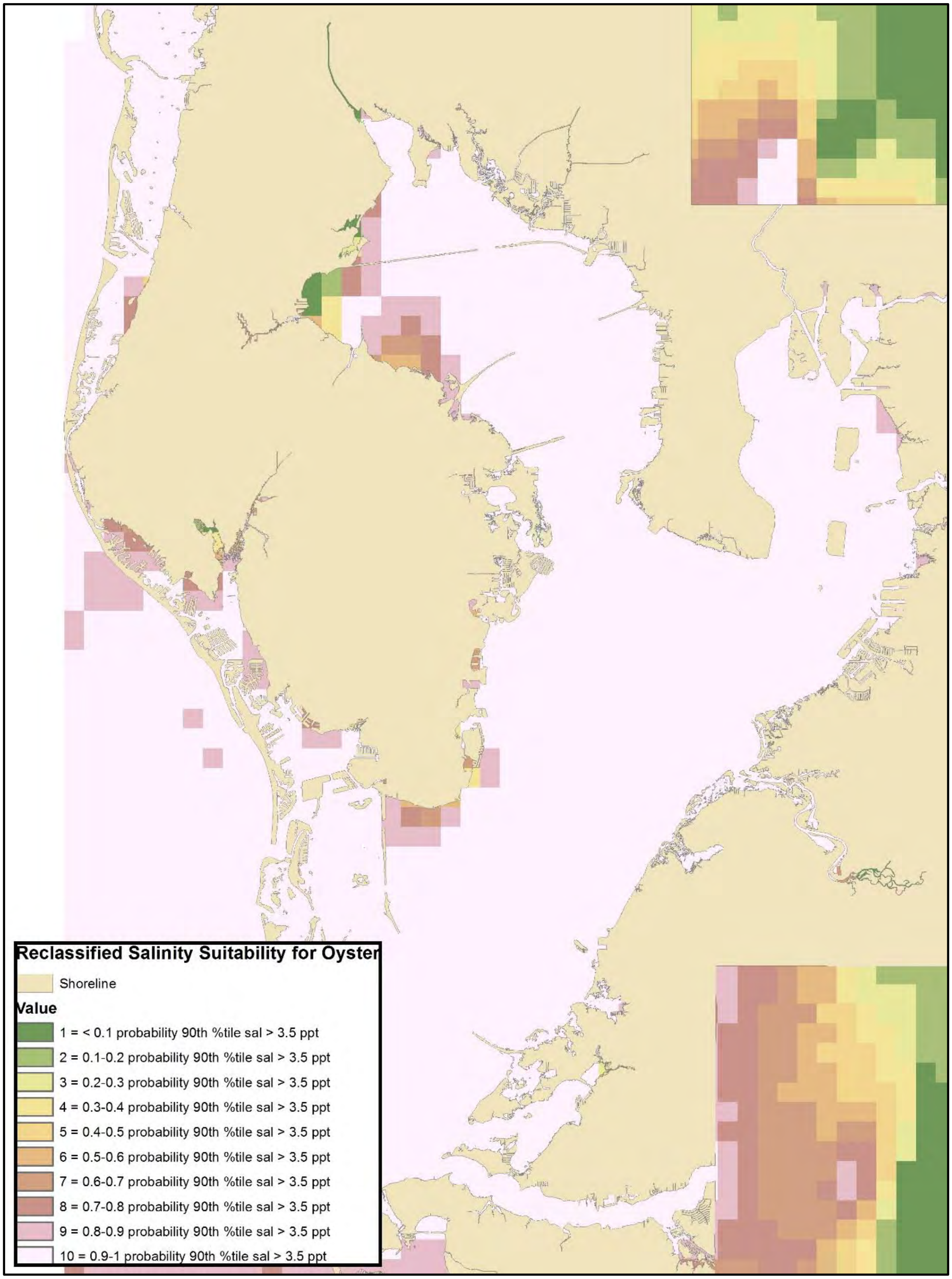

Figure 15. Interpolated salinity suitability for oyster constrained by land, to visualize data for open water of Tampa Bay only.

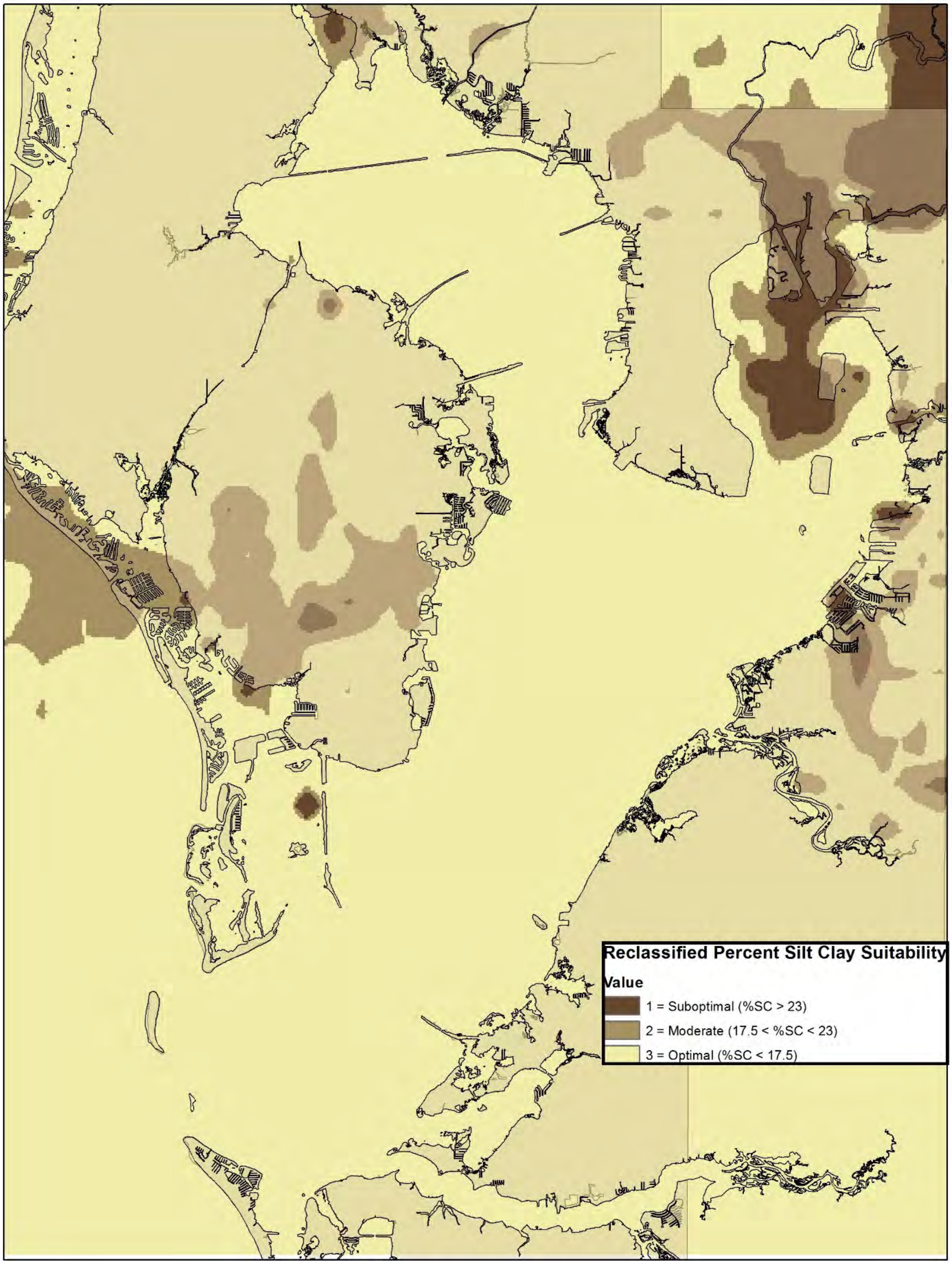

Figure 16. Suitability of Tampa Bay sediments (%silt/clay) for oysters.

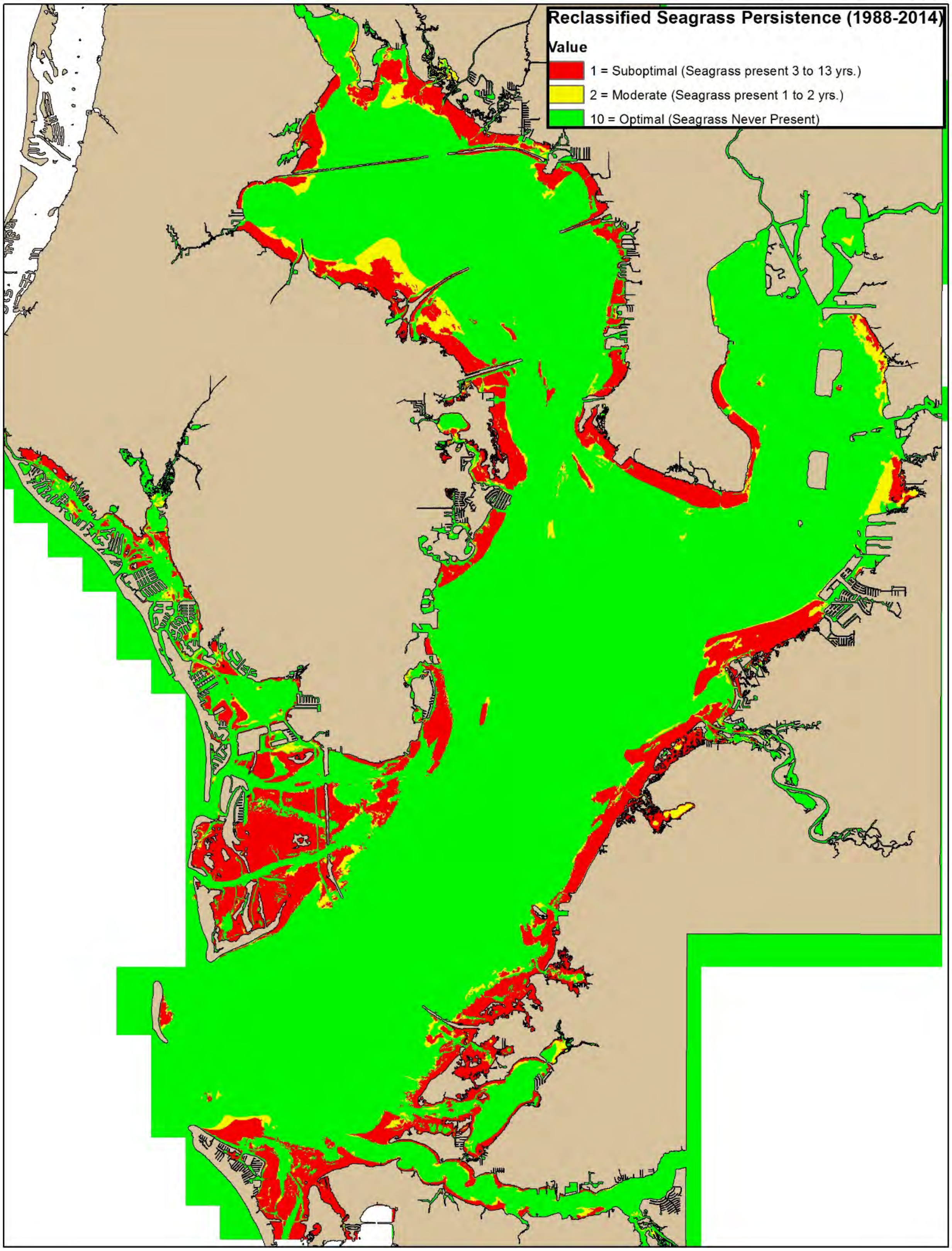

Figure 17. Tampa Bay suitability for oysters after excluding locations where seagrass persist.

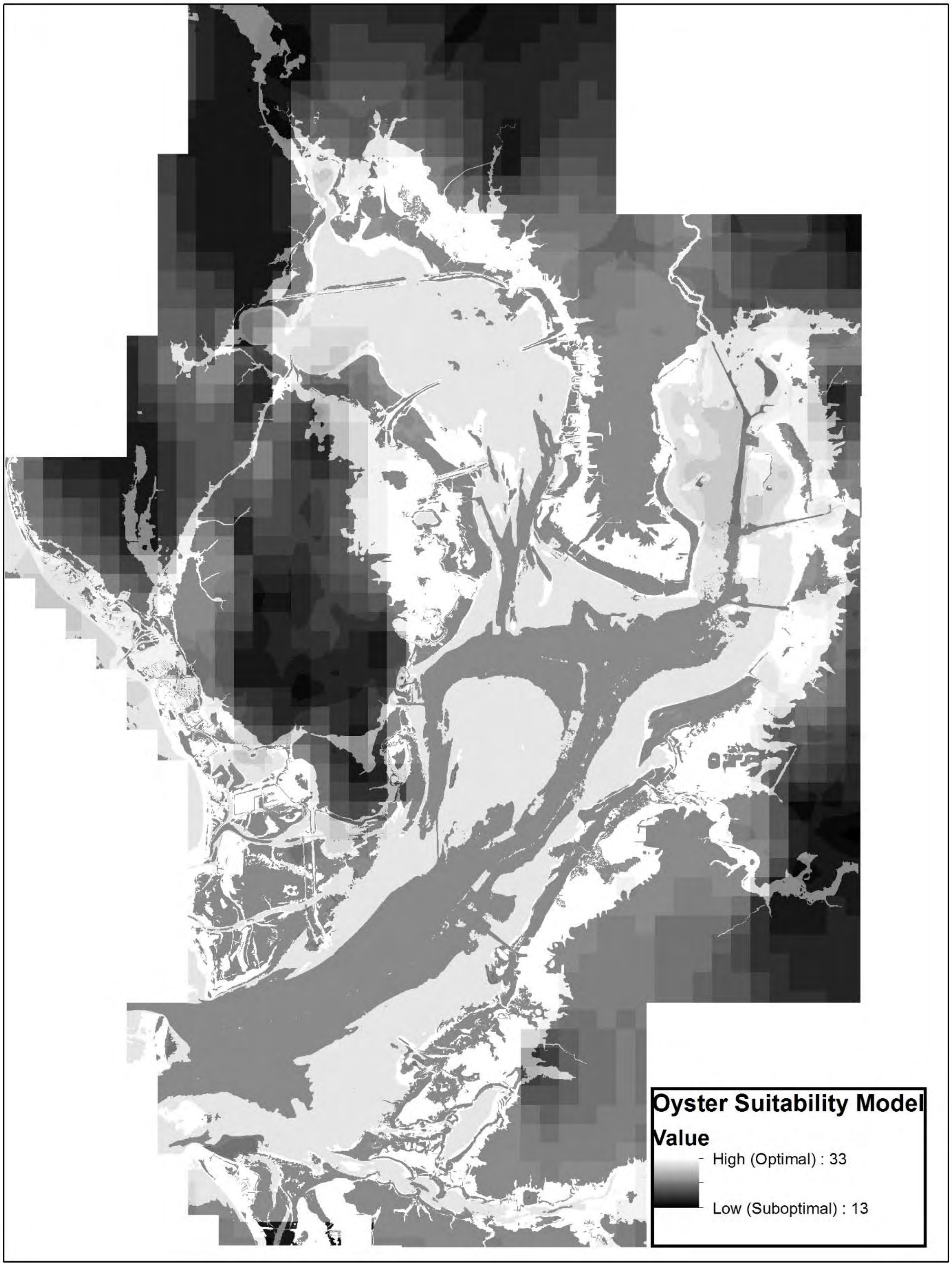

Figure18. Final oyster suitability model. Results have not been post-processed to remove scores for the data between the +0.37 to +1.0 contours.

Table 8. Model results for locations of known oyster substrate in 2014. Ranges or multiple values provided in the model output column represents data collected from multiple oyster polygons in the identified region. Higher output numbers indicate better potential oyster habitat.

Bay Segment	Key Locations	Model Output
Old Tampa Bay	Upper Tampa Bay Park	25
Old Tampa Bay	Double Branch Bayou	33
Old Tampa Bay	Hooker Point	24
Old Tampa Bay	Feather Sound Area	22-23
Old Tampa Bay	Rocky Point	24
Hillsborough Bay	Tampa Bay Watch McKay Bay Site	32
Boca Ceiga Bay	Clam Bayou	22-24, 29, 32
Boca Ceiga Bay	Tampa Bay Watch Ft. Desoto Site	24
Middle Tampa Bay	Outside Mouth of Little Manatee River	24-25, 33
Terra Ceia Bay	Terra Ceia	24

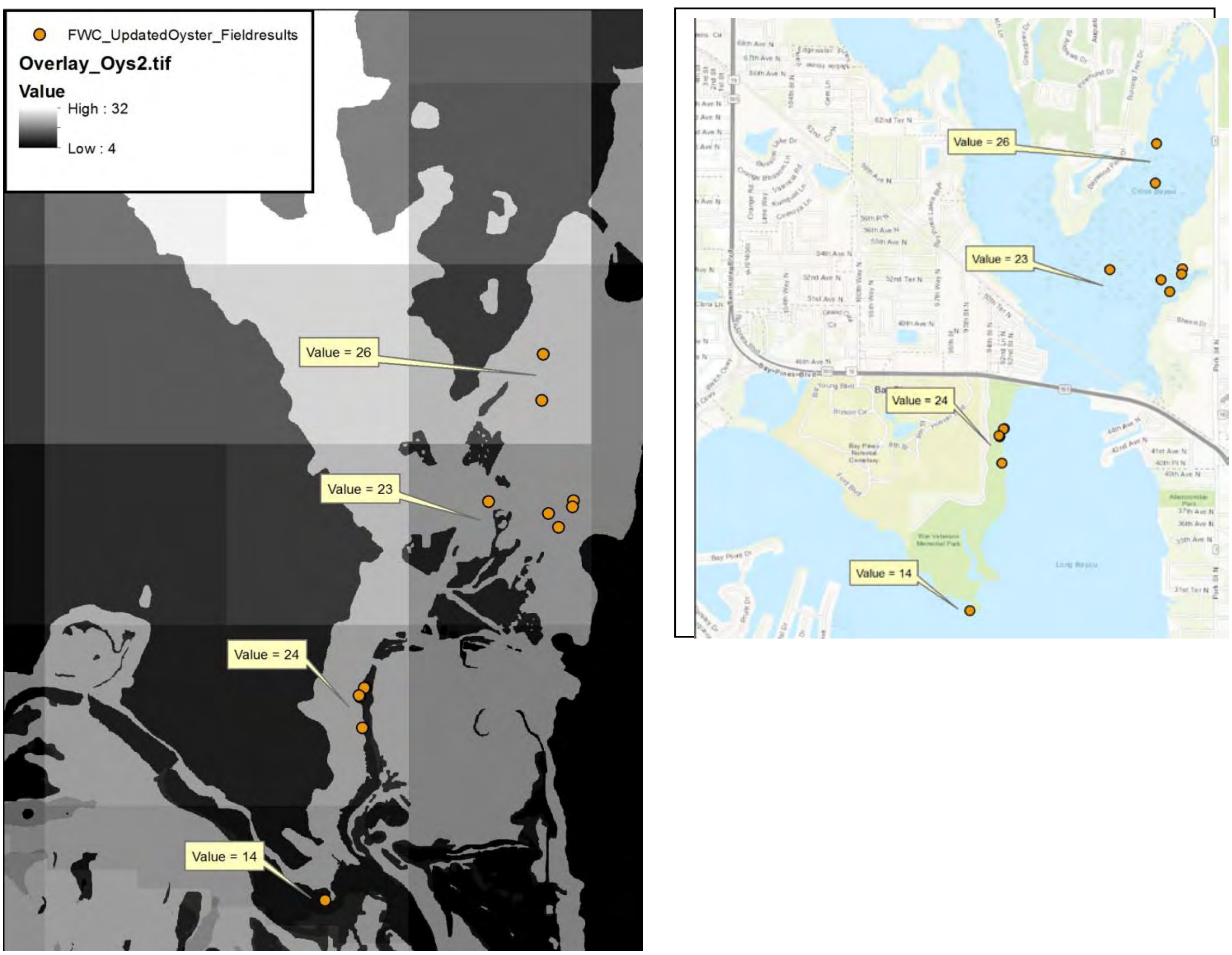

Figure 19. Oyster model output in Boca Ciega Bay displaying FWRI sample points where oysters are currently present. Accompanying map displays sampling point locations.

Oyster habitat resource recommendations from the TBEP target setting meetings included: 1) continue regular mapping of the habitat during seagrass mapping efforts; 2) attempt additional in-field verification of habitats during annual seagrass transect monitoring or other "fieldwork of opportunity"; 3) and continue modeling and filtration estimation efforts for the identification of restoration opportunities in the bay.

Tidal Flat

Ecological Significance

The TBEP Habitat Master Plan Update (Robison 2010) describes tidal flats as non-vegetated, intertidal bay bottom typically composed of a mixture of organic sediments and fine grained sands. Tidal flats occupy space between mean low water and the low marsh fringe. The Master Plan further describes the environmental context where these habitats are found to be along low energy shorelines and contained within backwaters less influenced by tides. In Tampa Bay, these types of locations accumulate organic matter creating invertebrate rich habitats with high enough bottom elevations to inhibit persistent seagrass communities from establishing (Robison 2010).

The description above explains how fine-grained unconsolidated sediments become a definable habitat due to the effects of their position in the landscape. The most important defining characteristic is the influence of tides and tidal exposure for this habitat. The subtle defining features of tidal flats have made accurately quantifying their broad scale extent and distribution challenging. A deficiency in the definition historically used as the District's FLUCCS mapping classification for tidal flats was that it did not adequately consider landscape position. In geospatial mapping, because there are almost no definable visual cues to differentiate visible bare sediment from tidal flat habitats, there is a higher level of subjectivity in classifying tidal flats. It is possible this has caused some inconsistencies in mapping over time. To assist in better understanding the unique features, Table 9 presents tidal flat definitions from several different classification schemes that offer several important descriptions for the defining elements of tidal flats at varying levels of specificity.

Historical Extent of Habitat in Tampa Bay

Tidal flats as a defined habitat were not found to be quantitatively described for Tampa Bay in available historical references and literature. The 1970s mapping completed for Phase 1 of the grant is the earliest mapping of tidal flat distribution for the AOI but is not available for the entire bay (Tables 2 and 3). Phase 1 documented the 1970s extent of tidal flats as defined by the District's modified FLUCCS classification prior to the 2014 revision. The two areas (Old Tampa Bay and the AOI) showed distinctly different trends regarding tidal flat acreage, with Old Tampa Bay tidal flats being reduced by 3,051.43 acres (39.6%) while the AOI tidal flat area increased by 263.40 acres (20.7%) between the early 1970s and 2014 (Figures 20 and 21). This could be due to changes in seagrass coverage over time as well as differences in hydrodynamics and changes in the long-shore bar systems. Anthropogenic impacts prior to 1950 due to nearshore dredge and fill activities and other bathymetric modifications during that time period may have significantly reduced various shallow water habitat types and changed conditions that would have contributed to additional creation or maintenance of tidal flat habitats. Therefore, available source datasets such as 1950s and 1970s aerial photography do not represent pristine conditions for habitat components like tidal flats in Tampa Bay.

Historical descriptions of bay bottom and bay sediments provide some context for the habitat changes that have occurred since development of the Tampa Bay watershed. Dawson (1953) speculated that loss of mangroves increased sedimentation to the bay from inland activities and that dredge and fill contributed to formation of extensive tidal flats where productive oyster habitat had previously occurred.

Table 9. Different habitat classification systems providing context for defining tidal flats. Bold language identified key contributions of interest to the topic.

Classification System	Class/Code Name	Definition
FLUCCS Level 1 (FDOT 1999)	Non vegetated (6500)	**Non-vegetated** classes, **plant establishment is hindered by water fluctuations**.
District Modified FLUCCS Level 4 (2014)	Tidal Flat (6510)	**Non-vegetated, intertidal shallow-water habitats**. These are unconsolidated sediments located in **low energy environments** and are capable of supporting seagrass if able to establish. A characteristic of this class is its alternating cycle of submergence and exposure to the atmosphere.
Smithsonian for IRL	Tidal Flat	Intertidal, non-vegetated, **soft sediment habitats**, between mean high and mean low water spring tide datums located in estuaries/low energy environments.
SCHEME (Madley et al. 2004)	Unconsolidated Sediments	Zero to **less than 10 percent SAV colonization**.
FNAI	Unconsolidated Sediments	Mud, mud/sand, sand, or shell that **may support large infaunal communities but lack dense populations of sessile plant** and animal species.
GPRA Reporting System (TBEP)	Submerged Mud Bottom	Intertidal **mudflats** or subtidal **substrate containing organic material and particles smaller in size than sand. These areas of loose, unconsolidated substrate generally lack rooted vegetation, but may provide appropriate habitat for shellfish beds**.
GPRA Reporting System (TBEP)	Submerged Sand Bottom	Intertidal **sand flats or sandy subtidal** areas; composed of loose, unconsolidated substrate characterized by fine to coarse-grained sediment, **and normally lacking rooted vegetation**.

Resource Distribution

The newly revised classification for tidal flat documented 14,813.48 acres of habitat bay-wide in 2014. In Tampa Bay, the wind waves, storm events, and tidal forces acting on the bay's sediments create a dynamic system where tidal flat habitats can be ephemeral. Tidal exposure changes throughout the year and sediment transport modifies the slope, elevation, and sediment composition of bay bottom. Deposition of sediment is transient in Tampa Bay with sediments being mobilized at short regular intervals (Brooks and Doyle 1992). This can result in tidal flat habitats transitioning to vegetated bottom if conditions become more hospitable for a particular vegetation type (i.e. expansion of seagrass beds or expansion of mangrove fringe). It is predicted if sea level rises 15 inches by 2100 in Tampa Bay, the majority of present day tidal flats (96 percent) will be lost (Glick and Clough 2006).

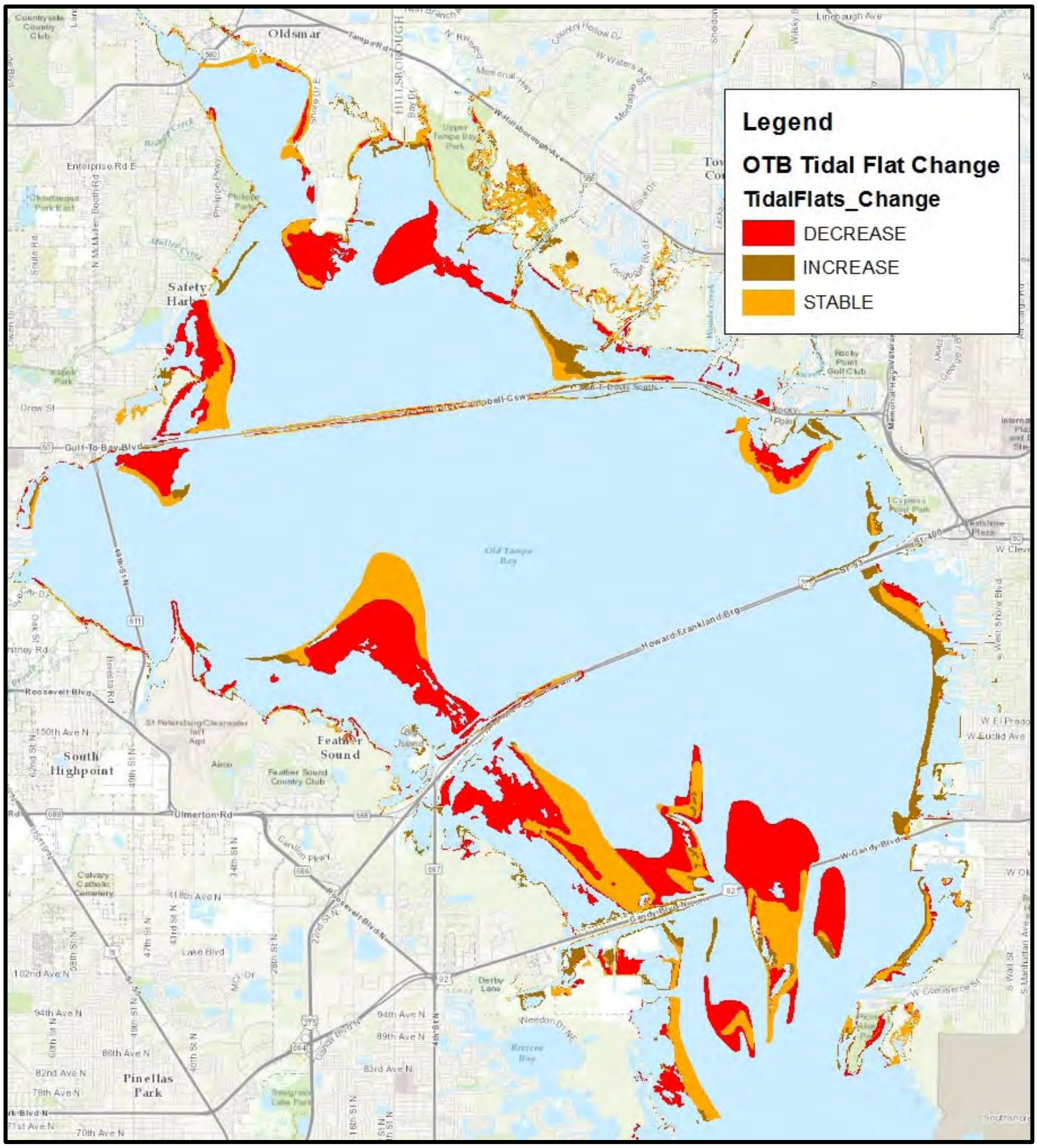

Figure 20. GIS comparison of the 1970s and 2014 tidal flat extents in Old Tampa Bay. Some change can be attributed to increases in seagrass cover overtime.

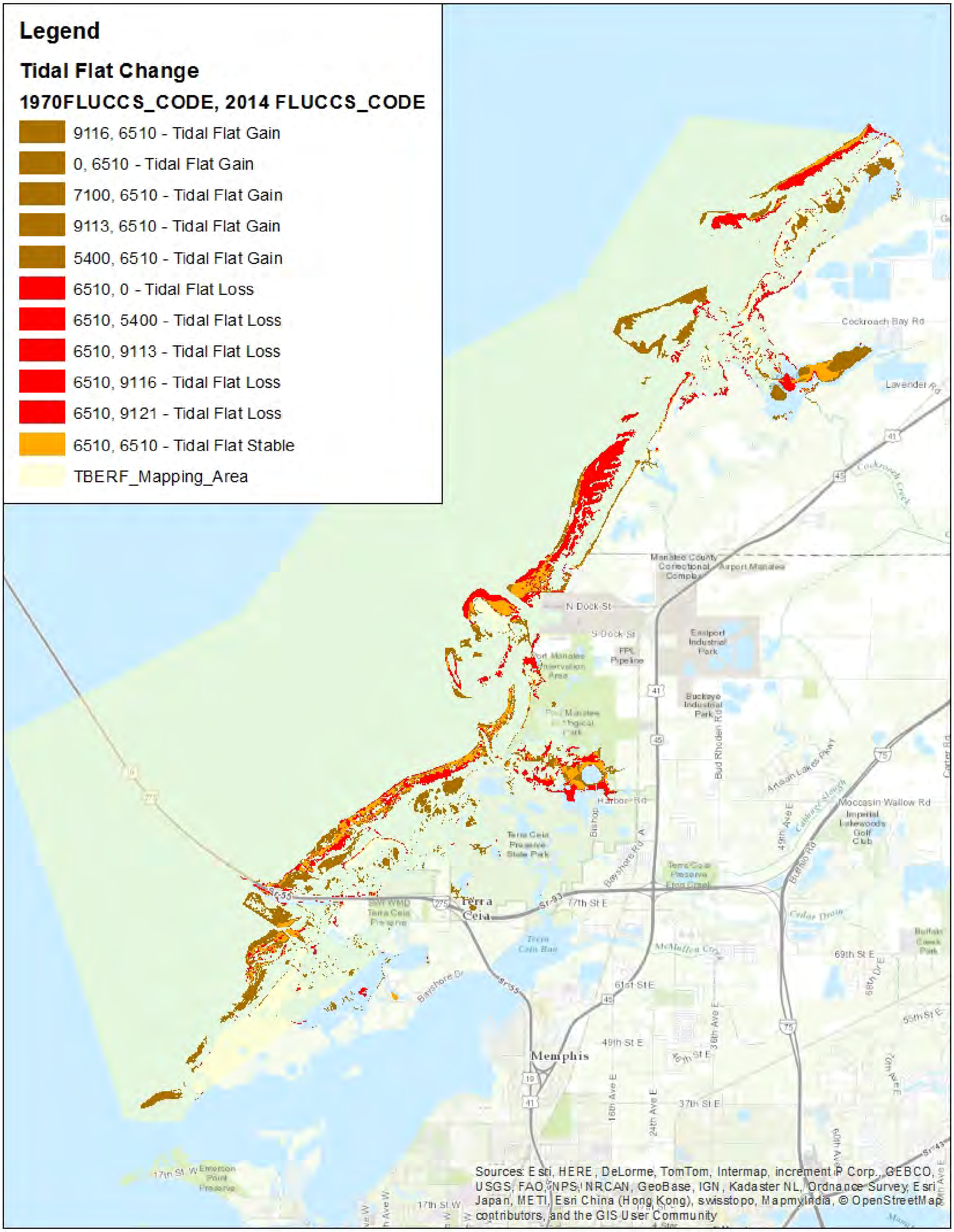

Figure 21. GIS comparison of tidal flat extent in 1970 and 2014 for the AOI. The map legend provides the classification changes that occurred between the two years.

Target Setting Objectives

Recommendations for tidal flat habitats from the TBEP target setting meetings included:

- Continue regular mapping of the habitat during seagrass mapping efforts;
- Synthesize available sediment and faunal data to better characterize the habitat;
- Analyze the combined datasets described above;
- Create preliminary habitat suitability models; and
- Focus on protection of the available resource.

Parameters for Target Setting

The landscape position and various tidal flat habitat descriptions from Table 9 can be used as a starting point for creating the tidal flat habitat suitability model structure. Although challenging to visualize, there is sufficient data on the environmental conditions that create tidal flat habitats in Tampa Bay. The parameters identified for possible representation of habitat conditions in a suitability model are:

1. USGS 2007 Bathymetry depth and elevation data
2. HCEPC sediment percent silt/clay data
3. HCEPC infaunal community diversity indices
4. District tidal flat distribution persistence map (1988-2014)
5. District seagrass (1988-2016) and oyster (2014-2016) map data as exclusionary parameters

The mean low water, mean high water, and mean higher high water lines can be extracted from the available topobathymetry data to characterize the spatial distribution of tidal influence on Tampa Bay. If definitions for intertidal and subtidal can be agreed upon for Tampa Bay based on two specific depth ranges they can be used to characterize bathymetry as well. A grain size range should be selected using best professional judgement or literature for defining "mud" and "sand" from sediment percent silt/clay data as it pertains to mud flat and sand flat habitats. Infauna data may play a role in providing additional characterization of the sediments for developing appropriate habitat ranges or used post-modeling to characterize the locations the model output identifies as suitable tidal flat habitat. Sediment contamination could be incorporated as an exclusionary parameter in the model or it could be applied to model results to characterize the health or functionality of the identified tidal flat locals. Oyster distribution data products from the District 2014 and 2016 maps and a District seagrass persistence map can be incorporated as exclusionary parameters in the model. A tidal flat persistence map can be created from the District's long-term seagrass map dataset (based on the FLUCCS 6510 code) for the years 1988 through 2014. Finally, available bay-wide circulation data can be explored as a model parameter to characterize "low energy" based on the relative nature of the Tampa Bay circulation patterns. Back bays and low energy zones could also be identified visually and incorporated as a layer in the model.

Hard Bottom

Ecological Significance

The term hard bottom can be used to describe both the geology of the sea floor as well as the live community of organisms that attach to the hard substrate and reside there. Although known to be distributed widely in Florida waters (Yates et al. 2011), the extent of Tampa Bay live hard bottom habitats has not been comprehensively documented. Reports of Tampa Bay hard bottom habitats note they support attached macroaglae, gorgonians (sea whips), sponges, boring sponges, and some hard corals (Yates et al. 2011). Anthropogenic activities that could cause disturbances to hard bottom include dredging, ship or boat groundings, and pollution spills.

Hard bottom habitats in Tampa Bay are considered dynamic. Typical communities have little or no relief from the unconsolidated sediment matrix around them (Ash and Runnels 2005). The very low relief makes the live communities susceptible to burial caused by normal or storm induced migration of shoals and sandbars, while erosional forces can be exposing new hard substrates to the sediment surface for live community colonization (Ash and Runnels 2005). Seasonal live community changes, hydrologic changes, and geomorphological changes all influence the habitat extent and structure further explaining their ephemeral nature (Ash and Runnels 2005).

Historical Extent of Habitat in Tampa Bay

Understanding the historical extent of hard bottom is a unique exercise as it should be investigated from a geologic time scale perspective. The defining feature of hard bottom habitats is the substrate which was formed well before any time period relevant for other habitats discussed in this project. Understanding when and where in the Tampa Bay seascape these substrates were formed provides the possible footprint of locations that are, or could be, exposed in the future as hard bottom substrates for live bottom communities to colonize. In Tampa Bay, natural hard bottom substrates are thought to be of geologic and biogenic origins, including arcadia limestone, beach rock, and relic oyster reef (Ash and Runnels 2003).

The west coast of Florida is a broad ancient carbonate platform, the inner west-central portion is characterized by a thin veneer of unconsolidated sediments which overlay a Miocene limestone surface (Berman et al. 2005 and references therein). The unconsolidated sediments are predominately coarse carbonate shell and fine-sand sized siliciclastic grains (Berman et al. 2005 and references therein). A Miocene limestone terrace runs sub parallel to the present shoreline (Berman et al. 2005). During geologic time, the limestone platform is thought to have undergone dissolution, creating the basins for Tampa Bay (Berman et al. 2005). Tampa Bay is characterized as having both low tidal and low wave energy, such that stronger forces associated with hurricanes and tropical or winter storm can significantly affect the system's sedimentary features (Berman et al. 2005). Sediment supply and underlying geology are determining factors for an area's bedform morphology.

Beyond any sparse descriptive observational accounts of hard bottom habitats available in historical navigation materials very little is known about their more contemporary historical extent. Although the distribution of hard bottom habitats in the 1950s was virtually unknown (except for navigation hazards), one limited account by Dawson (1953) described two locations in the bay with (rock) hard bottom. One small patch of rock bottom was off the southeast point of Terra Ceia Island. At this location small oyster beds were noted as attached to small rocks four to six feet deep. Dawson (1953) also observed rock bottom in a few patches near the Indian Rocks Bridge.

Resource Distribution

Contemporary characterization and documentation of hard bottom habitats in Tampa Bay began in 1981 (Derrenbacker and Lewis 1985). Their work built upon Dawson (1953) and went onto describe two additional locations of hard bottom in Tampa Bay. Qualitative community data was reported for two general areas: Old Tampa Bay around the Gandy Bridge (natural limestone and concrete rubble in 3 to 12 feet) and the area from Bishops Harbor to Terra Ceia Bay in Lower Tampa Bay (around the Skyway Bridge exposed limestone from dredge activities, and natural limestone in 4 to 22 feet of water).

The TBEP technical publication "Hard Bottom Mapping of Tampa Bay" by Savercool and Lewis (1994) reported efforts to map three locations of hard bottom using aerial interpretation and groundtruthing. This project included verification of two previously reported locations by Derrenbacker and Lewis (1985) and identification of a new location in Old Tampa Bay. The Old Tampa Bay location was around Booth and Rocky Points with naturally exposed native limestone and was associated with oyster substrate at depths of 0 to 9 feet. For the three locations examined, Savercool and Lewis (1994) reported 852.3 acres of hard bottom. The report's maps were scanned, georeferenced, and the original map polygons then re-digitized to allow for GIS-based analysis of the data. The newly created GIS file calculated the acreage of the map polygons by Savercool and Lewis (1994) to be 1,320 acres. This discrepancy is likely due to the difference in mapping technologies used at the time of the original map creation. The polygon locations and extents were compared to other available datasets for reasonableness and were determined to be a useful dataset to carry forward for additional analysis.

To date, no comprehensive geospatial mapping of hard bottom has been conducted for all of Tampa Bay, although multiple projects (including the information in this report) provide some components of a broader assessment. Intermittent ecological surveys have been performed for environmental impact assessments and state permit applications by: commercial interests, the Army Corps of Engineers, Port Tampa Bay, and Port Manatee. In general the surveys have been conducted for seafloor development purposes such as maintenance channel dredging, pipelines, or creation of new berths. In the AOI, the mapped extent of attached macroalgae (FLUCCS 9121) is speculated to be the best available proxy for hard bottom extent. The seasonal presence of the brown alga *Sargassum* spp. attached to areas of hard bottom has been routinely documented in District seagrass mapping efforts from 1990 to 2016. The combined footprint of macroalgae for years 1990 to 2016 was calculated in GIS. This data was combined with the District hard bottom maps for the AOI as well as northern Tampa Bay (Old Tampa Bay and the MacDill area) and the Savercool and Lewis (1994) data (Figure 22). The District hard bottom maps included polygons for all potential hard bottom habitat classes including: natural hard bottoms, artificial reef, and spoil areas. When all map information was combined, the new hard bottom footprint was calculated to be 2,368.7 acres (Figure 23). Locations recommended for future hard bottom mapping (Kaufman personal observations) are now under consideration for implementation and could increase the hard bottom inventory footprint in the near future (Figure 24).

Target Setting Objectives

For hard bottom, the next steps for target setting that were recommended within the series of three meetings from late 2016 included:

- Applying for additional grants to complete mapping of the bay;
- Consider creating a long-term monitoring program with permanent monitoring stations and transects; and
- Focus on protection of existing resources.

Parameters for Target Setting

Target setting for hard bottom may require a different approach compared to oysters and tidal flats. Protection of the known resources, the mapped 2,368.7 acres, should be the starting point. Additional information on the bay's resources can be found in Florida Department of Environmental Protection permit applications for various marine activities as well as academic studies. An effort to compile available data from these resources could provide additional information on where to target future mapping projects or supplement existing hard bottom habitat maps. Tampa Bay sediment transport information or models and available sub-bottom profile data may improve our understanding of the ephemeral habitats in the constantly shifting environment.

Conclusions

This report highlights preliminary investigations and analyses of oyster, tidal flat, and hard bottom habitat data for the purposes of resource target setting. Based on lessons learned and results of the analyses thus far, the initial work can be built upon and improved.

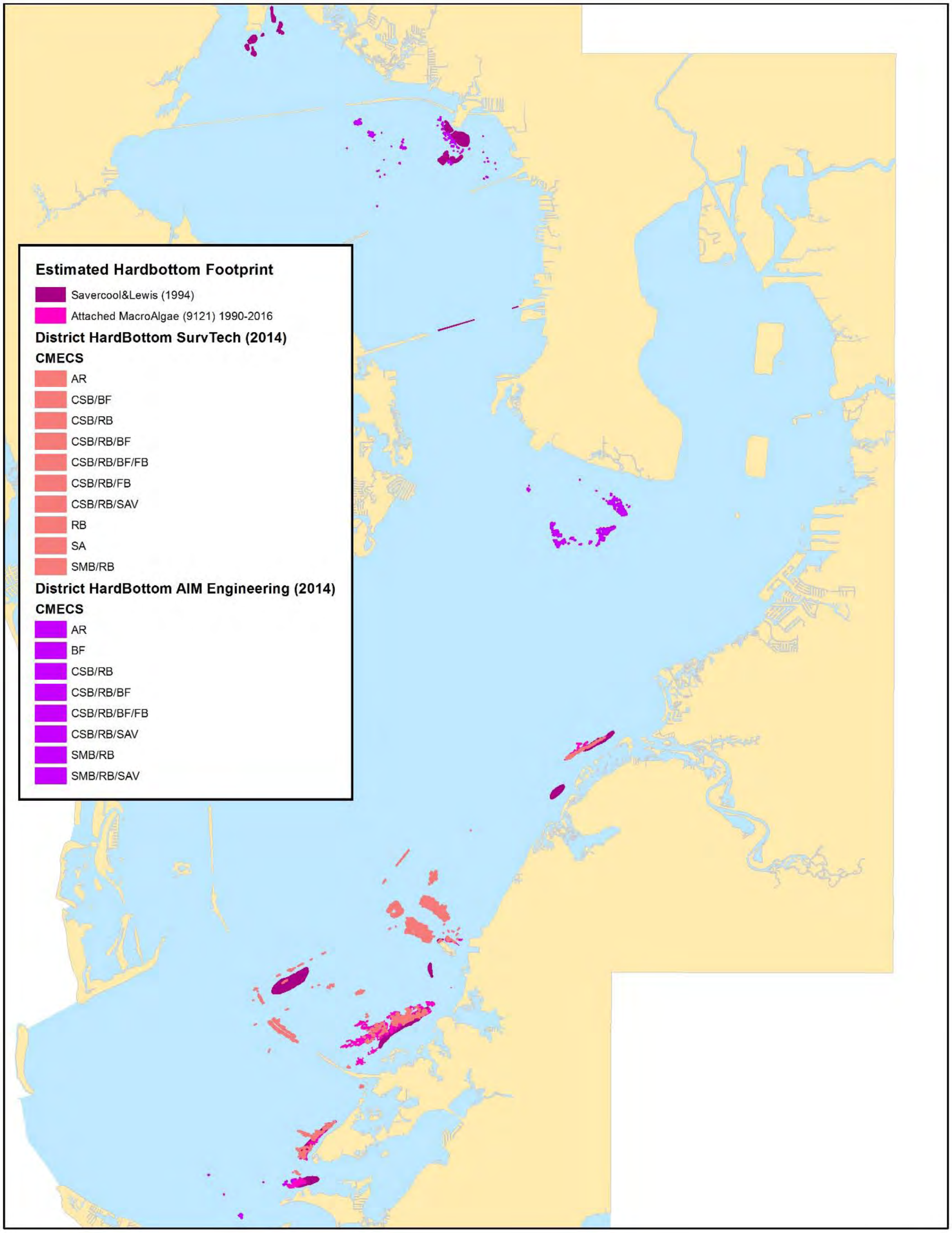

Figure 22. Display of available GIS hard bottom map data.

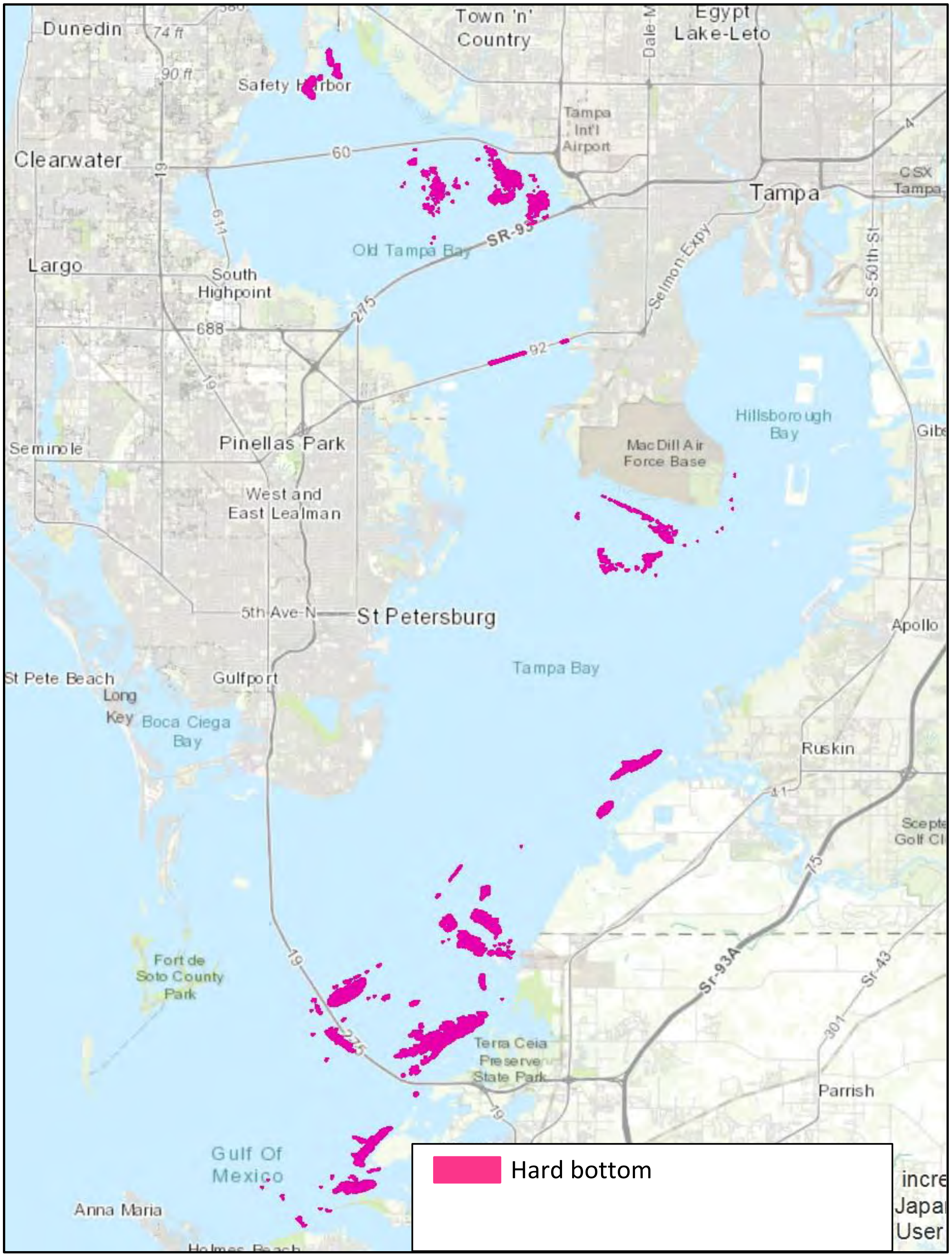

Figure 23. Estimated distribution of potential hard bottom for Tampa Bay.

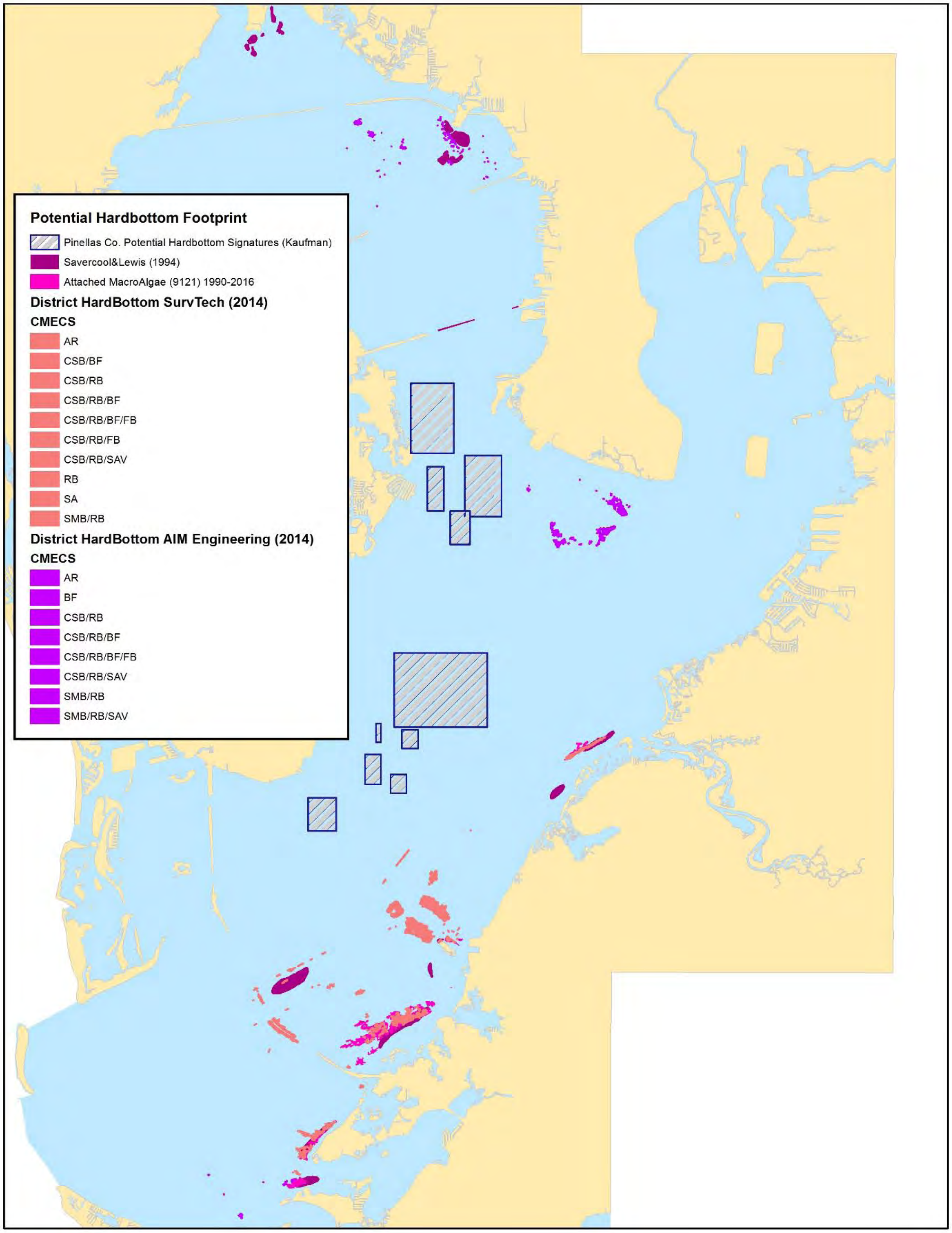

Figure 24. Compilation graphic of hard bottom habitat map data and areas for future investigation.

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