



# Development of the Geomorphological Map for Fire Island National Seashore

## *Principal Characteristics and Components*

Natural Resource Report NPS/NRSS/GRD/NRR—2015/941



**ON THE COVER**

Beach, dune and wetland topography in the Old Inlet portion of the Otis Pike Wilderness Area, Fire Island National Seashore. NASA imagery, obtained 6 March 2012 (pre-Sandy), extracted from Google Earth Pro on 24 March 2015.

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## Executive Summary

This report incorporates the geomorphological map, its philosophical underpinnings, legend descriptions, and the GIS data layers for the Fire Island National Seashore, Patchogue, New York. The theme of the map follows the current scientific organization of geomorphological mapping that includes morphometrics, causative processes, and evolutionary stages. Surface form was interpreted from data sets including recent orthophotos, recent Light Detection and Ranging (LiDAR) data sets, augmented with spatial information on soils and vegetation, and field visits.

The geomorphological features of the site include: 1) coastal topography that was created during an early phase of coastal barrier island development; 2) coastal topography that developed seaward of the early stage of barrier island evolution; and 3) anthropogenic modifications to the natural topography, consisting of fill or excavation. The geomorphological map and its legend portray the spatial and temporal association of the surface features created during these stages of landscape development, as well as the broad anthropogenic alterations of the landscape. This portrayal of surface form is based on data sets from 2010. A new post-Hurricane Sandy geomorphological map is being prepared.

The geomorphological map is viewable as a full compilation of all of the data layers as well as user specified combinations of the data. Each of the map layers contained in this report meets the standards of Federal Geographic Data Committee (FGDC) compliant metadata. The full set of organized data layers is available from the National Park Service, Geologic Resources Division, PO Box 25287, Denver, Colorado, 80225 or via the Geologic Resources Inventory publications page [http://www.nature.nps.gov/geology/inventory/gre\\_publications.cfm](http://www.nature.nps.gov/geology/inventory/gre_publications.cfm) (accessed 24 March 2015).

## Acknowledgements

Guidance and support for this project came from a host of Fire Island personnel that were sources of information and enthusiasm. Michael Bilecki, Patti Rafferty, and Diane Abell of Fire Island National Seashore were avid contributors throughout. Bruce Heise of the National Park Service (NPS) Geologic Resources Division of the NPS Natural Resource Stewardship and Science Directorate was a great sounding board and helped to steer our efforts toward the final product. And, a special tribute is extended to Jason Kenworthy, NPS Geologic Resources Division, for his considerable efforts in guiding the many drafts of our report to this publication. We are very appreciative of the great team of NPS personnel that were part of the entire review process. Our thanks are further extended to Erika Lentz, US Geological Survey (USGS) Woods Hole, and to Charles Finkl, Florida Atlantic University, for their insightful comments on the draft version of this report. Their efforts were very important in the production of the final paper.

## Introduction

Fire Island National Seashore (FIIS) is one of 270 National Park System units designated to have a digital geological map and an accompanying geologic resources inventory report. These products are intended to provide a valuable synthesis of the physical makeup of the site and assist in applying appropriate strategies in the management of its natural and cultural resources. Under the sponsorship of the NPS Geologic Resources Division, a scoping meeting was held at the Fire Island National Seashore Headquarters on June 24, 2010 to discuss and identify the geological character and variety of resources extant at the site, and to provide direction to the compilation of the geological map. The product of the scoping meeting was a document that identified themes of interest to the managers of the site, sources of data appropriate to the mapping effort, potential geomorphological features, and considerations for inclusion (Thornberry-Ehrlich 2011).

The traditional geological map incorporates many rock formations that extend across time horizons and shows considerable structural control of the surface configuration. However, the relatively small size of Fire Island National Seashore and the existence of a limited sedimentary formation caused a restructuring of the map to focus on the geomorphological character of the site; i.e., the configuration of the surface topography. As a result, FIIS is being represented by the elements of a geomorphological map rather than a geological map.

The concept of a geomorphological map traces its origins to Passarge (1914) and his representation of the surface character of the Stadtrempa, Germany quadrangle that emphasized the presence of river terraces as specific physical features in the landscape. Subsequent portrayals of the geomorphological character of the earth surface incorporated elements of the morphology as well as the origins of the features (processes) and chronological development (sequence of formation) (St. Onge 1968). The modern geomorphological map incorporates the elements of form, functional processes, and sequential development to depict the evolution of surficial and spatial characteristics (Dramas et al. 2011). The geomorphological map presented in this report follows the three-fold communication of form in the landscape, developmental processes, and stages in spatial evolution. It has a temporal sequence of features that is related to the stages of development of the surface characteristics of the site. It addresses the action of the earth-forming processes on the deposition, mobilization, and subsequent accumulation of sediments to produce the resulting geomorphological characteristics at FIIS. These processes continue to influence the development the landscape and, as a result, this map will serve to identify a stage in the evolution of the geomorphology of Fire Island. Many of the geomorphological features incorporated on these maps were affected by processes and responses associated with Hurricane Sandy in October 2012. A new series of geomorphological maps representing post-Sandy conditions is being prepared.

### Site and Situation

Fire Island National Seashore is located on Fire Island barrier island, situated on the south shore of Long Island, in Suffolk County, New York (Fig. 1). The entire barrier island extends east-west approximately 50 km between Moriches Inlet and Fire Island Inlet. The western 7.6 km is the site of Robert Moses State Park, whereas the eastern 10.3 km is occupied by Smith Point County Park. The



central 32.3 km portion of the island includes Fire Island National Seashore and 17 private communities. FIIS jurisdiction incorporates Smith Point County Park as well as a portion of the adjacent submarine environment (Fig. 1). At present, the surface of the island retains much of its geomorphological heritage, although there are several locations that have been greatly altered by cultural development in the several parks and in the communities.



**Figure 1.** Location of Fire Island and FIIS on the south shore of Long Island, New York; with locations of Robert Moses State Park, Smith Point County Park, and FIIS jurisdiction.

## Geomorphological Evolution

The conceptual approach to describing, depicting, and mapping the geomorphological characteristics of Fire Island is based on the components of morphometrics, causative processes, and temporal sequence of development of the surface of the island. This tripartite organization is the essence of modern geomorphological maps (Dramis et al. 2011) that combine the processes and the surface expression of the sedimentary formations (either in their erosional or depositional form). Further, the map legend (discussed later) is developed to track the evolution of the surface features and their associated causative processes, and to add the cultural imprint on to the landscape.

The surface topography of Fire Island represents several stages of sediment accumulation, sediment erosion, and sediment transport by a variety of formational processes over the span of the last 3,000 years, or so (McCormick and Toscano 1981; Psuty et al. 2005). Basically, Fire Island is a barrier island that has been created as sediment accumulated at modern sea level and amalgamated from a series of smaller barriers to form a more lengthy, relatively narrow island (Taney 1961; Leatherman and Allen 1985).

The dominant geomorphological processes creating the surface topography are the coastal waves and currents that transport and shape the ambient sediment supply to form an active beach and adjacent foredune. The foredune feature is the primary landform throughout Fire Island, as it is on all barrier islands. The active foredune represents the sand in storage above the active beach, and abandoned foredunes represent periods and locations of positive sediment budget that have prograded the island seaward and/or extended the island downdrift (to the west). Wind and water are the important formational processes that contribute sediment from the beach into the foredune position. Wind and water also aid in the disruption of the foredune, creating breaches and blowouts and breaks in continuity of the linear foredune feature.

Whereas the primary sand dune ridge is the active foredune immediately inland of the beach, there are many other dune ridge forms located inland from the beach (former foredunes). The entire barrier island is replete with abandoned foredune ridges that recount earlier shoreline positions as the barrier island went through stages of accumulation and erosion, as well as westward extension (Leatherman and Allen 1985; Allen et al. 2002; Psuty et al. 2005). In addition to the newer linear ridges, there are older groups of sand dunes that are less extensive and less continuous. They compose remnants of ancestral barrier islands that are now at the inner margin of the current Fire Island (Leatherman and Allen 1985; Psuty et al. 2005). Locations of former inlets are discerned in the pattern of foredune ridges, and the 1931 breach of the island to create Moriches Inlet has its own series of foredune ridges as the shoreline responded to the sediment transfers associated with the inlet.

The temporal sequence of the geomorphological evolution of Fire Island consists of an oldest series of foredune ridges near the bayside. The largest and most coherent old component is at Sailors Haven where a former individual island can be identified as consisting of a series of accretionary foredune ridges, marked with many blowouts and depressions. This area and similar inland features are ancestral components of the present-day barrier. Some of the ancestral landforms are major features in the landscape, other ancestral units are more subdued and less continuous, having been subjected

to erosion, especially by wind, and also inundated by sea-level rise since their development. The ancestral groupings of dunal features have been succeeded by a sediment accumulation phase that has shifted the shoreline seaward and has created a continuous beach-dune topography that extends along the length of Fire Island. Thus, the surface topography of the Fire Island barrier consists of a classic combination of ancestral and modern geomorphological features comprising an older segmented dune system on the inland side of the barrier island, bounded on the seaward margin by a more continuous, more recent active foredune. Together, they recount the variation in sediment supply interacting with the ambient coastal processes to create a geotemporal association of surface landforms, in keeping with the coastal foredune model and form assemblages described by Psuty (2004).

# Resources to Aid in Spatial Recognition of Features

A geographic information system (GIS) was developed for the construction of the geomorphological map of FIIS. The GIS includes orthophotos, light detection and ranging (LiDAR) data sets, and additional sources of geographical information that are described below.

## Orthophotography

A total of 58 image tiles collected by the National Oceanic and Atmospheric Administration (NOAA) National Geodetic Survey (NGS) with 0.35 m spatial resolution were accessed online from the NOAA Coastal Services Center (NOAA 2012). This coverage is part of the NOAA Integrated Ocean and Coastal Mapping (IOCM) initiative.

## LIDAR

The LiDAR data set was collected on November 25, 2011 by the NOAA NGS Remote Sensing Division and made available online through the NOAA Coastal Services Center (NOAA 2012). The data set incorporated topographical LiDAR data in LAS format with points classified as unclassified, ground, and water. The dataset also included LiDAR return intensity and RGB image values.

## Additional Sources

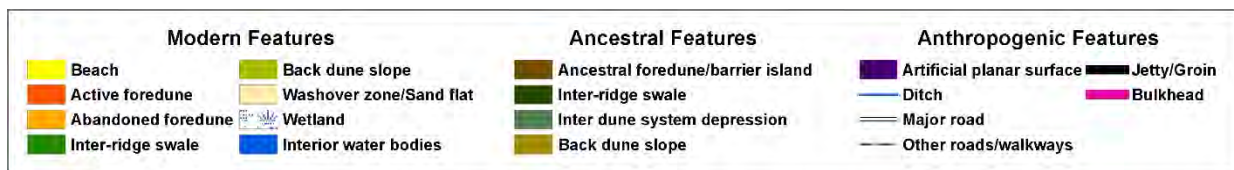
Additional sources of spatially-organized data (see Table 1) include a soils map (NPS 2005) and a vegetation map and report (Klopfer et al. 2002) downloaded from the NPS IRMA site, plus several geological reports (Gray Smith et al. 1999; Leatherman 1985; Psuty et al. 2005; Psuty and Silveira 2008), and sets of 9x9 stereo-pair aerial photos, 1:2400 scale, taken in 1992. A recent cultural history (Koppelman and Forman 2008) offered perspective on the variety and extent of anthropogenic modifications. Locations of buildings, infrastructure, and boundaries were accessed from the NPS Integrated Resource Management Application (IRMA) website. Roads and walkways were digitized from the orthophotos.

**Table 1.** Source and quality of spatial data.

Data	Year of Acquisition	Spatial Resolution	File Type	Source
Orthophotos	2011	0.35m	.jp2	NOAA
9x9 stereo aerial photos	1992	0.5 ft	paper	Rutgers University
LiDAR	2011	-	LAS	NOAA
Soil Map	2005	-	.shp	NPS IRMA
Vegetation	2002	-	.shp	NPS IRMA
Road/Walkways	2007	-	.shp	NPS IRMA and digitized from orthophotos

## Legend: Categories and Symbolization of Geomorphological Features

The legend is organized relative to the geomorphological evolution of the site, incorporating the spatial sequence of coastal landform development composed of ancestral and modern features (Fig. 2 and Table 2). Ancestral features are elements of the landscape that were created at an earlier time when the shoreline and shore processes were active at that location. It is likely that the ancestral features composed a series of smaller separate barrier islands. They are now represented by groupings of dunal features arranged discontinuously in the present landscape, usually at or near the inland margin of the barrier island. These groupings have since coalesced into a single island through the accumulation of sediment that has both joined the several smaller islands and has displaced the shoreline and its accompanying geomorphologies seaward. The modern features are associated with the lengthier continuous barrier that tends to have a more linear array of dunal ridges parallel to the shoreline. There are also instances of positive sediment budget that have caused a seaward displacement of the more recent foredunes, creating a progradational series of abandoned foredune ridges parallel to the modern shoreline. Their more uniform and consistent morphologies create a distinct separation from the more irregular and far more variable topographies of the ancestral groups, and thus establish a morphological distinction between the ancestral and modern features. In the broad spatial context of landform features on Fire Island, there is a separation between the segmented ancestral dunal features and the more continuous modern lineal dunal topographies, and there is a pattern of active and abandoned linear foredunes in the modern series. Further, because some portions of Fire Island have been largely modified and molded to accommodate park development and occupation (primarily in the county and state parks), a category of ‘planar surface’ has been added to the legend to describe topographies that are essentially a level surface in the landscape created by human manipulation. In a few locations, primarily on the bayside, some anthropogenic features (bulkheads, artificial fill) are superposed on the geomorphology.



**Figure 2.** Map legend, incorporating categories of geomorphological features, sequence of modern and ancestral features, and anthropogenic features.

**Table 2.** Geomorphological Features Found at Fire Island. Table continues on next page.

Classification	Conceptual Basis	Physical Description and Identification
<b>1. Modern Active Features</b>		
Beach	Wave-deposited accumulation of sediment, specifically the seaward portion of a beach profile between the low tide line and the upper limit of storm wave action. Regularly inundated by waves during high-water phases of the tidal cycle. Dominant direction of wave approach determines alongshore sediment flow.	Area of low, nearly planar elevation on oceanside and bayside of barrier island. A very prominent feature that tends to be broad, continuous, and has sparse to no vegetation. It extends from the lowest tide level to the toe of the active foredune.
Foredune	Ridge formed by eolian (wind-blown) sand at the inland margin of a beach, parallel to the coastline. It is vegetated by pioneer plant species that trap sediment. The foredune is actively participating in sediment exchange with the beach.	A continuous, linear feature of elevated topography (positive relief) that is parallel to the shoreline and immediately inland of the oceanside or bayside beach. The bayside foredune often has parabolic dune ridges extending inland. It is sparsely to moderately vegetated.
Wetland	A general term describing swamps and marshes, i.e., an area of very low elevation vegetated by saltwater, brackish water, and freshwater plants. Often found in areas sheltered from ocean waves such as the bayward side of the barrier island or isolated islands on the bayside.	Wetlands are roughly approximated by areas of very low (nearly sea-level) elevation. Marsh vegetation is often distinctly visible on orthophotos. In places where the exact position of the wetland boundary is uncertain, it is useful to consult vegetation maps showing where wetland plants exist. Old drainage ditches are sometimes recognized and represented as straight lines in the wetland areas.
Interior water bodies	Areas of open water within the boundaries of the barrier island, not connected by tidal channels to the bay or ocean. Often occurs as ponds within wetlands but may exist in other areas as well.	Inland water bodies are distinctly visible on orthophotos. Only water bodies visible at the map scale and not subject to tidal inundation are delineated in this category.
<b>2. Modern Abandoned Features</b>		
Abandoned foredune	A previously active foredune ridge that is no longer in sediment exchange with the beach. Often found parallel or adjacent to an active foredune on the oceanside as well as bayside. May have been reworked by winds into parabolic, hummocky, or dissected features.	Foredune ridge may be generally linear and intact or dissected, depending on the age of the feature, the influence of wind, and the dimensions of the original feature. The original, relatively high elevation is often preserved long after the dune has been abandoned. It is usually in relatively close proximity to the active foredune ridge; i.e., ridges not separated by a major interdune depression.
Inter-ridge swale	Accumulation of sand between dune ridges that forms during time of abundant sediment supply (shoreline progradation), and occupies the space between the sequential, parallel foredune ridges.	A linear hollow or topographical low between parallel dune ridges, it is usually parallel to the shoreline. The swale will have lower elevation and negative relief in relationship to the adjacent dune ridges. Swales are indicative of a positive sediment budget that creates accretionary foredune ridges in a seaward location

**Table 2.** Geomorphological Features Found at Fire Island (continued). Table continues on next page.

Classification	Conceptual Basis	Physical Description and Identification
Back dune slope	Area immediately inland of the leeward slope of the innermost dune ridge. It is related to the dune-forming terrestrial processes.	Elevation is generally low and tends to decrease toward bay side (i.e., slopes away from the dune ridge toward the water)
Washover zone/sand flat	Remnant of an episodic storm event that penetrated inland of the foredune ridge toward the bayside margin of the barrier. A relatively flat blanket of sediment deposited in place of previously existing features, often including an washover fan-shaped deposit on the landward side of the barrier island.	May be visible as an uncharacteristic break in continuous, shore-parallel linear features of positive relief such as the active foredune or abandoned foredune. A low, bare sand planar surface inland of the foredune location. The previously existing dunes may be retained adjacent to the washover fan as low, hummocky dune features.
<b>3. Ancestral Features</b>		
Ancestral foredune/ barrier island	An ancestral barrier island component that has been incorporated into and forms the accretionary core of the modern-day barrier island. This feature is temporally distinct from the more recently-created abandoned and active foredunes. The ancestral foredune is more dissected and less continuous than the modern foredune and its associated abandoned foredune ridges. There is a distinct spatial gap between the more recent coherent ridge forms and the more irregular ancestral foredune features, represented by a significant inter dune system depression.	Inactive dunal ridge at the inland margin of the barrier, it may be highly dissected and reworked by wind or overwash. Often physically separated from more recent ridges by a significant inter dune system depression. Forms the core of highly stable, broad sections of the barrier island. Feature may be large and coherent or low and dissected. It is spatially and morphologically separated from the shore-parallel active foredune.
Inter-ridge swale	Accumulation of sand between dune ridges that forms during time of abundant sediment supply (shoreline progradation), and occupies the space between the sequential, parallel foredune ridges.	A linear hollow or topographical low between parallel dune ridges, that is usually parallel to the shoreline at that time. Swale will have lower elevation and negative relief in relationship to the adjacent dune ridges. Swales are indicative of a positive sediment budget that creates accretionary foredune ridges at the time of development
Back dune slope	Area immediately inland of the leeward slope of the inner dune ridge.	Elevation is generally low and tends to decrease toward bay side (i.e., slopes away from the dune ridge toward the water).
Inter dune system depression	Accumulation of sand that forms during time of abundant sediment supply (shoreline progradation), it is a topographical low separating the development of active foredune systems from the ancestral foredune system. It is a prominent linear depression at a lower elevation than adjacent ridge systems.	Substantial area of lower elevation (negative relief) between major dune systems. Often parallel to the coastline. In some areas where the older dune system has been substantially reworked, it can be difficult to distinguish the inter dune system depression from the back dune slope.

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**Table 2.** Geomorphological Features Found at Fire Island (continued).

Classification	Conceptual Basis	Physical Description and Identification
<b>4. Anthropogenic Features</b>		
Artificial planar surface, modified by people	A human-made flat or planar surface that has been leveled or built-up to site some sort of structure or human use, such as a building, parking area, or commercial activity. Underlying topography is destroyed or covered and replaced by created surface. Irregular dunal ridge and swale topography may be leveled to create a uniform surface. Or, sediment may be introduced by dredging or truck to elevate a surface above tidal levels.	Elevation of the surface is nearly or completely homogeneous and level. This surface produces an abrupt interruption of adjacent naturally-occurring topography. Boundary of surface is often sharply-defined and clearly visible on the orthophotos. On the bayside, it is usually associated with bulkheads and housing or marinas on the orthophotos and in the field. Fill may also cover pre-existing wetlands and provide a dry foundation for human occupation
Jetty/Groin	An engineered structure that projects perpendicular to the shoreline. A jetty is a large structure with the purpose to stabilize the location of an inlet channel. A groin is a smaller structure in the beach, built to trap sand and stabilize a portion of a sandy beach.	Jetties exist on the ends of the island to stabilize margins of the inlets. Several groins occur on the oceanside and cause an offset in the beach. Small groins occur on the bayside, usually near a dock or marina. They often cause a displacement of the shoreline.
Bulkhead	An erosion control structure that is constructed at and parallel to the shoreline to harden the shoreline next to existing development or to maintain water-dependent uses such as marinas. Erosion-control structures include bulkheads, riprap, marinas or other structures that harden the shoreline.	Erosion control structures are identified from LiDAR, from a prepared data source, orthophotos, and in the field. These structures are found in developed portions of the island.
Drainage ditch	Waterways historically dug in wetlands in a parallel grid pattern in order to drain wetlands and control mosquito populations. They are usually abandoned, no longer maintained as a water course.	Wetland mosquito ditches tend to be clearly visible on orthophotos. Abandoned or unmaintained ditches may be filled in with sediment. Only ditches visible at the map scale are delineated as straight blue lines.



## Methodology of Topography Development

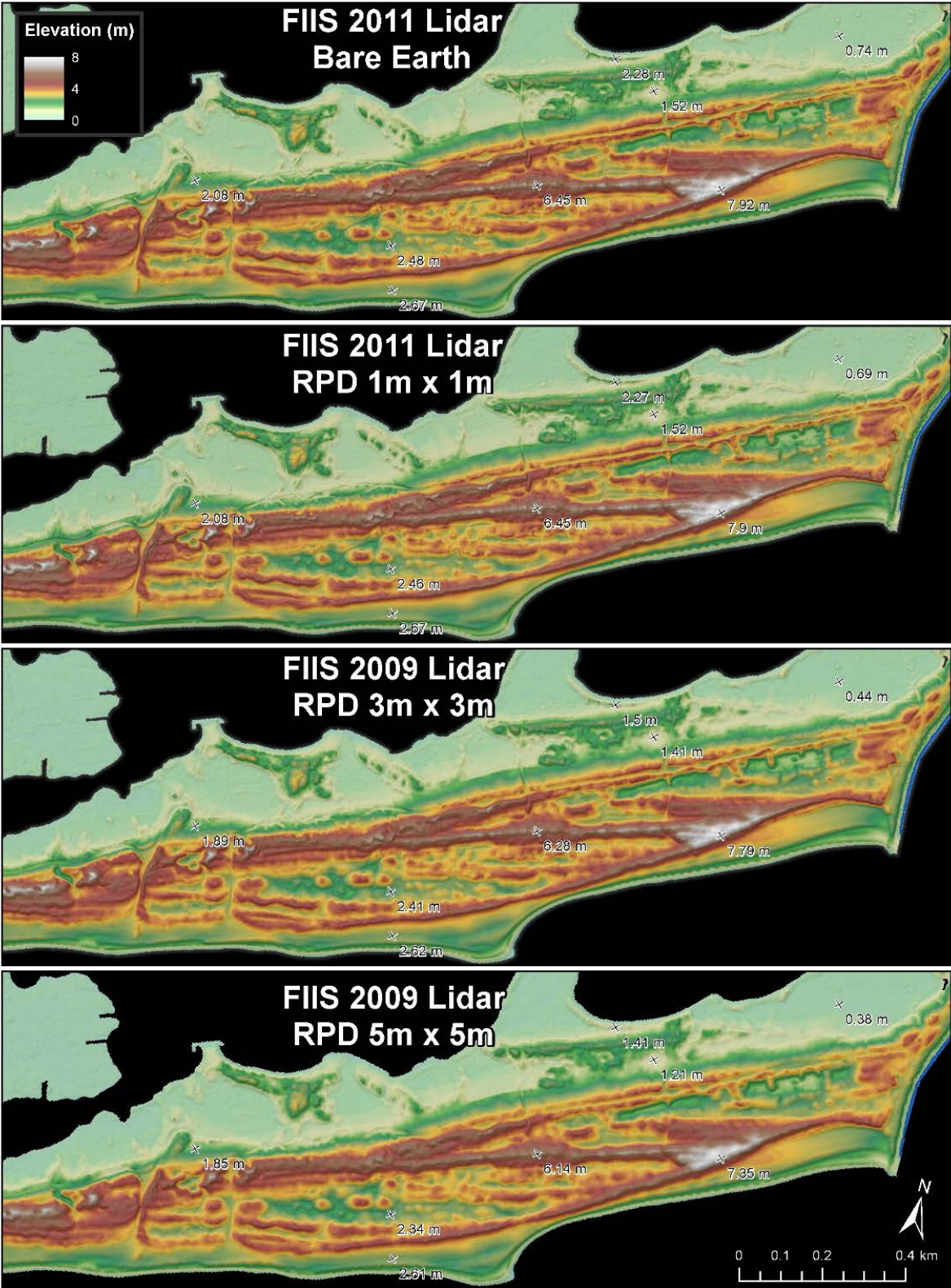
The initial approach of landform identification used recent orthophotos of the island (see example in Fig. 3) to establish the geographical coordinates of the geomorphological units. The next phase utilized the 2011 bare earth LiDAR data sets for Fire Island provided by the NOAA NGS Remote Sensing Division to create the topography of the landscape. However, the LiDAR bare earth DEM produced by the NOAA data set exhibited some noise due to areas of dense vegetation and buildings. To minimize these surface perturbations, the raw LiDAR data points were filtered using the Reduce Point Density method via Airborne LiDAR Data Processing and Analysis Tools (ALDPAT) (Zhang and Cui 2007) software to create a new bare earth DEM.



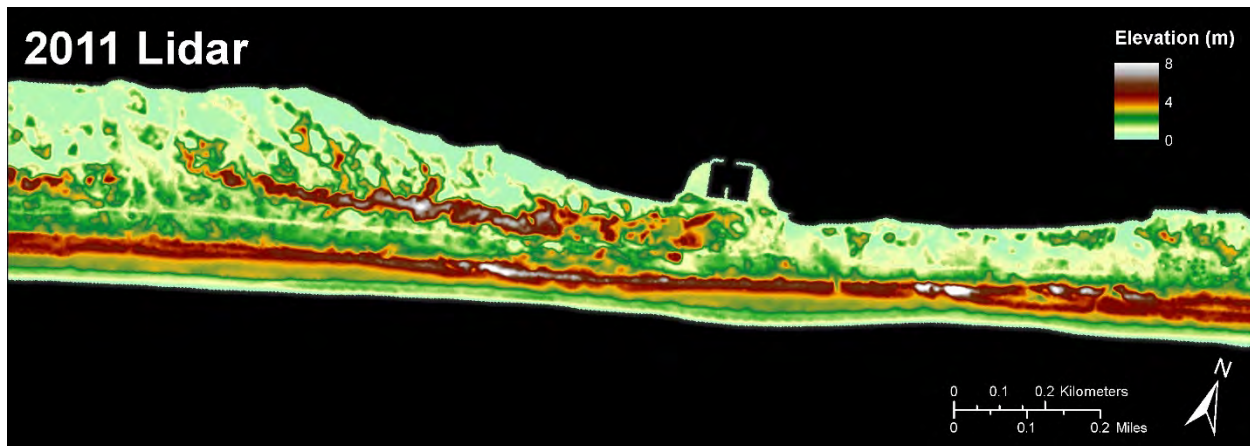
**Figure 3.** Orthophoto of Sailors Haven area, Fire Island National Seashore. (Source: NOAA)

The Reduced Point Density method searches for and chooses the point of minimum elevation within a specified area, or window, to represent that location. Several iterations of this filtering procedure were applied to the bare earth LiDAR points, enlarging the window each time. An example of this procedure is provided for a portion of the topography near Moriches Inlet (Fig. 4). The data set was filtered using area windows of 1m, 3m, and 5m on a side. Each subsequent iteration was applied to the filtered data points of the previous iteration. The third iteration, which inherently carries an average point distance slightly over 5 m, provided sufficient relief to determine the spatial boundaries of the geomorphological features while discarding most noise associated with non-ground points. The reduced density point cloud was then interpolated into a 2.5 m resolution DEM using the Kriging method with a 50 m search radius. The resulting product of the reduced point density approach is a DEM that is less detailed than the original DEM because the minor variations have smoothed to emphasize the general trends in elevation (see the sequence in Fig. 4).

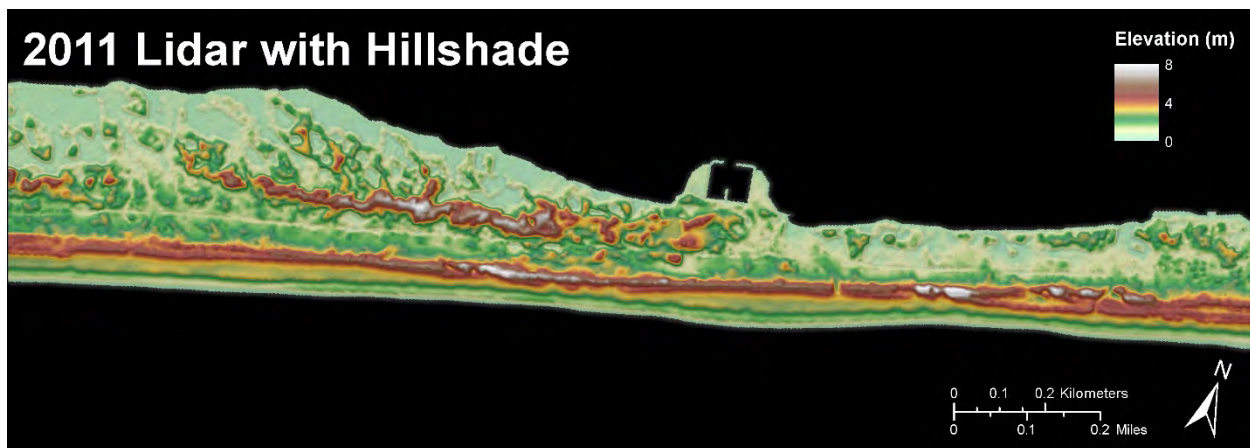
Several additional steps are conducted in distinguishing and applying the landform categories identified in Table 2. An example is provided of the Sailors Haven area that has considerable variation of landforms within a limited area. Given the initial orthophoto that provides the geographical base (Fig. 3) and the initial DEM created by the filtering process, the topographical model was analyzed through the application of elevational categories (Fig. 5). Additionally, spatial



**Figure 4.** Sequence of filtering to generate bare earth DEMs by selectively choosing the lowest elevations in windows of increasing sizes, grading through 1, 3, and 5 m windows. Site in this example is west of Moriches Inlet.



**Figure 5.** Digital elevation model (DEM) with elevation categories created from 2011 LiDAR data set with reduced point density, Sailors Haven area, Fire Island National Seashore (Data available through NOAA (2012)).



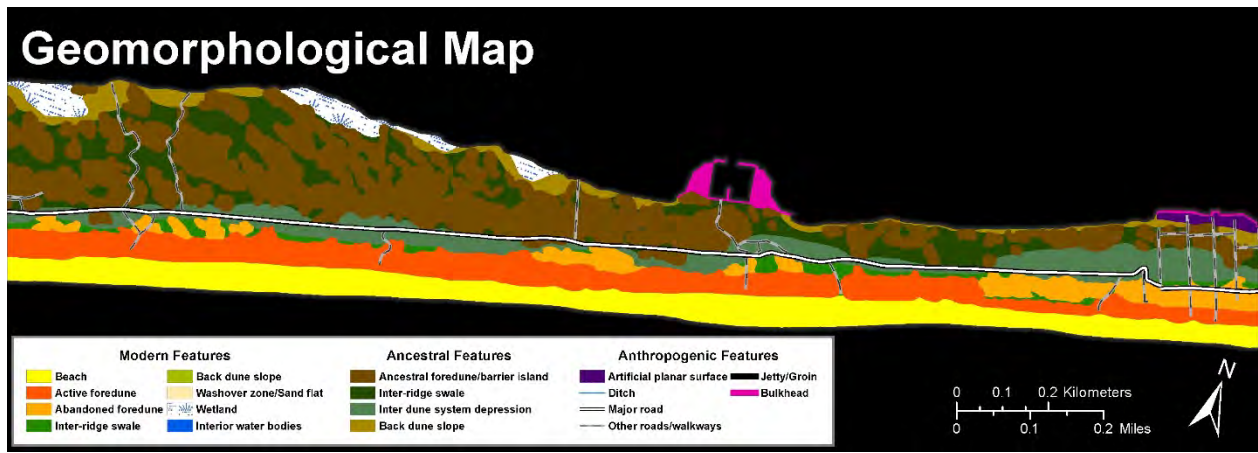
**Figure 6.** DEM with elevation categories and hillshade effect, Sailors Haven area, Fire Island National Seashore.

patterns of elevation, slopes, and relief portrayed together by overlaying raster datasets derived from the original LiDAR DEM outlined the distribution of the variety of dune ridges and intervening swales of various dimensions and continuity. Further, rasters created through the application of the ArcGIS hillshade tool provided an enhanced depiction of the topography (Fig. 6). After the juxtaposition of dune features was determined, their sequential evolution was interpreted using the fundamentals of sediment transport direction, sediment supply, and sediment budget. Other resources used in the identification, digitization, and classification of the geomorphological features included a vegetation map, soils map, orthophotos, and stereo aerial photos.

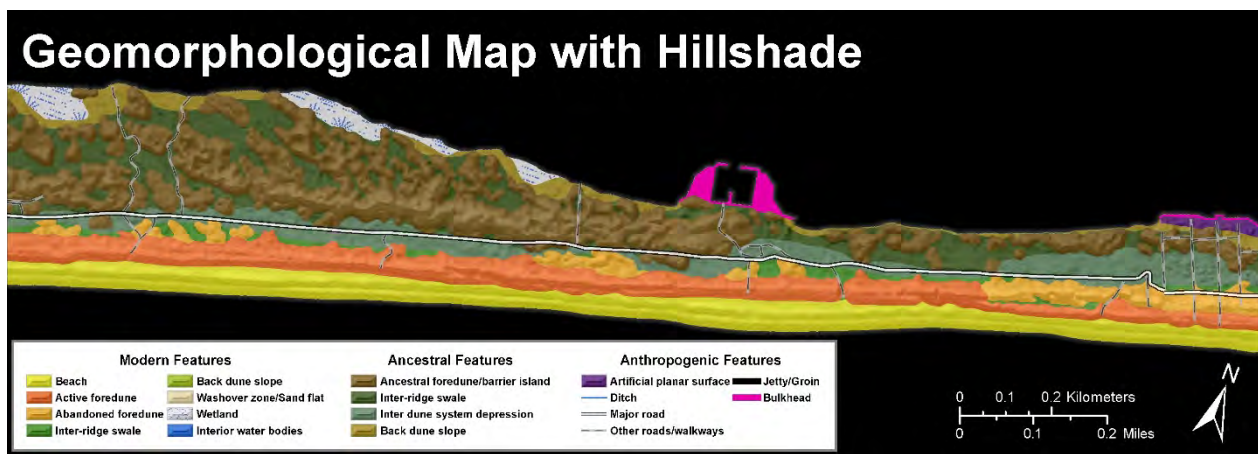
Orthophotos were the primary source of geographical information regarding the positioning of community modifications of the topography, erosion-control structures at the shoreline, beaches on the oceanside and bayside, and other natural and anthropogenic features on the landscape. The geomorphological features were plotted on the 2011 orthophoto base map, and orthophotos from 1994 and 2004 were referenced as well to assist in the interpretation of the spatial evolution of the

surface characteristics. The topographical interpretations in areas of dense vegetation and low relief were verified with field visits to Fire Island.

Through the combined analysis of the surface topography, vegetation and soil maps, and a variety of aerial photographs, the surface features were classified using the tripartite geomorphological descriptors of topography, creative process, and developmental groupings (Fig. 7). A further step consisted of discriminating the spatial distribution of the modern categories of landforms from the ancestral geomorphological features. Finally, the hillshade effect was incorporated in the geomorphological map to provide a pseudo 3D effect that emphasized the element of slope within the landform categories (Fig. 8).



**Figure 7.** Distribution of geomorphological features, incorporating the linear dune features, and separating the older (ancestral) segmented coastal foredune system from the more recent and more continuous active foredune ridge, Sailors Haven area, Fire Island National Seashore.



**Figure 8.** Distribution of geomorphological features, with relief emphasized through the application of hillshade, Sailors Haven area, Fire Island National Seashore.

## Final Product

The Fire Island geomorphological map is the spatial portrayal of the evolution of the barrier island system that developed from a series of several discrete ancestral units through its consolidation into a continuous barrier. It has topographical features that show a series of accretionary dunal ridges that recount the westerly extension into Fire Island Inlet, and a series of accretionary ridges that show the enforced locational stability at the jettied Moriches Inlet. The Fire Island geomorphological map consists of 17 panels, covering the extent of the island from Fire Island Inlet to Moriches Inlet. Two additional panels are provided that portray the geomorphological characteristics of several bay islands within the Park jurisdiction. One set of panels portrays the distribution of geomorphological features without hillshade. One set of panels incorporates hillshade in their depiction.

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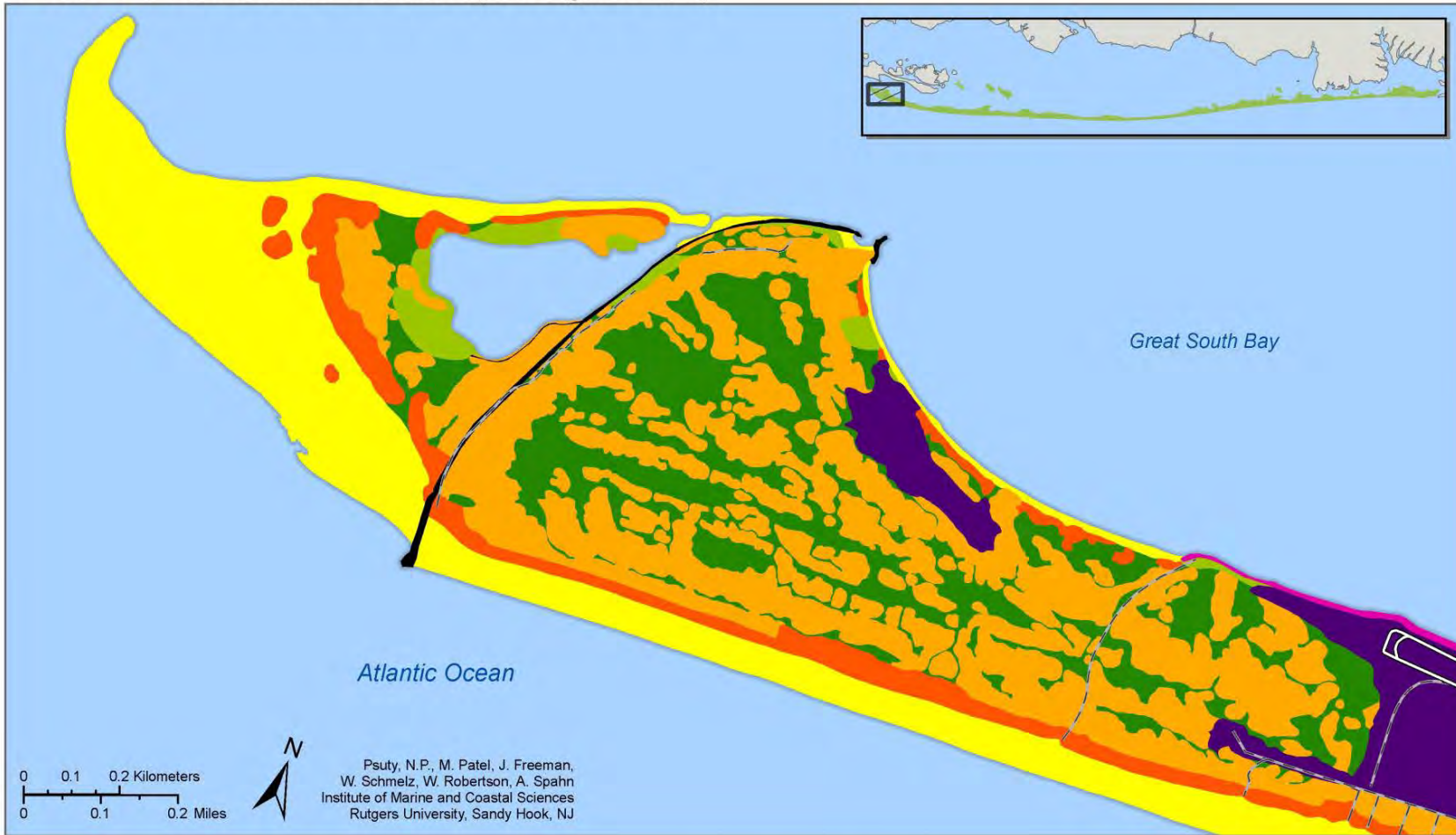
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## **Appendix: Maps of Fire Island Geomorphology, with and without Hillshade**



# "Zone 1", Fire Island Geomorphological Map



## Modern Features

- Beach
- Active foredune
- Abandoned foredune
- Inter-ridge swale
- Back dune slope
- Washover zone/Sand flat
- Wetland
- Interior water bodies

## Ancestral Features

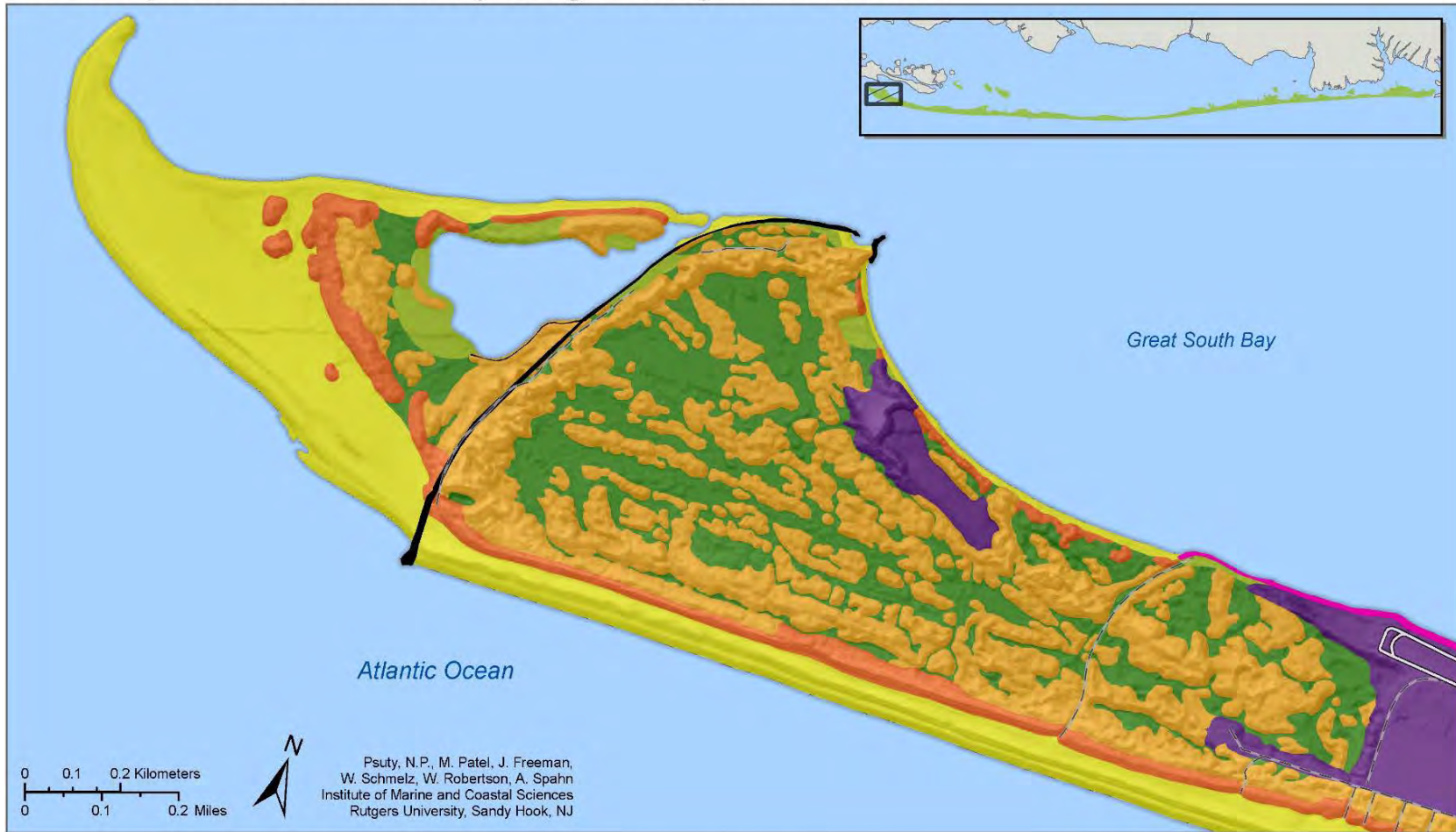
- Ancestral foredune/barrier island
- Inter-ridge swale
- Inter dune system depression
- Back dune slope

## Anthropogenic Features

- Artificial planar surface
- Ditch
- Major road
- Other roads/walkways
- Bulkhead
- Jetty/Groin

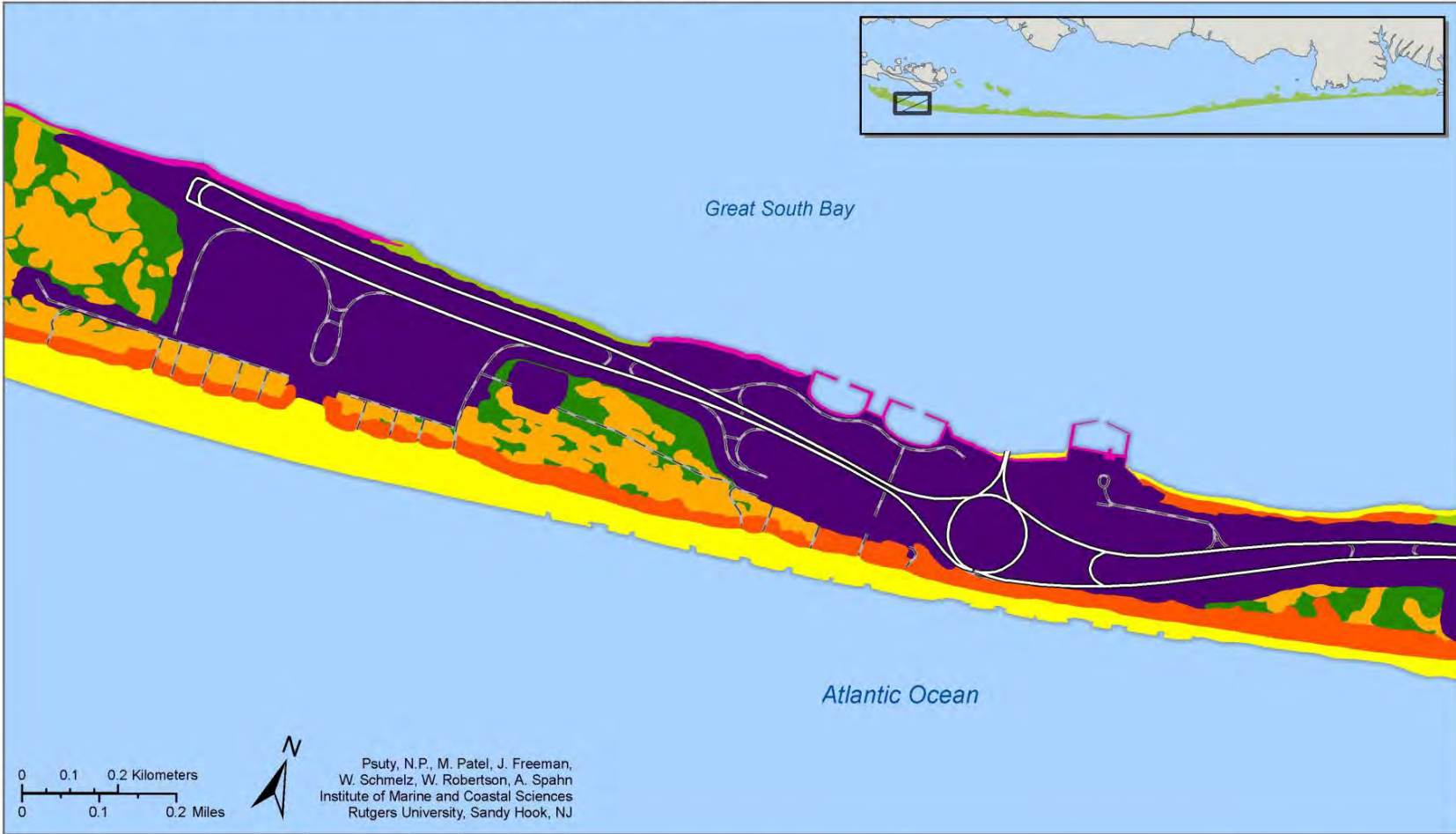
# "Zone 1", Fire Island Geomorphological Map with Hillshade

19



Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 2", Fire Island Geomorphological Map



20

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

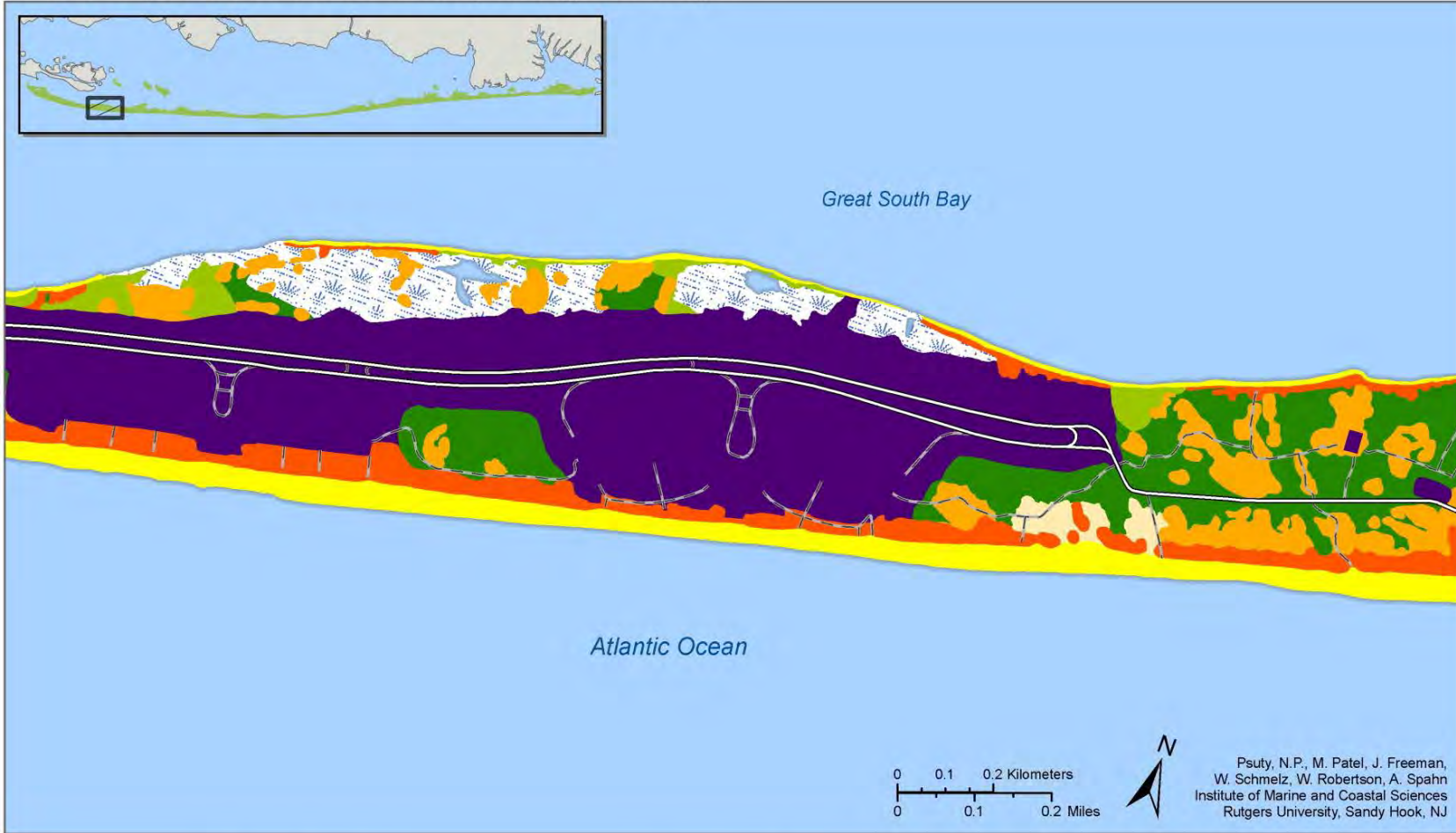
# "Zone 2", Fire Island Geomorphological Map with Hillshade



21

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 3", Fire Island Geomorphological Map



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

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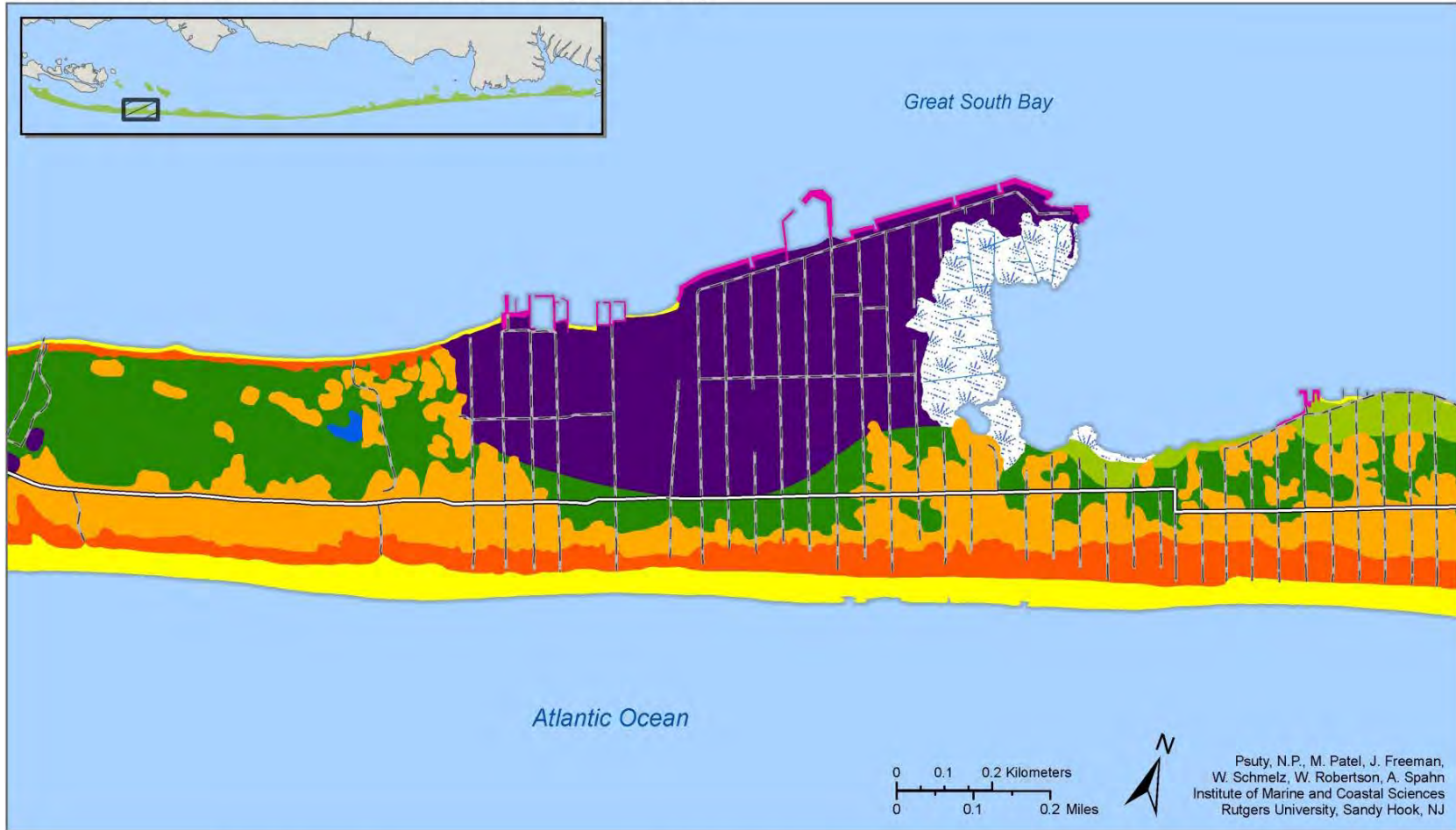
# "Zone 3", Fire Island Geomorphological Map with Hillshade



23

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

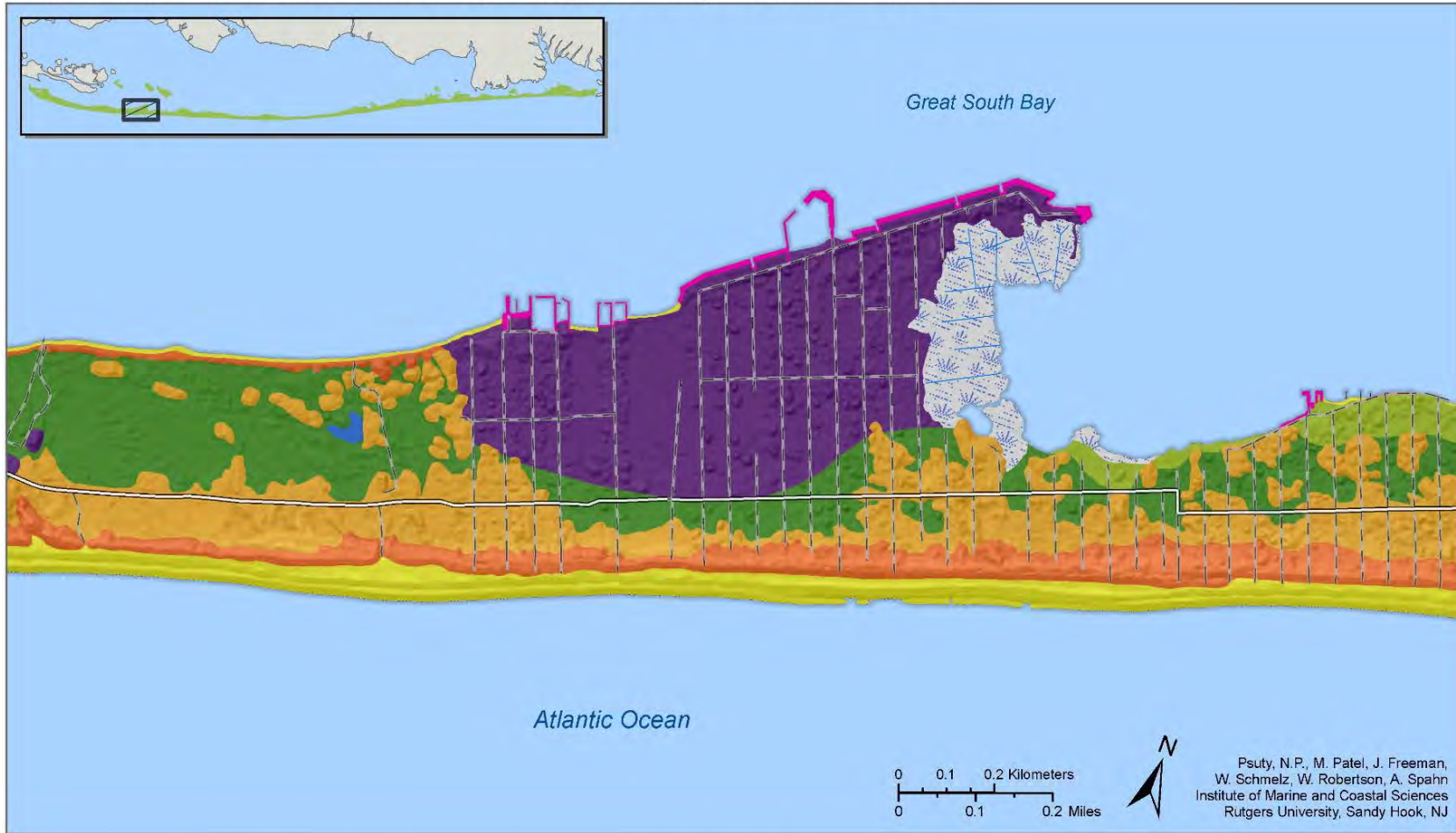
# "Zone 4", Fire Island Geomorphological Map



24

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Artificial planar surface	Jetty/Groin	Bulkhead
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Ditch	Major road	
Abandoned foredune	Wetland	Inter dune system depression	Other roads/walkways		
Inter-ridge swale	Interior water bodies	Back dune slope			

# "Zone 4", Fire Island Geomorphological Map with Hillshade



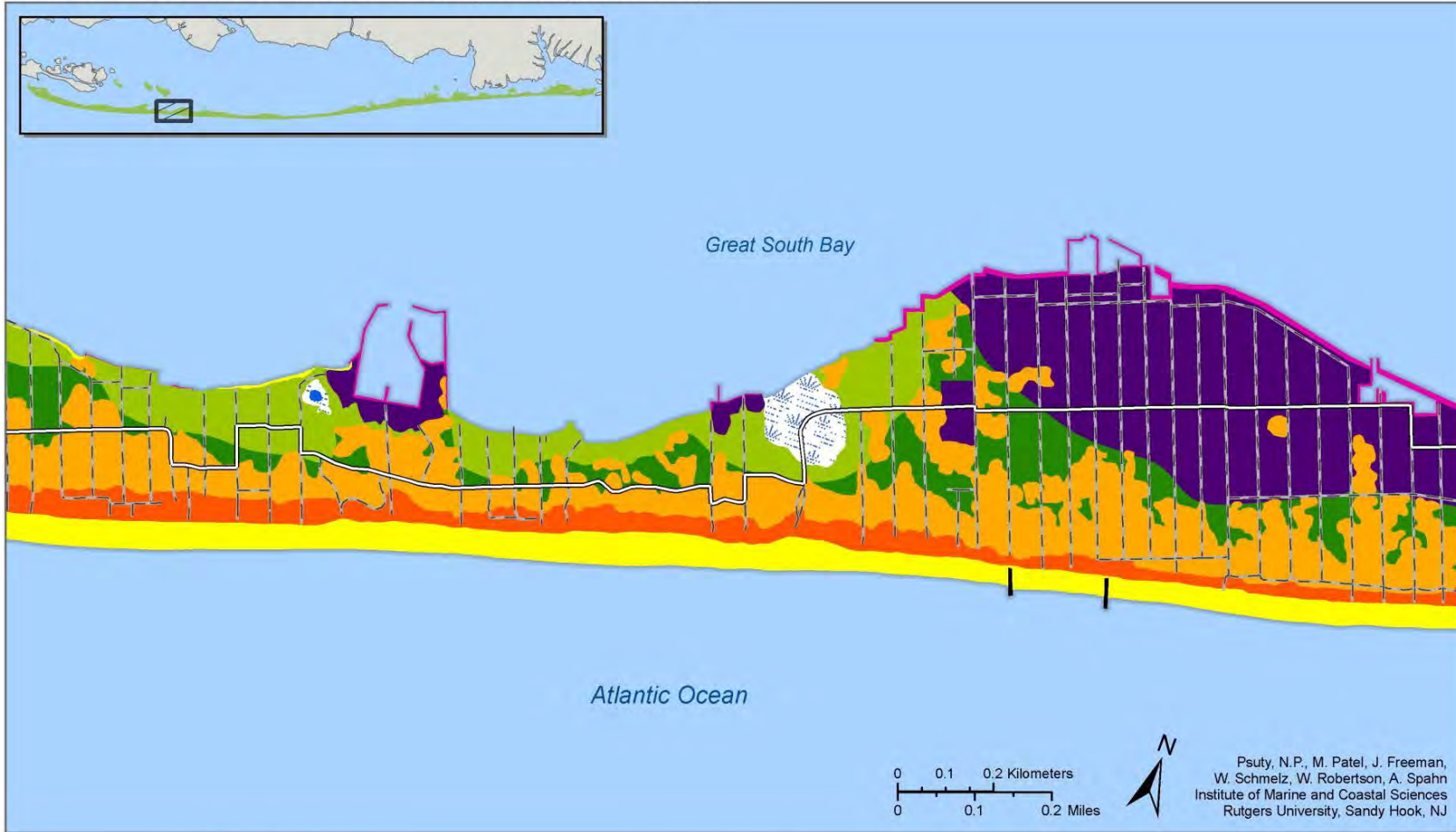
25

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	



# "Zone 5", Fire Island Geomorphological Map

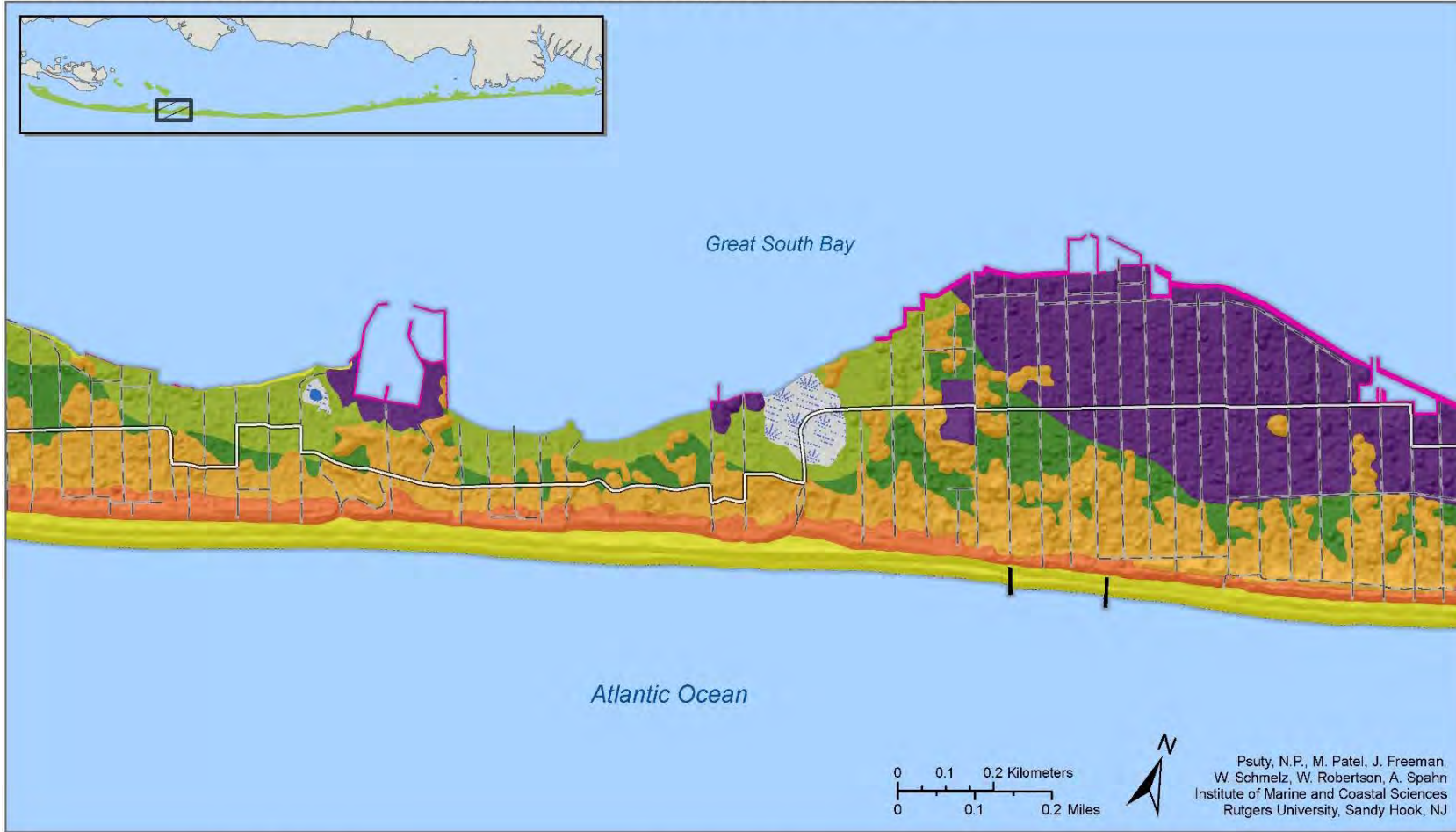
26



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies	Back dune slope		Other roads/walkways	

# "Zone 5", Fire Island Geomorphological Map with Hillshade

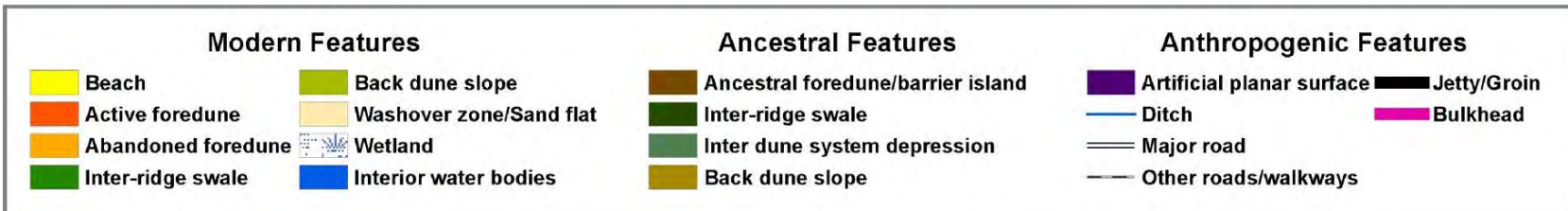


27

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 6", Fire Island Geomorphological Map

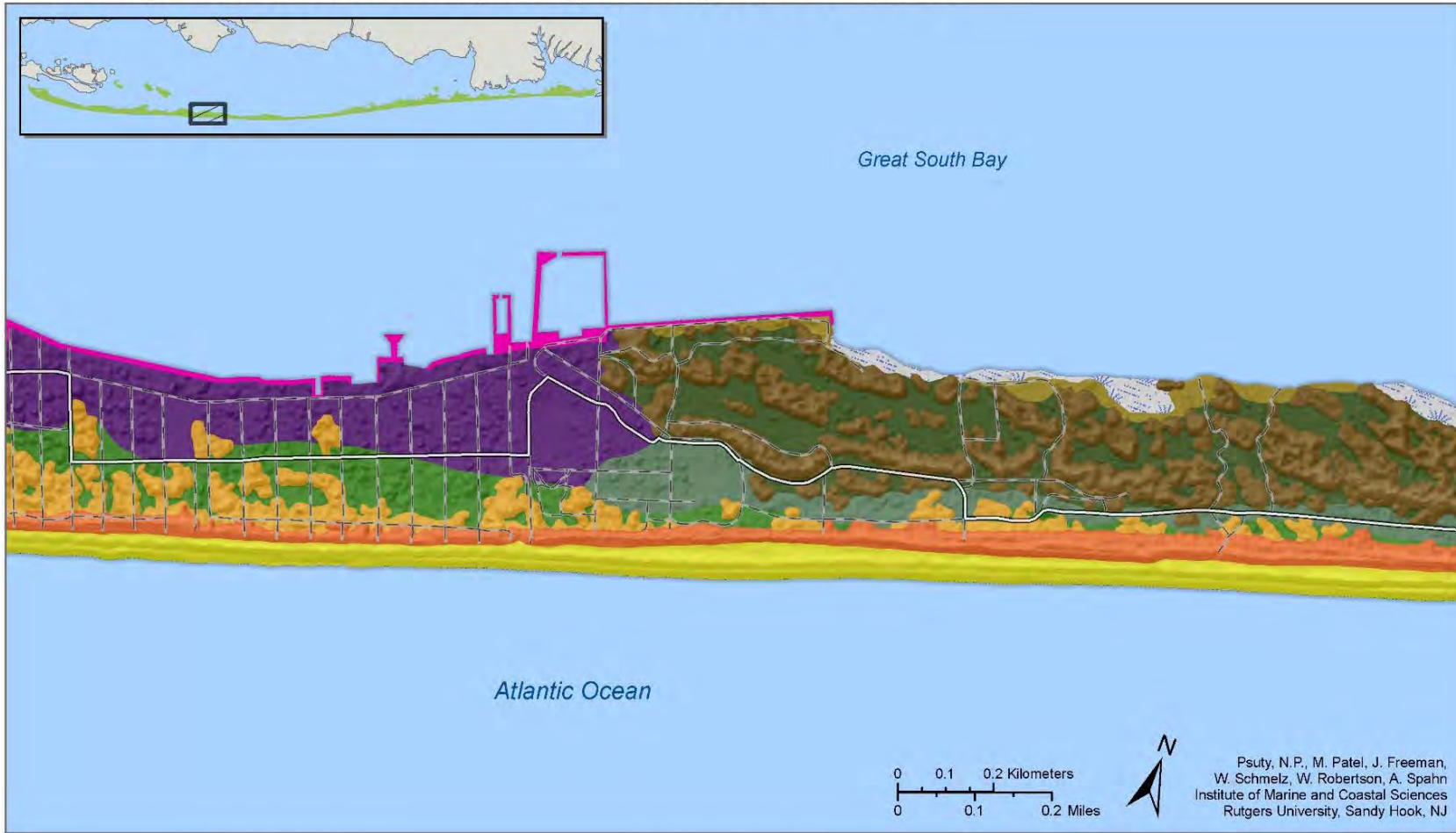
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# "Zone 6", Fire Island Geomorphological Map with Hillshade

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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 7", Fire Island Geomorphological Map

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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies	Back dune slope		Other roads/walkways	

# "Zone 7", Fire Island Geomorphological Map with Hillshade



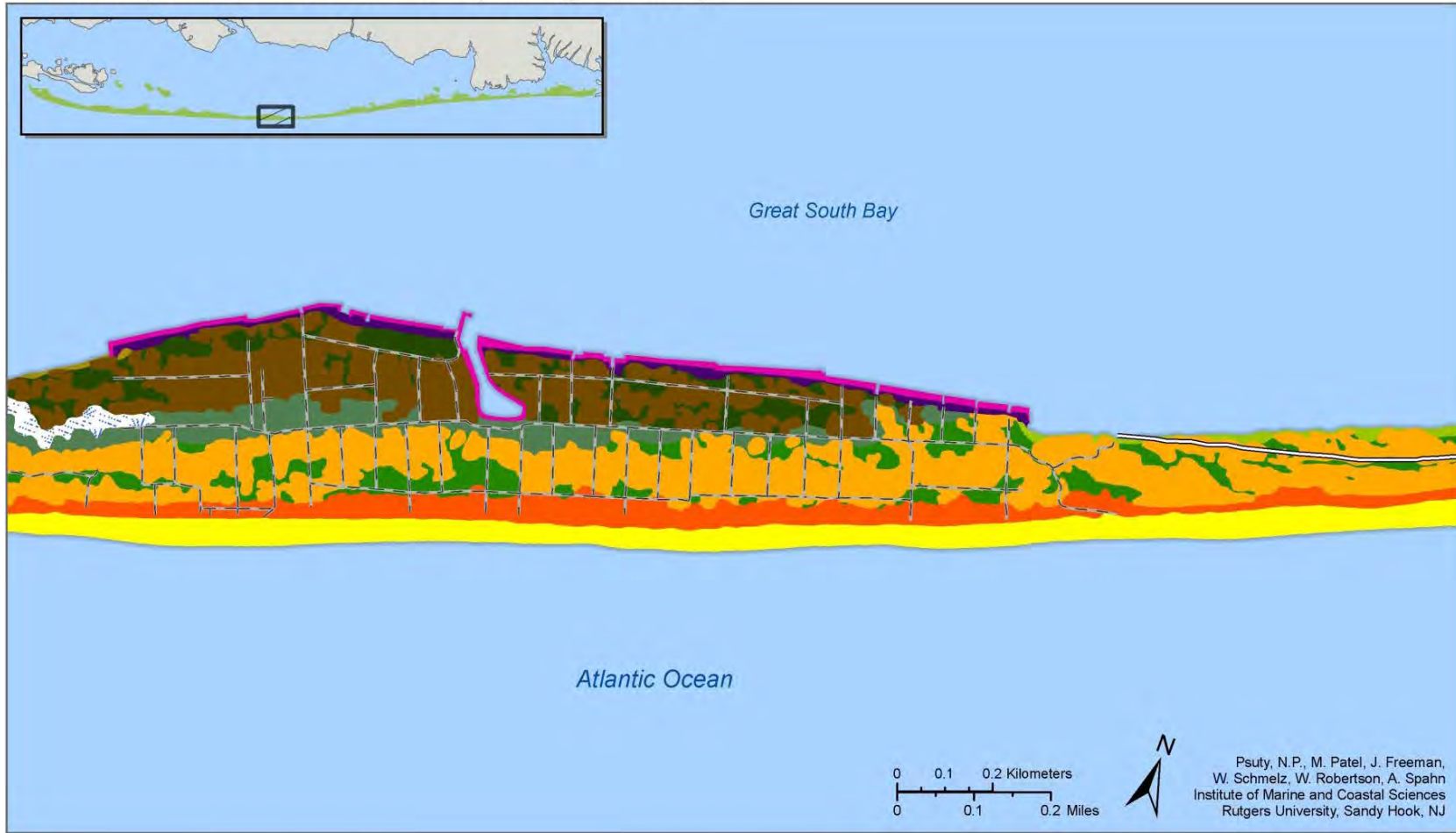
31

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-dune system depression	Back dune slope	Ditch	Bulkhead
Abandoned foredune	Wetland			Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

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# "Zone 8", Fire Island Geomorphological Map

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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies	Back dune slope		Other roads/walkways	

# "Zone 8", Fire Island Geomorphological Map with Hillshade



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	



# "Zone 9", Fire Island Geomorphological Map



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter-dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter-dune system depression	Inter-dune system depression	Major road	
Inter-ridge swale	Interior water bodies	Back dune slope		Other roads/walkways	

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# "Zone 9", Fire Island Geomorphological Map with Hillshade



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies	Back dune slope		Other roads/walkways	

# "Zone 10", Fire Island Geomorphological Map



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 10", Fire Island Geomorphological Map with Hillshade



37

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Artificial planar surface	Jetty/Groin	Bulkhead
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Ditch	Major road	
Abandoned foredune	Wetland	Inter dune system depression	Other roads/walkways		
Inter-ridge swale	Interior water bodies	Back dune slope			

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# "Zone 11", Fire Island Geomorphological Map



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies	Back dune slope		Other roads/walkways	

# "Zone 11", Fire Island Geomorphological Map with Hillshade



39

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 12", Fire Island Geomorphological Map



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Inter dune system depression	Major road	
Inter-ridge swale	Interior water bodies	Inter dune system depression	Inter dune system depression	Other roads/walkways	
		Back dune slope			

# "Zone 12", Fire Island Geomorphological Map with Hillshade



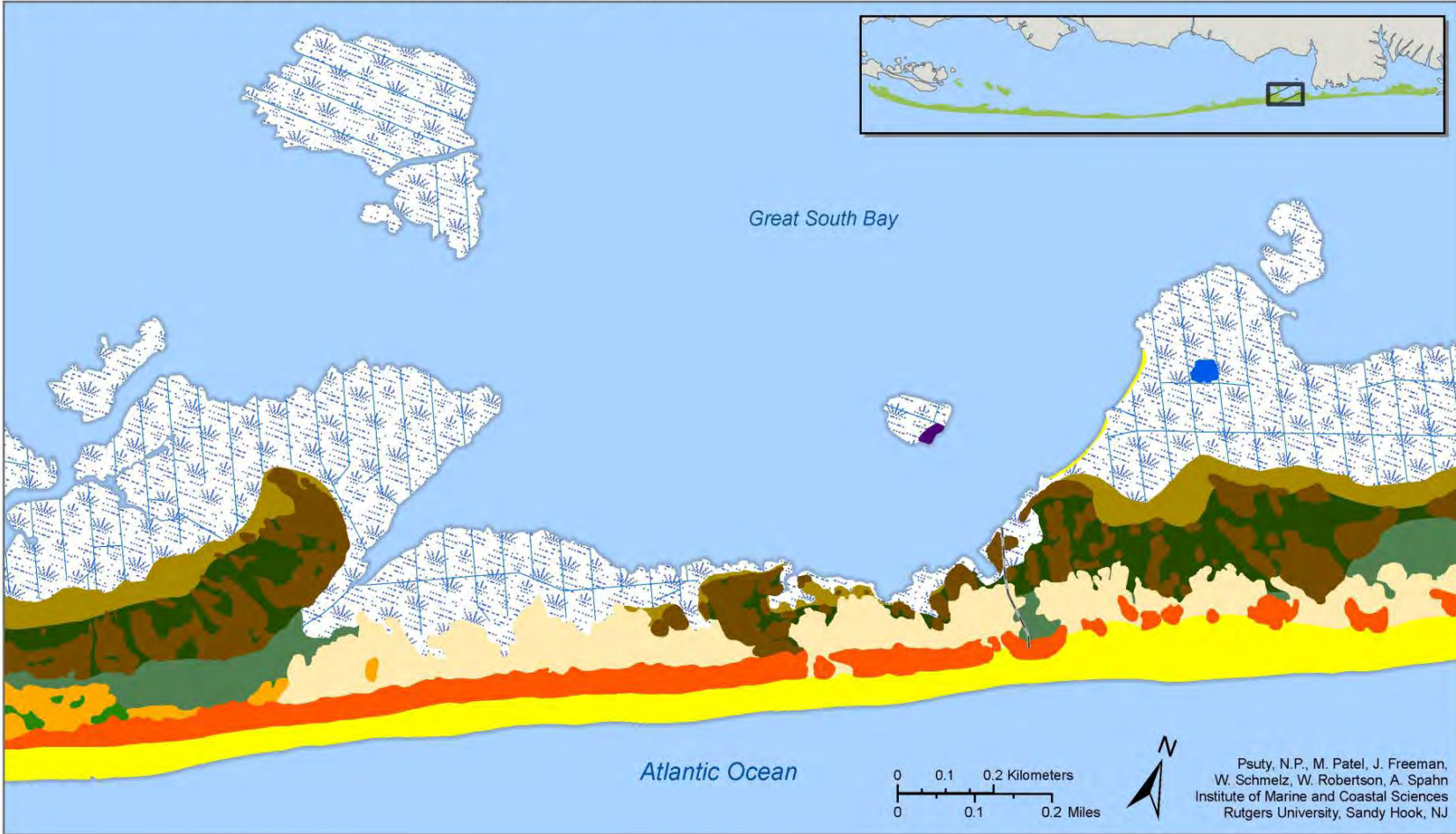
41

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

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# "Zone 13", Fire Island Geomorphological Map

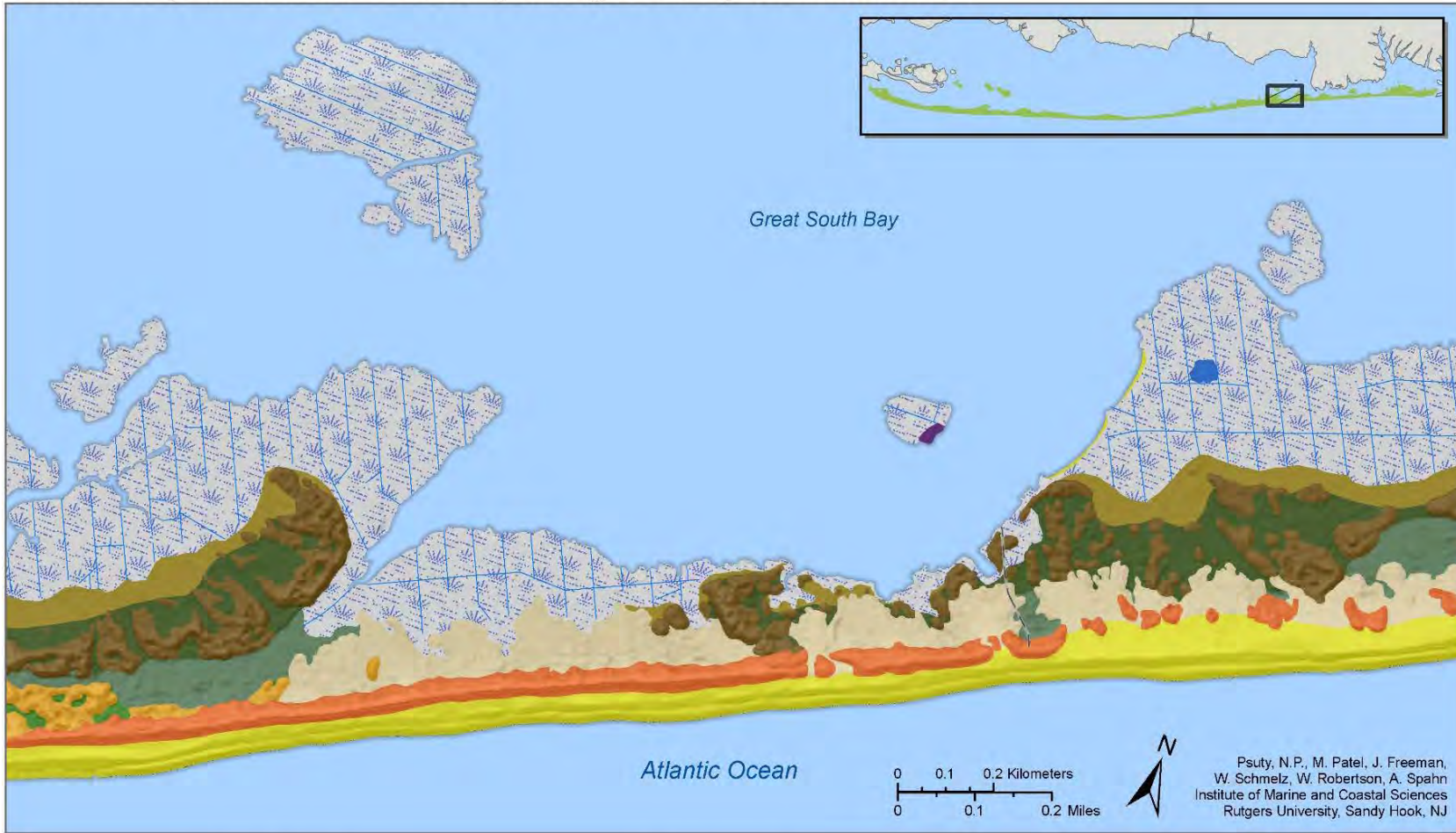


42

Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Back dune slope		Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 13", Fire Island Geomorphological Map with Hillshade

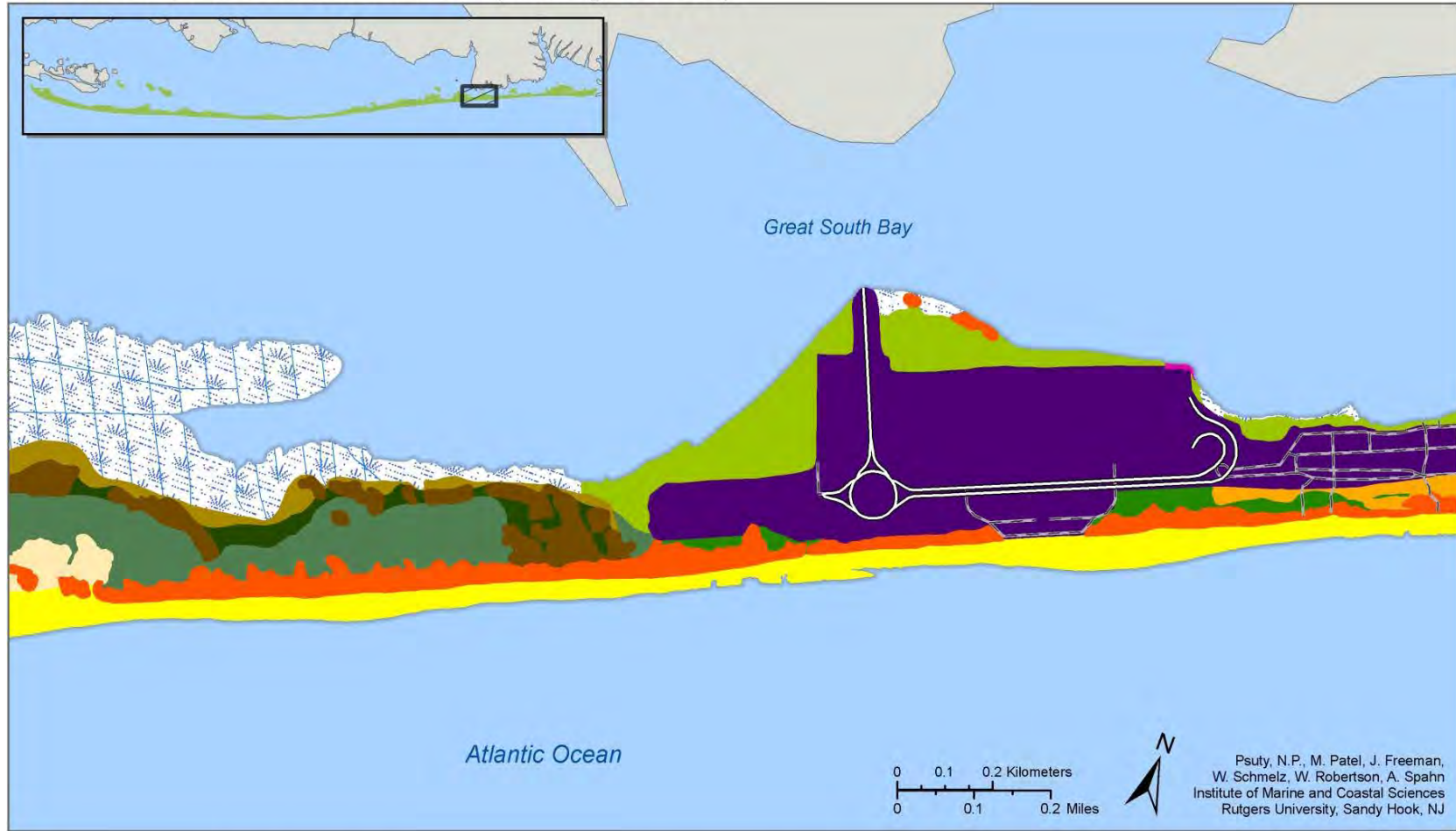
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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies	Back dune slope		Other roads/walkways	

# "Zone 14", Fire Island Geomorphological Map



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies	Back dune slope		Other roads/walkways	

# "Zone 14", Fire Island Geomorphological Map with Hillshade

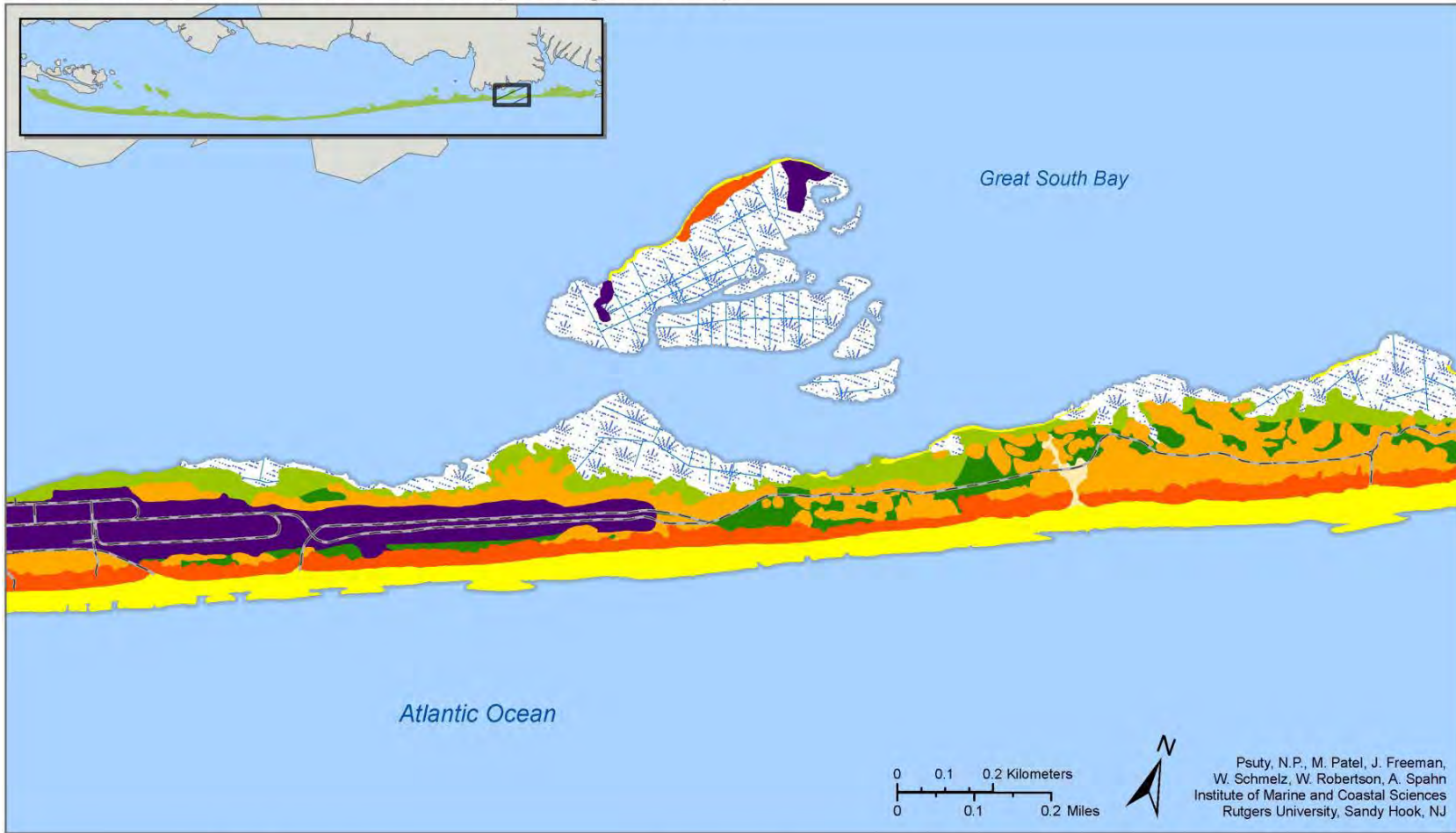
45



Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

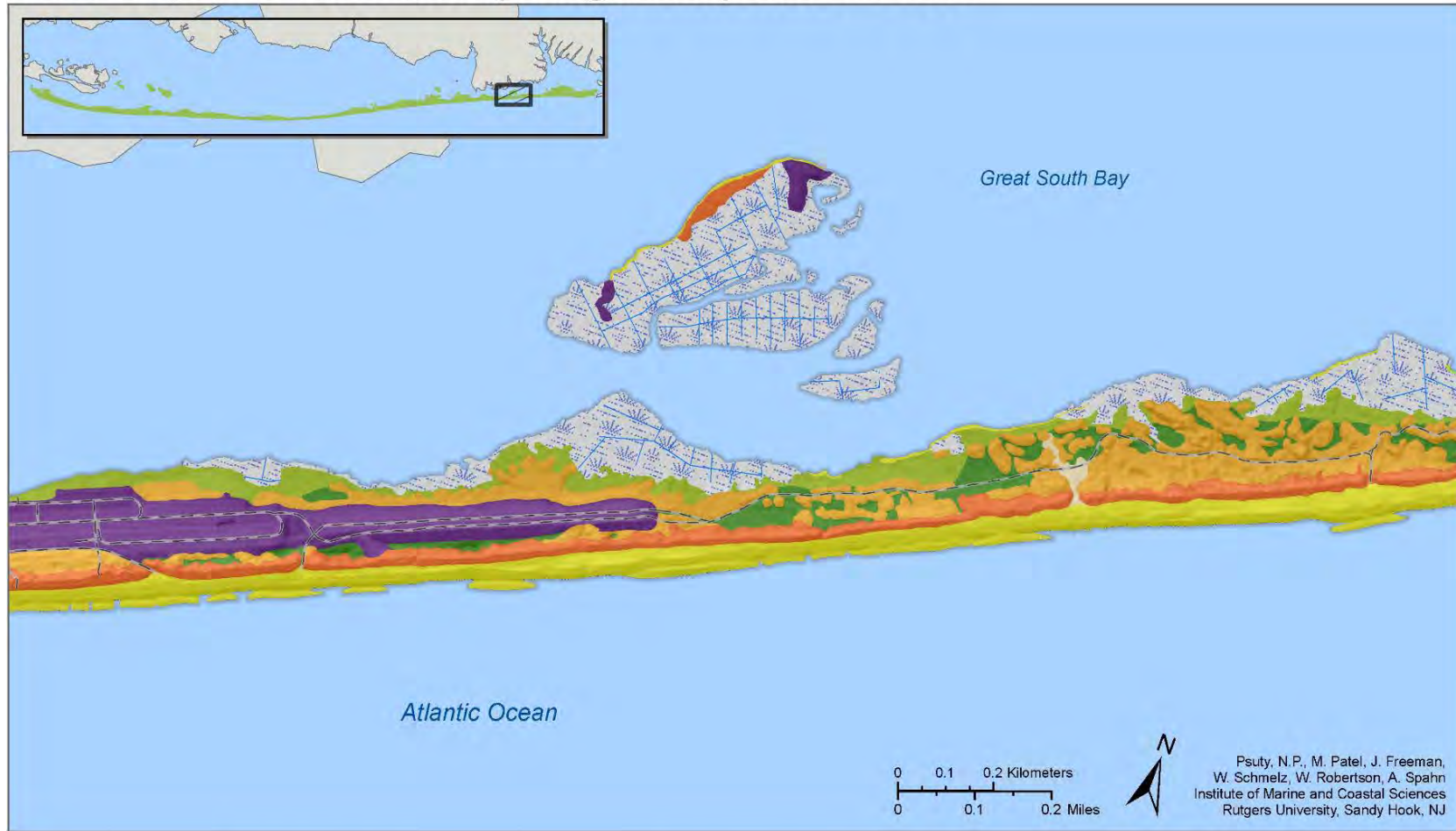
# "Zone 15", Fire Island Geomorphological Map

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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies	Back dune slope		Other roads/walkways	

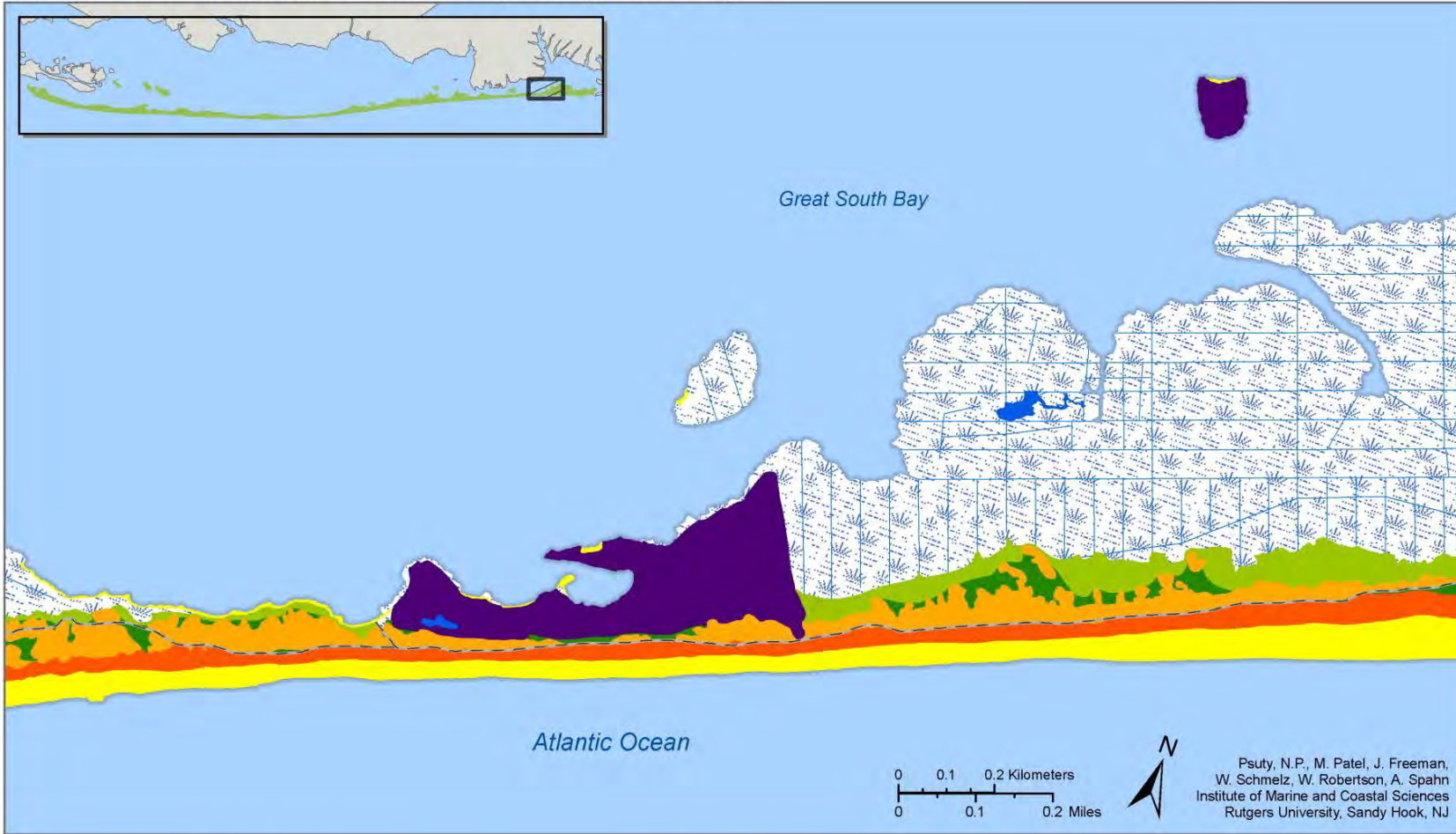
# "Zone 15", Fire Island Geomorphological Map with Hillshade



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 16", Fire Island Geomorphological Map



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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Back dune slope		Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 16", Fire Island Geomorphological Map with Hillshade

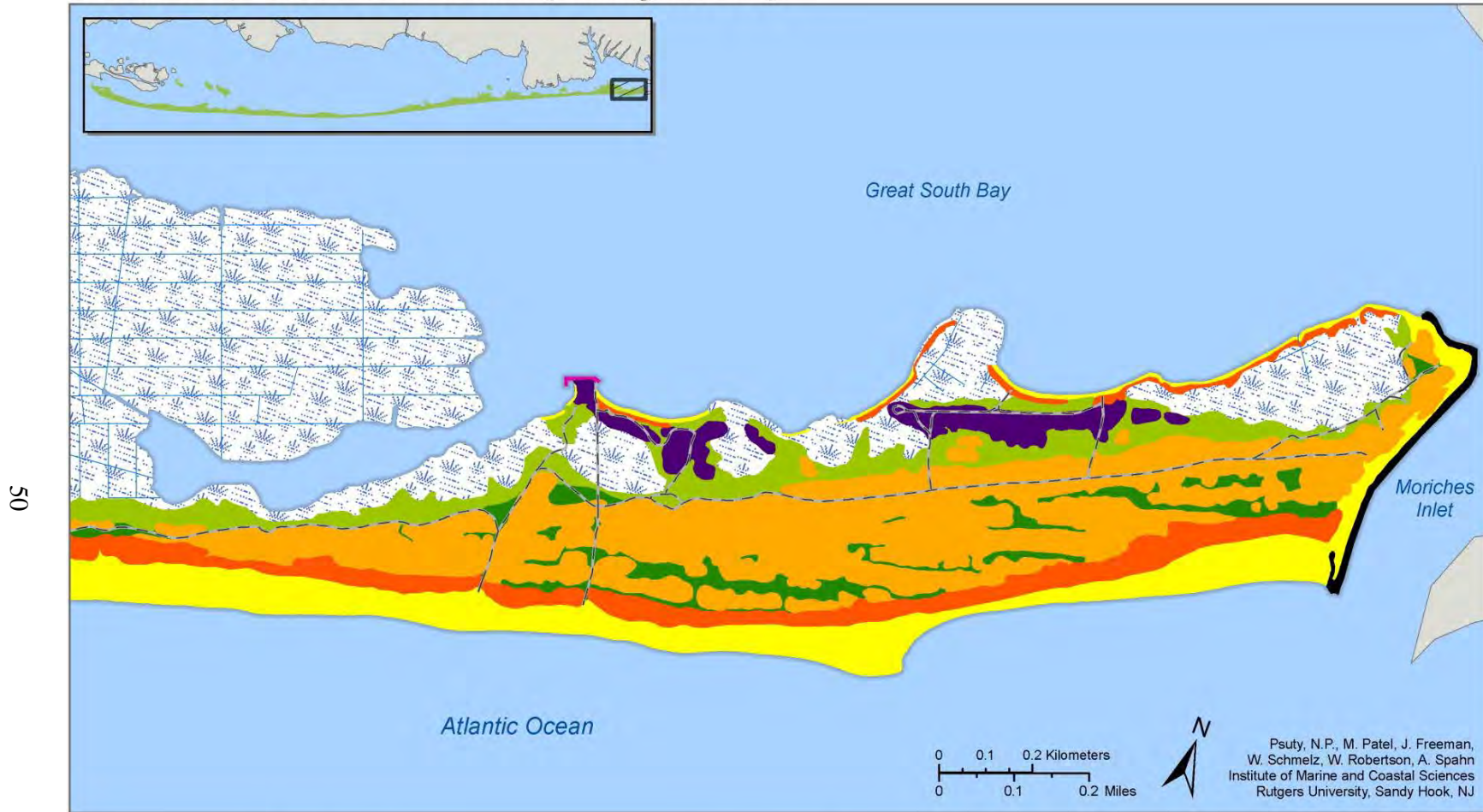
49



Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Inter dune system depression	Back dune slope	Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	



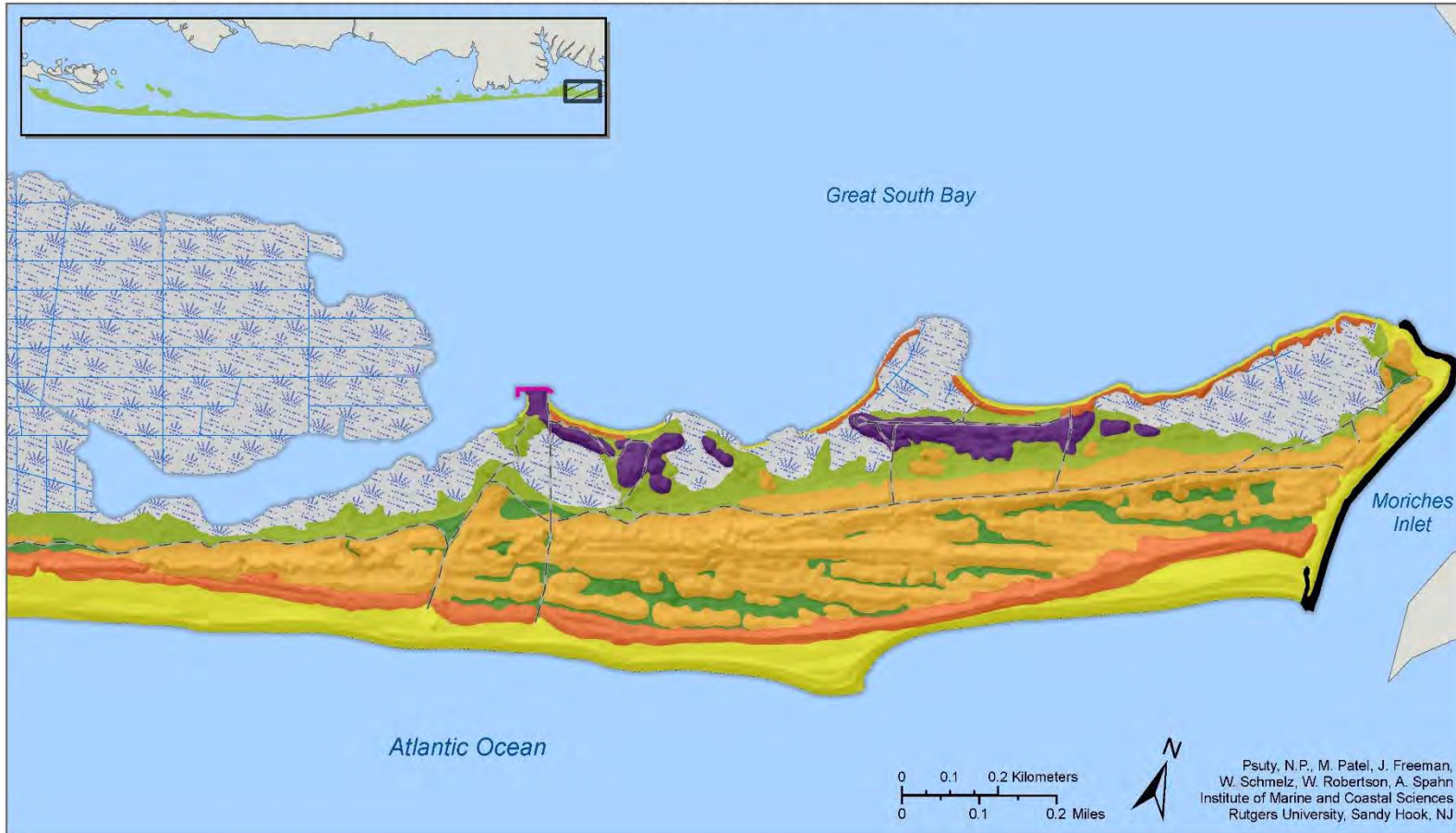
# "Zone 17", Fire Island Geomorphological Map



Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Artificial planar surface	Jetty/Groin	Bulkhead
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Ditch	Major road	
Abandoned foredune	Wetland	Inter dune system depression	Other roads/walkways		
Inter-ridge swale	Interior water bodies	Back dune slope			

# "Zone 17", Fire Island Geomorphological Map with Hillshade

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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Back dune slope		Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 18", Fire Island Geomorphological Map



### Modern Features

- Beach
- Active foredune
- Abandoned foredune
- Inter-ridge swale
- Back dune slope
- Washover zone/Sand flat
- Wetland
- Interior water bodies

### Ancestral Features

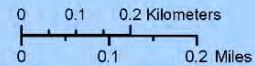
- Ancestral foredune/barrier island
- Inter-ridge swale
- Inter dune system depression
- Back dune slope

### Anthropogenic Features

- Artificial planar surface
- Jetty/Groin
- Bulkhead
- Ditch
- Major road
- Other roads/walkways

# "Zone 18", Fire Island Geomorphological Map with Hillshade

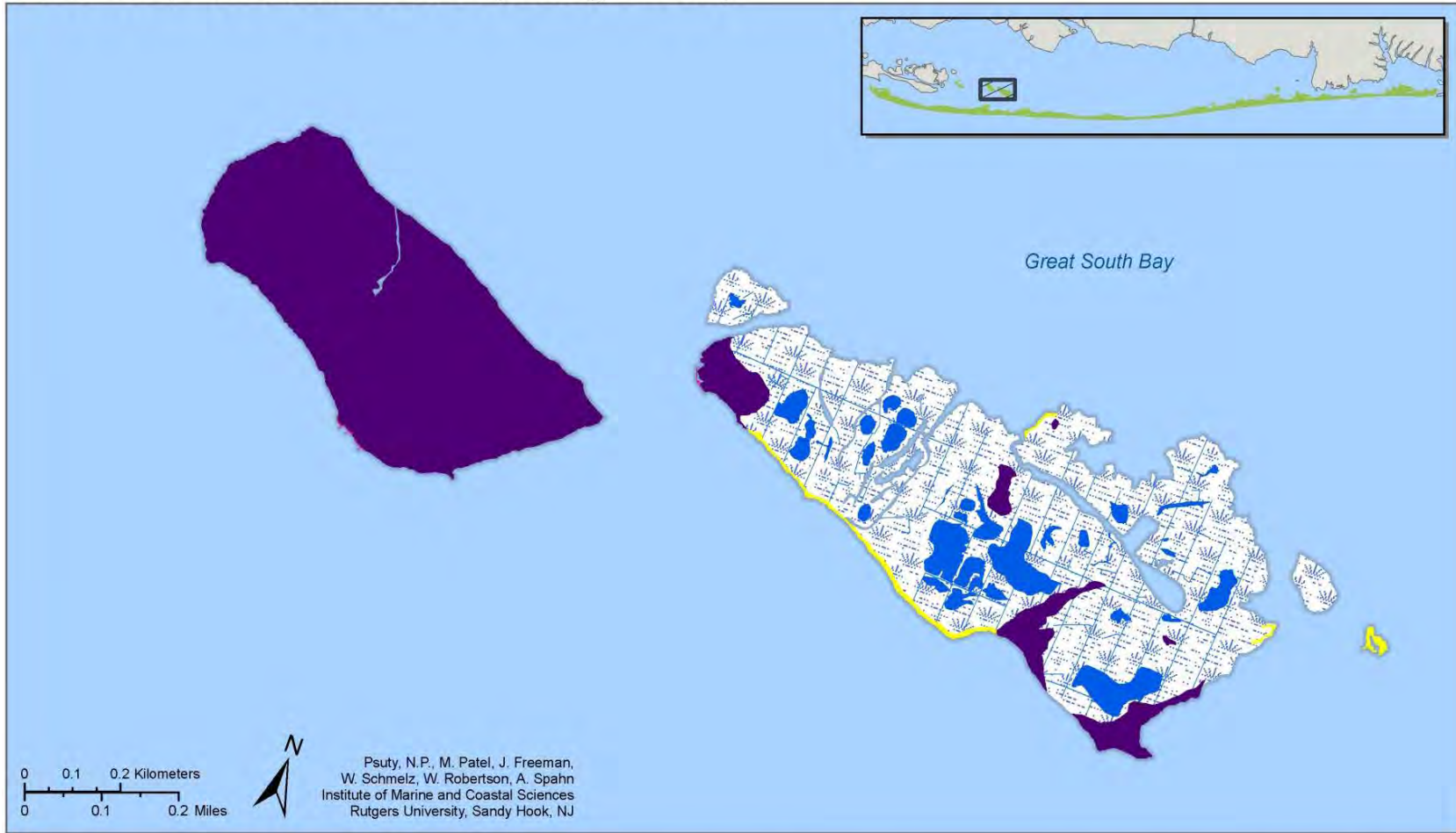
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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Back dune slope		Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

# "Zone 19", Fire Island Geomorphological Map



## Modern Features

- Beach
- Active foredune
- Abandoned foredune
- Inter-ridge swale
- Back dune slope
- Washover zone/Sand flat
- Wetland
- Interior water bodies

## Ancestral Features

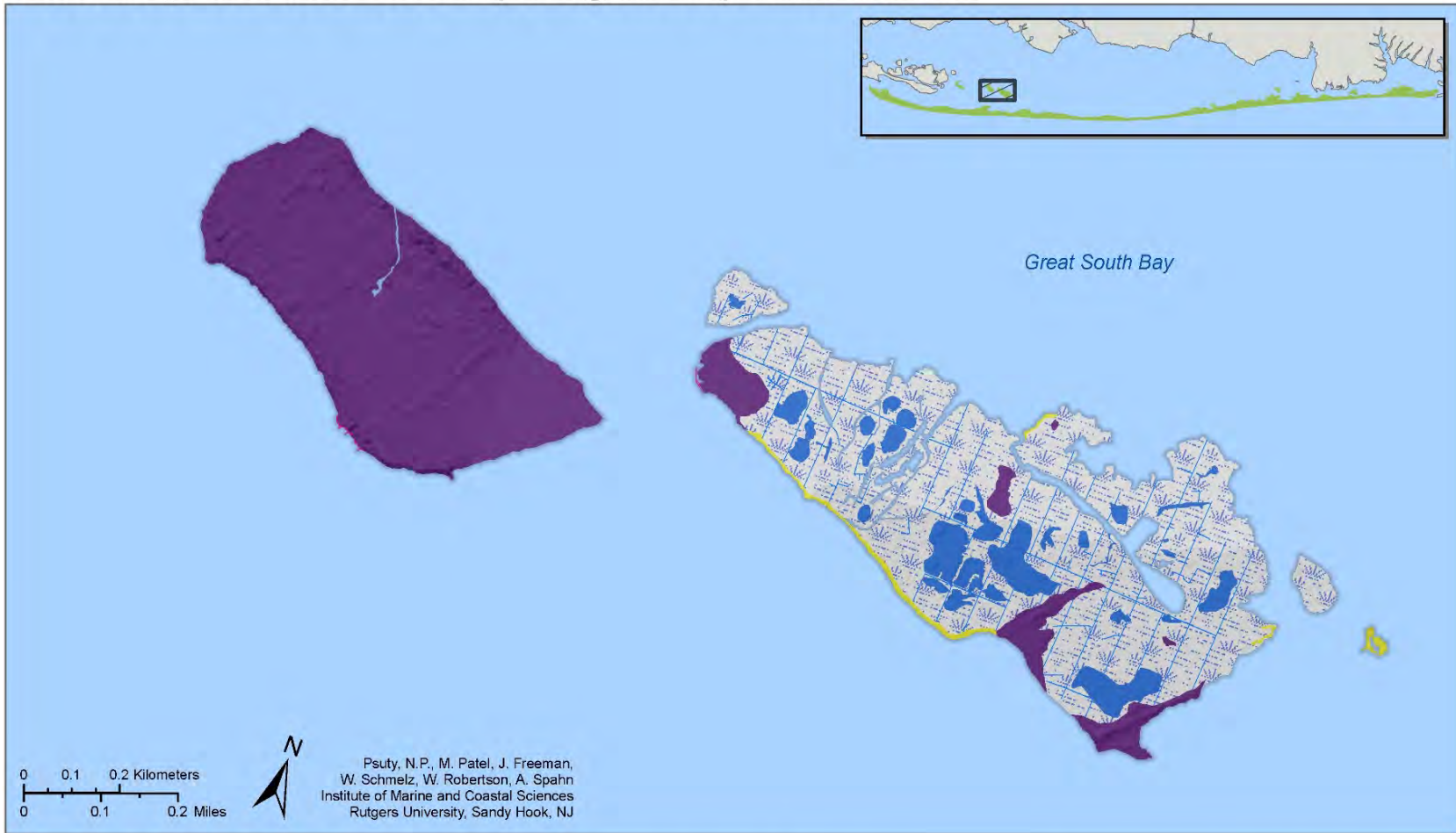
- Ancestral foredune/barrier island
- Inter-ridge swale
- Inter dune system depression
- Back dune slope

## Anthropogenic Features

- Artificial planar surface
- Jetty/Groin
- Ditch
- Bulkhead
- Major road
- Other roads/walkways

# "Zone 19", Fire Island Geomorphological Map with Hillshade

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Modern Features		Ancestral Features		Anthropogenic Features	
Beach	Back dune slope	Ancestral foredune/barrier island	Inter-ridge swale	Artificial planar surface	Jetty/Groin
Active foredune	Washover zone/Sand flat	Inter-ridge swale	Inter dune system depression	Ditch	Bulkhead
Abandoned foredune	Wetland	Back dune slope		Major road	
Inter-ridge swale	Interior water bodies			Other roads/walkways	

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 615/128340, March 2015

**National Park Service**  
**U.S. Department of the Interior**



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