GEOLOGICAL SURVEY OF ALABAMA

Berry H. (Nick) Tew, Jr.
State Geologist

GEOLOGIC INVESTIGATIONS PROGRAM

COMPREHENSIVE SHORELINE MAPPING, BALDWIN AND MOBILE COUNTIES, ALABAMA: PHASE I

OPEN FILE REPORT 0921

by

Stephen C. Jones, David K. Tidwell, and Steve B. Darby

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INTRODUCTION

The purpose of this study is to classify shore protections and shoreline types and quantify shoreline change where applicable, mainly within Mobile Bay, Weeks Bay, and selected tributaries. This report represents the initial effort, or "Phase I," of a cooperative effort between Alabama Department of Conservation and Natural Resources, Lands Division, Coastal Section and the Geological Survey of Alabama to accomplish the aforementioned tasks for Alabama's coastal zone.

Shoreline type and stabilization methods play an important role in the Alabama coastal area with both adverse and favorable impacts. As a result of natural processes and anthropogenic influences, the tidal shoreline of Alabama is constantly changing and change can occur very rapidly or slowly. Regardless of the rate of shoreline change, continuous development along the coastal zone shoreline is inevitable and is a dominant cause of change. Shoreline stabilization is the ultimate goal of erosion control projects, and because of their utility in preventing coastal erosion, hard shoreline structures and non-structural shoreline protection types are found throughout coastal Alabama.

Although erosion is a natural process along a tidal shoreline, hard shoreline stabilization techniques can limit erosion and potential effects of sea level rise. However, the installation of hard shoreline structures can negatively impact nearshore, intertidal, and upland habitat; alter sediment drift and shoreline dynamics; destroy existing marsh and curtail marsh development seaward of hard structures; decrease the aesthetic value of property; and accelerate impacts on adjoining properties (Kana and others, 1995; Pennsylvania Department of Environmental Protection, 2001; LaRoche, 2007; National Park Service, 2009). Based on work by Stewart (2001), Johannessen and MacLennan (2006) LaRoche (2007), and the Louisiana Department of Natural Resources (2009), shoreline stabilization and type mapping can be used as follows:

- to assist federal, state, and local governments with shoreline planning, permitting coastal zone activities, Coastal Zone Management oversight, and development of regulatory guidelines;
- to provide an effective tool for assessing and forecasting shoreline change and understanding cumulative and compounding effects of natural and anthropogenic influences through data acquisition.

- to prioritize or evaluate protected shorelines for future conversion to a soft shoreline protective measure or alternative method and identify potential demonstration project areas for alternative methods;
- to allow coastal managers access to up-to-date shoreline stabilization trends and characteristics through geospatial mapping;
- to promote assessment of sediment management issues, coastal erosion, habitat protection, and flooding projects;
- to promote new and improved methods for shoreline stabilization measures that have a positive impact on natural habitat, adjoining properties, and aesthetics; and
- to promote governing and public education and awareness.

This report briefly describes shore protection, general shoreline type, and shoreline change estimates within sections of the Alabama coastal zone in support of Section 309 of the Coastal Zone Management Act of 1972. Currently, no inventory of geographic information system (GIS) thematic layers representing shoreline protection, shoreline type, and comprehensive compilation of public and private boat ramps for coastal Alabama exists. In addition, there is a need to further quantify short-term erosion within Mobile Bay. The main objectives of this study, through the application of GIS, are to classify shoreline protection methods, classify general shoreline types, and quantify shoreline rates of change based on the available orthophotography.

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STUDY AREA

Baldwin and Mobile Counties encompass over 2,800 square miles consisting mainly of mixed forest, evergreen forest, and agriculture-grassland cover types (U.S. Census Bureau, 2007; Keller and Bowman, 2006). These counties lie within two physiographic districts: the Southern Pine Hills and the Coastal Lowlands (Sapp and Emplaincourt, 1975) (fig. 1). The Southern Pine Hills district is characterized by broad, rounded hills of low relief with segregated flat upland areas. Stream channels in the Southern Pine Hills tend to be well defined with low to moderate relief and narrow riparian buffers. Incised channel valleys are more numerous away from the alluvial deltaic plain. The Coastal Lowlands district is of very low relief and is characterized by abundant sand which allows for broad floodplains, steep stream banks, and wide riparian wetlands. The study area is underlain by the Citronelle Formation of Pliocene and Pleistocene age and the Miocene series undifferentiated. Alluvial, terrace, and coastal deposits underlie the Mobile River delta area and several major tributaries to Mobile and Perdido Bays and streams draining into Mississippi.

Alabama's coastline is restricted to Mobile and Baldwin Counties which are bordered to the west and east, respectively, by Jackson County, Mississippi, and Escambia County, Florida (fig. 2). Alabama has approximately 53 statute miles of general coastline and 607 statute miles of tidal shoreline (National Atlas of the United States, 2005). Tides can be described as diurnal and biweekly neap tides and microtidal (high and low tidal range of less than 2 feet). The study area described herein is the Mobile Bay shoreline which extends from Cedar Point in southwest Mobile Bay and northward to U.S. I-10, eastward to D'Olive Bay, southward along the eastern shore and including Bon Secour Bay and north Morgan Peninsula and totals about 135 miles of shoreline (fig. 2). The study area also includes Weeks Bay, Fish River, Magnolia River, Fly Creek, and the Deer River System. Estimated shoreline lengths within Weeks Bay and the rivers mapped are about 11 and 64 miles, respectively.

PREVIOUS INVESTIGATIONS

Limited work has been done on the classifications of shoreline armoring and type, erosion estimates, and infilling of marsh to support further coastal zone development within the tidal zone of Baldwin and Mobile Counties, Alabama (figs. 1, 2).

As part of a broad characterization of estuaries in Alabama, Chermock (1974) pointed out that the construction of causeways and breakwaters can influence hydrodynamics of estuaries thus altering erosion and deposition patterns.

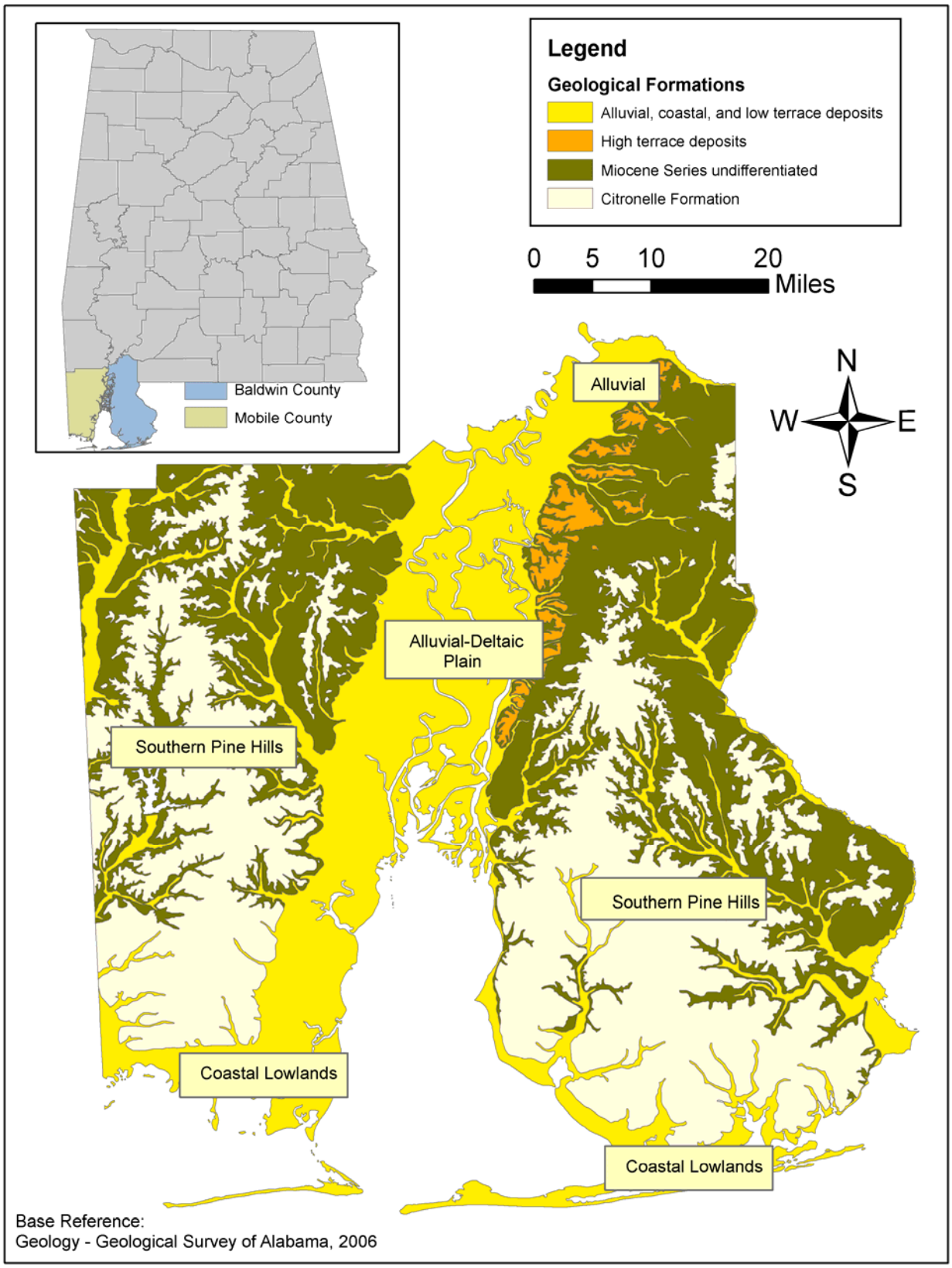

Figure 1. —Generalized geology and physiography in Baldwin and Mobile Counties, Alabama.

Figure 2. —Study area map.

Altered shorelines in estuaries often involve the loss of essential habitats and area within the intertidal zone to development and thus create artificial shorelines. Between 1953 and 1968, 858 acres of Mobile Bay were filled to accommodate development; within Mississippi Sound, Mobile Bay, Mobile Delta, Perdido Bay, and Little Lagoon, 2,152 acres were filled and developed (Chermock 1974). As developed artificial shorelines are stabilized with native vegetation and are exposed to natural coastal processes, they become increasingly difficult to recognize.

Investigating shoreline changes in coastal Alabama through remote sensing and satellite imagery, Hardin and others (1976) explained the dynamic state of the shoreline as a function of both natural processes and human development, where armored shorelines are restricted from adjusting to a point of equilibrium. Hardin and others (1976) determined about 56 percent of the coastal Alabama shoreline is eroding (ranging between 0 – 5 feet per year (ft/yr) to more than 10 ft/yr); for developed areas, primarily along the western shore of Mobile Bay (average of 3.17 ft/yr; maximum at Cedar Point of 8.56 ft/yr), Dauphin Island, and the northern shoreline of Morgan Peninsula (average of about 3 ft/yr). Of interest to this project, the authors calculated an estimated shoreline length of 816 miles.

In 1976, Sapp and others completed a study based on remote sensing techniques of historical data that suggested early development dating back into the 1700s included the construction of jetties, groins, and seawalls as well as the destruction of marsh habitat to expand land for development. At the expense of natural shoreline aesthetics, private property owners as well as governing entities have constructed shoreline structures to minimize shoreline erosion.

As part of a broad approach to introduce multidisciplinary coastal resources, the Alabama Coastal Area Board (ACAB, 1980) summarized shoreline erosion estimates indicating that natural causes for shoreline erosion included littoral supply, sea level rise, scouring, and waves. Of about 504 miles of estuarine and gulf-fronting shoreline, 44 percent was determined to be receding. The ACAB depicted 94 percent and 33 percent, respectively, of the gulf-fronting and estuarine shorelines as subject to erosion. Areas common to this study included the eastern and westerns shore of Mobile Bay and the northern shore of Morgan Peninsula. The western shore of Mobile Bay was classified as a narrow sand or marsh shoreline with numerous privately owned shoreline protection structures; widespread erosion represented by bank undercutting and threatened structures (such as homes, roads, and shoreline protection) was estimated to average less than 5 ft/yr (ACAB, 1980). The shorelines between Dog River Point and Fowl River Point and between Delchamps Bayou and Cedar Point represent areas of

highest erosion, and Cedar Point was found to have receded about 488 feet between 1917 and 1974 (ACAB, 1980). Most of the eastern shoreline of Mobile Bay was estimated to be stable with periodic erosion north of Great Point Clear, Red Bluff, Seacliff, and areas along the lower part of the bay; north of Great Point Clear the average erosion was 5 ft/yr between 1917 and 1956 (ACAB, 1980). Erosion was common along the north Morgan Peninsula (Bon Secour River to Mobile Point) with rates estimated to be more than 10 ft/yr with the following shoreline loss determined between 1917 to 1974: (1) 170 feet between Bon Secour River and Catlins Bayou even with sporadic filling and construction of bulkheads and groins by property owners, (2) between 50-100 feet between Catlins Bayou and Three Rivers, (3) 200-800 feet between Little Point Clear and St. Andrews Bay, and (4) 200 feet between Navy Cove and Fort Morgan (ACAB, 1980).

Smith (1981) investigated the relationship between physical and biological systems in the Alabama coastal area. Included within this report were introductions to changes to the coastal environment, mainly through erosion and human activity, and erosion control. Interpreted from 1917 and 1974 base maps, erosion was most notable on the western shoreline of Mobile Bay (about 5 ft/yr along much of this area to as high as 8.5 ft/yr at Cedar Point); with no rate quantified, the author noted that the eastern shore was slightly accreting to stable and the northern shoreline of Morgan Peninsula was eroding (Smith, 1981). Human activity included clearing of pine savannah and maritime forest habitat, beach and dune modifications, development of canals and channels, and shoreline stabilization by construction of jetties, seawalls, and other structures. Shoreline stabilization measures were employed to curtail further or prevent additional shoreline erosion. Smith (1981) estimated that 1,600 acres of land has been created from dredging. Interestingly, Smith (1981) stated that jetties and seawalls (north Morgan Peninsula) in the coastal zone were successful in the short term at retaining sediment but had almost negligible impacts when compared to the washover deposition associated with hurricanes. Although briefly summarized, shoreline stabilization was not assessed in this study.

Douglass and Pickel (1999a, 1999b) investigated alternatives to bulkheads and the rate of hard shoreline armoring in Mobile Bay. Using field and aerial data this work established that: (1) 30 percent of the shoreline in Mobile Bay was structured with bulkheads, “trash revetments”, and rubble-mound revetments in 1997, an increase of about 22 percent from 1955, (2) shoreline stabilization directly correlates with human development, (3) a loss of intertidal habitat from bulkhead construction reflects as much as 20 acres, and (4) a headland beach and breakwater system is an effective alternative to a bulkhead to minimize the impact to the intertidal zone. The shoreline measurements of Douglass and Pickel (1999) are provided in table 1. Based on field

reconnaissance and aerial data, Douglass and Pickel (1999b) determined that of the 153,400 feet of armored shoreline, 71 percent, 21 percent, and 8 percent were bulkhead, rubble-mound revetment, and trash revetment, respectively. These results indicate that the rate of shoreline armoring between 1955 and 1997 is about 0.5 percent/year on Mobile Bay shoreline. Lastly, Douglass and Pickel (1999b) reported that the relationship between bulkhead and revetment shoreline stabilization, as found in Dog River, Weeks Bay, and Mobile Bay is strongest where fetch is in the order of hundreds of feet, the wave climate is limited to boat wake, and the littoral transport is minimal.

Table 1.—Determined length of armored and natural shoreline in Mobile Bay, Alabama (modified from Douglass and Pickel, 1999a).

Year	Armored	Natural	Area of Significant Change in Shoreline Armoring
1955	39,900 ft (8%)	475,600 ft (92%)	Point Clear, Mullet Point
1974	72,000 ft (14%)	443,500 ft (86%)	Point Clear to Mullet Point, Morgan Peninsula, and slight western Mobile Bay
1985	132,000 ft (26%)	383,500 ft (74%)	West Mobile Bay, Mullet Point to Weeks Bay
1997	153,400 ft (30%)	362,100 ft (70%)	Fairhope to Weeks Bay, west Mobile Bay

METHODOLOGY

This assessment was primarily based on developing shoreline protection and type classification data during field reconnaissance and estimating shoreline rates of change by compiling existing historical orthophotography and developing a shoreline vector modeling database.

Geographic Information System thematic development and modifications were performed using the Environmental Systems Research Institute, Inc. (ESRI®) ArcGIS® ArcInfo® 9.3 platform, ArcCatalog™, and ArcToolbox™. These software provided the necessary tools for data development, management, and portability. One modification to the GIS platform was needed to facilitate data acquisition. The visual basic script for ArcGIS, “legend attribute,” was acquired and installed to attribute polyline and point shapefiles with unique classification entries (Hare, 2006). The script not only promoted initial development of the classifications, but it was

essential for further modification or definition of additional attributes during field data collection (Gallant, 2009).

The color orthophotography or base layer selected for the project is 0.5-meter pixel resolution (mission date: March 2006; horizontal position accuracy: 5 meters) orthophotography collected and processed by Aerials Express, LLC for the U.S. Geological Survey (USGS) in order to supply "best available" orthophotography to end users for urban coverage and pre- and post-hurricane planning in coastal areas (USGS, 2007). Although this image set does not include the middle waters of Mobile Bay or northern Baldwin and Mobile Counties, the resulting file is smaller and coverage outside the project area is eliminated.

It should be noted that because GIS themes were developed, metadata documentation was processed through ArcCatalog and written to provide specific theme reference information such as abstract, purpose, lineage, data quality, time and scale of data, spatial reference, process step(s), attributes, disclaimers, and other information. Metadata was formally parsed using mp 2.7.33 developed by the USGS in October 2002. The function of the mp program is to identify errors within a metadata document that are inconsistent with the Content Standard for Digital Geospatial Metadata (CSDGM) (FGDC, 1998). Every effort was made to identify and correct discrepancies and warnings in compliance with CSDGM while retaining the metadata record as developed by the originator.

Shoreline mapping was conducted using a 20-foot Blue Wave® 200 V-Bay boat (fig. 3) provided by ADCNR and a Fujitsu LifeBook® T5010 tablet personal computer preloaded with GIS software, project base layer orthophotography, and GIS themes. Field data acquisition was expedited through real-time GPS tracking within the GIS and continuous editing of the shapefiles. Shoreline protection and type were classified by visual interpretation. The shoreline protection classification was conducted by evaluating material placed in one of three places: seaward of the shoreline, along the shoreline, or landward of the shoreline. The shoreline was used to classify shoreline type, but when prohibited by shoreline stabilization, type was evaluated landward up to 50 yards behind the shore face to determine the shoreline type. For Phase I, field work began on March 16, 2009, and ended November 6, 2009.

Figure 3. —Project Blue Wave® 200 V-Bay boat.

SHORELINE CLASSIFICATION SCHEME

The initial shoreline protection and shoreline type categories were developed by researching similar mapping projects in other states. Although basic working classification schemes were developed using publications (ACAB, 1980; Smith, 1981; Stewart, 2001; Toft and others, 2003), in cooperation with ADCNR, classifications were modified to fit the characteristics of coastal Alabama. ACAB (1980) pointed out that structural methods of shoreline protection were mainly wood, concrete, or steel bulkheads to minimize wave effects, seawalls to disperse high energy waves, sloped reinforced wall revetments, breakwaters, groins, and jetties; non-structural methods include shoreline restoration and nourishment, nearshore placement, and construction or restoration of wetland and submerged aquatic vegetation. Table 2 represents shoreline protection and type classifications which are illustrated in appendices A and B. In addition to base layer data, the classification aspect consists of four geospatial thematic layers: shoreline protection polylines, shoreline type polylines, public and private boat ramp point locations, and photo point locations.

Table 2. —Shoreline protection and type mapping classifications.

Shore Protection Classification (Shoreline Armoring)	Shoreline Type Classification (Natural Shoreline Characteristics)
1. Natural 2. Seawall (concrete, steel piles) 3. Bulkhead (concrete, rock) 4. Bulkhead (concrete, rock with riprap) 5. Bulkhead (concrete, rock with riprap and groin) 6. Bulkhead (steel, wood) 7. Bulkhead (with groin) 8. Bulkhead (with riprap) 9. Bulkhead (with riprap and groin) 10. Bulkhead (with retaining walls and riprap) 11. Bulkhead (with retaining walls and groin) 12. Bulkhead (with retaining walls) 13. Bulkhead (with riprap and sill) 14. Bulkhead (with riprap, sill, and groin) 15. Bulkhead (with sill) 16. Abutment 17. Revetment 18. Breakwater (offshore) 19. Bioengineered (vegetated) 20. Groin 21. Jetty (steel pile, rock, concrete) 22. Sill (rock, shell) 23. Sill (wood) 24. Sill (wood with riprap) 25. Beach nourishment 26. Rubble/riprap 27. Rubble/riprap (with groin) 28. Rubble/riprap (with tires) 29. Boat ramp 30. Silt fence 31. Tires	1. Artificial 2. Vegetated bank shoreline a. Bluff b. High bank c. Low bank 3. Sediment bank shoreline a. Bluff b. High bank c. Low bank 4. Organic shorelines a. Open shoreline vegetated fringe b. Swamp forest c. Marsh 5. Inlet 6. Pocket beach 7. Rock bank (low)

SHORE PROTECTION CLASSIFICATION

Fourteen categories were designated to describe shore protection. The categories for bulkhead, bioengineered, and sill were further divided using modifiers or subcategories to better depict the types of shoreline protection observed.

Natural, unretained shoreline represents a natural setting with vegetation or sediment exposed and no apparent shoreline modification to protect the land behind it (fig. A1). The natural shore protection classification is commonly associated with wetland environments, undeveloped properties, and protected habitats such as Weeks Bay. Seawalls (fig. A2) and bulkheads (figs. A3 through A13) are sometimes used as interchangeable terms when actually they are different. A seawall can be defined as a structure that provides shoreline protection from wave energy but also retains soil; a bulkhead is a vertical shoreline stabilization structure that primarily retains soil with minimal protection from waves (Blankenship, 2004). Bulkhead, the most common type of shore protection, is a broad category with numerous subtypes. Further modifiers or subdivisions represent the various construction materials (concrete, steel, wood), and convey additional shore protections placed seaward or landward of the bulkhead (groins, riprap, retaining walls).

Rubble/riprap, abutments, revetments, breakwaters, sills, boat ramps, groins, jetties, beach nourishment, and silt fences represent the remaining portion of shore protection types. Concrete or wood abutments are found where bridges intersect most mapped waterways. Mainly cabled concrete mattresses or carefully placed rock revetments are installed as permanent sloping structures along sloping shoreline (fig. A14). Breakwater (fig. A15) shore protection is typically used to dissipate wave energy where natural shoreline is wanted. Breakwaters are constructed some minimal distance offshore and are commonly shoreface detached. Breakwaters may be either fixed or floating depending on the application. Groins are typically associated with bulkheads but can be found isolated (fig. A16). Jetty shore protection is typically associated with an inlet and is constructed normal to slightly oblique to the shoreline (fig. A17). Jetties are also commonly constructed around boat ramps and channels for either industrial or recreational traffic to flow through without running aground on shoals. Although beach nourishment is typically associated with gulf-fronting shorelines, small beach nourishment projects are located on private land and public parks (fig. A18). Rubble/riprap shore protection (figs. 19 through 21) is similar to a revetment except that its installation is not commonly engineered but rather haphazardly placed by the property owner. Material can consist of rock, concrete and wood debris, and tires. Most have no aesthetic value and can take up much of the

seaward shoreline. Constructed mainly from wood, sills are miniature versions of a breakwater designed to break wave action and allow sediment to fall out of suspension as wave energy dissipates (figs. A22 through 24). Boat ramps (fig. A25), silt fencing (fig. A26), and tires (fig. A27) were also classified with shore protection types.

SHORELINE TYPE CLASSIFICATION

Seven categories were designated to describe shoreline type. Several subcategories were developed to better depict shoreline types and are mainly applied to vegetated bank, sediment bank, and organic categories.

Artificial shorelines are shorelines built in areas previously occupied by water. Typically built for industrial and commercial use, examples include causeways, infilling, and shoreline extensions (fig. B1).

Vegetated bank shorelines (figs. B2 through B4) occur where vegetation either meets the water or adjoins landward of shore protection. Three types of vegetated bank are low (0-5 feet above high tide line), high (5-20 feet above high tide line), and bluff (greater than 20 feet above high tide line). The distinction between low, high, and bluff is based on the elevation of the coastline within the first 50 yards behind the shoreline.

Sediment bank shorelines (figs. B5 through B7) occur where sediment either meets the water or meets shore stabilization that is placed in front of the beach for protection. The three types of sediment bank, low, high and bluff, are defined by the same vertical characteristics as vegetated bank.

The organic shoreline classification (figs. B8 though B10) has three subcategories: open shoreline vegetated fringe, marsh, and swamp forest. Open shoreline vegetated fringe occurs where water grasses flourish just in front of the shoreline in shallow water. Marsh shoreline is where saltwater or freshwater marsh habitat adjoins open water. Swamp forest shorelines typically occur where periodically inundated low lying forests meet the shoreline.

The inlet classification (fig. B11) is used where unnavigable tributaries meet the open water, at furthest mapped upstream locations, and in shallow channels within marsh habitat. A pocket beach is mainly located between two shore-normal hard structures (fig. B12).

SHORELINE RATE OF CHANGE

The GSA used the Digital Shoreline Analysis System (DSAS) version 4.0 (Himmelstoss and others, 2009; Thieler and others, 2009) for shoreline change analysis in order to incorporate the inherent benefits of digital data and GIS technology. The DSAS model is an extension that

enhances the normal functionality of ArcGIS to model shoreline change rates and generates statistics from historical shoreline vector data. These data are provided in the GIS project and are attributed to the transect vectors. Incorporating the DSAS model into shoreline monitoring allows for repeatable, first approximation shoreline change analysis, creates an environment suitable for site specific analysis, facilitates updates as needed, and implements an existing modeling tool recognized across governmental agencies. DSAS functionality and attributes are described in the user guide (Morton and others, 2004; Himmelstoss and others, 2009).

Imagery for the years of 1996, 1997, 2001, 2002, 2005, 2006, and 2008 was collected from sources such as the Baldwin County Commission, the Mobile County Department of Revenue, and the United States Geological Survey. These data were evaluated for spatial accuracy using ArcGIS®. Shoreline vectors were created for each year by digitizing the wet/dry line in ArcGIS. This process was conducted at a close (large) scale to minimize spatial error. However, a continuous shoreline vector was not possible due to various factors, including vegetated or canopied shorelines, bulkheads, or other man-made or natural features that obscured or prohibited change of the shoreline. Those segments of shoreline were not digitized. As pointed out by Stewart (2001) and further modified during this study, the use of orthophotography for shoreline vector development and DSAS modeling is limited mainly by the resolution of source orthophotography; availability of historic orthophotography for the study area; and shadows, glare, aquatic vegetation, and over-head obstructions which preclude the development of shoreline vectors. Further, because shoreline erosion is significantly impacted by the presence (or absence) of hard shoreline structures (such as riprap, bulkheads, and revetments) and the dates of recent shoreline stabilization techniques are unknown, shoreline vectors were not developed where hard shoreline protection was mapped. An estimate of error (Table 3) has been calculated for each vector as described in Fletcher and others (2003), Morton and others (2004), and Jones and Patterson (2007).

Table 3.—Shoreline vectors and error estimates used in Digital Shoreline Analysis System (DSAS) reach analysis .

Measurement Errors	1996, 50' (m)	1996, 100' (m)	1996, 200' (m)	1996, 400' (m)	1997 (m)
Rectification Error (E_r)	0.381	0.762	1.524	3.048	1.524
Digitizing Error (E_d)	2	2	2	2	2
T-Sheet Surveying Error (E_t)	0	0	0	0	0
Shoreline Proxy Offset (E_o)	0	0	0	0	0
Lidar Position Error (E_l)	0	0	0	0	0
Total Position Error ($E_{sp)}$	2.04	2.14	2.51	3.65	2.51
	2001 (m)	**2002 (m)**	**2005 (m)**	**2006 (m)**	**2008 (m)**
Rectification Error (E_r)	0.762	1.524	0.762	1.524	3.34
Digitizing Error (E_d)	2	2	2	2	2
T-Sheet Surveying Error (E_t)	0	0	0	0	0
Shoreline Proxy Offset (E_o)	0	0	0	0	0
Lidar Position Error (E_l)	0	0	0	0	0
Total Position Error ($E_{sp)}$	2.14	2.51	2.14	2.51	3.89

A baseline was constructed seaward and parallel to the shoreline trend. Using DSAS modeling, at a 10 meter spacing and perpendicular to the baseline, transects were established from the baseline to the shoreline vectors. Transects were a standard length of 600 meters with the exception of the shoreline near Little Point Clear on Morgan Peninsula, where transects were 50 meters in length to accommodate the close-quartered and circuitous shape of the shoreline in that area. A confidence interval of 90% was applied. Fletcher and others (2003) reported vector error as random, uncorrelated, and unbiased and therefore, it can be absorbed into the confidence interval calculated by the linear regression model.

To prevent inaccurate calculations, select transects were manually eliminated in areas represented by less than three historical shoreline vectors. Data validation included examining transect regression coefficients (R^2). The linear regression statistical technique for expressing shoreline rates of change was applied because it has been shown to be the most statistically robust quantitative method when limited data are available (Crowell and others, 1997; Crowell and Leatherman, 1999). The DSAS model calculates the correlation coefficient (R^2) and standard error of estimate (LSE) and these values were also evaluated. The standard error of estimate supports the accuracy of the rate prediction of shoreline change. Morton and others (2004) considered linear regression to be adequate only as a first approximation for shoreline change estimates because of inherent nonlinear behavior.

RESULTS

SHORELINE MAPPING

The results are broken up into sections. Mobile Bay (fig. 2) is divided into southwest Mobile Bay (Cedar Point to the mouth of Fowl River), west-central Mobile Bay (Fowl River to Dog River), northwest Mobile Bay (Dog River to McDuffie Island), north Mobile Bay (McDuffie Island along the I-10 to Daphne and Ragged Point), northeast Mobile Bay (Ragged Point to Point Clear), east-central Mobile Bay (Point Clear to Fish River Point), and southeast Mobile Bay (Fish River Point to Bon Secour River). Morgan Peninsula is divided into east Morgan Peninsula (Bon Secour River to Edith Hammock) and west Morgan Peninsula. Sections are included for Weeks Bay and the tributaries Fish River, Magnolia River, Deer River system, and Fly Creek. The photo index point theme, as seen on following illustrations, shows locations of photos taken for new shore protection or shoreline types.

SOUTHWEST MOBILE BAY

SHORE PROTECTION

Shore protection in southwest Mobile Bay is very diverse having eleven different types of shore protection observed, which are classified as follows: boat ramps, bulkhead (concrete, rock), bulkhead (steel, wood), bulkhead (with retaining walls), bulkhead (with groin), bulkhead (with riprap), bulkhead (with riprap and groin), bulkhead (with retaining walls and riprap), natural, revetment, and rubble/riprap. The detailed shore protection values for southwest Mobile Bay are listed in table 4. These shore protection types make up 58,714 feet, or about 11.1 miles, of shore protection that were encountered in southwest Mobile Bay. Figure 4 illustrates the distribution of shore protection in southwest Mobile Bay.

The longest portion of shore protection in southwest Mobile Bay is bulkhead having about 29,371 feet (5.6 miles) or about 50.0 percent of the total shore protection mapped. Bulkhead (with riprap) and bulkhead (steel, wood) shore protections are the longest of the eight bulkhead subdivisions and are about 13,287 feet (2.5 miles) or about 22.6 percent and 12,425 feet (2.4 miles) or about 21.2 percent of the total shore protection in southwest Mobile Bay, respectively.

Table 4.— Southwest Mobile Bay shore protection classification lengths and percentages.

Southwest Mobile Bay		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat Ramp	137	0.2
Bulkhead (concrete, rock with riprap)	186	0.3
Bulkhead (concrete, rock)	481	0.8
Bulkhead (steel, wood)	12,425	21.2
Bulkhead (with groin)	464	0.8
Bulkhead (with retaining walls and riprap)	424	0.7
Bulkhead (with retaining walls)	1,748	3.0
Bulkhead (with riprap and groin)	356	0.6
Bulkhead (with riprap)	13,287	22.6
Groin	557	0.9
Natural	21,157	36.0
Revetment	90	0.2
Rubble/riprap	7,100	12.1
Rubble/riprap (with groin)	300	0.5
Total	58,714	100.0

Natural, unretained shoreline makes up about 21,157 feet (4.0 miles) or about 36.0 percent of the total shore protection in southwest Mobile Bay. Other classifications of shore protection include rubble/riprap (7,100 feet or about 12.1 percent), groins (557 feet or 0.9 percent), and revetment (90 feet or about 0.2 percent). One private boat ramp and three public boat ramps were present, totaling making up about 137 linear feet, or about 0.2 percent, of the total shore protection in the southwest Mobile Bay section.

In summary, southwest Mobile Bay consists mainly of hard shore protection. There are about 11.1 miles of shoreline in southwest Mobile Bay with 7.1 miles or 63.9 percent having hard shore protection; 4 miles or 36.0 percent having unretained, natural shoreline. The main hard shore protection in southwest Mobile Bay is from bulkheads having 5.6 miles or 50 percent of the total hard shore protection.

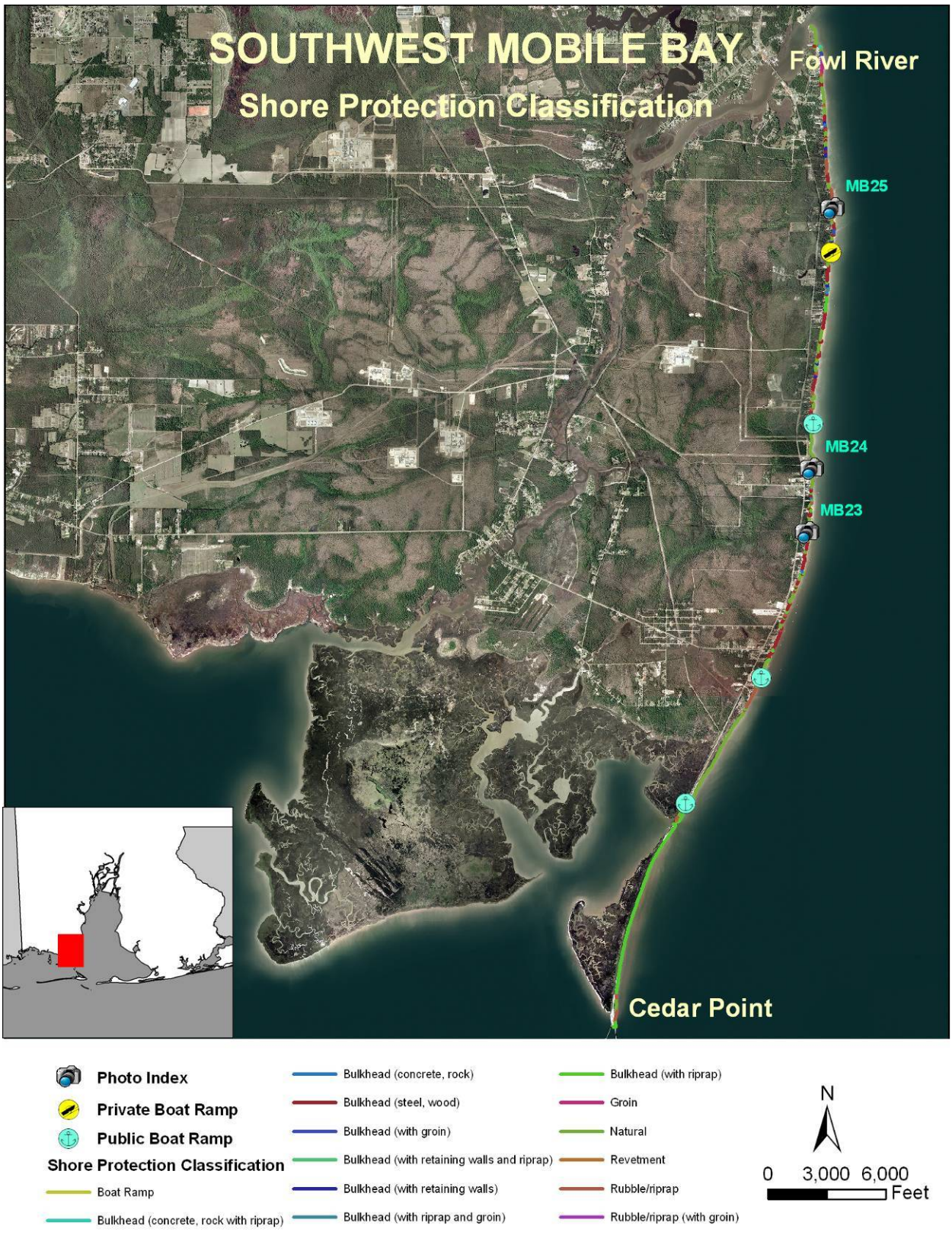

Figure 4.—Shore protection classification map of southwest Mobile Bay.

SHORELINE TYPES

There were eight different shoreline types identified in southwest Mobile Bay which were classified as follows: artificial, inlet, organic (open, vegetated fringe), organic (swamp forest), sediment bank (high), sediment bank (low), vegetated bank (high), and vegetated bank (low). Detailed shoreline type values for the southwest Mobile Bay are listed in table 5. Figure 5 illustrates the distribution of the shoreline types in southwest Mobile Bay.

Vegetated bank shoreline makes up about 30,555 feet (5.8 miles) or about 52.3 percent of the total shoreline mapped in southwest Mobile Bay. Occurring along roadways, artificial shoreline type makes up about 13,299 feet (2.5 miles) or about 22.8 percent of the total. Sediment bank makes up about 8,701 feet (1.6 miles) or about 14.9 percent of the total shoreline type mapped in this section. Organic shoreline type makes up about 5,711 feet (1.1 miles) or about 9.8 percent. Four inlets or about 112 feet of this shore type were mapped.

Table 5.— Southwest Mobile Bay shoreline type classification lengths and percentages.

Southwest Mobile Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	13,299	22.8
Inlet	112	0.2
Organic (open, vegetated fringe)	5,145	8.8
Organic (swamp forest)	566	1.0
Sediment bank (high, 5 - 20 ft)	5,491	9.4
Sediment bank (low, 0 - 5 ft)	3,210	5.5
Vegetated bank (high, 5 - 20 ft)	14,131	24.2
Vegetated bank (low, 0 - 5 ft)	16,424	28.1
Total	58,378	100.0

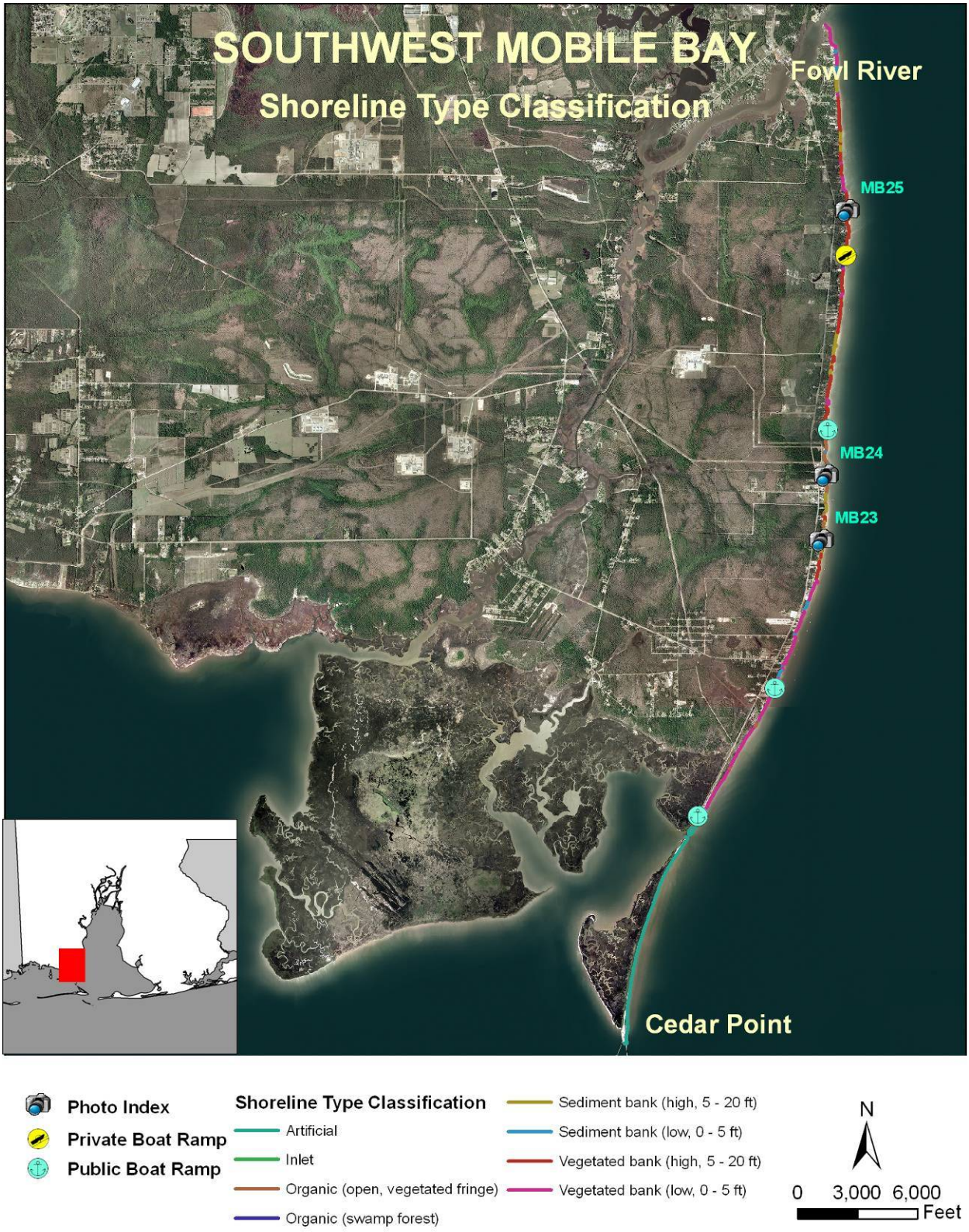

Figure 5.—Shoreline type classification map of southwest Mobile Bay.

WEST-CENTRAL MOBILE BAY

SHORE PROTECTION

Like southwest Mobile Bay, there are numerous shore protection types in west-central Mobile Bay. Fourteen were mapped including boat ramp, bulkhead (concrete, rock), bulkhead (steel, wood), bulkhead (with groin), bulkhead (with riprap and groin), bulkhead (with riprap and sill), bulkhead (with riprap), bulkhead (with sill), groin, natural, revetment, rubble/riprap, rubble/riprap (with groin) and sill (wood). About 93,710 feet (17.8 miles) of shore protection were mapped and the results are tabulated in table 6. Figure 6 illustrates the distribution of shore protection in west-central Mobile Bay.

Table 6.— West-central Mobile Bay shore protection classification lengths and percentages.

West-central Mobile Bay		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat Ramp	102	0.1
Bulkhead (concrete, rock)	2,755	2.9
Bulkhead (steel, wood)	12,578	13.4
Bulkhead (with groin)	2,642	2.8
Bulkhead (with riprap and groin)	384	0.4
Bulkhead (with riprap and sill)	67	0.1
Bulkhead (with riprap)	2,754	2.9
Bulkhead (with sill)	52	0.1
Groin	182	0.2
Natural	62,049	66.2
Revetment	5,444	5.8
Rubble/riprap	3,787	4.0
Rubble/riprap (with groin)	429	0.5
Sill (wood)	485	0.5
Total	93,710	100.0

The predominant type of shoreline in west-central Mobile Bay is natural, unretained having about 62,049 feet (11.8 miles) or about 66.2 percent of the total mapped. Bulkhead (steel, wood) shore protection, longest of the seven types of bulkheads, makes up about 12,578 feet (2.4 miles) or about 13.4 percent of the total shore protection in west-central Mobile Bay. Rock revetment shore protection makes up about 5,444 feet (~ 1mile) or about 5.8 percent of the total shore protection in west-central Mobile Bay. Rubble/riprap shore protection makes up about 3,787 feet or about 4.0 percent of the total shore protection in west-central Mobile Bay.

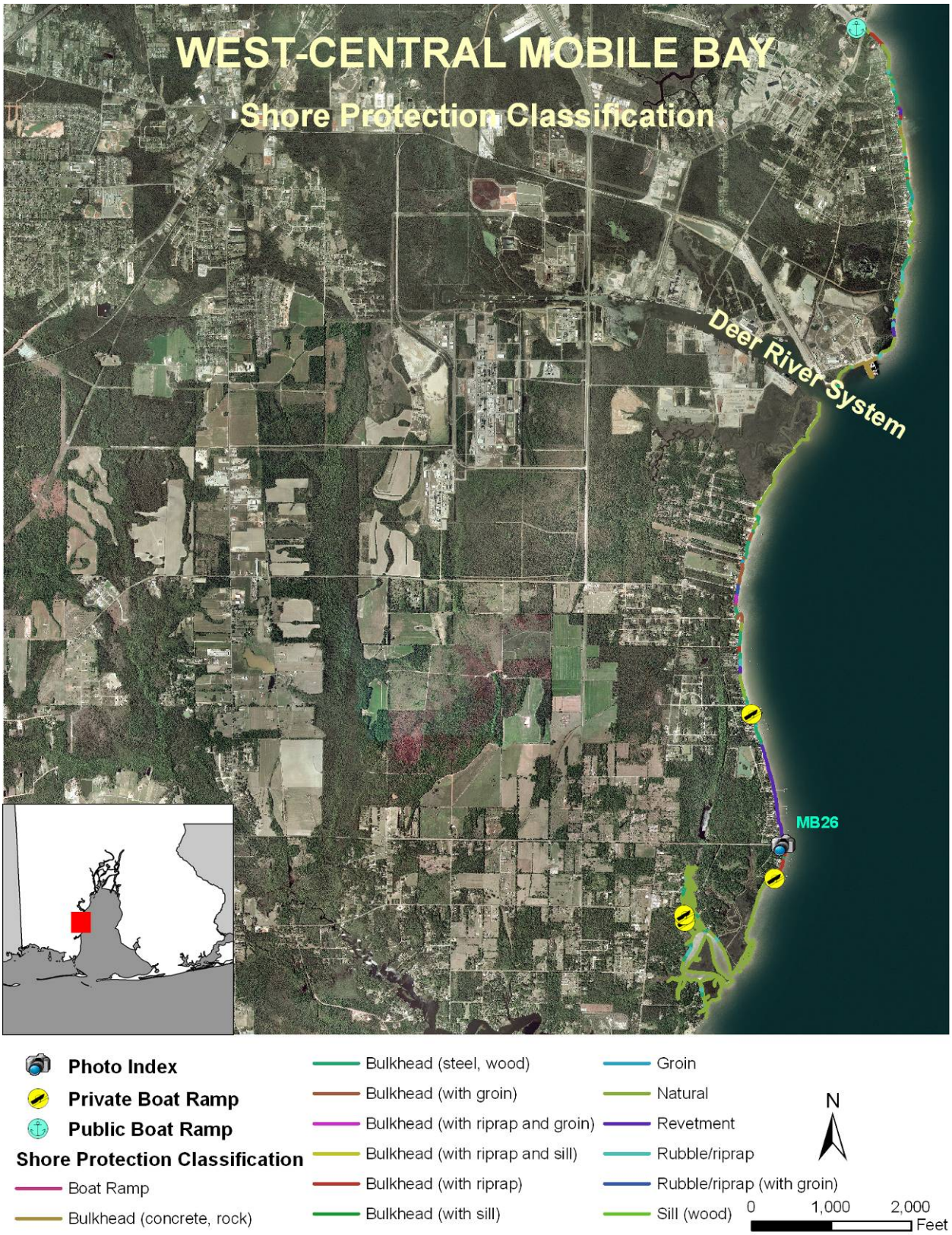

Figure 6.—Shore protection classification map of west-central Mobile Bay.

Sill (wood), groins, and other bulkhead types compose the remaining types of shore protection. Two private and one public boat ramp were mapped making up about 102 linear feet (0.1 percent) of the total shore protection in west-central Mobile Bay.

Of an estimated 17.8 miles of shore protection in west-central Mobile Bay, 6.0 miles or 33.8 percent has hard shoreline protection. The main stabilization structure in west-central Mobile Bay is bulkheads at about 4.0 miles (22.7 percent of the total hard shore protection).

SHORELINE TYPES

Listed in table 7 with tabulated lengths and percentages, nine different shoreline types were mapped in west-central Mobile Bay; organic (marsh) and vegetated bank (low) were the most dominant. An estimated 93,581 feet, or about 17.7 miles, were mapped in west-central Mobile Bay. The distribution of shoreline types is depicted in figure 7. Organic shoreline type makes up about 40,232 feet (7.6 miles) or about 43.0 percent of the total shoreline type in west-central Mobile Bay. Vegetated bank and sediment bank shoreline types make up about 39,321 feet (7.4 miles) or about 42.0 percent, and 11,373 feet (2.2 miles) or about 12.2 percent of the total shoreline type, respectively. Artificial shoreline type makes up about 2,410 feet or about 2.6 percent of the total shoreline type in west-central Mobile Bay. There were seven inlets identified in west-central Mobile Bay.

Table 7.— West-central Mobile Bay shoreline type classification lengths and percentages.

West-central Mobile Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	2,410	2.6
Inlet	247	0.3
Organic (marsh)	29,640	31.7
Organic (open, vegetated fringe)	9,622	10.3
Organic (swamp forest)	970	1.0
Sediment bank (high, 5 - 20 ft)	1,751	1.9
Sediment bank (low, 0 - 5 ft)	9,622	10.3
Vegetated bank (high, 5 - 20 ft)	16,913	18.1
Vegetated bank (low, 0 - 5 ft)	22,408	23.9
Total	93,581	100.0

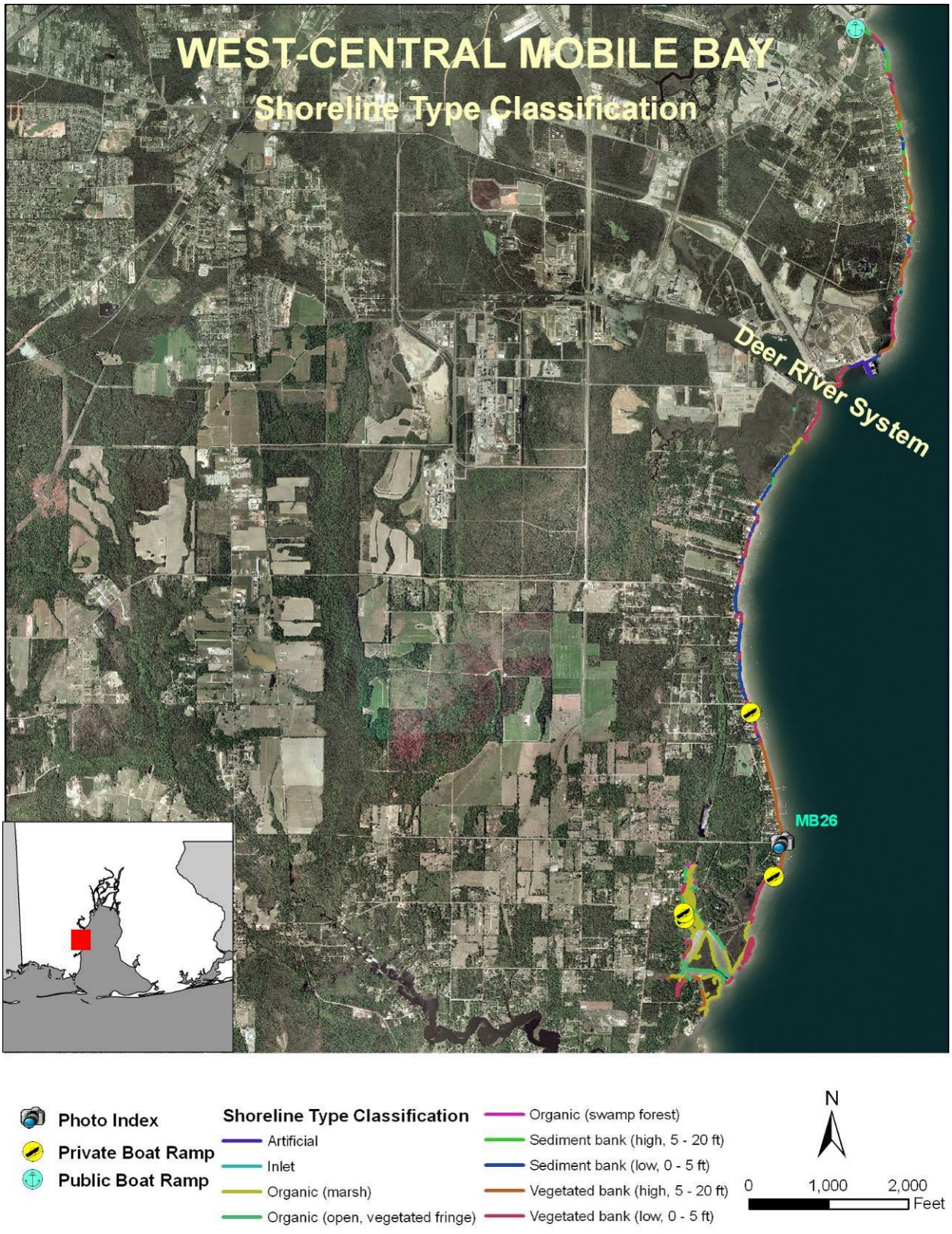

Figure 7.—Shoreline type classification map of west-central Mobile Bay.

NORTHWEST MOBILE BAY

SHORE PROTECTION

Shore protection in northwest Mobile Bay is very diverse having twelve different types classified with bulkhead (concrete, rock), bulkhead (steel, wood), natural, and rubble/riprap most prominent. Rubble/riprap (with tires), seawall (concrete, steel piles), jetty (steel pile, rock, concrete), and bioengineered (vegetated) were documented as well. The detailed shore protection values for northwest Mobile Bay are listed in table 8. Mapped in northwest Mobile Bay were 101,353 feet (19.2 miles) of shore protection. Figure 8 illustrates the distribution of shore protection in northwest Mobile Bay.

Table 8.— Northwest Mobile Bay shore protection classification lengths and percentages.

Northwest Mobile Bay		
Shore protection classification	**Length (ft)**	**Percent (%)**
Bioengineered (vegetated)	1,325	1.3
Boat Ramp	97	0.1
Bulkhead (concrete, rock with riprap)	1,318	1.3
Bulkhead (concrete, rock)	5,210	5.1
Bulkhead (steel, wood)	4,934	4.9
Bulkhead (with groin)	469	0.5
Bulkhead (with riprap)	2,460	2.4
Jetty (steel pile, rock, concrete)	1,746	1.7
Natural	50,781	50.1
Rubble/riprap	32,137	31.7
Rubble/riprap (with tires)	47	0.0
Seawall (concrete, steel piles)	829	0.8
Total	101,353	100.0

The dominant shore protection classification in northwest Mobile Bay is natural, having about 50,781 feet (9.6 miles), or about 50.1 percent, of the total shore protection. Rubble/riprap shore protection makes up about 32,137 feet (6.1 miles), or about 31.7 percent, of the total shore protection in northwest Mobile Bay. Of the five types of bulkheads documented, bulkhead (concrete, rock) and bulkhead (steel, wood) shore protection make up about 5,210 feet (~ 1 mile; 5.1 percent) and 4,934 feet (4.9 percent) of the total shore protection mapped, respectively. There were two private boat ramps and one public boat ramp encountered in northwest Mobile Bay making up about 97 linear feet of shore protection.

Figure 8.—Shore protection map classification of northwest Mobile Bay.

Shore protection in northwest Mobile Bay comprises both engineered and natural types. There are about 19.2 miles of shoreline in northwest Mobile Bay with 9.6 miles or 50.0 percent having natural shore protection and 9.6 miles or 50.0 percent having engineered shore protection. The main hard shore protection in northwest Mobile Bay is from rubble/riprap comprising 6.1 miles or 31.7 percent of the total hard shore protection.

SHORELINE TYPES

Shoreline types identified in northwest Mobile Bay include: artificial, inlet, organic (marsh), organic (open, vegetated fringe), sediment bank (high), sediment bank (low), vegetated bank (bluff), vegetated bank (high) and vegetated bank (low). Shoreline type values for northwest Mobile Bay are tabulated in table 9. These shoreline types make up 100,389 feet or about 19.0 miles mapped. Figure 9 illustrates the distribution of the shoreline types mapped in northwest Mobile Bay.

Table 9.— Northwest Mobile Bay shoreline type classification lengths and percentages.

Northwest Mobile Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	15,417	15.4
Inlet	154	0.2
Organic (marsh)	15,969	15.9
Organic (open, vegetated fringe)	10,072	10.0
Sediment bank (high, 5 - 20 ft)	258	0.3
Sediment bank (low, 0 - 5 ft)	7,513	7.5
Vegetated bank (bluff, > 20 ft)	587	0.6
Vegetated bank (high, 5 - 20 ft)	26,929	26.8
Vegetated bank (low, 0 - 5 ft)	23,490	23.4
Total	100,389	100.0

Vegetated bank shoreline type makes up about 51,006 feet (9.7 miles) or 50.8 percent of the total. Organic shoreline type makes up about 26,040 feet (4.9 miles; 25.9 percent of the total). Artificial and sediment bank shoreline types makes up about 15,417 feet (2.9 miles; 15.4 percent) and 7,771 feet (1.5 miles; 7.7 percent) of the total shoreline type mapped in northwest Mobile Bay, respectively. There were three inlets encountered in northwest Mobile Bay totaling 154 linear feet.

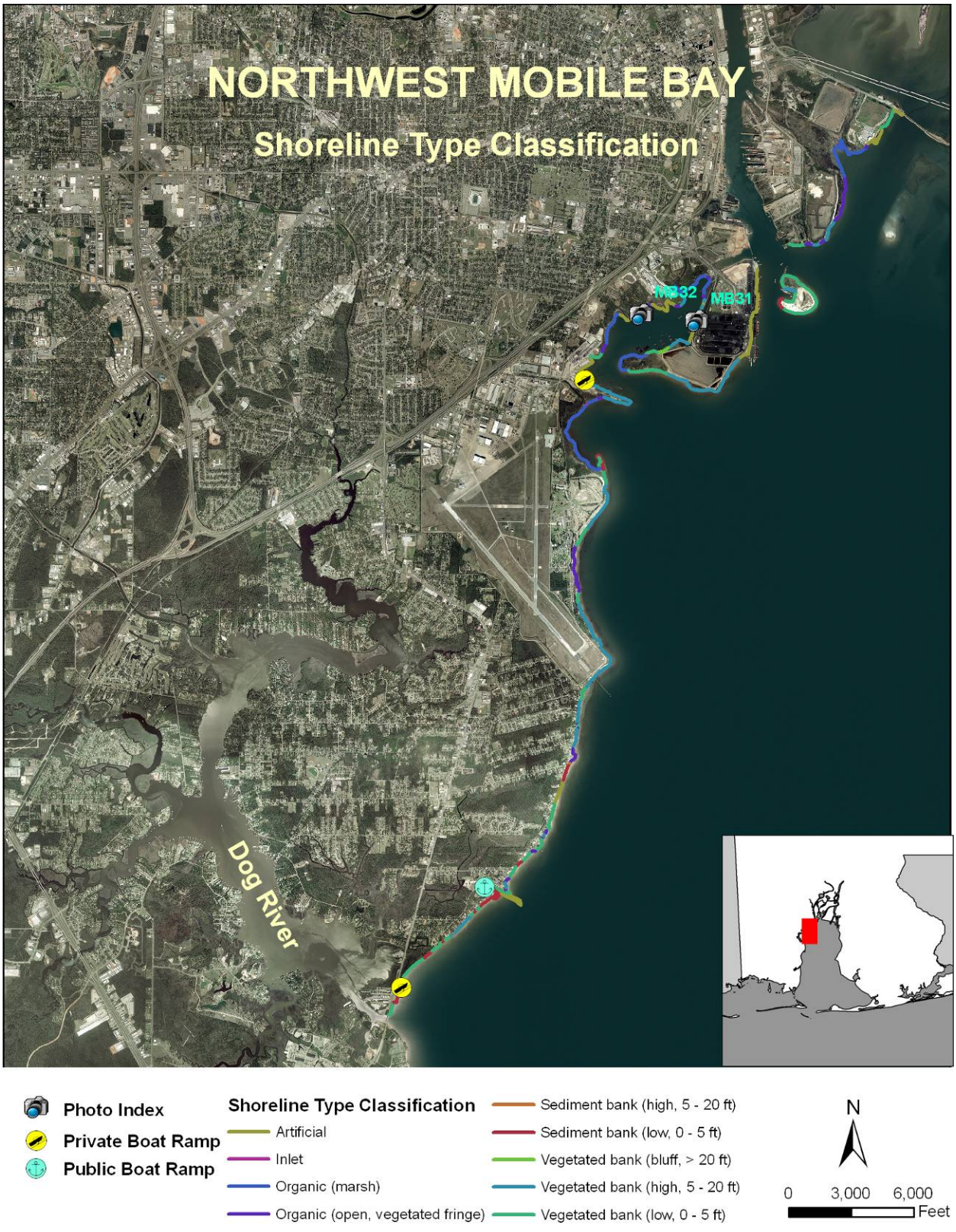

Figure 9.—Shoreline type classification map of northwest Mobile Bay.

NORTH MOBILE BAY

SHORE PROTECTION

Ten types of shore protection were identified along and adjacent to the Mobile Bay Causeway (U.S. 90/98) in north Mobile Bay, including: abutment, boat ramp, bulkhead (concrete, rock), bulkhead (concrete, rock with riprap), bulkhead (steel, wood), bulkhead (with retaining walls), bulkhead (with riprap), natural, revetment and rubble/riprap. The detailed shore protection values for the north Mobile Bay are listed in table 10. These shore protection types make up about 135,727 feet (25.7 miles) of shore protection that were mapped. Figure 10 illustrates the distribution of shore protection on the north Mobile Bay.

Table 10.— North Mobile Bay shore protection classification lengths and percentages.

North Mobile Bay		
Shore protection classification	**Length (ft)**	**Percent (%)**
Abutment	95	0.1
Boat Ramp	80	0.1
Bulkhead (concrete, rock with riprap)	5,475	4.0
Bulkhead (concrete, rock)	3,082	2.3
Bulkhead (steel, wood)	947	0.7
Bulkhead (with retaining walls)	206	0.2
Bulkhead (with riprap)	1,041	0.8
Natural	121,951	89.9
Revetment	287	0.2
Rubble/riprap	2,563	1.9
Total	135,727	100.0

The predominant shore protection classification was natural, unretained at about 121,951 feet (23.1 miles; 89.9 percent of the total). The main two hard structures were bulkhead (concrete, rock with riprap) and bulkhead (concrete, rock) at about 5,475 feet (~ 1 mile; 4.0 percent) and 3,082 feet (2.3 percent) of the total, respectively. Rubble/riprap shore protection makes up about 2,563 feet or about 1.9 percent of the total shore protection on the Mobile Bay Causeway. One private and one public boat ramp were encountered in northern Mobile Bay totaling about 80 linear feet of shoreline.

Because of shoal and marsh habitat south and adjoining the Mobile Bay Causeway, north Mobile Bay consists mainly of natural shore protection. There is about 25.7 miles of shoreline on the north Mobile Bay with 23.1 miles or 89.9 percent having natural shore protection and 2.6 miles or 10.1 percent having engineered shore protection.

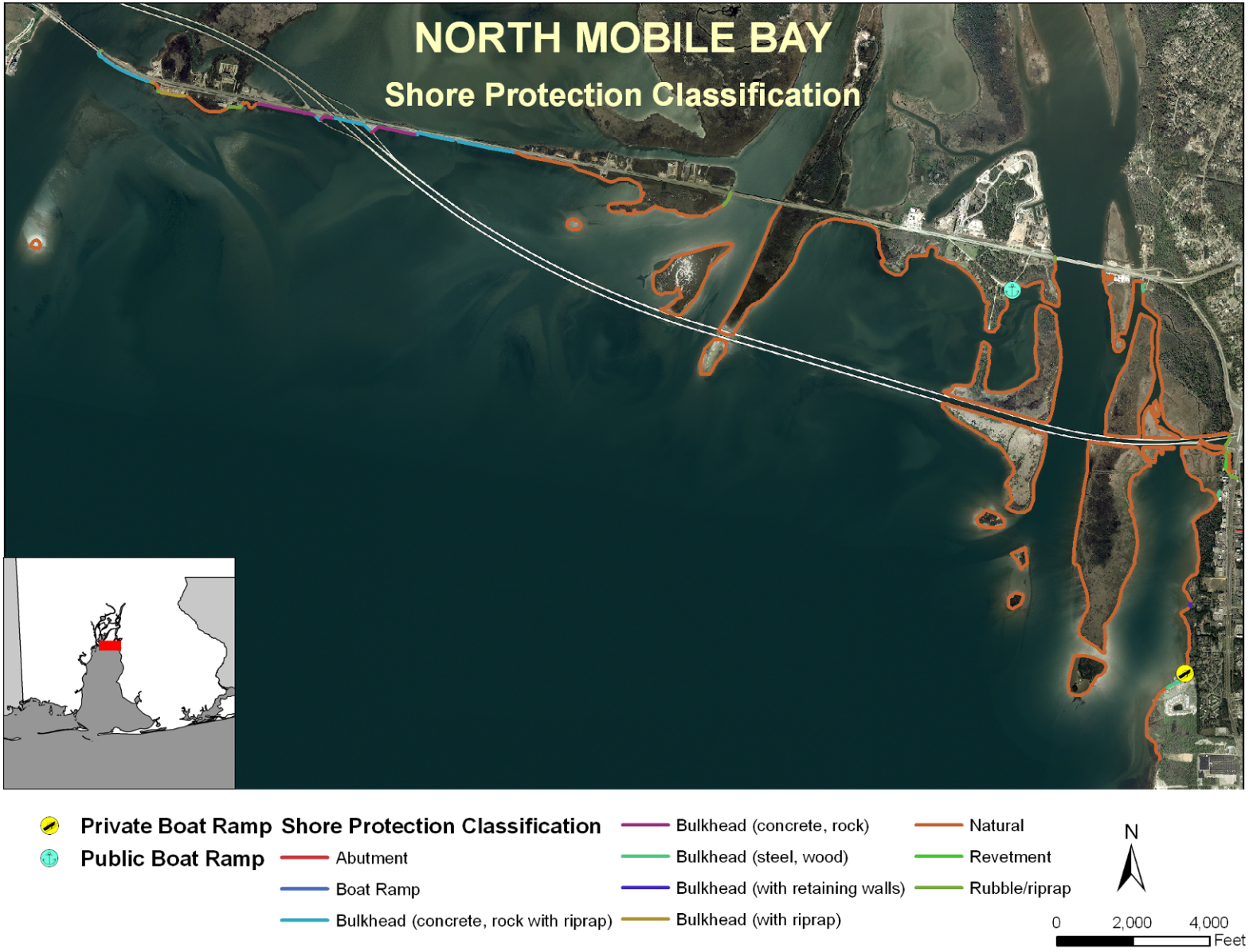

Figure 10.—Shore protection classification map of north Mobile Bay area.

The main engineered shore protection in north Mobile Bay is from bulkheads totaling 2.0 miles or 7.9 percent of the total shore protection.

SHORELINE TYPES

There are nine different types of shoreline identified along and adjacent to the Mobile Bay Causeway in north Mobile Bay, which were classified as follows: artificial, inlet, organic (marsh), organic (open, vegetated fringe), organic (swamp forest), sediment bank (low), sediment bank (high), vegetated bank (high) and vegetated bank (low). The detailed shoreline type values for north Mobile Bay are tabulated in table 11. Figure 11 illustrates the distribution of the shoreline types.

Table 11.— North Mobile Bay shoreline type classification lengths and percentages.

North Mobile Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	10,524	7.7
Inlet	364	0.3
Organic (marsh)	82,798	60.9
Organic (open, vegetated fringe)	29,957	22.1
Organic (swamp forest)	1,755	1.3
Sediment bank (high, 5 - 20 ft)	369	0.3
Sediment bank (low, 0 - 5 ft)	706	0.5
Vegetated bank (high, 5 - 20 ft)	1,992	1.5
Vegetated bank (low, 0 - 5 ft)	7,381	5.4
Total	135,847	100.0

The dominant shoreline type for north Mobile Bay is organic making up about 114,510 feet (21.7 miles), or about 84.3 percent, of the total shoreline. Artificial shoreline type makes up about 10,524 feet (2.0 miles), or about 7.7 percent of the total shoreline type in north Mobile Bay. Vegetated bank shoreline type makes up about 9,373 feet (1.8 miles) or about 6.9 percent of the total shoreline type in north Mobile Bay. Sediment bank shoreline type makes up about 1,075 feet, or about 0.8 percent, of the total shoreline type in north Mobile Bay. There were only four inlets identified in accessible areas along and adjacent to north Mobile Bay (364 linear feet).

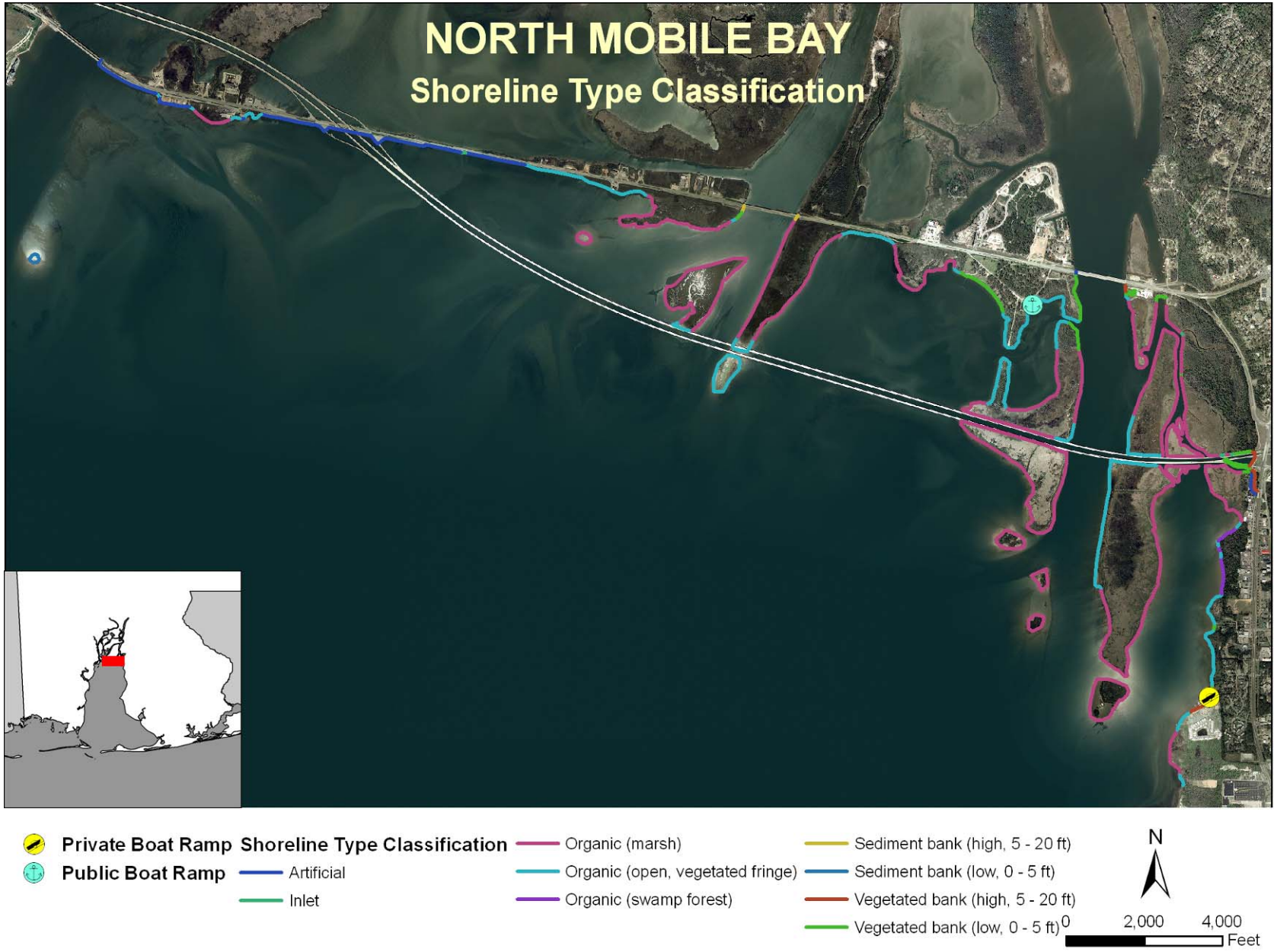

Figure 11.—Shoreline type classification map of north Mobile Bay area.

NORTHEAST MOBILE BAY

SHORE PROTECTION

Numerous shore protection types were mapped in northeast Mobile Bay and were classified as follows: beach nourishment, boat ramp, bulkhead (concrete, rock), bulkhead (steel, wood), bulkhead (with groin), bulkhead (with retaining walls and groin), bulkhead (with retaining walls), bulkhead (with riprap and groin), bulkhead (with riprap), groin, jetty (steel pile, rock, concrete), natural, revetment, rubble/riprap, and seawall (concrete, steel piles). The tabulation and depiction of distribution of shore protection data are in table 12 and figure 12, respectively.

Table 12.— Northeast Mobile Bay shore protection classification lengths and percentages.

Northeast Mobile Bay		
Shore protection classification	**Length (ft)**	**Percent (%)**
Beach Nourishment	2,730	4.1
Boat Ramp	157	0.2
Bulkhead (concrete, rock)	2,326	3.5
Bulkhead (steel, wood)	10,839	16.2
Bulkhead (with groin)	9,861	14.8
Bulkhead (with retaining walls and groin)	306	0.5
Bulkhead (with retaining walls)	650	1.0
Bulkhead (with riprap and groin)	163	0.2
Bulkhead (with riprap)	3,587	5.4
Groin	2,075	3.1
Jetty (steel pile, rock, concrete)	352	0.5
Natural	30,130	45.2
Revetment	178	0.3
Rubble/riprap	647	1.0
Seawall (concrete, steel piles)	2,711	4.1
Total	66,712	100.0

The natural, unretained shoreline type classification makes up about 30,130 feet (5.7 miles), or about 45.2 percent, of the total shore protection. Bulkhead (steel, wood) makes up 10,839 feet (2.0 miles), or 16.2 percent, of the total; bulkhead (with groin) protection makes up about 9,861 feet (1.9 miles), or about 14.8 percent, of the total. The remaining bulkhead types account for 7,032 feet (1.3 miles), or 10.6 percent, of the total. Only three public boat ramps were mapped.

Northeast Mobile Bay consists mainly of engineered shore protection. About 12.6 miles of shoreline were documented in northeast Mobile Bay with 6.9 miles, or 54.8 percent, having engineered shore protection and 5.7 miles, or 45.2 percent, having natural shore protection. The

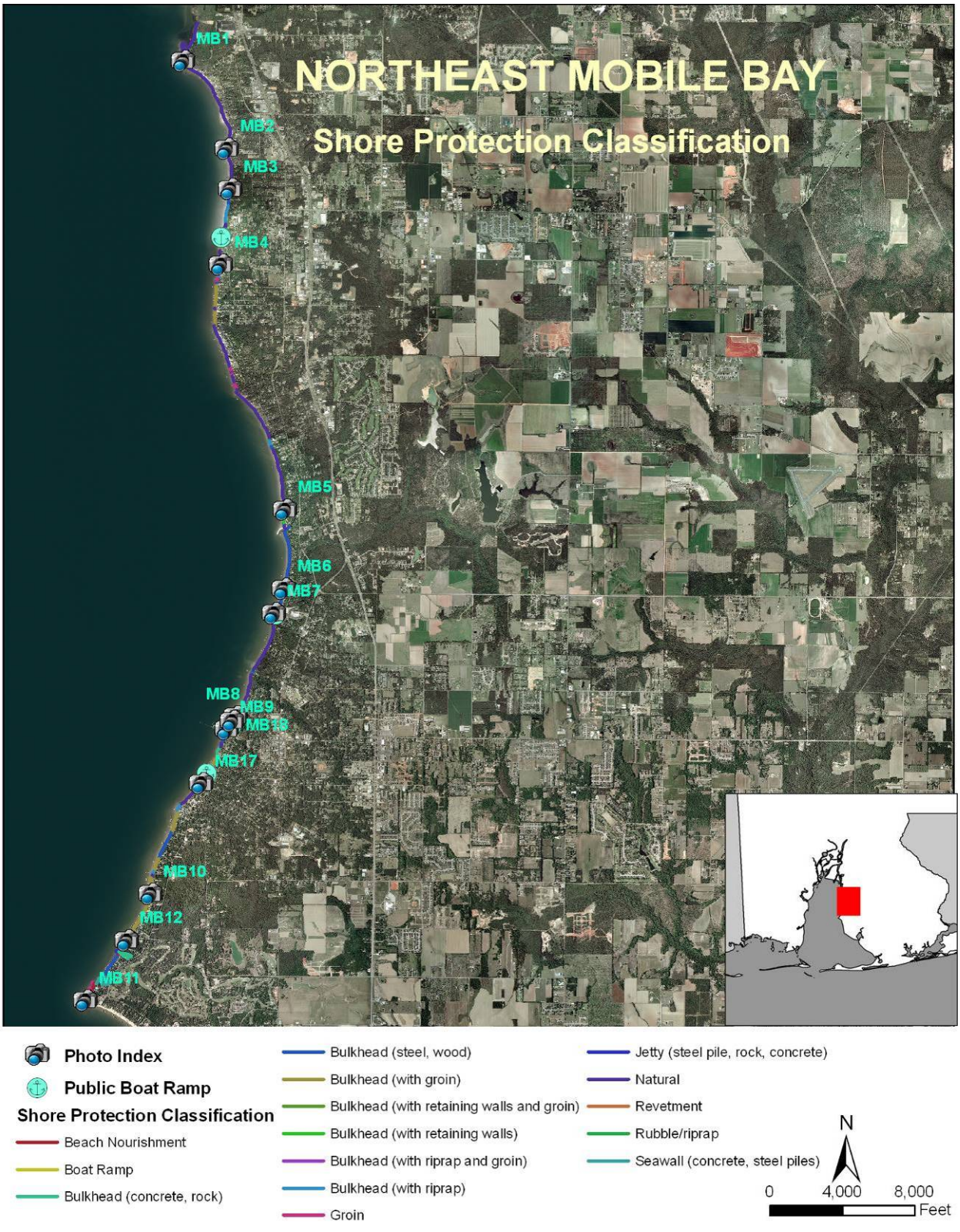

Figure 12.—Shore protection classification map of northeast Mobile Bay.

most common engineered shore protection in northeast Mobile Bay is bulkheads having 5.3 miles, or 41.6 percent, of the total shore protection.

SHORELINE TYPES

The different shoreline types identified in northeast Mobile Bay include inlet, organic (open, vegetated fringe), sediment bank (low), sediment bank (high), vegetated bank (low), vegetated bank (high), and vegetated bank (bluff) (table 13). Figure 13 illustrates the distribution of the shoreline types in northeast Mobile Bay.

Table 13.— Northeast Mobile Bay shoreline type classification lengths and percentages.

Northeast Mobile Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	1,662	2.4
Inlet	748	1.1
Organic (open, vegetated fringe)	2,277	3.3
Sediment bank (bluff, > 20 ft)	4,631	6.8
Sediment bank (high, 5 - 20 ft)	6,191	9.1
Sediment bank (low, 0 - 5 ft)	23,640	34.7
Vegetated bank (bluff, >20 ft)	8,576	12.6
Vegetated bank (high, 5 - 20 ft)	6,097	8.9
Vegetated bank (low, 0 - 5 ft)	13,399	19.7
Total	68,132	100.0

The dominant shoreline type in northeast Mobile Bay is sediment bank making up about 34,462 feet (6.5 miles), or about 50.6 percent, of the total shoreline type. Vegetated bank shoreline makes up about 28,072 feet (5.3 miles), or about 41.2 percent, of the total shoreline type. Organic (open, vegetated fringe) makes up about 2,277 feet or about 3.4 percent of the total shoreline type. There were eighteen inlets identified mapped comprising of 748 linear feet or about 1.1 percent of the total shoreline type.

EAST-CENTRAL MOBILE BAY

SHORE PROTECTION

Shore protection in east-central Mobile Bay is very diverse having sixteen different types of shore protection encountered which were classified as follows: beach nourishment, boat ramp, breakwater (offshore), six types of bulkheads, groin, jetty (steel pile, rock, concrete), natural, revetment, rubble/riprap, seawall (concrete, steel piles) and sill (rock, shell). Shore

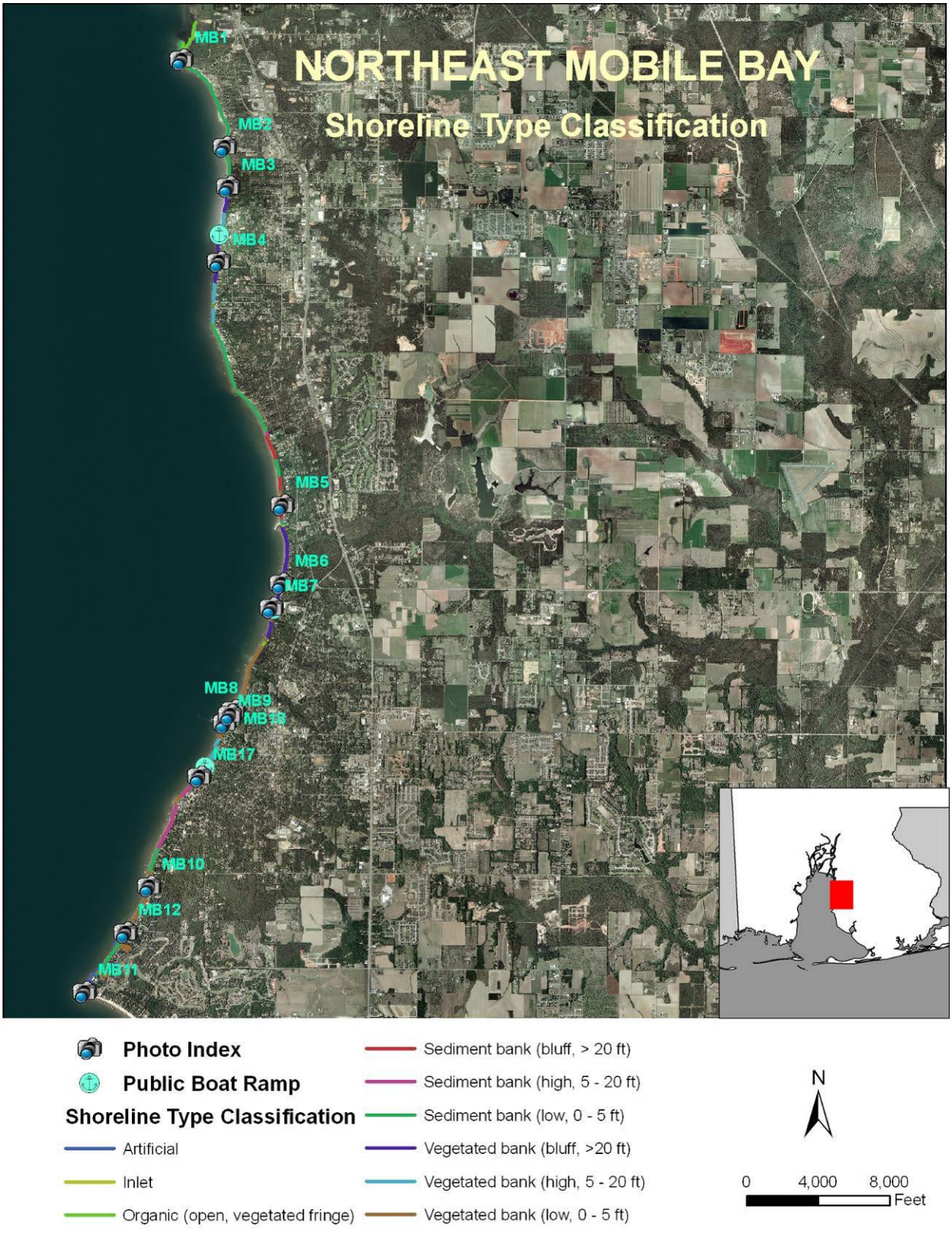

Figure 13.—Shoreline type classification map of northeast Mobile Bay.

protection values are tabulated in table 14. Figure 14 is an illustration of the distribution of shore protection in east-central Mobile Bay.

Table 14.— East-central Mobile Bay shore protection classification lengths and percentages.

East-central Mobile Bay		
Shore protection classification	**Length (ft)**	**Percent (%)**
Beach Nourishment	211	0.4
Boat Ramp	43	0.1
Breakwater (offshore)	102	0.2
Bulkhead (concrete with riprap and groin)	299	0.5
Bulkhead (steel, wood)	14,433	24.6
Bulkhead (with groin)	16,852	28.7
Bulkhead (with riprap)	7,192	12.3
Bulkhead (with riprap and groin)	3,257	5.6
Bulkhead (concrete with riprap)	73	0.1
Groin	2,168	3.7
Jetty (steel pile, rock, concrete)	167	0.3
Natural	10,303	17.6
Revetment	797	1.4
Rubble/riprap	1,907	3.3
Seawall (concrete, steel piles)	320	0.5
Sill (rock, shell)	540	0.9
Total	58,665	100.0

The dominant shore protection type in east-central Mobile Bay is bulkhead making up 42,106 feet (8.0 miles) or 71.8 percent of the total shore protection. Bulkhead (with groin) is the longest representing about 16,852 feet (3.2 miles) or about 28.7 percent of the total. Natural, unretained shoreline makes about 10,303 feet (2 miles) or about 17.6 percent of the total. There were 2 private boat ramps classified in east-central Mobile Bay making up about 43 linear feet or about 0.1 percent of the total shore protection.

East-central Mobile Bay consists mainly of hard shore protection. There is about 58,665 feet (11.1 miles) of shore protection in east-central Mobile Bay, where 9.2 miles or 82.4 percent is hard shore protected and 3.8 miles or 19.9 percent natural shoreline. The main hard shore protection in east-central Mobile Bay is from bulkheads comprising of 8.0 miles or 71.8 percent of the total hard shore protection.

Figure 14.—Shore protection classification map of east-central Mobile Bay.

SHORELINE TYPES

Five different shoreline types were mapped in east-central Mobile Bay: artificial, inlet, organic (open, vegetated fringe), sediment bank (low), and vegetated bank (low). All classifications are tabulated in table 15, and figure 15 illustrates the distribution of the shoreline types in east-central Mobile Bay. Vegetated bank (low) shoreline type makes up about 46,126 feet (8.7 miles) or about 79.2 percent of the total. The second largest type mapped is sediment bank (low) with about 9,720 feet (1.8 miles) or about 16.7 percent of the total. Five inlets identified make up about 144 linear feet or 0.2 percent of the total shoreline type.

Table 15.— East-central Mobile Bay shoreline type classification lengths and percentages.

East-central Mobile Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	801	1.4
Inlet	144	0.2
Organic (open, vegetated fringe)	1,421	2.4
Sediment bank (low, 0 - 5 ft)	9,720	16.7
Vegetated bank (low, 0 - 5 ft)	46,126	79.2
Total	58,211	100.0

SOUTHEAST MOBILE BAY

SHORE PROTECTION

The southeast portion of Mobile Bay is mainly undeveloped and within the Weeks Bay National Estuarine Research Reserve, and therefore much bay-front real estate is possibly restricted from hard shore stabilization. Eight different types of shore protection were classified in southeast Mobile Bay, which included boat ramp, three types of bulkheads, groin, jetty (steel pile, rock, concrete), natural, and rubble/riprap. Tabulated data and the distribution of shore protection for southeast Mobile Bay are in table 16 and figure 16, respectively. Natural, unretained shore protection is the longest of the shore protection types making up about 37,252 feet (7.1 miles) or about 85.6 percent of the total. Bulkhead (with groin) is the predominant hard shore stabilization method and makes up about 4,763 feet or about 10.9 percent of the total shore protection in this section. Three boat ramps were mapped totaling 81 linear feet.

Figure 15.—Shoreline type classification map of east-central Mobile Bay.

Southeast Mobile Bay consists mainly of natural, unretained shoreline due to the Weeks Bay National Estuarine Research Reserve. There is about 8.2 miles of shoreline in southeast Mobile Bay with 7.0 miles or 85.6 percent having natural shore protection and 1.2 miles or 14.4 percent having hard shore protection. The main hard shore protection in southeast Mobile Bay is from bulkheads, representing 1.1 miles or 13.1 percent of the total hard shoreline.

Table 16.— Southeast Mobile Bay shore protection classification lengths and percentages.

Southeast Mobile Bay		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat Ramp	81	0.2
Bulkhead (steel, wood)	663	1.5
Bulkhead (with groin)	4,763	10.9
Bulkhead (with riprap)	285	0.7
Groin	191	0.4
Jetty (steel pile, rock, concrete)	222	0.5
Natural	37,252	85.6
Rubble/riprap	48	0.1
Total length	43,505	100.0

SHORELINE TYPES

Six different shoreline types were mapped in southeast Mobile Bay: artificial, inlet, organic (marsh), organic (swamp forest), sediment bank (low) and vegetated bank (low) (table 17). Figure 17 depicts the distribution of shoreline types in southeast Mobile Bay. The dominant shoreline type in southeast Mobile Bay is vegetated bank (low) making up about 18,246 feet (3.5 miles) or about 42.2 percent of the total. Organic (swamp forest) shoreline type, the longer of the two organic types classified, makes up about 14,272 feet (2.7 miles) or about 33.0 percent of the total. Organic (marsh) makes up about 10,345 feet (~2 miles) or about 23.9 percent of the total.

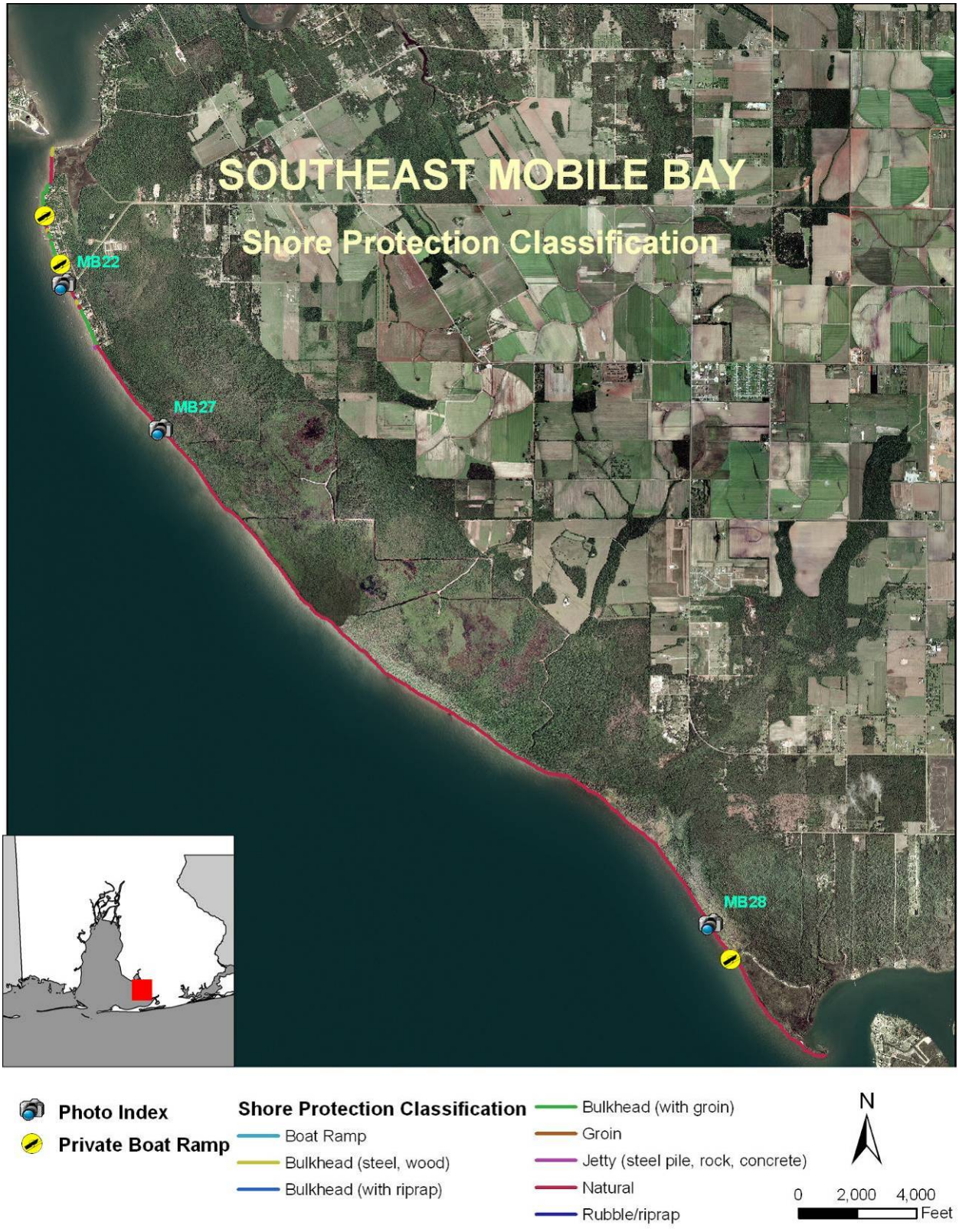

Figure 16.—Shore protection classification map of southeast Mobile Bay.

Table 17.— Southeast Mobile Bay shoreline type classification lengths and percentages.

Southeast Mobile Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	222	0.5%
Inlet	121	0.3%
Organic (marsh)	10,345	23.9%
Organic (swamp forest)	14,272	33.0%
Sediment bank (low, 0 - 5 ft)	54	0.1%
Vegetated bank (low, 0 - 5 ft)	18,246	42.2%
Total	43,260	100%

EAST MORGAN PENINSULA

SHORE PROTECTION

There were eighteen different types of shore protection encountered on east Morgan Peninsula: boat ramp, ten bulkhead subtypes, natural, groin, rubble/riprap, riprap (with groin), sill (rock, shell), sill (wood), and jetty (steel pile, rock, concrete) (table 18). An estimated 52,004 feet (9.8 miles) of shore protection were mapped on east Morgan Peninsula. Figure 18 illustrates the distribution of shore protection on east Morgan Peninsula.

Table 18.—East Morgan Peninsula shore protection classification lengths and percentages.

East Morgan Peninsula		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat Ramp	232	0.4
Bulkhead (concrete, rock)	51	0.1
Bulkhead (steel, wood)	8,543	16.4
Bulkhead (with retaining walls)	693	1.3
Bulkhead (with riprap and sill)	1,315	2.5
Bulkhead (with riprap, sill, and groins)	223	0.4
Bulkhead (with sill)	796	1.5
Bulkhead (with groin)	889	1.7
Bulkhead (with riprap)	6,229	12.0
Bulkhead (with riprap and groin)	706	1.4
Bulkhead (with retaining walls and riprap)	260	0.5
Groin	1,838	3.5
Jetty (steel pile, rock, concrete)	56	0.1
Natural	25,028	48.1
Riprap (with groin)	526	1.0
Rubble/riprap	2,621	5.0
Sill (rock, shell)	544	1.0
Sill (wood)	1,454	2.8
Total	52,004	100.0

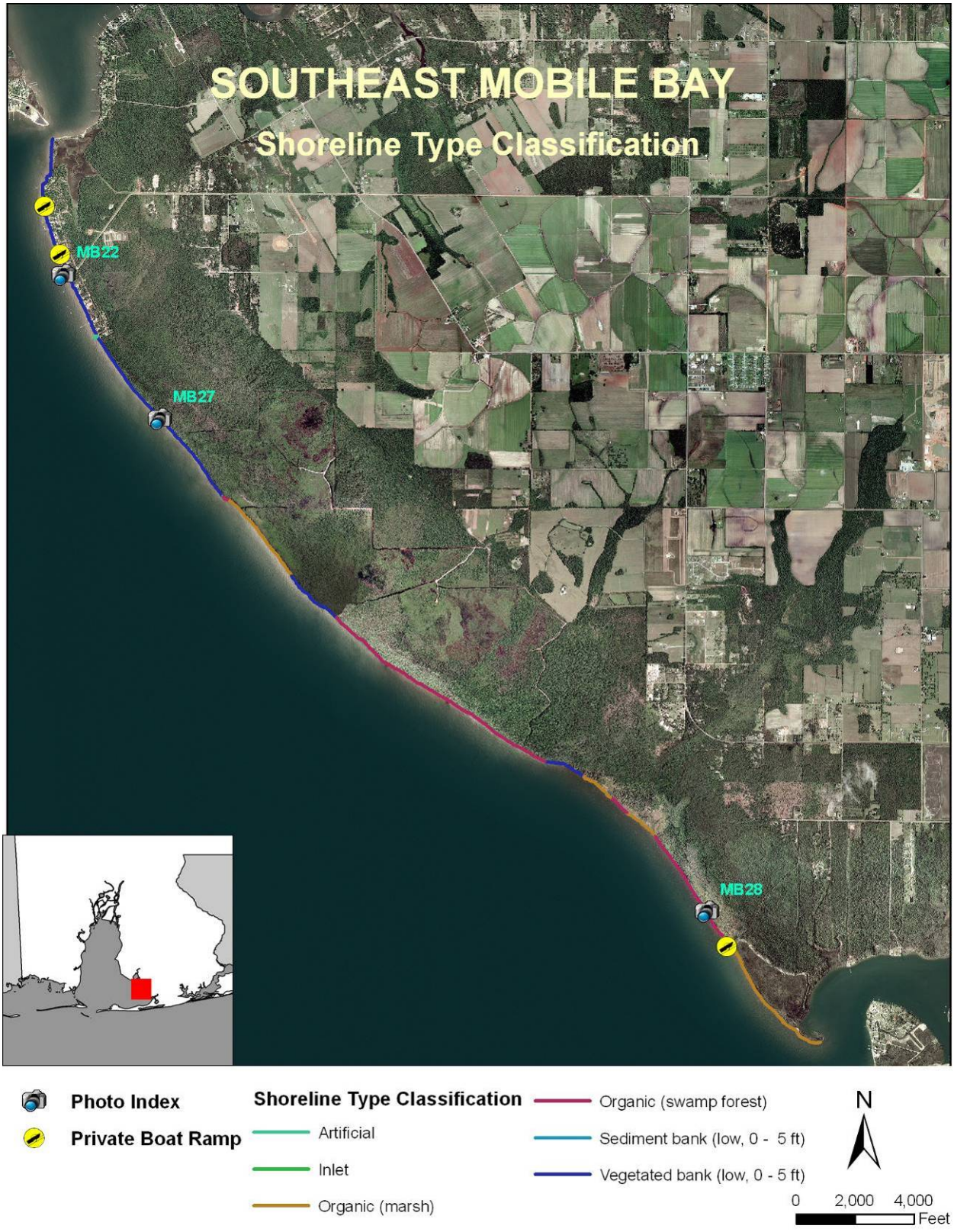

Figure 17.—Shoreline type classification map of southeast Mobile Bay.

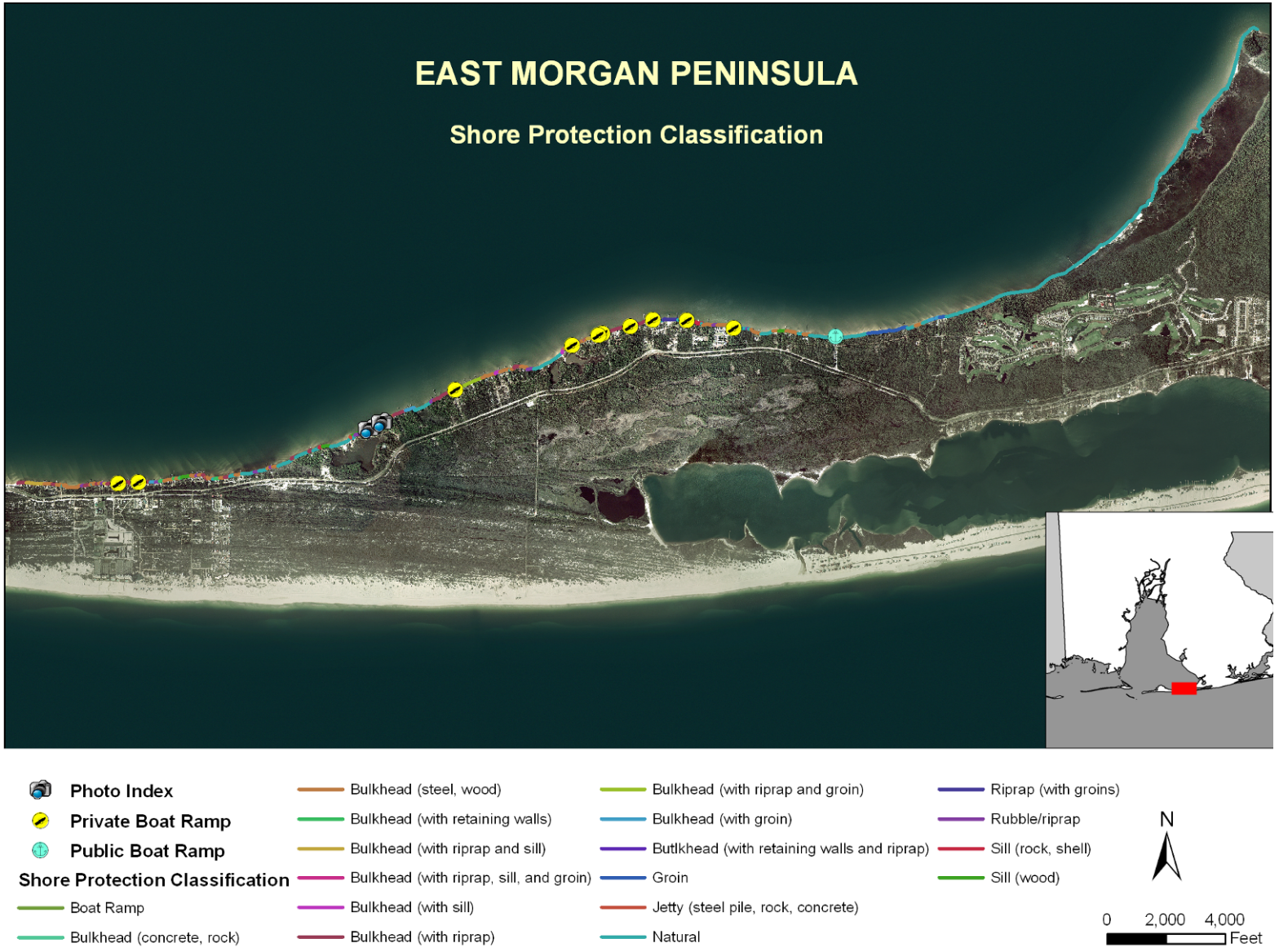

Figure 18.—Shore protection classification map of east Morgan Peninsula.

Natural, unretained shoreline was mapped at about 25,028 feet (4.7 miles) or about 48.1 percent of the total. The five different types of bulkheads made up 19,937 feet (3.8 miles) or 38.3 percent of the total. Bulkhead (steel, wood) is the longest having about 8,543 feet (1.6 miles) or about 16.4 percent of the total. Ten private and two public boat ramps were mapped.

Of the 9.8 miles of shore protection mapped on east Morgan Peninsula, 5.1 miles or 51.9 percent have hard shoreline structures and 4.7 miles or 48.1 percent have an unretained shoreline. The main hard shore protection on east Morgan Peninsula is from bulkheads representing 3.8 miles or 38.3 percent of the total hard shore protection.

SHORELINE TYPES

Six different shoreline types were mapped on east Morgan Peninsula: inlet, organic (open, vegetated fringe), sediment bank (low), sediment bank (high), vegetated bank (high), and vegetated bank (low). Findings for shoreline types on east Morgan Peninsula are detailed in table 19 and illustrated on figure 19. Vegetated bank (low) is the longest having about 32,336 feet (6.1 miles) or about 62.9 percent of the total. Vegetated bank (high) shoreline type makes up about 12,294 feet (2.3 miles) or about 23.9 percent of the total.

Table 19.—East Morgan Peninsula shoreline type classification lengths and percentages.

East Morgan Peninsula		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Inlet	392	0.8%
Organic (open, vegetated fringe)	3,326	6.5%
Sediment bank (high, 5 - 20 ft)	920	1.8%
Sediment bank (low, 0 - 5 ft)	2,178	4.2%
Vegetated bank (high, 5 - 20 ft)	12,294	23.9%
Vegetated bank (low, 0 - 5 ft)	32,336	62.9%
Total	51,446	100%

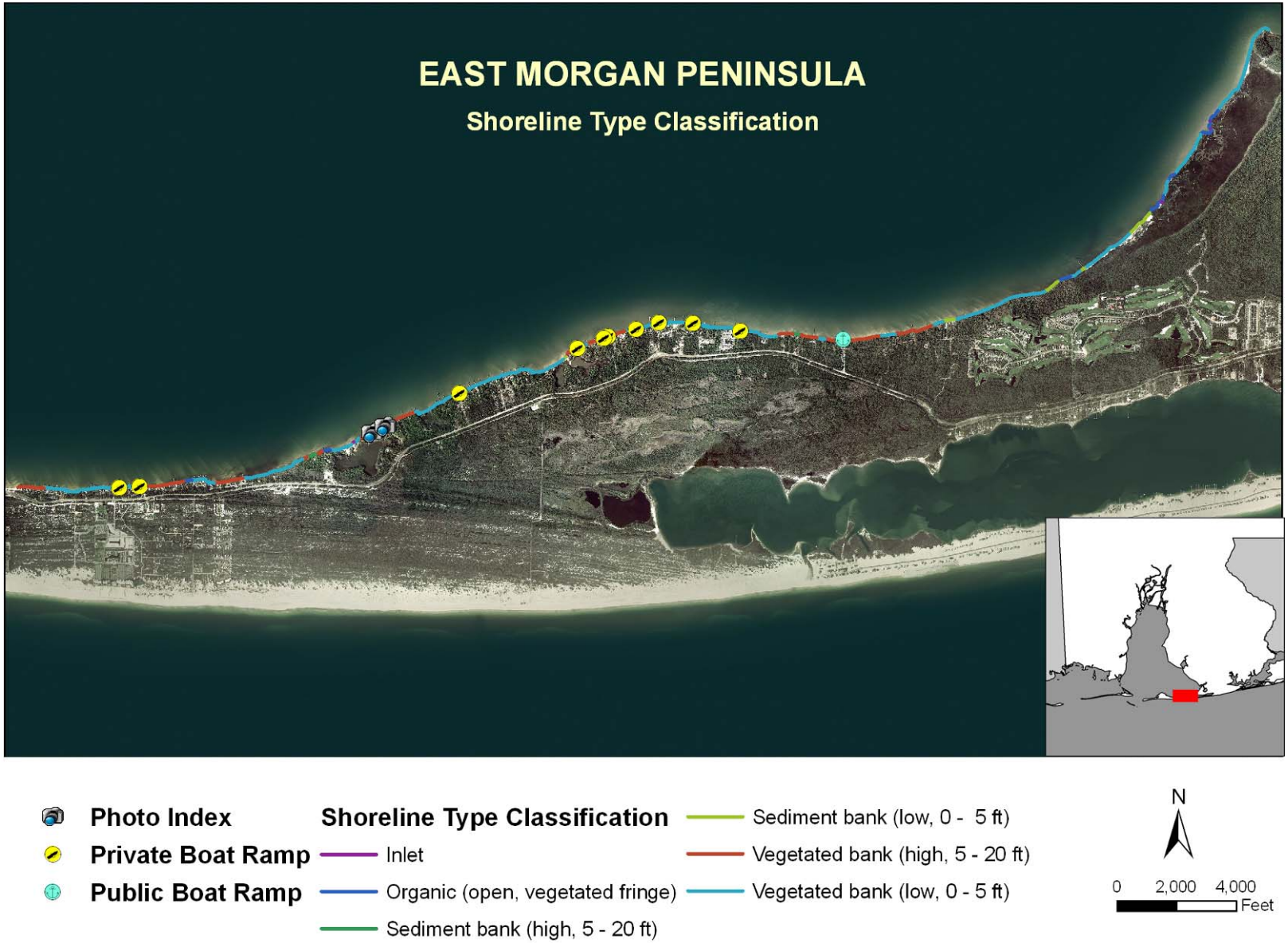

Figure 19.—Shoreline type classification map of east Morgan Peninsula.

WEST MORGAN PENINSULA

SHORE PROTECTION

Less diversity of shore protection was found on west Morgan Peninsula than on east Morgan Peninsula. Boat ramp, bulkhead (steel, wood), bulkhead (with riprap), groin, jetty (steel pile, rock, concrete), natural, revetment, rubble/riprap, seawall (concrete, steel pile), sill (rock, shell), and sill (wood) are the protective types classified. The detailed shore protection values for west Morgan Peninsula are tabulated in table 20. These shore protection types make up 100,408 feet or about 19.0 miles of shore protection mapped on west Morgan Peninsula. Figure 20 illustrates the distribution of shore protection on west Morgan Peninsula.

Natural, unretained shoreline was the longest shore protection classification mapped on west Morgan Peninsula having about 81,006 feet (15.3 miles) or about 80.7 percent due to protected properties within the Bon Secour National Wildlife Refuge. Bulkhead (steel, wood), the longer of the two bulkhead classifications, makes up about 7,735 feet (1.5 miles) or about 7.7 percent of the total shore protection. Rubble/riprap shore protection makes up about 4,505 feet or about 4.5 percent of the total shore protection on west Morgan Peninsula.

West Morgan Peninsula consists mainly of natural shore protection. There is about 19.0 miles of shoreline on west Morgan Peninsula with 15.2 miles or 80.1 percent having natural shore protection and 3.8 miles or 19.9 percent having hard shore protection. The main hard shore protection on west Morgan Peninsula is from bulkheads representing 1.8 miles or 9.3 percent of the total hard shore protection.

Table 20.—West Morgan Peninsula shore protection classification lengths and percentages.

West Morgan Peninsula		
Shore Protection Classification	**Length (ft)**	**Percent (%)**
Boat Ramp	266	0.3
Bulkhead (steel, wood)	7,735	7.7
Bulkhead (with riprap)	1,559	1.6
Groin	104	0.1
Jetty (steel pile, rock, concrete)	2,589	2.6
Natural	81,006	80.7
Revetment	1,455	1.4
Rubble/riprap	4,505	4.5
Seawall (concrete, steel piles)	710	0.7
Sill (rock, shell)	272	0.3
Sill (wood)	207	0.2
Total	100,408	100.0

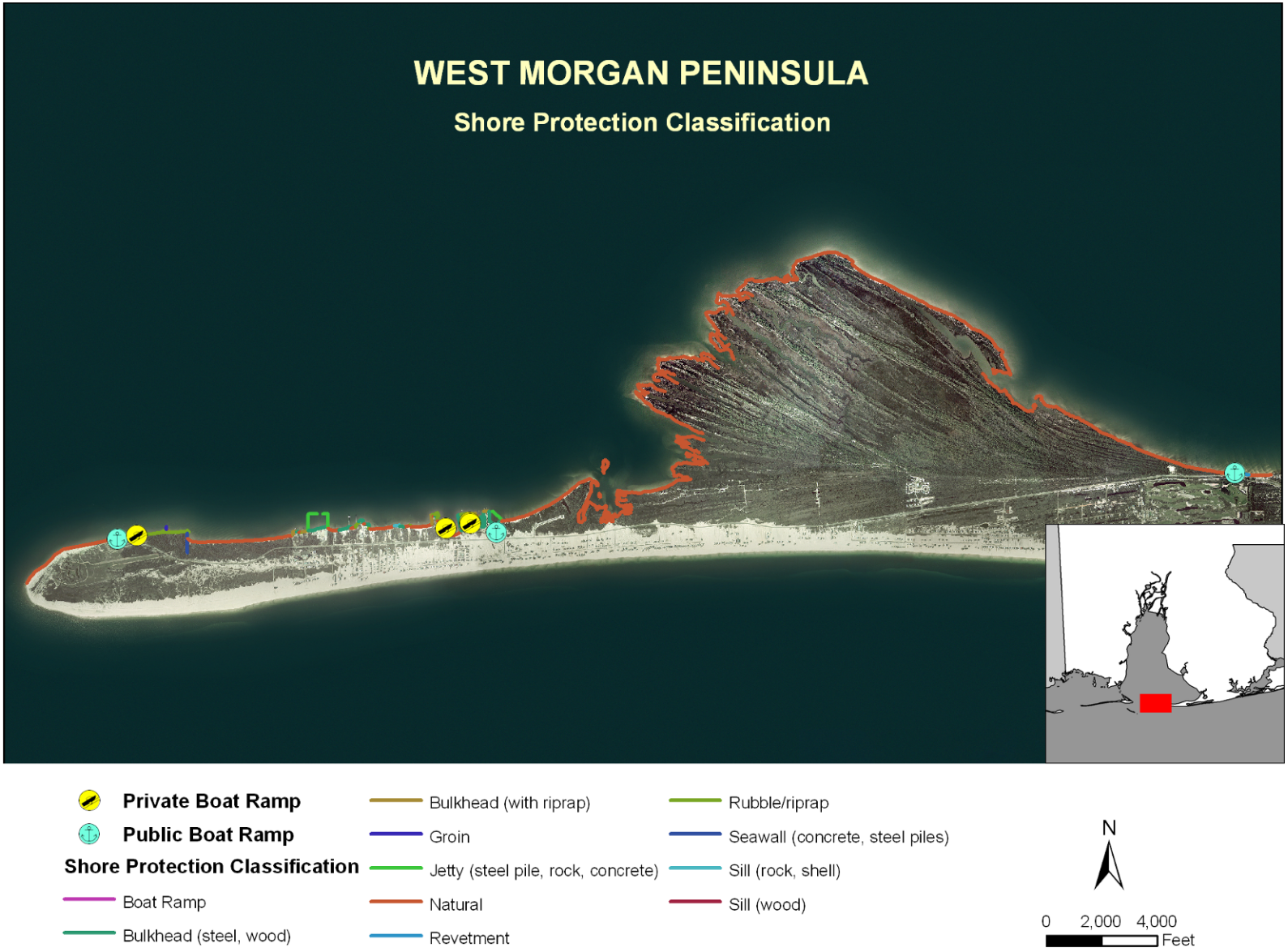

Figure 20.—Shore protection classification map of west Morgan Peninsula.

SHORELINE TYPES

Six different shoreline types on west Morgan Peninsula were mapped: artificial, inlet, organic (marsh), organic (open, vegetated fringe), sediment bank (low), sediment bank (high), vegetated bank (high), and vegetated bank (low) (table 21). Figure 21 is an illustration of the shoreline types on west Morgan Peninsula. Organic makes up about 47,080 feet (8.9 miles) or about 49.1 percent, vegetated makes up about 32,733 feet (6.2 miles) or about 34.2 percent, and sediment makes up about 14,719 feet (2.8 miles) or about 15.4 percent of the total shoreline type on west Morgan Peninsula. There were four inlets encountered on west Morgan Peninsula.

Table 21.—West Morgan Peninsula shoreline type classification lengths and percentages.

West Morgan Peninsula		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	1,015	1.1
Inlet	265	0.3
Organic (marsh)	42,049	43.9
Organic (open, vegetated fringe)	5,032	5.3
Sediment bank (high, 5 - 20 ft)	1,507	1.6
Sediment bank (low, 0 - 5 ft)	13,211	13.8
Vegetated bank (high, 5 - 20 ft)	903	0.9
Vegetated bank (low, 0 - 5 ft)	31,830	33.2
Total	95,812	100.0

WEEKS BAY

SHORE PROTECTION

Although the majority of the shoreline in Weeks Bay is natural and is located in the Weeks Bay National Estuarine Research Reserve, Weeks Bay has numerous types of shore protection. Specifics for the thirteen different shore protection types mapped in Weeks Bay (boat ramp, four types of bulkheads, groin, natural, rubble/riprap, rubble/riprap (with tires), seawall (concrete, steel piles), sill (wood), sill (wood with riprap), and silt fence) are tabulated in table 22. Figure 22 illustrates the distribution of shore protection in Weeks Bay.

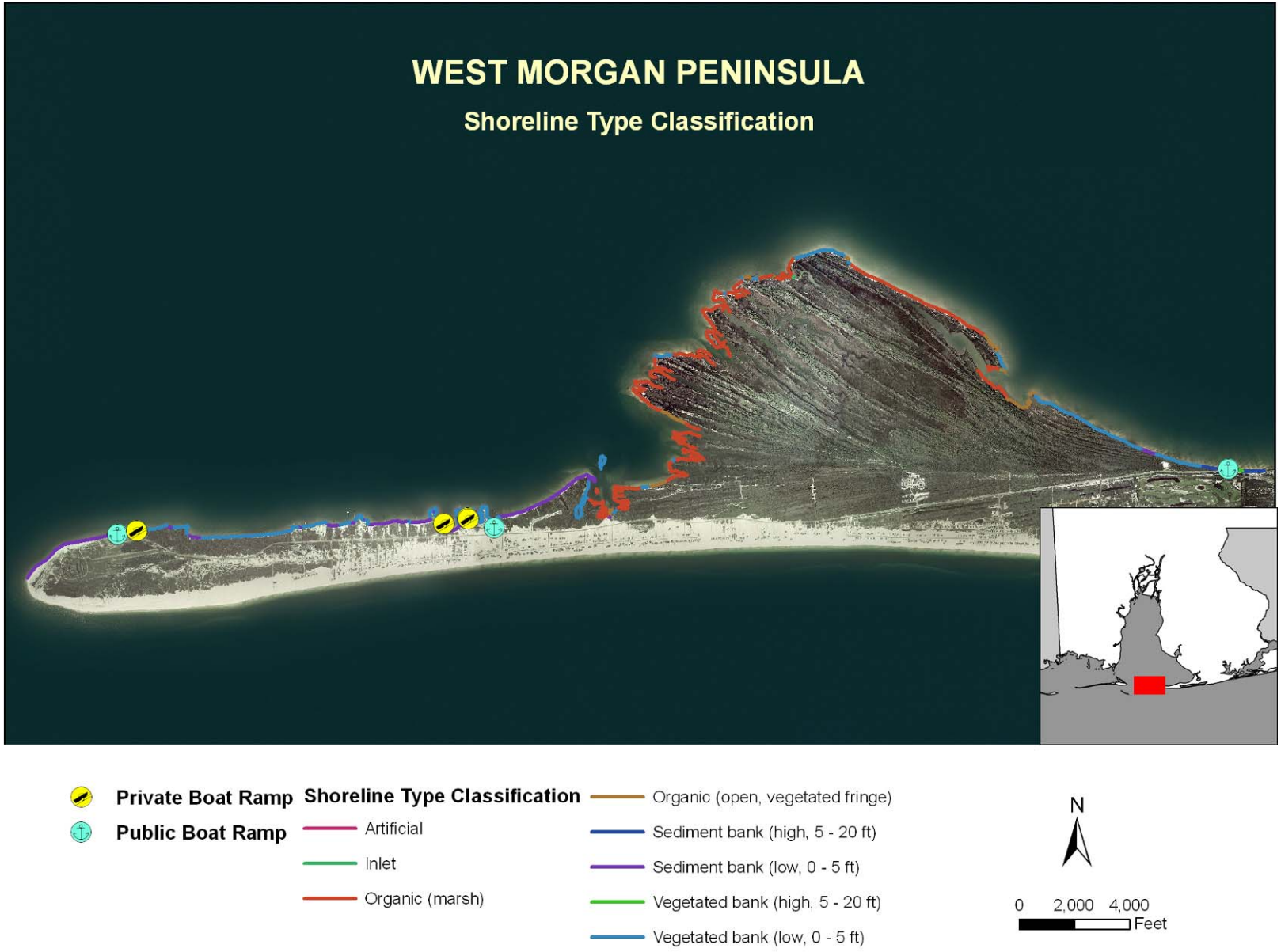

Figure 21. Shoreline type classification map of west Morgan Peninsula.

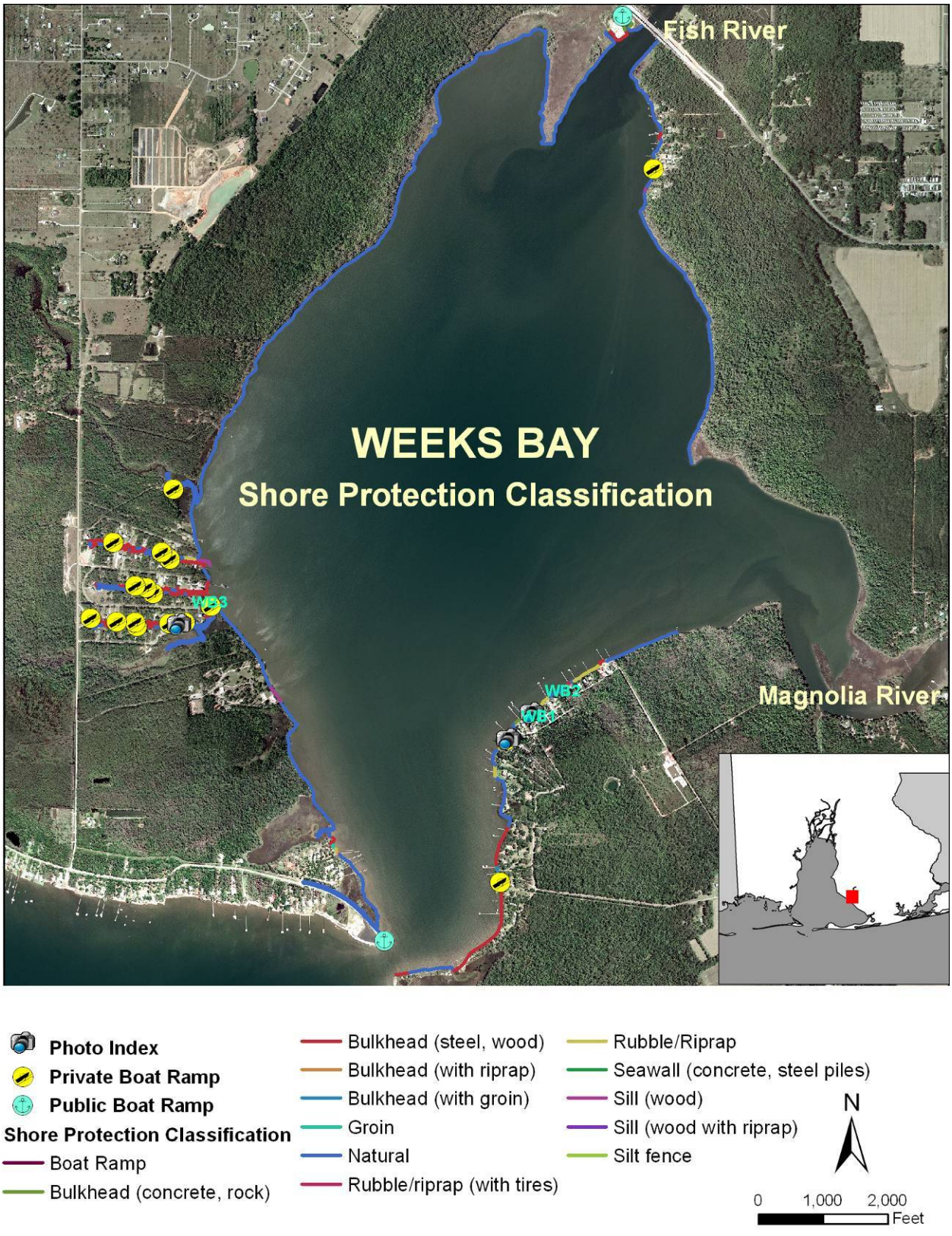

Figure 22.—Shore protection classification map of Weeks Bay.

Natural, unretained shoreline is the dominant shore protection classification in Weeks Bay with about 44,485 feet (8.4 miles) or about 74.0 percent of the total shore protection. Bulkhead (steel, wood), the longest of the four subtypes, makes up about 11,740 feet (2.2 miles) or about 19.5 percent of the total shore protection in Weeks Bay.

Of the 11.4 miles of shoreline mapped in Weeks Bay, 8.4 miles (73.9 percent) were natural and 3.0 miles (26.1 percent) were hard shore protection. Bulkheads are the main hard shore protection representing 2.5 miles or 21.4 percent of the total hard shore protection.

Table 22.—Weeks Bay shore protection classification lengths and percentages.

Weeks Bay		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat Ramp	440	0.7
Bulkhead (concrete, rock)	857	1.4
Bulkhead (steel, wood)	11,740	19.5
Bulkhead (with groin)	268	0.4
Bulkhead (with riprap)	76	0.1
Groin	103	0.2
Natural	44,485	74.0
Rubble/riprap	1,408	2.3
Rubble/riprap (with tires)	89	0.1
Seawall (concrete, steel piles)	116	0.2
Sill (wood)	403	0.7
Sill (wood with riprap)	87	0.1
Silt fence	55	0.1
Total	60,127	100.0

SHORELINE TYPES

There were seven different shoreline types indentified in Weeks Bay: artificial, inlet, organic (marsh), organic (open, vegetated fringe), sediment bank (low), vegetated bank (high), and vegetated bank (low). Shoreline type measurements for Weeks Bay are provided in table 23, while figure 23 illustrates their distribution. Organic shoreline makes up about 38,312 feet (7.3 miles) or about 63.8 percent and vegetated shoreline makes up about 20,971 feet (4.0 miles) or about 34.9 percent of the total shoreline type in Weeks Bay. There were seven inlets classified in Weeks Bay.

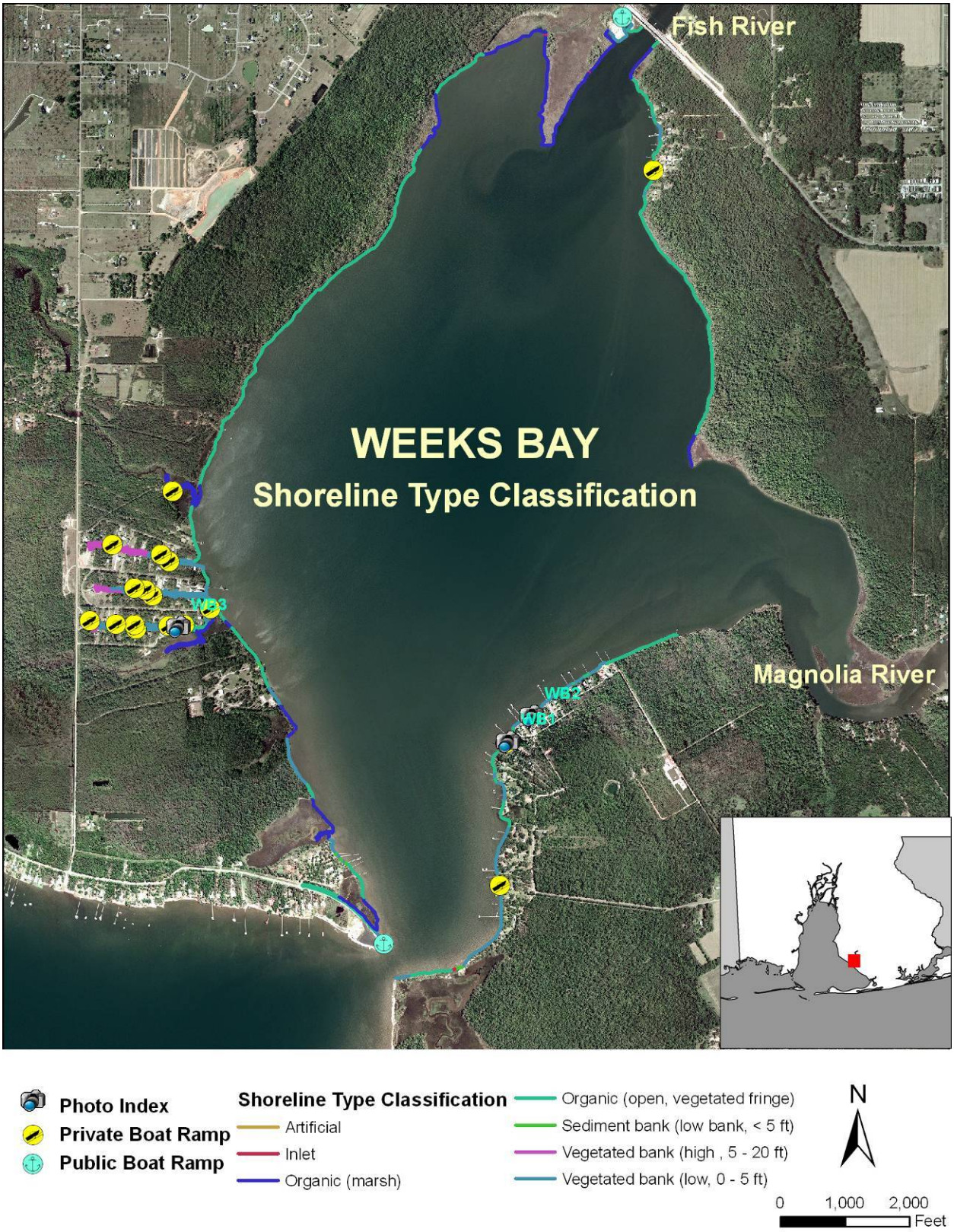

Figure 23.—Shoreline type classification map of Weeks Bay.

Table 23.—Weeks Bay shoreline type classification lengths and percentages.

Weeks Bay		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	141	0.2
Inlet	250	0.4
Organic (marsh)	14,727	24.5
Organic (open, vegetated fringe)	23,586	39.3
Sediment bank (low, 0 - 5 ft)	338	0.6
Vegetated bank (high, 5 - 20 ft)	3,790	6.3
Vegetated bank (low, 0 - 5 ft)	17,181	28.6
Total	60,013	100.0

FISH RIVER

SHORE PROTECTION

The Fish River extent is between the Baldwin County Road 32 bridge and Alabama Highway 98 bridge on the south end where Fish River empties into Weeks Bay (fig. 24). Thirteen shore protection types were mapped on Fish River: abutment, beach nourishment, boat ramp, four types of bulkheads, natural, revetment, rubble/riprap, sill (rock, shell), sill (wood), and silt fence. These shore protection types (table 24) make up 159,167 feet (30.1 miles) of shore protection that were mapped on Fish River. Figure 24 illustrates the distribution of shore protection on Fish River.

The longest shore protection classification on Fish River is natural, unretained shoreline having about 120,510 feet (22.8 miles) or about 75.7 percent of the total. Bulkhead (steel, wood) shore protection, the longest of the four types mapped, makes up about 26,967 feet (5.1 miles) or about 16.9 percent of the total. There were 44 private and 3 public boat ramps encountered in Fish River making up about 887 feet or about 0.6 percent of the total.

Of the 30.1 miles of shoreline on Fish River mapped, 22.8 miles (75.7 percent) is natural and 7.3 miles (24.3 percent) is hard shore protection. The main hard shore protection on Fish River is from bulkheads accounting for 5.8 miles (19.2 percent) of the total hard shore protection.

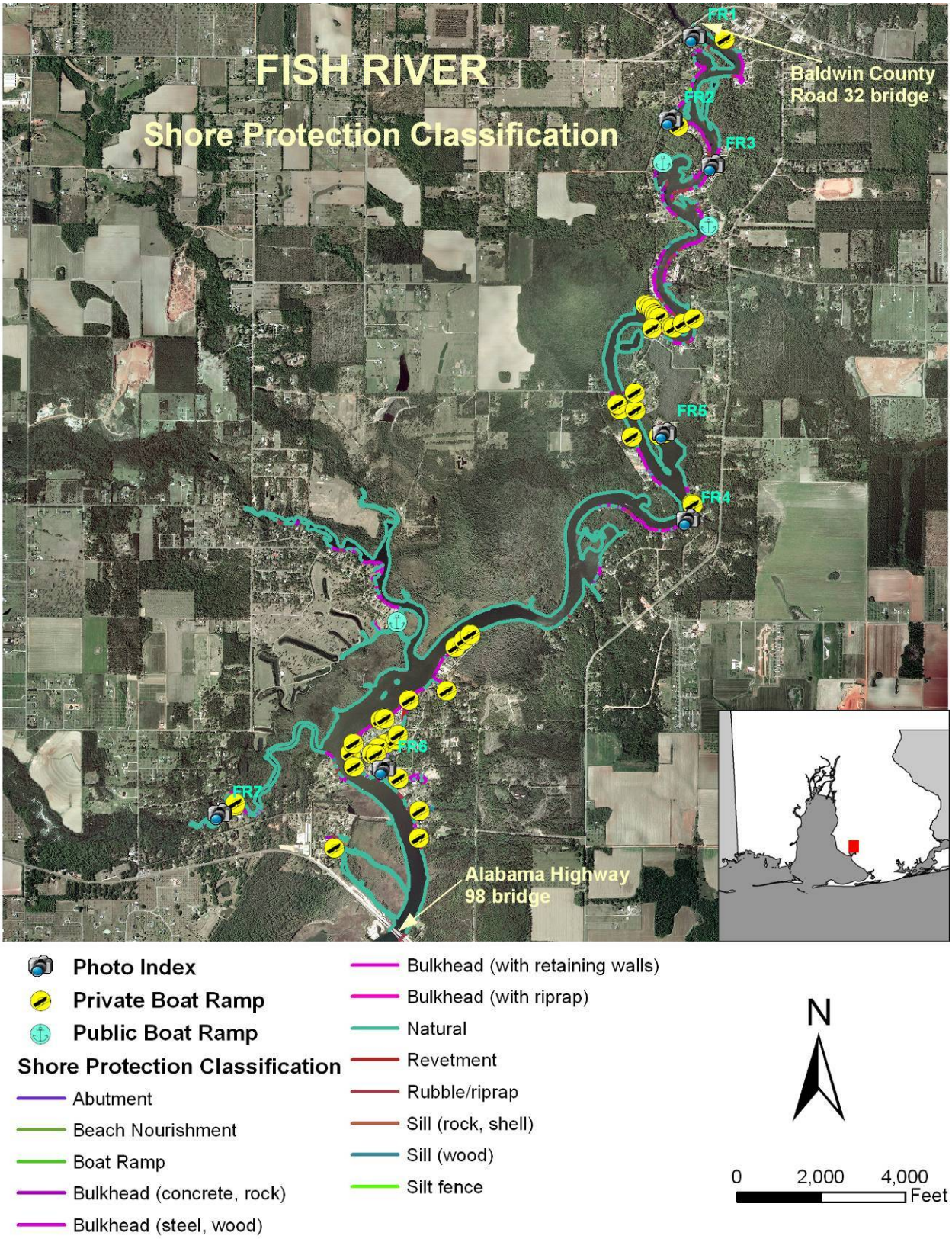

Figure 24.—Shore protection classification map of Fish River.

Table 24.—Fish River shore protection classification lengths and percentages.

Fish River		
Shore protection classification	**Length (ft)**	**Percent (%)**
Abutment	86	0.1
Beach Nourishment	63	0.0
Boat Ramp	887	0.6
Bulkhead (concrete, rock)	2,117	1.3
Bulkhead (steel, wood)	26,967	16.9
Bulkhead (with retaining walls)	705	0.4
Bulkhead (with riprap)	722	0.5
Natural	120,510	75.7
Revetment	494	0.3
Rubble/riprap	5,612	3.5
Sill (rock, shell)	36	0.0
Sill (wood)	833	0.5
Silt fence	138	0.1
Total	159,167	100.0

SHORELINE TYPES

There were nine different shoreline types identified on Fish River: artificial, inlet, organic (marsh), organic (open, vegetated fringe), organic (swamp forest), pocket beach, vegetated bank (bluff), vegetated bank (high), and vegetated bank (low). Shoreline type values for Fish River are tabulated in table 25. Figure 25 illustrates the distribution of shoreline types on Fish River. The longest shoreline type on Fish River is vegetated making up about 78,714 feet (14.9 miles) or about 49.7 percent of the total. Organic shoreline types make up about 78,294 feet (14.8 miles) or about 49.4 percent of the total. There were 30 inlets identified in Fish River, totaling 987 linear feet. Pocket beach makes up about 446 feet or about 0.3 percent of the total shoreline type on Fish River.

Table 25.—Fish River shoreline type classification lengths and percentages.

Fish River		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	86	0.1
Inlet	987	0.6
Organic (marsh)	8,611	5.4
Organic (open, vegetated fringe)	23,214	14.6
Organic (swamp forest)	46,469	29.3
Pocket Beach	446	0.3
Vegetated bank (high, 5 - 20 ft)	1,696	1.1
Vegetated bank (low, 0 - 5 ft)	6,398	4.0
Vegetated bank (bluff, > 20 ft)	70,620	44.5
Total	158,528	100.0

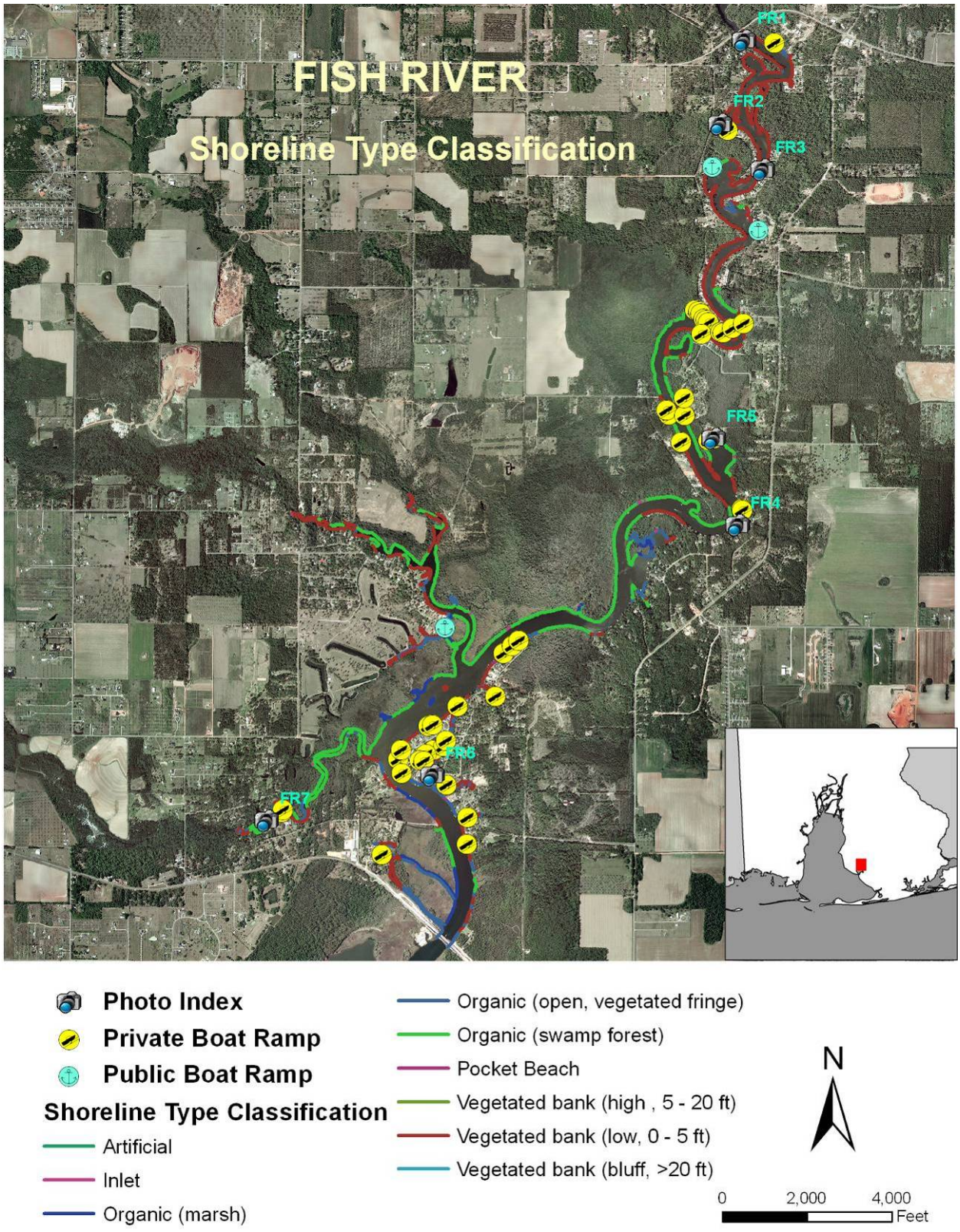

Figure 25.—Shoreline type classification map of Fish River.

MAGNOLIA RIVER

SHORE PROTECTION

Eight different shore protection types were documented on Magnolia River: natural, bulkhead (steel, wood), bulkhead (concrete, rock), rubble/riprap, sill (rock, shell), sill (wood), boat ramp, and groin. The detailed shore protection type values for Magnolia River are listed in table 26. About 81,373 feet (15.4 miles) of shore protection were mapped on Magnolia River between the eastern limit of navigable water and the west end where Magnolia River meets Weeks Bay. Figure 26 illustrates the distribution of shore protection on Magnolia River.

The dominant shore protection classification on Magnolia River is natural, unretained shoreline having about 67,915 feet (12.9 miles) or about 83.5 percent of the total shore protection. Bulkhead (steel, wood) shore protection, the more prevalent of the two bulkhead types classified, makes up about 6,721 feet (1.3 miles) or about 8.3 percent of the total shore protection on Magnolia River. Rubble/riprap shore protection makes up about 2,298 feet (0.4 miles) or about 2.8 percent of the total. There were 8 private and 2 public boat ramps identified.

The shore protection along Magnolia River is primarily natural at about 85 percent. Only 2.5 miles (16.5 percent) is hard shore protection. Most of the hard shore protection on Magnolia River is from bulkheads at 2.0 miles (13.0 percent) of the total.

Table 26. Magnolia River shore protection classification lengths and percentages.

Magnolia River		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat ramp	239	0.3
Bulkhead (concrete, rock)	3,841	4.7
Bulkhead (steel, wood)	6,721	8.3
Groin	20	0.0
Natural	67,915	83.5
Rubble/riprap	2,298	2.8
Sill (rock, shell)	169	0.2
Sill (wood)	170	0.2
Total length	81,373	100.0

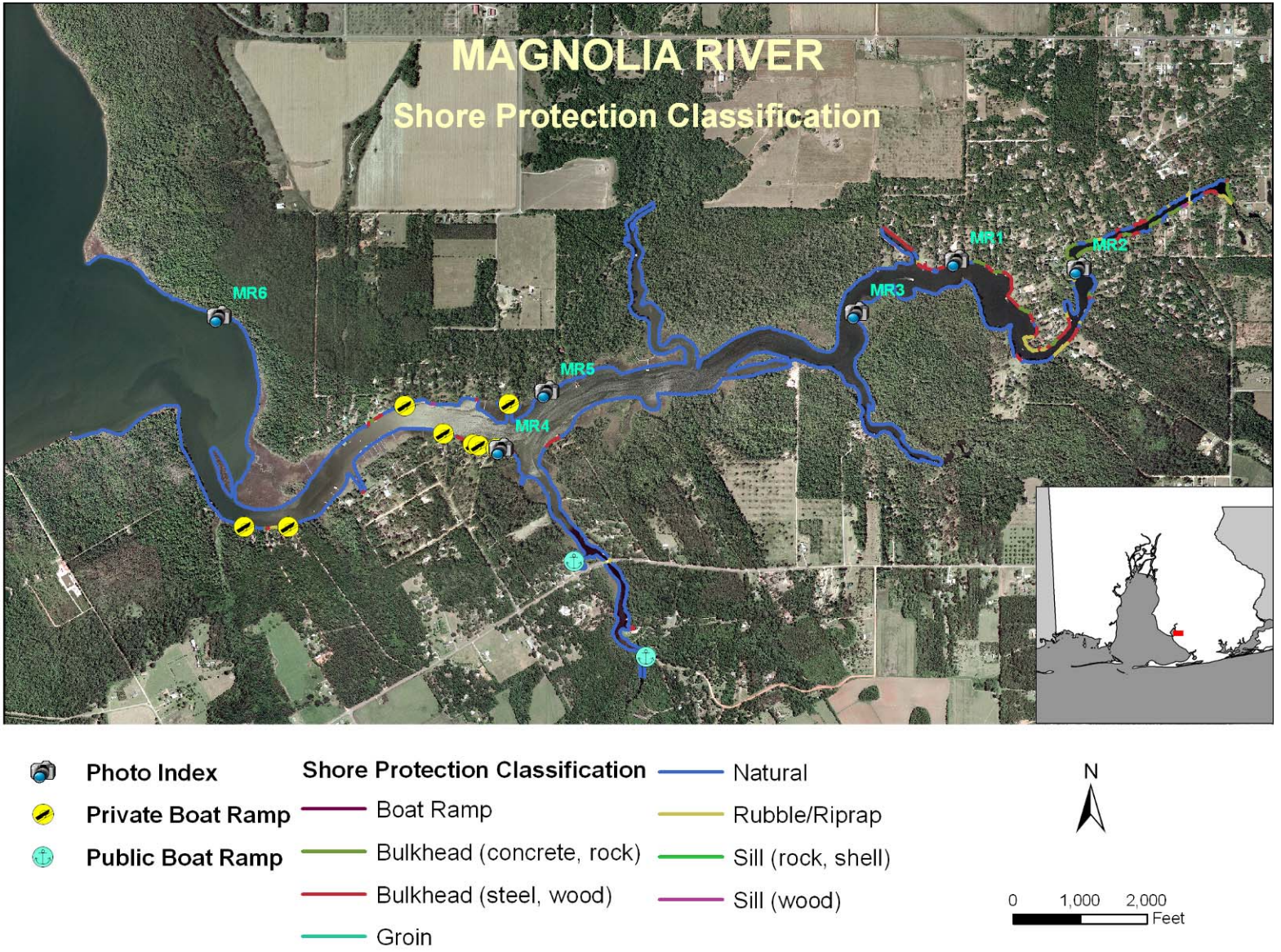

Figure 26. Shore protection classification map of Magnolia River.

SHORELINE TYPES

There are eight different types of shoreline types identified on Magnolia River, which were classified as follows: artificial, inlet, organic (marsh), organic (open, vegetated fringe), organic (swamp forest), rock (low bank), vegetated bank (high), and vegetated bank (low). Shoreline type values for Magnolia River are tabulated in table 27. Figure 27 illustrates the distribution of the shoreline types on Magnolia River. Organic shoreline type makes up about 40,972 feet (7.8 miles) or about 50.4 percent of the total shoreline type on Magnolia River. Vegetated shoreline type makes up about 39,474 feet (7.5 miles) or about 48.6 percent of the total shore protection. There were 15 inlets encountered on Magnolia River totaling 484 linear feet. Rock (low bank) makes up about 38 feet or about 0.1 percent of total shoreline type on Magnolia River.

Table 27. Magnolia River shoreline type classification lengths and percentages.

Magnolia River		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	312	0.4
Inlet	484	0.6
Organic (marsh)	21,702	26.7
Organic (open, vegetated fringe)	14,475	17.8
Organic (swamp forest)	4,795	5.9
Rock (low bank)	38	0.0
Vegetated bank (high, 5 - 20 ft)	1,813	2.2
Vegetated bank (low, 0 - 5 ft)	37,661	46.3
Total	81,280	100.0

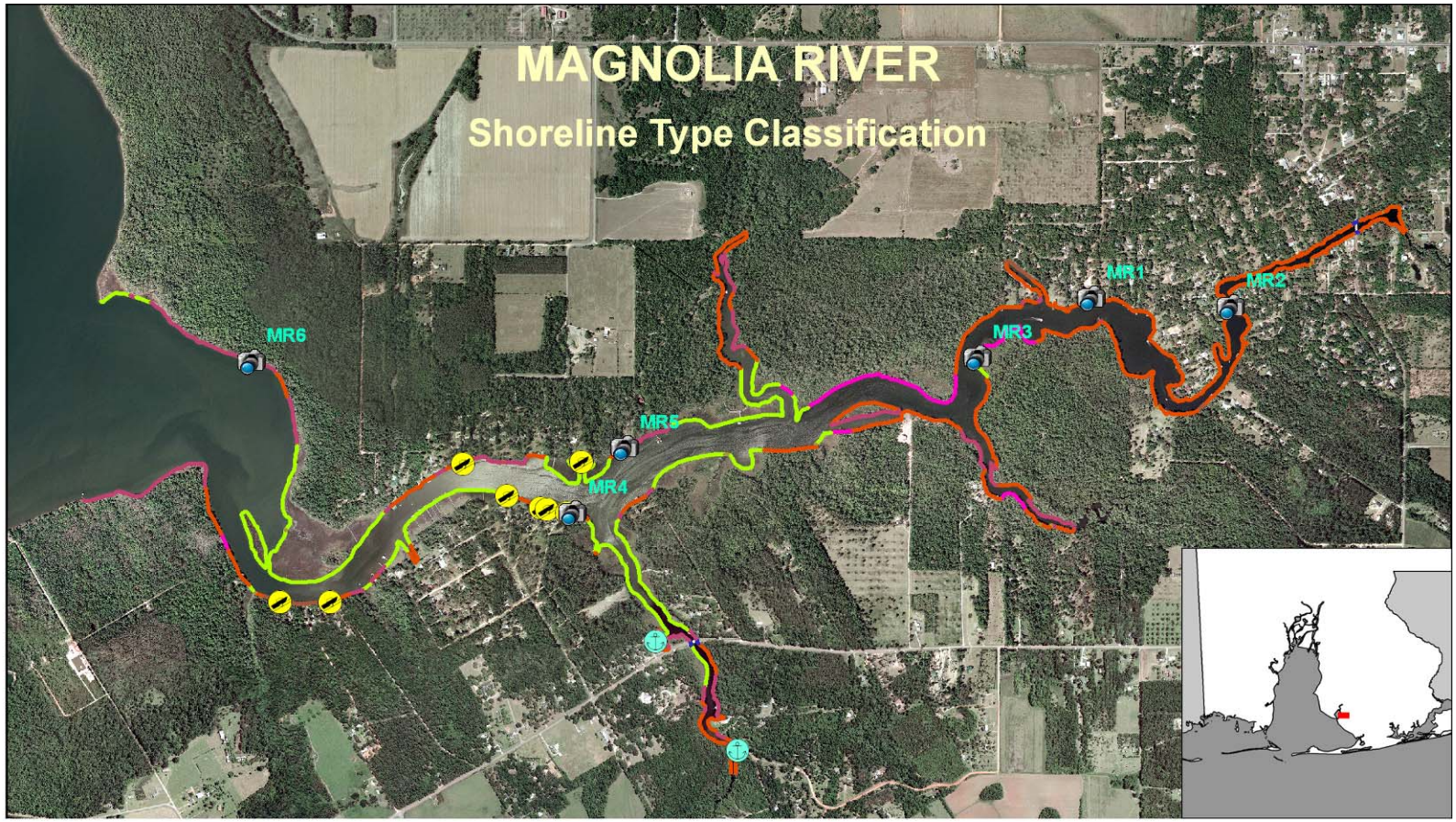

Figure 27. Shoreline type classification map of Magnolia River.

DEER RIVER SYSTEM

SHORE PROTECTION

The Deer River system (Middle Fork Deer River, North Fork Deer River, and South Fork Deer River) was mapped with nine different shore protection types: abutment, boat ramp, bulkhead (concrete, rock), bulkhead (steel, wood), natural, revetment, rubble/riprap, sill (wood) and tires (table 28). Shore protection types total 80,384 feet (15.2 miles) in the Deer River system. The distribution of shore protection is illustrated in figure 28.

The dominant shore protection classification in the Deer River system is natural, unretained shoreline, having about 55,402 feet (10.5 miles) or about 68.9 percent of the total. Bulkhead (steel, wood) shore protection, the longer of the two bulkhead types, makes up about 7,540 feet (1.4 miles) or about 9.4 percent of the total. There were nine private boat ramps and one public boat ramp encountered in the Deer River system (268 feet). Tires, the least prevalent shore protection type in the Deer River system, makes up about 73 feet or about 0.1 percent of the total shore protection.

The dominant shore protection classification in The Deer River system consists of unretained natural shoreline. There is about 15.2 miles of shoreline in the Deer River system with 10.5 miles (68.9 percent) having natural shore protection and 4.7 miles (31.1 percent) having hard shore protection. The main hard shore protection in the Deer River system is from bulkheads, which represent 2.3 miles (15.2 percent) of the total hard shore protection mapped.

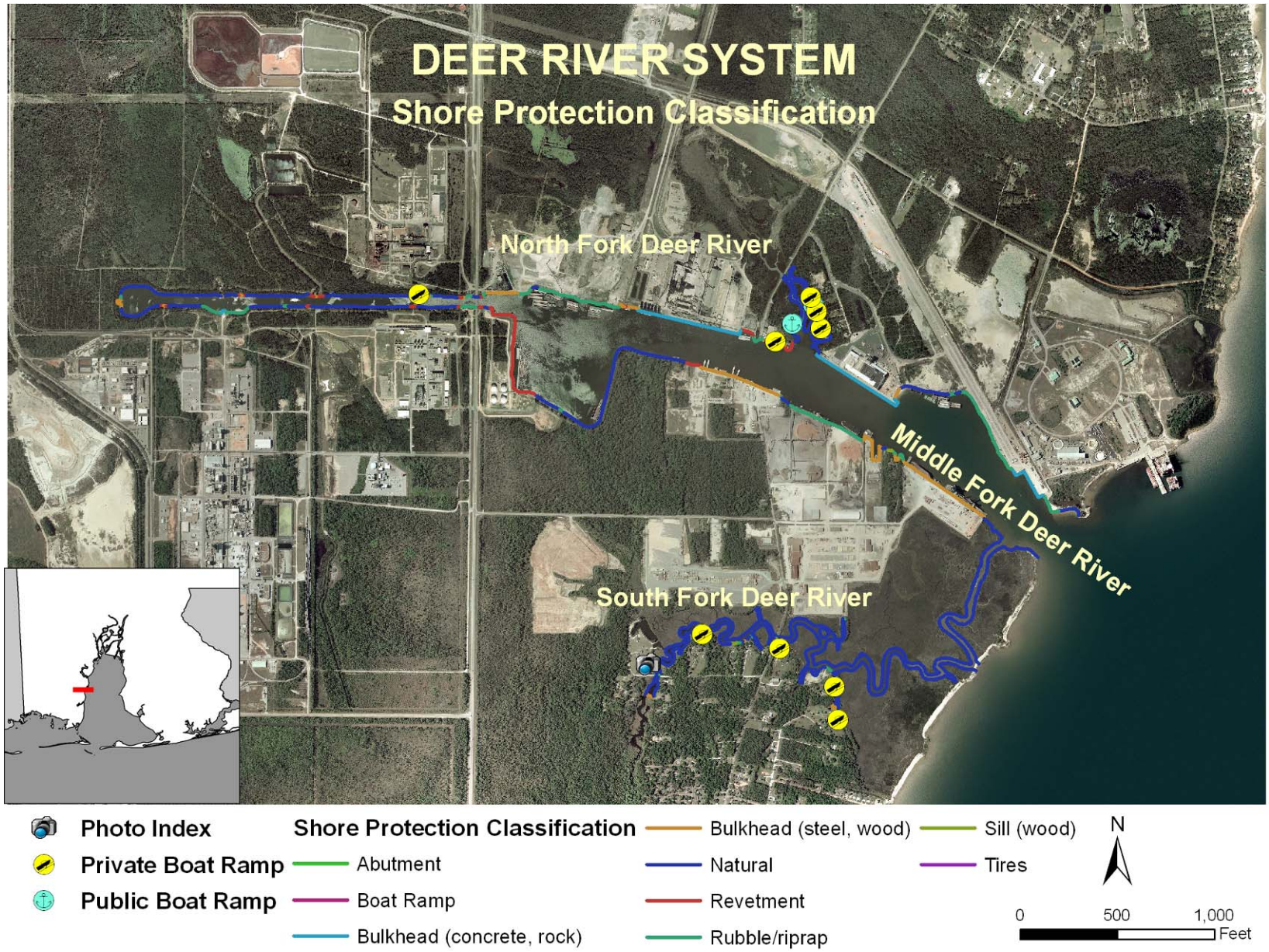

Figure 28. Shore protection classification map of the Deer River system.

Table 28. Deer River system shore protection classification lengths and percentages.

Deer River system		
Shore protection classification	**Length (ft)**	**Percent (%)**
Abutment	161	0.2
Boat Ramp	268	0.3
Bulkhead (concrete, rock)	4,687	5.8
Bulkhead (steel, wood)	7,540	9.4
Natural	55,402	68.9
Revetment	3,811	4.7
Rubble/riprap	8,265	10.3
Sill (wood)	178	0.2
Tires	73	0.1
Total	80,384	100.0

SHORELINE TYPES

Eleven different shoreline types were mapped in the Deer River System which were classified as follows: artificial, inlet, organic (marsh), organic (open, vegetated fringe), organic (swamp forest), sediment bank (bluff), sediment bank (high), sediment bank (low), vegetated bank (bluff), vegetated bank (high) and vegetated bank (low) (table 29). Figure 29 illustrates the distribution of the shoreline types in the Deer River system. Organic shoreline types dominate the Deer River system having about 35,282 feet (6.7 miles) or about 43.7 percent of the total. Vegetated shoreline type makes up about 24,976 feet (4.7 miles) or about 31.0 percent, sediment bank makes up about 12,632 feet (2.4 miles) or about 15.7 percent, and artificial makes up about 6,631 feet (1.3 miles) or about 8.2 percent of the total shoreline in the Deer River system. Totaling 1,130 linear feet, there were thirty-one inlets identified in the Deer River System.

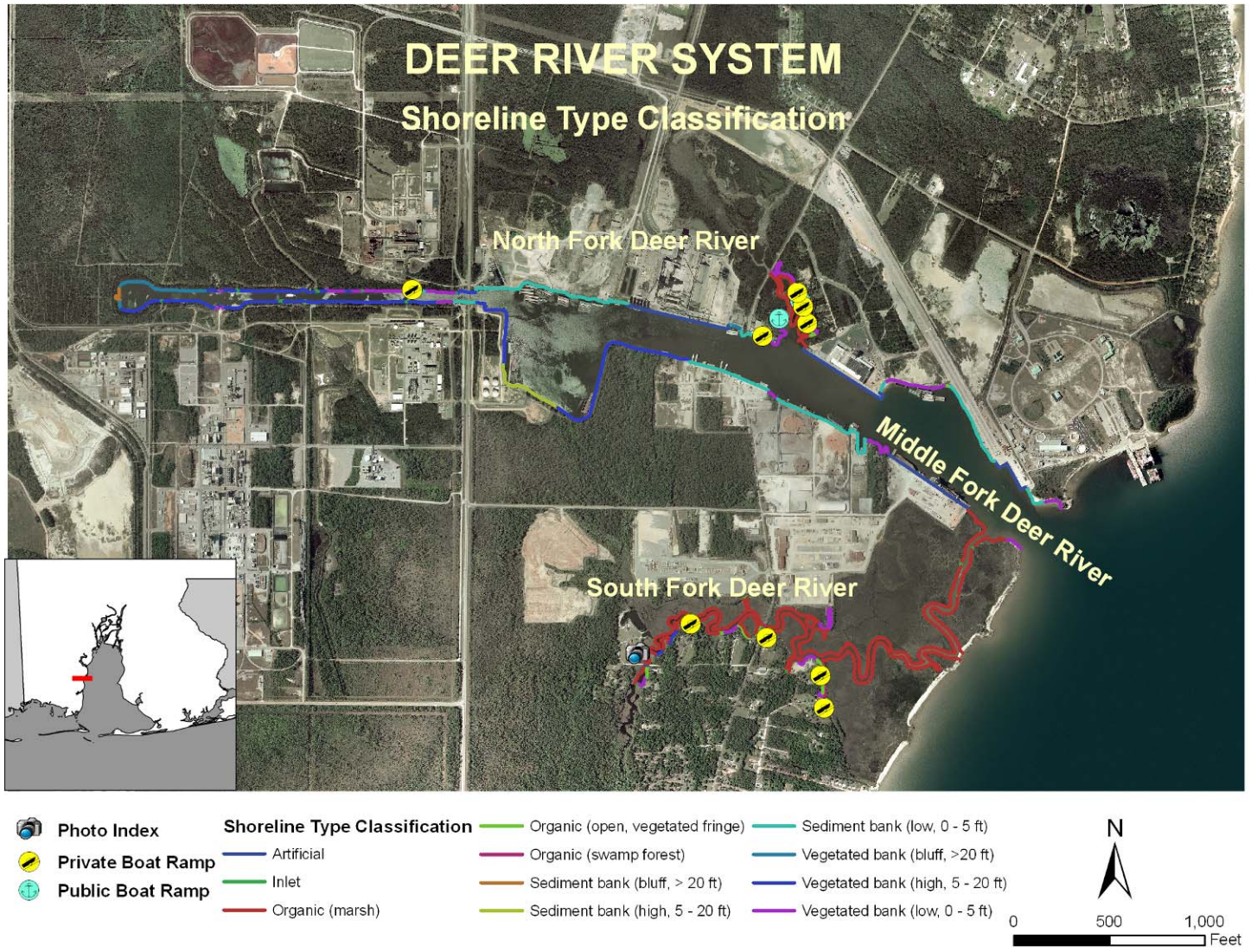

Figure 29. Shoreline type classification map of the Deer River system.

Table 29. Deer River system shoreline type classification lengths and percentages.

Deer River system		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	6,631	8.2
Inlet	1,130	1.4
Organic (marsh)	32,540	40.3
Organic (open, vegetated fringe)	1,825	2.3
Organic (swamp forest)	918	1.1
Sediment bank (bluff, > 20 ft)	359	0.4
Sediment bank (high, 5 - 20 ft)	1,327	1.6
Sediment bank (low, 0 - 5 ft)	10,945	13.6
Vegetated bank (bluff, > 20 ft)	1,880	2.3
Vegetated bank (high, 5 - 20 ft)	13,116	16.3
Vegetated bank (low, 0 - 5 ft)	9,980	12.4
Total	80,651	100.0

FLY CREEK

SHORE PROTECTION

Fly Creek is a small tributary of Mobile Bay, and with the exception of the marina located at the mouth of the creek, little shore protection was mapped. Fly Creek runs through a sparse residential area, but the majority of the shoreline is natural and unretained mainly due to the creek being relatively narrow and shallow.

The five different shore protection classifications identified in Fly Creek included boat ramp, bulkhead (steel, wood), rubble/riprap, jetty (steel pile, rock, concrete) and natural (table 30). Figure 30 is an illustration of the distribution of shore protection classification in Fly Creek. Mainly within the marina, bulkhead (steel, wood) protection was the longest mapped making up about 7,288 feet (1.4 miles) or about 48.2 percent of the total shore protection in Fly Creek. Natural, unretained shoreline composed about 7,144 feet (1.4 miles) or about 47.2 percent of the total. Jetty (steel pile, rock, concrete) makes up about 499 feet or about 3.3 percent of the total shore protection at the inlet to Fly Creek. Only 1 public boat ramp was classified.

About 2.9 miles of shoreline was mapped in Fly Creek with 1.5 miles (52.8 percent) having hard shore protection and 1.4 miles (47.2 percent) of natural, unretained shoreline. Bulkheads make up 1.4 miles (48.2 percent) of the total hard shore protection classification.

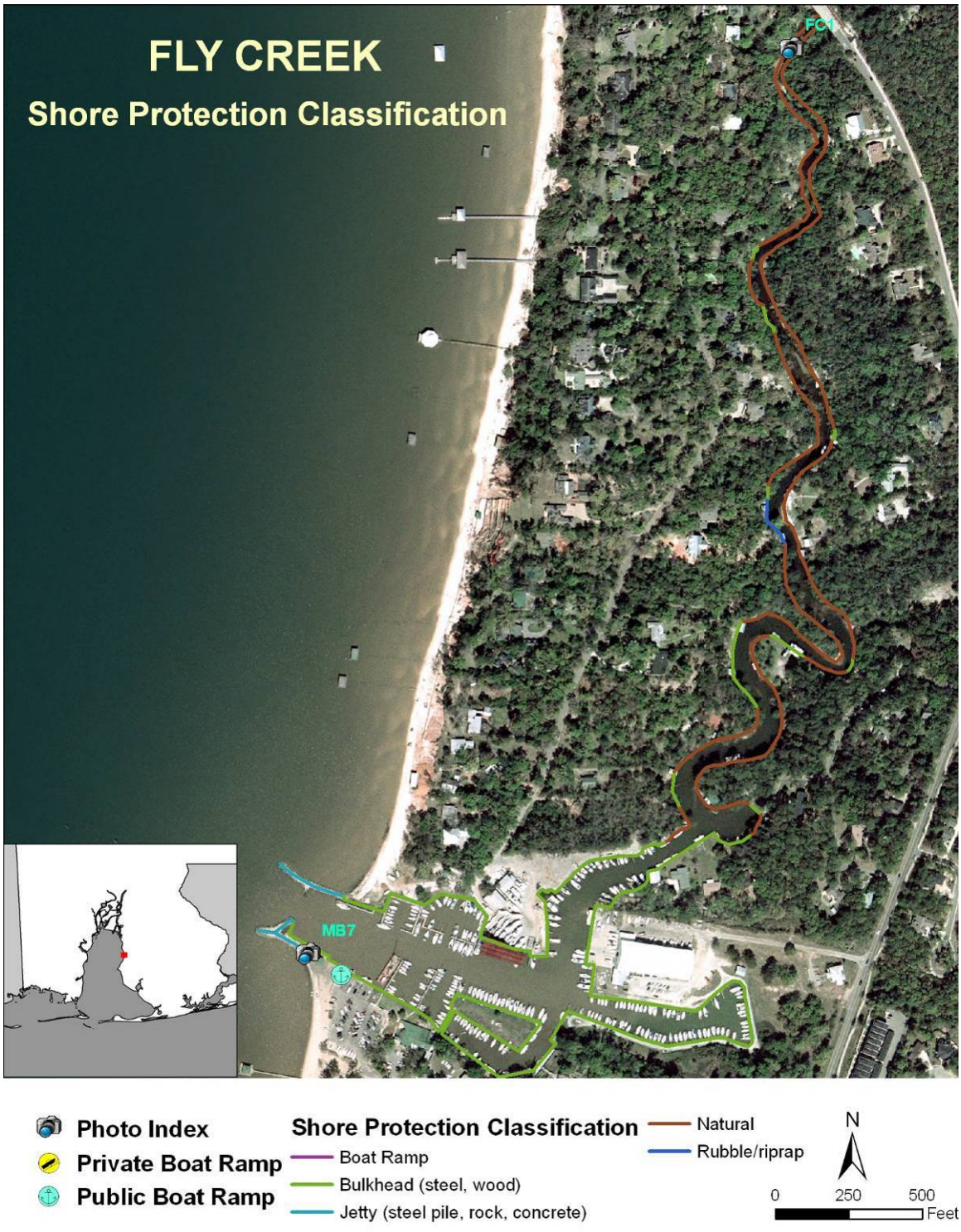

Figure 30. Shore protection classification map of Fly Creek.

Table 30. Fly Creek shore protection classification lengths and percentages.

Fly Creek		
Shore protection classification	**Length (ft)**	**Percent (%)**
Boat Ramp	16	0.1
Bulkhead (steel, wood)	7,288	48.2
Natural	7,144	47.2
Rubble/Riprap	177	1.2
Jetty (steel pile, rock, concrete)	499	3.3
Total	15,125	100.0

SHORELINE TYPES

Four different shoreline types were classified in Fly Creek: artificial, inlet, vegetated bank (high), and vegetated bank (low) (table 31). Figure 31 illustrates the distribution of the shoreline types classified in Fly Creek. The dominant shoreline type in Fly Creek is vegetated bank, of which vegetated bank (low) comprises 13,493 feet (2.6 miles) or about 89.7 percent of the total.

Table 31. Fly Creek shoreline type classification lengths and percentages.

Fly Creek		
Shoreline type classification	**Length (ft)**	**Percent (%)**
Artificial	652	4.3
Inlet	111	0.7
Vegetated bank (high, 5 - 20 ft)	784	5.2
Vegetated bank (low, 0 - 5 ft)	13,493	89.7
Total	15,041	100.0

Figure 31. Shoreline type classification map of Fly Creek.

SHORELINE CHANGE ANALYSIS

Results from the Digital Shoreline Analysis System (DSAS) (table 32; fig. 32) show a clear erosional trend in Mobile Bay from 1996 to 2008. Data from armored sections of the shoreline were discarded, as well as those with poor regression values. Of the 2,049 transects that showed good regression values (R^2 >=0.75) and a LSE value of 5.0 or less, 92.7 percent indicated shoreline erosion. Limited amounts of accretion were measured in northern areas of the bay and along the tip of Morgan Peninsula.

Western Mobile Bay exhibited moderate erosional trends in the vicinity of Deer River and Point Judith. A mean shoreline change rate of -8.2 ± 4.5 feet per year is indicated near the mouth of Deer River, with lower values on the northern side of the river mouth due to a higher occurrence of shoreline armoring. To the south, natural shoreline is predominant. Moderate erosion is indicated at other locations along western Mobile Bay, such as Point Judith, Alabama Port, Delchamps Bayou, and Brookley.

Significant erosion can be seen in southern Mobile Bay in the vicinity of St. Andrews Bay, Little Point Clear, and Three Rivers on Morgan Peninsula. Near St. Andrews Bay, rates of shoreline erosion range from -5.0 ± 1.3 to -29.3 ± 4.5 feet on the western approach and a negligible -2.4 ± 8.6 and -6.6 ± 6.0 feet on the eastern. The stretch of shoreline extending from Little Point Clear to Edith Hammock displayed similar trends, with a mean shoreline change rate of -5.4 ± 2.3 feet per year. The predominance of naturally vegetated shoreline in this region is a contributing factor to this erosional trend.

Eastern Mobile Bay exhibited erosional trends south of Ragged Point, with a mean shoreline change rate of -2.9 ± 2.0 feet per year. Locations along Bon Secour Bay showed similar trends. From Fish River Point to Seymour Bluff a mean shoreline change rate of -3.9 ± 2.7 feet per year is indicated. Aside from the approaches to Weeks and Oyster Bays, natural shoreline is the predominant shoreline type in this area. Figures 33 and 34 are field photographs taken in March and November 2009 at Red Bluff, northeast Mobile Bay. Slope failure is clearly evident over the course of eight months, as are previous and new shoreline stabilization methods. Although the location of bulkheads prevented DSAS modeling, erosion can remain an issue even with the presence and construction of hard shoreline protection.

Table 32.—Tabulated results from Digital Shoreline Analysis System modeling.

		All Transects	Selected Transects
Number of Transects		4,500	2,049
Mean Shoreline Change Rate (ft/yr)		-3.5 ± 5.9	-4.9 ± 3.2
Erosion %		85.6	95.6
Erosion Rates (ft/yr)	Max	-38.0 ± 48.7	-29.3 ± 4.5
	Mean	-4.6 ± 5.9	-5.3 ± 3.2
Accretion %		14.2	4.4
Accretion Rates (ft/yr)	Max	22.9 ± 30.9	22.4 ± 25.5
	Mean	2.6 ± 6.2	4.5 ± 4.3
No Change %		0.2	0.0

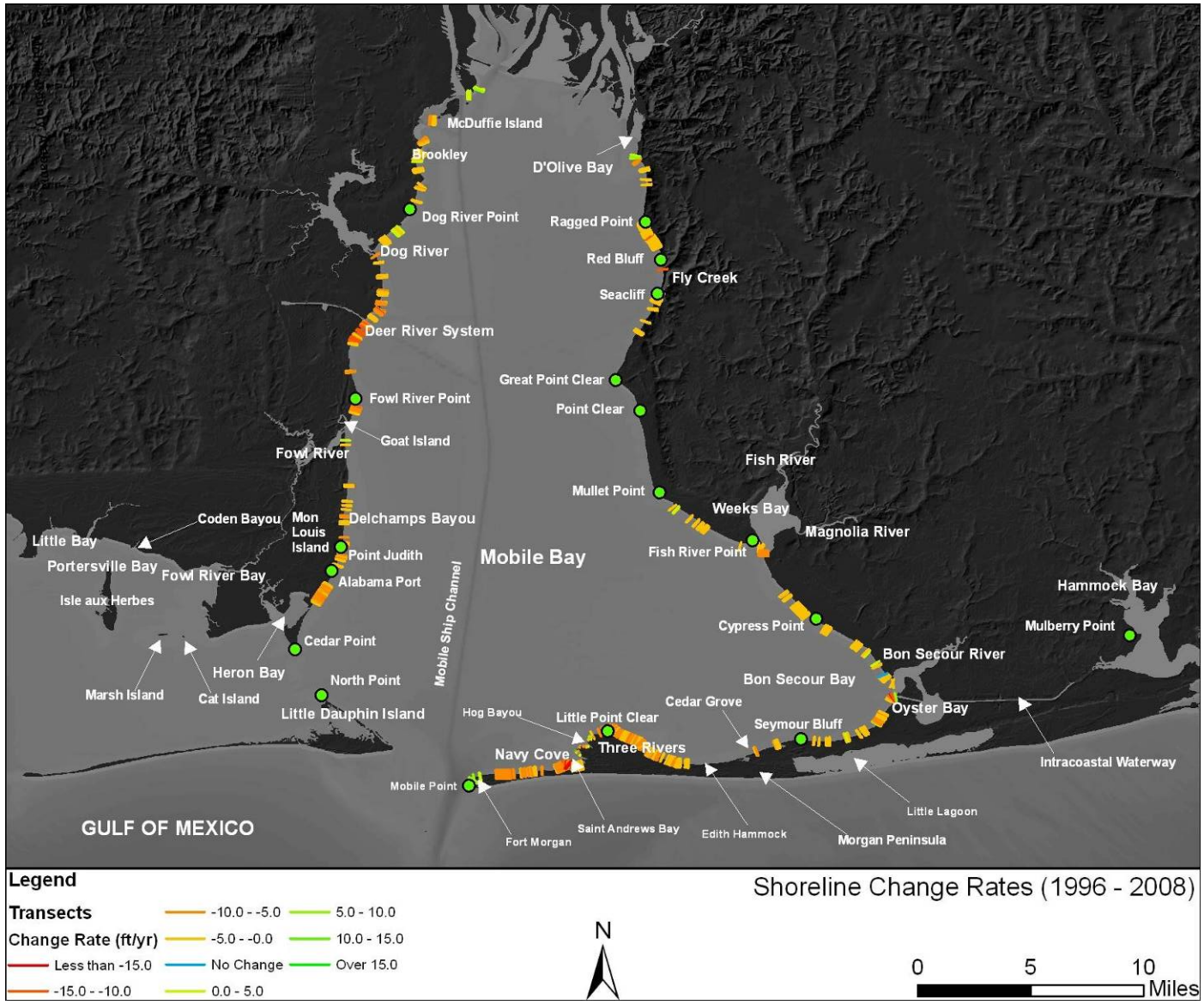

Figure 32.—Results from Digital Shoreline Analysis System (1996 through 2008).

Figure 33.—Shoreline erosion at Red Bluff, northeast Mobile Bay on March 17, 2009.

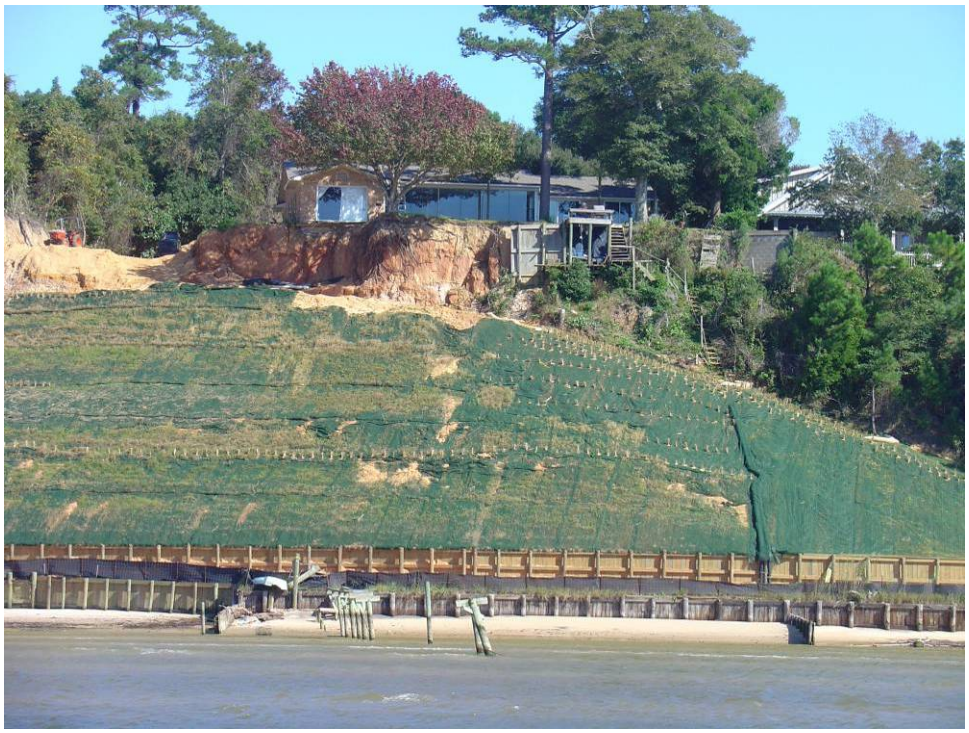

Figure 34.— Shoreline erosion at Red Bluff, northeast Mobile Bay on November 5, 2009.

CONCLUSIONS

In cooperation with the Alabama Department of Conservation and Natural Resources, State Lands Division, Coastal Section and funded, in part, by a grant from the National Oceanic and Atmospheric Administration (NOAA), Office of Ocean and Coastal Resource Management, Award No. 08NOS4190462, the Geological Survey of Alabama completed Phase I of a comprehensive shoreline mapping and shoreline change study in coastal Alabama. Through the application of geographic information system technology, shoreline protection methods and general shoreline types were mapped within Mobile Bay, Weeks Bay, Fish River, Magnolia River, Deer River system, and Fly Creek. In addition, rates of change were quantified within Mobile Bay. Phase I field work began on March 16, 2009, and ended November 6, 2009.

About 136.7 miles were mapped in Mobile Bay for shore protection with 86.6 miles in Baldwin County and 50.1 miles in Mobile County. Natural, unretained shoreline is the dominant shore protection classification with a total of about 83.4 miles or 61.0 percent of the total shore protection in Mobile Bay. The main engineered shore protection in Mobile Bay is from bulkheads totaling 36.1 miles or 26.4 percent of the total engineered shore protection. The second longest shore protection in Mobile Bay is rubble/riprap totaling 10.7 miles or 7.8 percent of the total engineered shore protection. An estimated 52.5 miles or 38.4 percent of Mobile Bay shoreline is protected by hard armoring.

Of the 11.4 miles of shoreline mapped in Weeks Bay, 8.4 miles (73.9 percent) were natural and unretained, and 3.0 miles (26.1 percent) were hard shore protected. Fish and Magnolia Rivers are tributaries to Weeks Bay. About 30.1 miles of shoreline on Fish River were mapped with 22.8 miles (75.7 percent) natural and 7.3 miles (24.3 percent) hard shore protected. Of the total shoreline on Magnolia River, 12.9 miles (83.5 percent) are natural and 2.5 miles (16.5 percent) are hard shore protected. The Deer River system shore protection classification had 15.2 miles of shoreline mapped, with 10.5 miles (68.9 percent) having natural, unretained shoreline and 4.7 miles (31.1 percent) having hard shore protection. Fly Creek shore protection classification had about 2.9 miles of mapped shoreline with 1.5 miles (52.8 percent) having hard shore protection and 1.4 miles (47.2 percent) having natural, unretained shoreline.

Mobile Bay has 133.5 miles of shoreline type that was classified into three major types: vegetated having 56.8 miles or 42.6 percent, organic having 50.2 miles or 37.6

percent, and sediment having 17.2 miles or 12.9 percent of the total. Weeks Bay has 11.4 miles of shoreline type that is classified into three major types: organic, having 7.3 miles or 63.8 percent; vegetated, having 4 miles or 42.6 percent; and sediment, having 338 feet or 0.6 percent of the total shoreline types. Fish River has 30.0 miles of shoreline type that is classified into three major types: vegetated, having 14.9 miles or 49.7 percent; organic, having 14.8 miles or 49.4 percent; and pocket beach (sediment), having 446 feet or 0.3 percent of the total shoreline types. Magnolia River has 15.4 miles of shoreline type that is classified into two major types: organic, having 7.8 miles or 50.4 percent and vegetated, having 7.5 miles or 48.6 percent of the total shoreline types. Deer River system has 15.3 miles of shoreline type that is classified into three major types: organic, having 6.7 miles or 43.7 percent; vegetated, having 4.7 miles or 31.0 percent; and sediment, having 2.4 miles or 15.7 percent of the total shoreline types. Fly Creek has 2.8 miles of shoreline type that is dominated by one major classification of vegetated, having 2.7 miles or 94.9 percent of the total shoreline types.

Results from the Digital Shoreline Analysis System show a clear erosional trend in Mobile Bay from 1996 to 2008. Of the 2,268 transects that showed good regression values (R^2 >=0.75) and a low Standard Error of the Estimate (5.0 or less), 92.7 percent indicated shoreline erosion. Limited accretion was measured in northern areas of the bay and along the tip of Morgan Peninsula. Western Mobile Bay exhibited erosional trends in the vicinity of Deer River and Point Judith. A mean shoreline change rate of -8.2 ± 4.5 feet per year is indicated near the mouth of Deer River. Moderate erosion is indicated at other locations along western Mobile Bay, such as Point Judith, Alabama Port, Delchamps Bayou, and Brookley. Significant erosion was quantified in Mobile Bay on Morgan Peninsula in the vicinity of St. Andrews Bay, Little Point Clear, and Three Rivers. Near St. Andrews Bay, rates of shoreline erosion range from -5.0 ± 1.3 to -29.3 ± 4.5 feet on the western approach, and -2.4 ± 8.6 and -6.6 ± 6.0 feet on the eastern. The stretch of shoreline extending from Little Point Clear to Edith Hammock displayed similar trends, with a mean shoreline change rate of -5.4 ± 2.3 feet per year. The predominance of naturally vegetated shoreline in this region contributes to this erosional trend. Eastern Mobile Bay exhibited slight erosional trends south of Ragged Point, with a mean shoreline change rate of -2.9 ± 2.0 feet per year. Locations along Bon Secour Bay showed similar trends. From Fish River Point to Seymour Bluff a mean shoreline change rate of -3.9 ± 2.7 feet per year is indicated.

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APPENDIX A

Photographs of shore protection types

Figure A1.—Natural shore protection (MB1).

Figure A2.—Seawall shore protection, Point Clear (MB 11).

Figure A3—Bulkhead (concrete, rock) shore protection (MR1).

Figure A4.—Bulkhead (concrete with riprap) shore protection.

Figure A5.—Bulkhead (concrete with riprap and groin) shore protection (MB 20).

Figure A6.—Bulkhead (with riprap) shore protection (FR 3).

Figure A7.—Bulkhead (with riprap and groin) shore protection (MB 4).

Figure A8.—Bulkhead (with retaining walls and groin) shore protection (MB 5).

Figure A9.—Bulkhead (with retaining walls) shore protection (FR 4).

Figure A10.—Bulkhead (wood, steel) shore protection.

Figure A11.—Bulkhead (with groin) shore protection (MB 10).

Figure A-12.—Bulkhead (with riprap, sill and groin) shore protection.

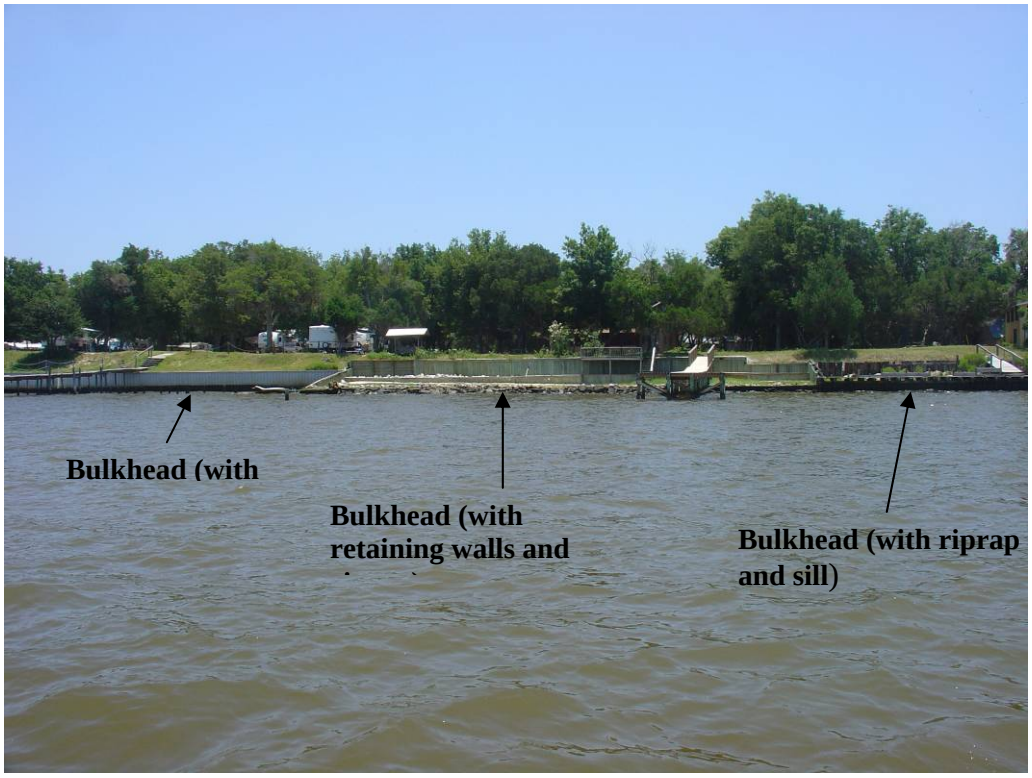

Figure A13.—Different types of bulkhead shore protection (MB 30).

Figure A14.—Revetment shore protection (MB 16).

Figure A15.—Breakwater shore protection, entrance to Weeks Bay (MB21).

Figure A16.—Groin shore protection (MB 14).

Figure A17.—Jetty shore protection (MB 7).

Figure A18.—Beach nourishment shore protection (MB 8).

Figure A19.—Rubble/riprap (with tires) shore protection (WB 2).

Figure A20.—Typical rubble/riprap shore protection installation (WB 1).

Figure A21.—Rubble/riprap groin shore protection (MB 11).

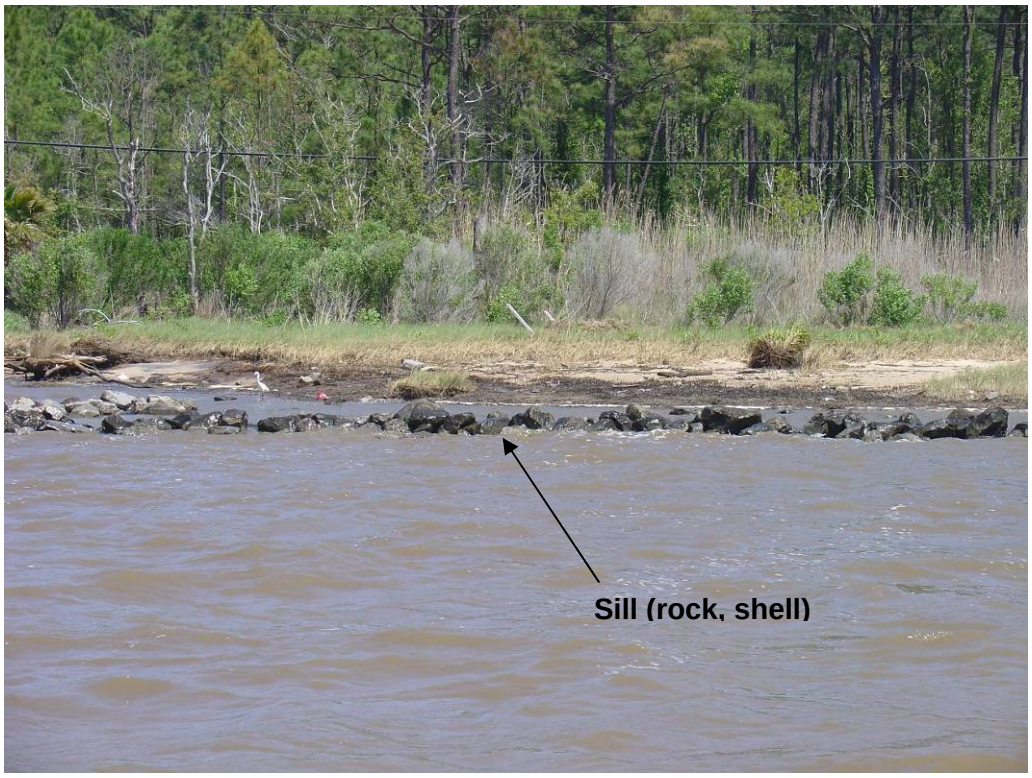

Figure A22.—Sill (rock, shell) shore protection (MB 19).

Figure A23.—Sill (wood) shore protection.

Figure A24.—Sill (wood with riprap) shore protection (WB 4).

Figure A25.—Boat ramp shore protection (MR 4).

Figure A26.—Silt fence shore protection (FR 2).

Figure A27.—Tire shore protection (DRS 1).

APPENDIX B

Photographs of shoreline types.

Figure B1.—Artificial shoreline type classification (MB 32).

Figure B2.—Vegetated bank (bluff) shoreline type (MB 6).

Figure B3.—Vegetated bank (high) shoreline type (FC 1).

Figure B4.—Vegetated bank (low) shoreline type (MB 15).

Figure B5.—Sediment bank (bluff) shoreline type classification (MB 5).

Figure B6.—Sediment bank (high) shoreline type classification (MB 2).

Figure B7.—Sediment bank (low) shoreline type (MB 13).

Figure B8.—Open shoreline vegetated fringe shoreline type (MR 6).

Figure B9.—Swamp forest shoreline type (MR 3).

Figure B10.—Marsh shoreline type.

Figure B11.—Inlet shoreline type.

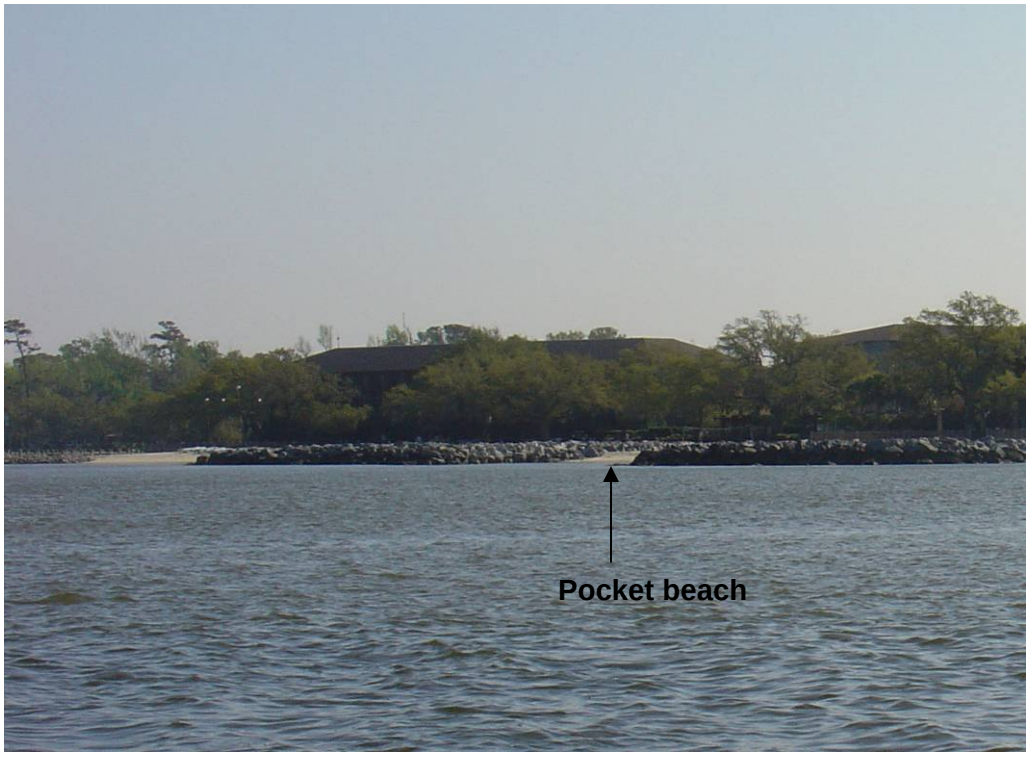

Figure B12.—Pocket beach shoreline type (MB 11).

GEOLOGICAL SURVEY OF ALABAMA
P.O. Box 869999
420 Hackberry Lane
Tuscaloosa, Alabama 35486-6999
205/349-2852

Berry H. (Nick) Tew, Jr., State Geologist

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