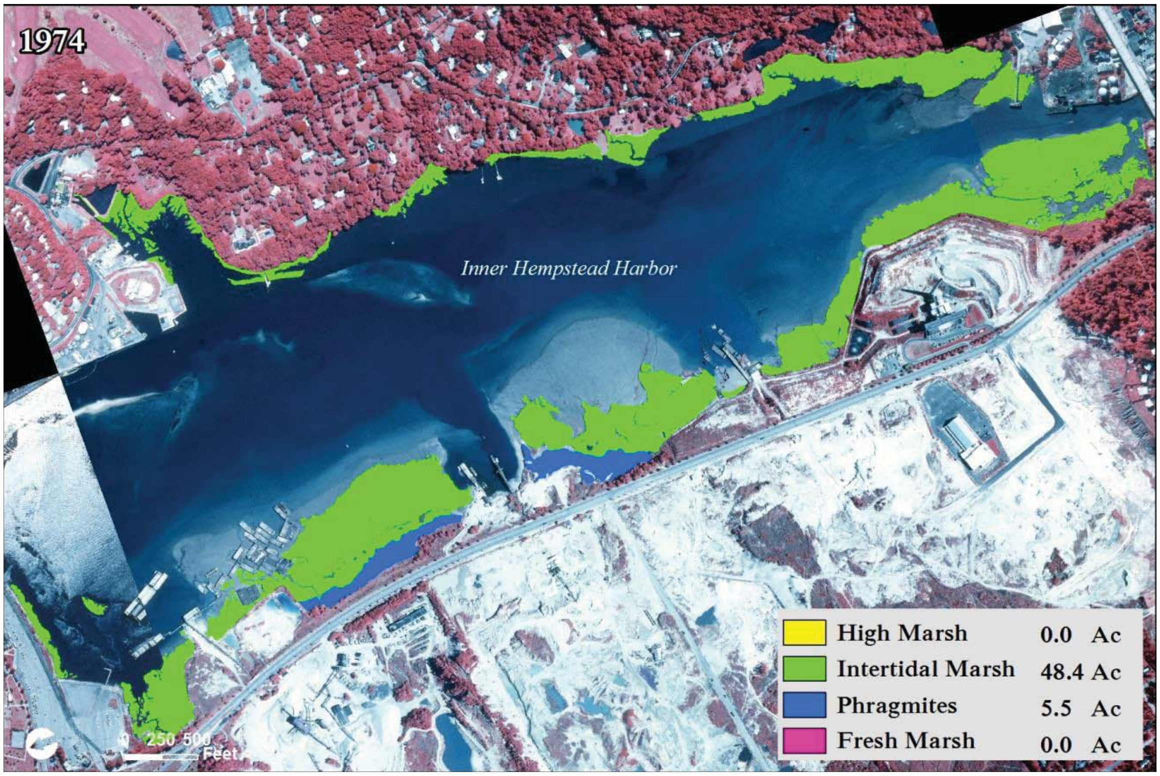
Figure 43: Inner Hempstead Harbor West (Complex ID #267)

[See Page E2, Appendix I for Locator Map]



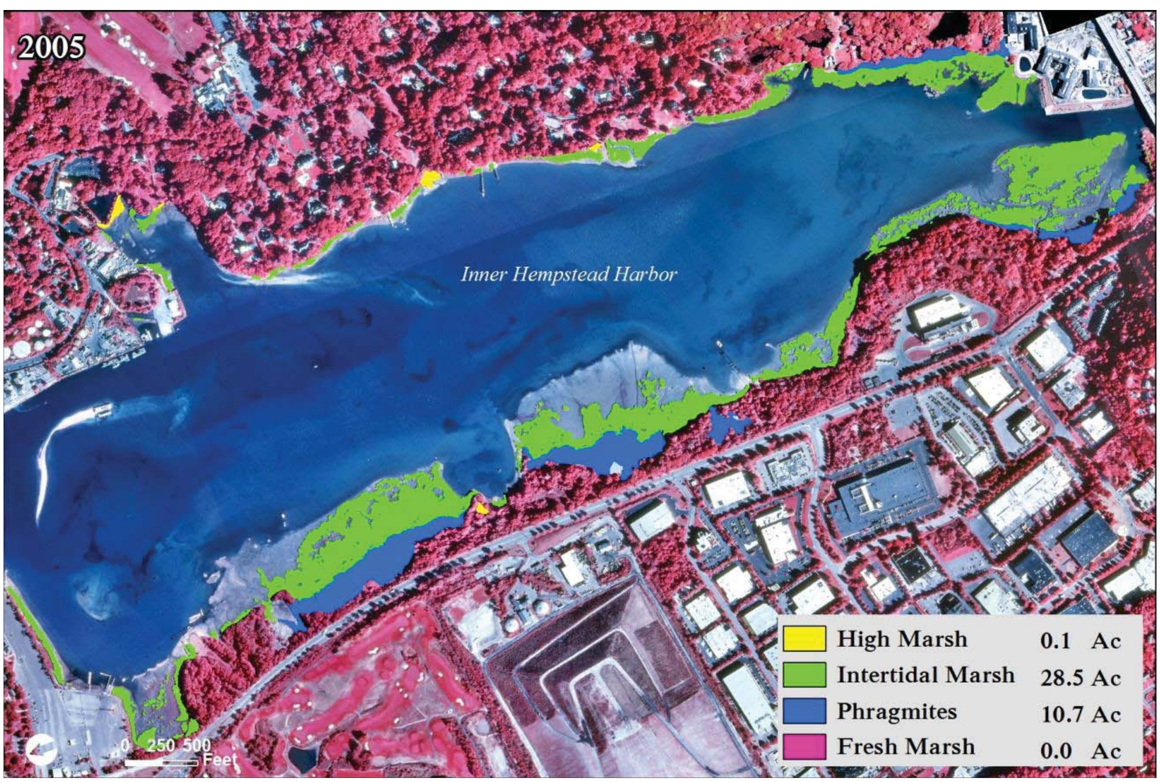


Figure 44: Baiting Hollow (Complex ID #85)

[See Page D6, Appendix I for Locator Map]

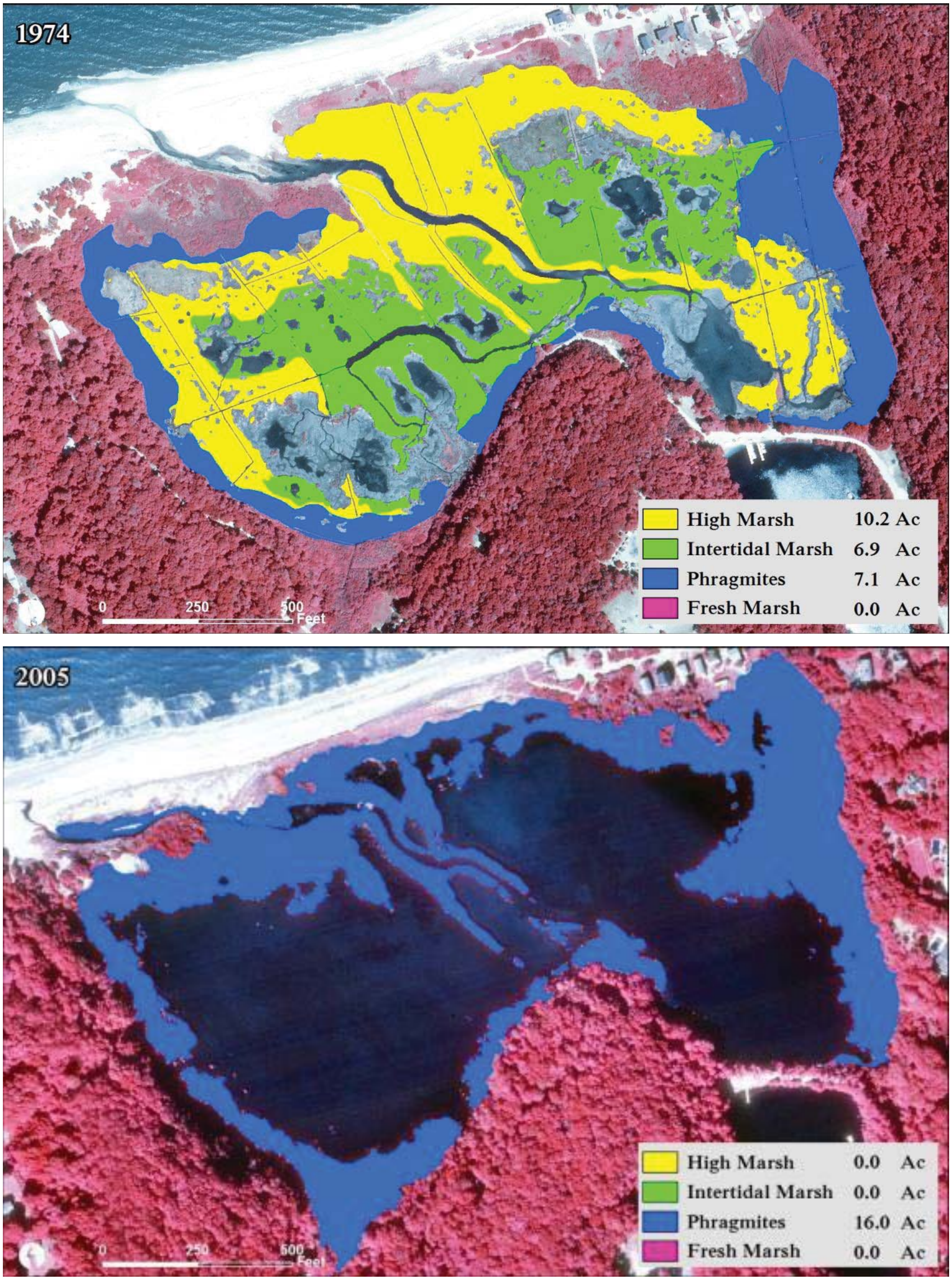


Figure 45: Sheets Creek Channel (Complex ID #275)

[See Page E1, Appendix I for Locator Map]

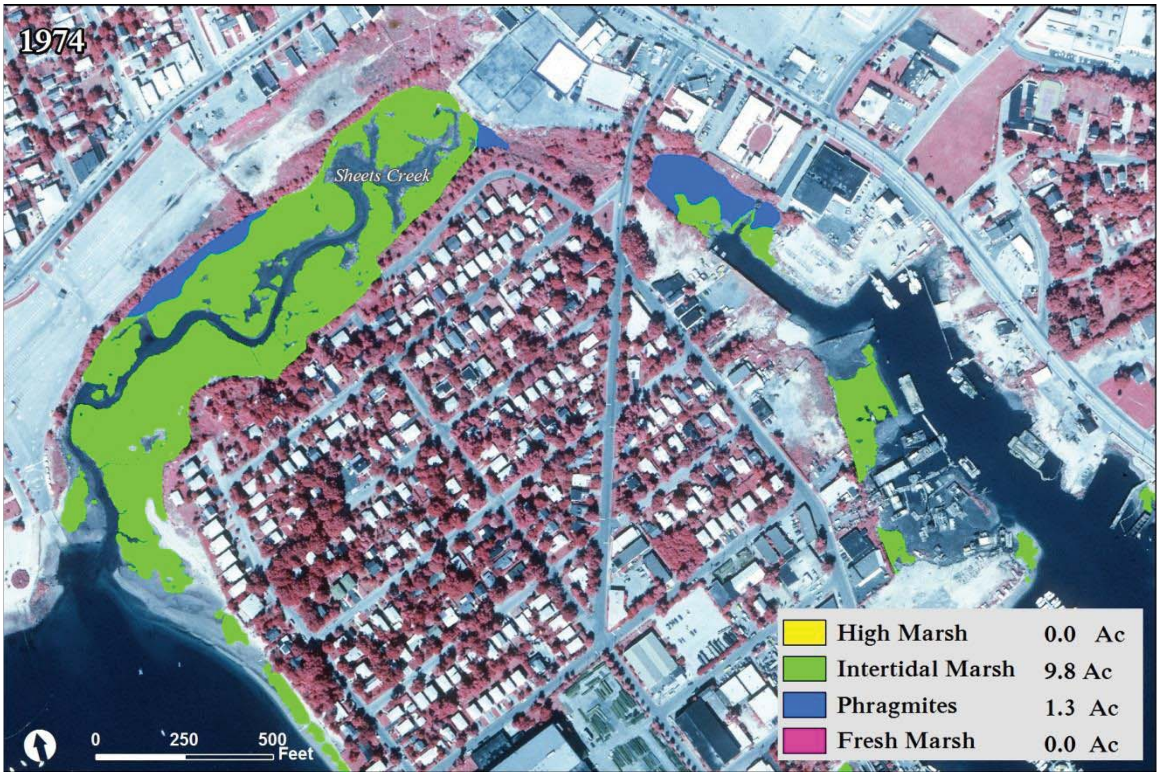
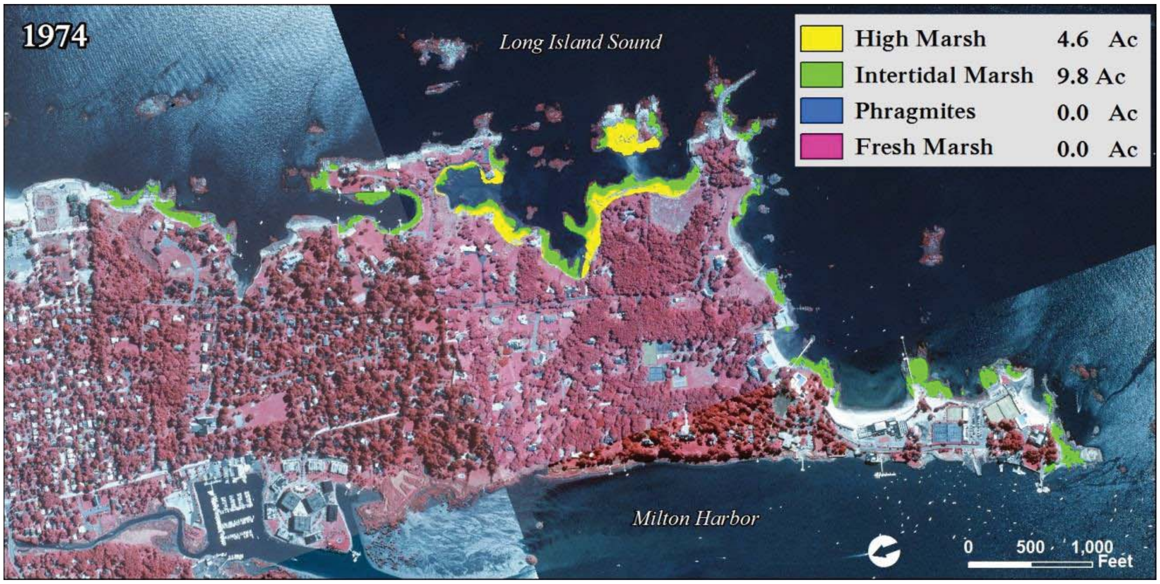


Figure 46: Long Island Sound-Milton Point to Rye Beach (Complex ID #314)
[See Page D1, Appendix I for Locator Map]



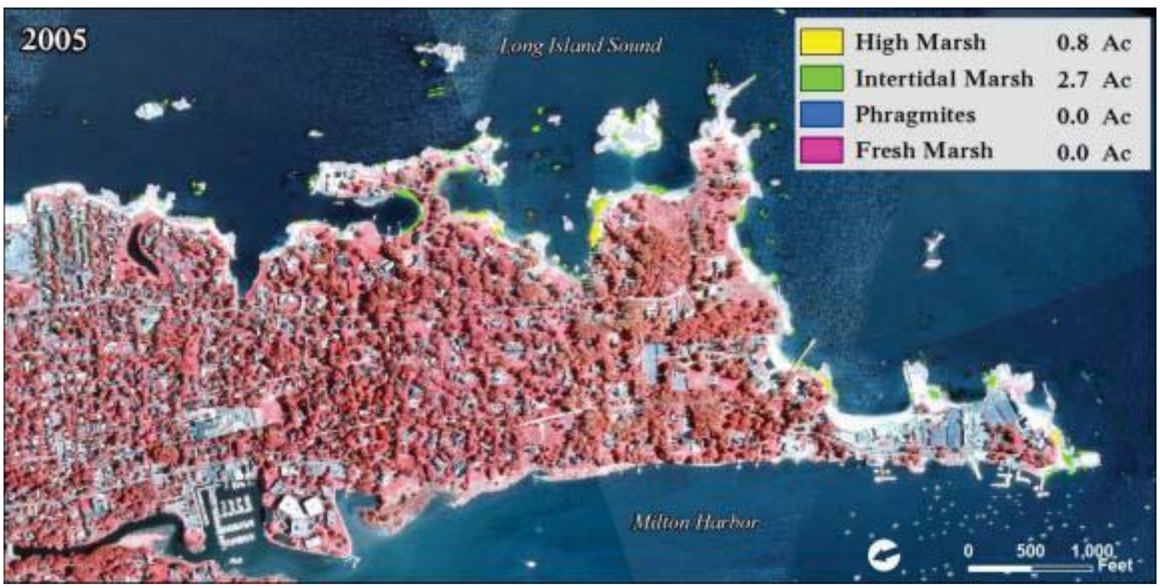
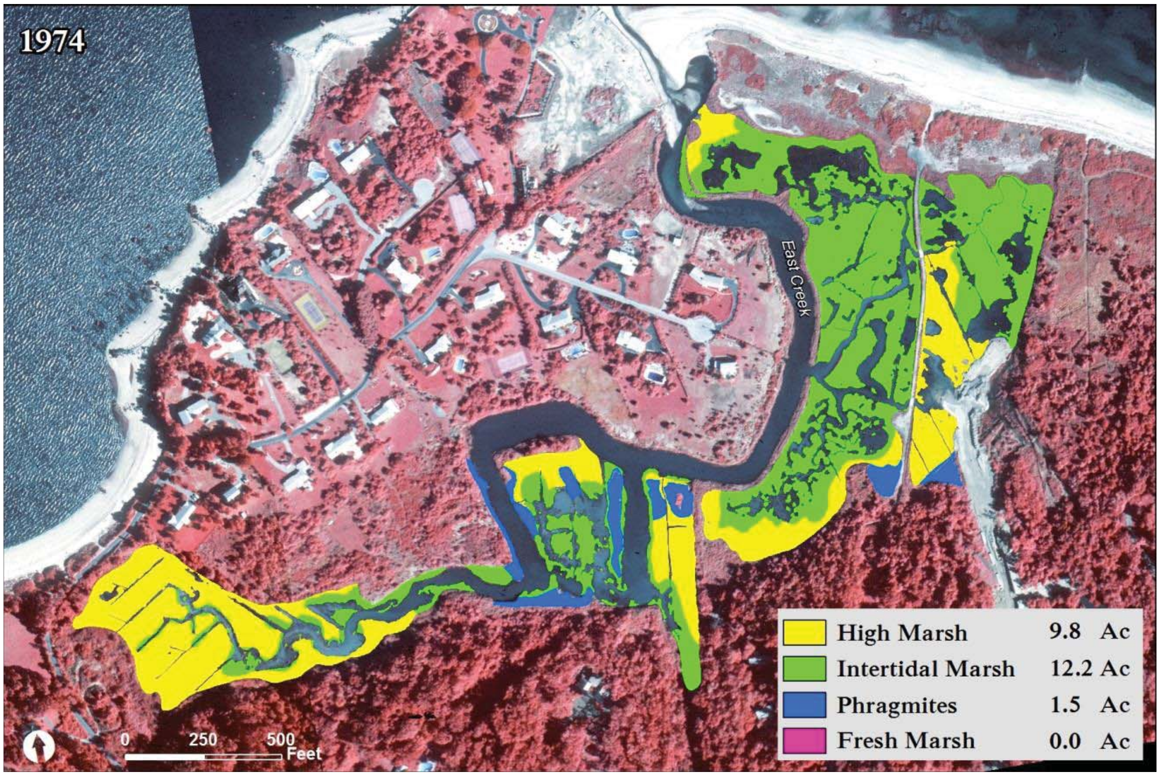


Figure 47: Prospect Point/East Creek (Complex ID #272)

[See Page D1, Appendix I for Locator Map]



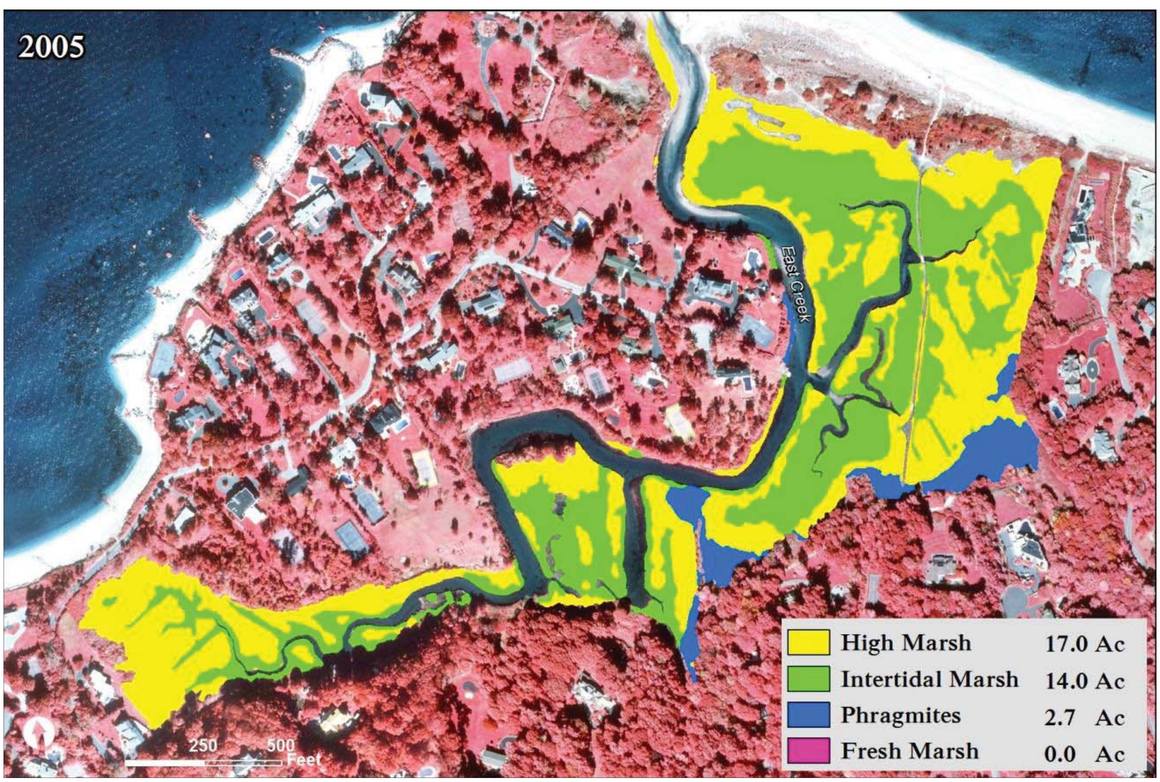
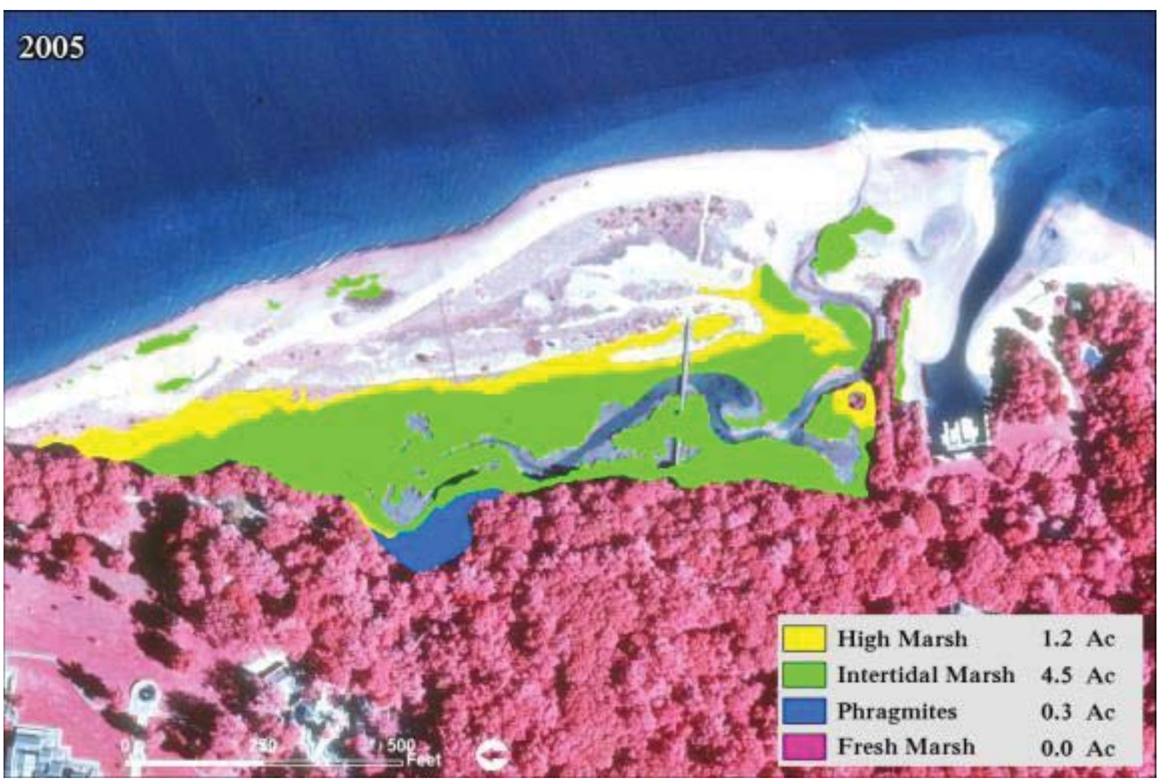


Figure 48: Sagamore Hill Marsh (Complex ID #243)
[See Page D2, Appendix I for Locator Map]



Peconic Estuary

The Peconic Estuary was divided into 159 marsh complexes, ranging in size from less than 1 acre to 253 acres of vegetated tidal wetlands. At the estuary level, the Peconic Estuary exhibited a lower percentage of native marsh loss (10.5 percent, or 362.8 acres) than the Long Island Sound, South Shore Estuary, and South Fork Ponds (Table 3).

Table 37: Tidal Wetland Area Change (1974-2005) in the Peconic Estuary by Class

Wetland Type	1974 Wetland Area (acres)	2005 Wetland Area (acres)	Change (%)
Intertidal Marsh	1,457.1	1,652.6	13.4
High Marsh	1,865.9	1,393.8	-25.3
Coastal Fresh Marsh	117.2	31.0	-73.5
Marsh Subtotal	3,440.2	3,077.4	-10.5
Phragmites australis	304.3	573.6	88.5
Vegetated Area Total	3,744.5	3,651.0	-2.5

The Peconic Estuary spans the Towns of East Hampton, Riverhead, Shelter Island, Southampton and Southold. As shown in Table 38, most of the Peconic Estuary"s Year 2005 marsh habitat (91%) is evenly distributed among the Towns of East Hampton (908.3 acres), Southampton (1,048.7 acres), and Southold (850.6 acres). East Hampton sustained the largest loss of marsh habitat, losing 145.8 acres for a 13.8 percent decrease from 1974 to 2005. The Town of Southold lost nearly 10 percent of marsh habitat from 1974 through 2005, while the Town of Riverhead exhibited a slight gain in native tidal wetland area. The highest percentage loss of marsh habitat occurred in the Town of Shelter Island where marsh habitat decreased in area by 17.5 percent.

Table 38: Tidal Wetland Area Change in the Peconic Estuary by Town

Municipality	1974 IM+HM+FM (acres)	2005 IM+HM+FM (acres)	Δ IM+HM+FM (acres)	Δ IM+HM+FM (%)
East Hampton	1,054.1	908.3	-145.8	-13.8
Riverhead	51.9	57.1	5.2	+9.9
Shelter Island	258.0	212.8	-45.2	-17.5
Southampton	1,133.4	1,048.7	-84.7	-7.5
Southold	942.8	850.6	-92.2	-9.8
Total	3,440.2	3,077.4	-362.8	-10.5

Despite lower rates of tidal wetland loss compared to other Long Island estuaries, indicators of significant marsh change and deterioration were also observed in the Peconic Estuary"s wetlands. For example, high marsh habitat in the Peconic Estuary decreased by approximately 25.3 percent from 1974 to 2005 (Table 37). Several Peconic Estuary wetland complexes, including Accabonac Harbor (ID # 156), Northwest Creek (ID # 165), Napeague Meadows (ID # 154), are among the marsh complexes with the greatest observed losses of high marsh (in acreage and percentage) (Table 39). In the Peconic Estuary, areas of lost high marsh generally converted to intertidal marsh or were overtaken by *Phragmites australis* with less panne or pond formation than the other Long Island estuaries. Reduced panne formation and reduced erosion of the seaward edge of marshes in the Peconic is the likely explanation for the high rate of high marsh loss and lower rate of overall native marsh area loss compared to the other estuaries (Table 3). For example, intertidal marsh in the Peconic Estuary increased by 13.4 percent between 1974 and 2005 compared to a -25 and -1 percent reduction in the Long Island Sound and South Shore Estuary, respectively. This conversion of high marsh to intertidal marsh is apparent in Figure 49-Figure 52 showing Accabonac Harbor, Northwest Creek, West Neck Creek (ID # 196), and Napeague Meadows. These complexes with the highest acreage and percentage of high marsh loss were also among the complexes with the greatest increase in intertidal marsh area.

Table 39: Complexes with Largest Tidal Wetland Area Loss in the Peconic Estuary

Complex (ID#)	1974 IM+HM+FM (acres)	2005 IM+HM+FM (acres)	Δ IM+HM+FM (acres)	Δ IM+HM+FM (%)
Accabonac Harbor (156)	260.9	214.4	-46.5	-17.8
Northwest Creek (165)	162.4	137.2	-25.2	-15.5
Gardiner's Island Bostwick Creek (109)	27.3	4.4	-22.9	-83.8
West Neck Creek (196)	218.5	201.6	-16.9	-7.7
Little Reed Pond (150)	20.5	5.4	-15.1	-73.8
Little Northwest Creek (167)	47.0	33.3	-13.7	-29.1
Goose Creek (11)	72.8	59.3	-13.4	-18.5
Little Sebonac Creek/Sebonac Island (197)	79.9	66.8	-13.1	-16.4
Richmond Creek (58)	36.5	24.7	-11.8	-32.4
Alewife Brook & Pond (163)	32.3	22.2	-10.1	-31.2

Another primary mechanism of native marsh loss in the Peconic Estuary is the expansion of invasive *Phragmites australis*. *Phragmites australis* abundance in the Peconic Estuary increased by 88.5 % (270 acres) from 1974 to 2005. The Peconic Estuary had a greater increase in percentage of *Phragmites australis* than the Long Island Sound (106.6 acres, +33.6%) and the Fire Island Inlet to Smith Point reach of the South Shore Estuary (157.9 acres, +20.1%); the South Fork Ponds (Mecox Bay, Sagaponack Pond, and Georgica Pond) incurred the greatest increase in Phragmites australis expansion (85.0 acres, +395.7%) (Table 11). Large expansion of *Phragmites australis* stands is apparent at Accabonac Harbor, Northwest Creek, Gardiner"s Island Bostwick Creek (ID # 109), Little Reed Pond (ID # 150), Plum Pond (ID # 126), and a portion of the Peconic River (ID # 2) (Figure 49, Figure 50, and Figure 53-Figure 56). These complexes were also among the complexes with the largest decreases in native marsh habitats in the Peconic Estuary (Table 39 and Table 40).

Table 40: Complexes with Highest Percent Loss of Tidal Wetlands in the Peconic Estuary

Complex (ID #)	1974 IM+HM+FM (acres)	2005 IM+HM+FM (acres)	Δ IM+HM+FM (%)	Δ IM+HM+FM (acres)
Gardiner's Island Bostwick Creek (109)	27.29	4.43	-83.8	-22.9
Little Reed Pond (159)	20.48	5.37	-73.8	-15.1
Plum Pond (126)	13.07	3.67	-71.9	-9.4
Peconic River Tributary (2)	12.31	4.66	-62.1	-7.7
Gardiner's Island Tobaccolot Pond (116)	19.04	9.44	-50.4	-9.6
Gardiner's Island Little Pond (113)	10.10	5.64	-44.2	-4.7
Brushs Creek (70)	10.35	6.67	-35.6	-3.7
Dam Pond (34)	15.59	10.11	-35.1	-5.5
Deep Hole Creek (67)	13.30	8.90	-33.1	-4.4
Richmond Creek (58)	36.51	24.68	-32.4	-11.8

Table 39 lists the marsh complexes that have sustained the largest reductions in native marsh habitat from 1974 through 2005. The top five marshes, in terms of area of habitat loss, are depicted in Figure 49-Figure 51, Figure 53, and Figure 54. Collectively, the ten marshes listed in Table 39 account for approximately 52 percent of all marsh habitat loss in the Peconic Estuary. With six of the 10 most heavily affected marshes are located in the Town of East Hampton.

Table 40 lists the percent loss of habitat for the ten marshes that sustained the highest proportion of marsh loss from 1974 to 2005. Though the figures for percent of marsh loss are high, e.g., ranging from 32.4 to 83.8 percent, the actual losses in marsh habitat area are relatively small, especially in comparison with the ten largest marsh habitat losses provided in Table 40. The percentage losses listed in Table 39 were sustained by marshes that are relatively small in area. In fact, with two exceptions, the marshes listed in Table 40 are smaller than the average marsh size for the Peconic Estuary. If the list of marshes in Table 40 were to be expanded to include the next 20 marshes, then the top 30 marshes by highest percent of marsh loss would comprise only 31 percent of total marsh loss in the estuary for Year 1974 to 2005. In contrast, by expanding to include the top 30 marshes in terms of area loss, these 30 marshes would account for 86.1 percent of the total marsh loss in the Peconic Estuary from 1974 to 2005. Thus, the distribution of marsh loss in the Peconic Estuary is skewed toward the larger marsh complexes.

Table 41: Complexes with Largest Phragmites australis Expansion in the Peconic Estuary

Complex (ID #)	1974 Phramgites (acres)	2005 Phramgites (acres)	Δ Phragmites (acres)
Accabonac Harbor (156)	2.9	41.4	38.4
Northwest Creek (165)	32.1	55.6	23.4
Gardiner's Island Bostwick Creek (109)	0.0	22.9	22.9
Alewife Brook & Pond (163)	1.1	16.5	15.4
Little Northwest Creek (167)	0.0	15.0	15.0
Little Reed Pond (150)	0.0	14.3	14.3
Gardiner's Island Tobaccolot Pond (116)	0.0	11.8	11.8
Oyster Pond (149)	1.8	11.3	9.5
Plum Pond (126)	0.4	9.7	9.3
Peconic Bay Boulevard (544)	11.1	19.4	8.3

The top ten marshes with respect to *Phragmites australis* expansion are listed in Table 41. Collectively, the expansion of *Phragmites australis* in these ten marshes represented 62.5 percent of the total *Phragmites australis* expansion in the Peconic Estuary. Increases in *Phragmites australis* in the Peconic Estuary occurred largely at the expense of coastal fresh marsh and high marsh communities. *Phragmites australis* encroachment resulted in a 73.5% decrease in the areas mapped as coastal fresh marshes in 1974 (Table 37). The proliferation of *Phragmites australis* in the Peconic Estuary is somewhat counterintuitive considering the lower development density and, presumably, reduced nutrient impairment to ground and surface waters in eastern Long Island. However, while many areas of the Peconic Estuary have lower development density, the results of this study indicate that the impacts and disturbance to the Peconic‟s wetlands have been sufficient in magnitude for widespread invasion and expansion of this invasive species. *Phragmites australis* colonization and expansion within and adjacent to tidal wetlands has typically been attributed to disturbance of native wetland and upland communities, soil salinity, and nitrogen availability (Bertness and Silliman, 2003). This study did not review and compare *Phragmites australis* increases relative to existing surface or groundwater monitoring data. However, the proliferation of *Phragmites australis* in the Peconic Estuary, particularly its coastal fresh marsh habitats, emphasizes the importance of soil salinity, years since the initial invasion, the original species composition of the invaded wetland, and hydrological and physical characteristics of the invaded site‟s soils in explaining *Phragmites australis* invasions.

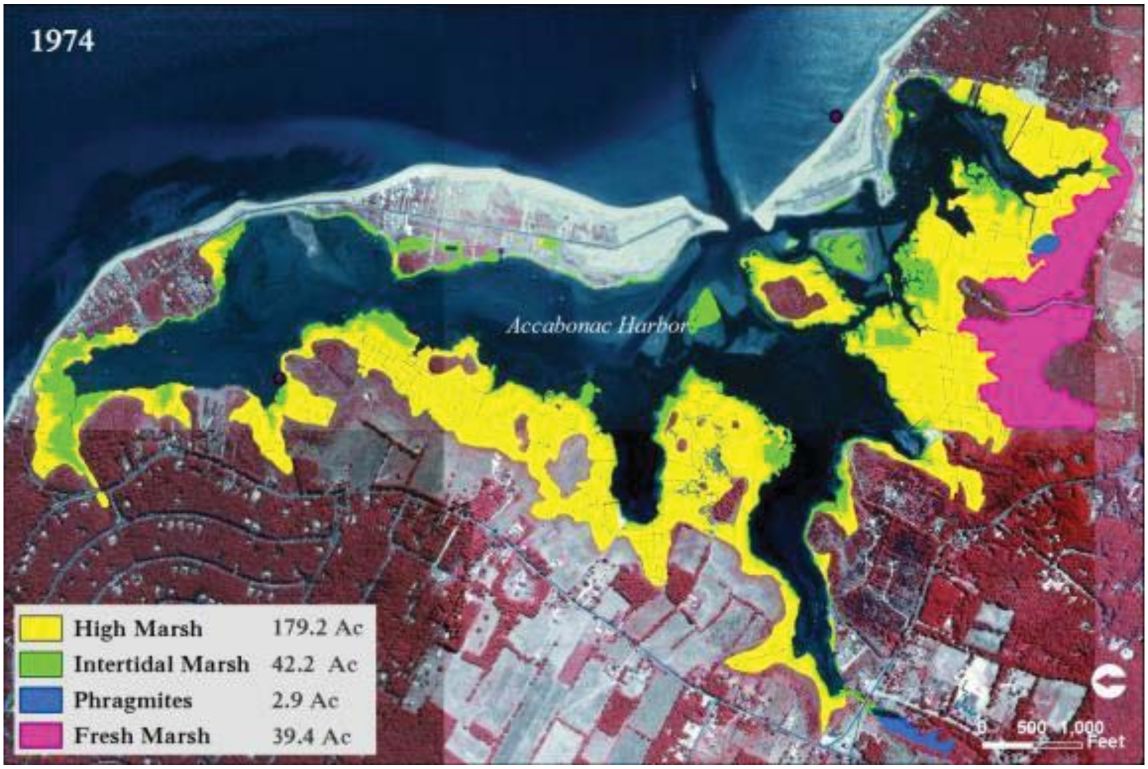
From 1974 through 2005, native marsh habitat expanded in 41 of the 159 marsh complexes in the Peconic Estuary, accounting for approximately 79.9 acres of new habitat (Table 42). This gain, however, was insufficient to offset marsh habitat losses. In 30 other complexes where marsh habitat increased – not including those listed in Table 42 – the expansion was less than 2 acres for each. Thus, gains in marsh habitat are skewed towards larger marshes. For example, the five marsh complexes listed in Table 42 accounted for more than half, or 53 percent, of the gains in tidal wetland area in the Peconic Estuary. Figure 52, Figure 57, and Figure 58 depict the marsh gains in Napeague Meadows (ID # 154), Napeague Harbor (ID # 153) and Cold Spring Pond West (ID # 204), respectively.

Table 42: Complexes with Largest Gain in Tidal Wetland Area in the Peconic Estuary

Complex (ID #)	1974 IM+HM+FM (acres)	2005 IM+HM+FM (acres)	Δ IM+HM+FM (acres)
Napeague Meadows (154)	237.0	253.0	16.0
Napeague Harbor (153)	29.5	39.8	10.3
Three Mile Harbor Shoreline (159)	7.7	12.1	4.4
Cold Spring Pond West (204)	2.2	6.9	4.7
Terry's Creek (81)	16.1	19.6	3.5
Hubbard Creek (14)	143.7	147.1	3.4

Gains in tidal wetlands areas can result from natural processes such as the conversion of *Phragmites australis* or low-lying upland habitats to tidal wetlands due to increased tidal inundation caused by either improved tidal exchange between the wetland and the bays or sea level rise. However, wetland complexes with large increases in tidal wetlands areas must be examined to verify that these increases are not due to improved identification of tidal wetlands during the current mapping effort. Figure 52 and Figure 57 for Napeague Meadows and Napeague Harbor, respectively, show both actual and artifact increases in tidal wetlands. In the southwestern headwaters of the Napeague Meadows complex, coastal fresh marshes consisting of mixed stands of *Typha angustifolia*, *Phragmites australis*, *Baccharis halimifolia*, and other woody vegetation were located in the current study, but not the 1974 tidal wetlands inventory. However, actual increases in tidal wetlands are also observed in the northwestern portion of this complex, as high marsh vegetation appears to have expanded in low-lying sandy areas. Tidal wetland expansion also appears to have occurred on the eastern shore of Napeague Harbor (Figure 57) as *Iva frutescens* and herbaceous high marsh vegetation have increasingly colonized the low, sandy swales and brackish meadows of Goff Point likely due to increased, but infrequent, flooding from two small channels along the eastern shore of Napeague Harbor. Similar to Sagamore Hill (Figure 48), the landward migration of tidal wetlands on Long Island appears to occur in low-lying sandy areas adjacent to tidal wetlands where expansion is not impeded by development, topography, upland forests or hardwood swamps, or *Phragmites australis*–dominated marshes or uplands. Cold Spring Pond West (ID # 204) in Sebonac (Southampton) shows a natural expansion of tidal wetland vegetation (approximately 3.7 acres) along the northern and southern shorelines of Cold Spring Pond (Figure 58). It is likely that some of this expansion has resulted from recovery of the tidal wetlands communities after the dredging and disturbance associated with the development of the residential neighborhood on Sandgate and Lands End Lanes. However, Cold Spring Harbor is consistent with Napeague Harbor and Sagamore Hill in that tidal wetlands expansion and landward migration appear to occur most frequently on sparsely vegetated sandy areas with shallow slopes.

Figure 49: Accabonac Harbor (Complex ID #156)
[See Page C10, Appendix I for Locator Map]



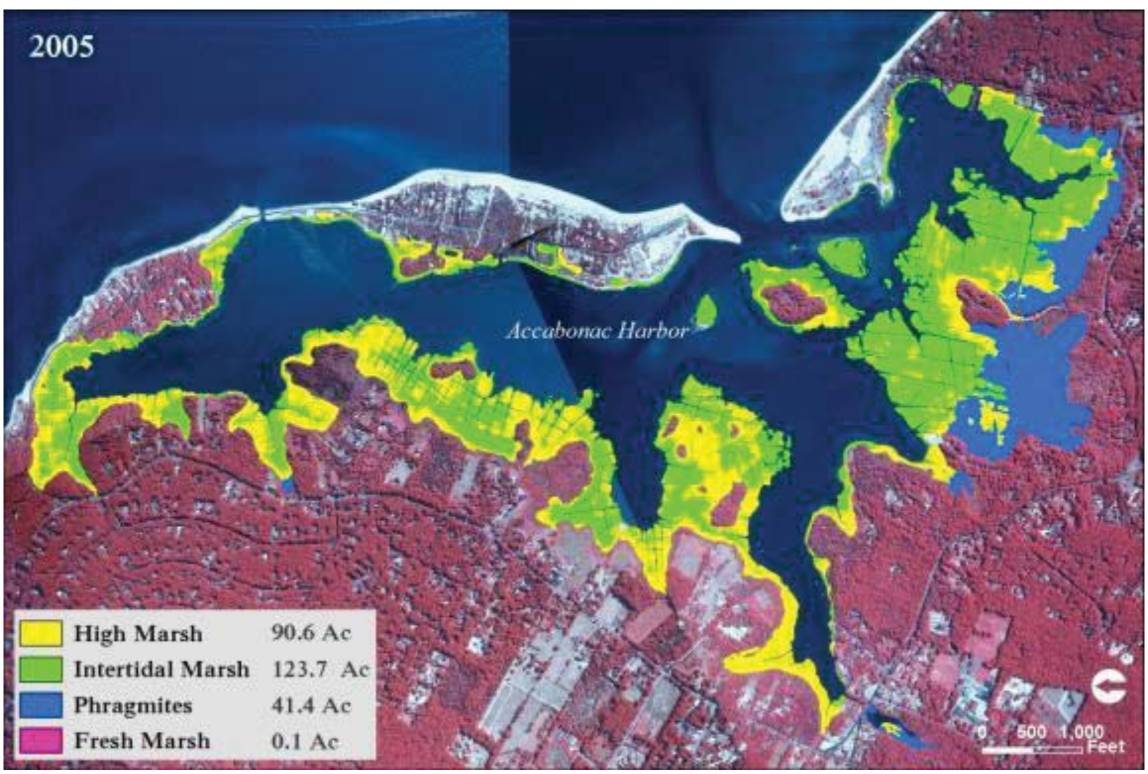
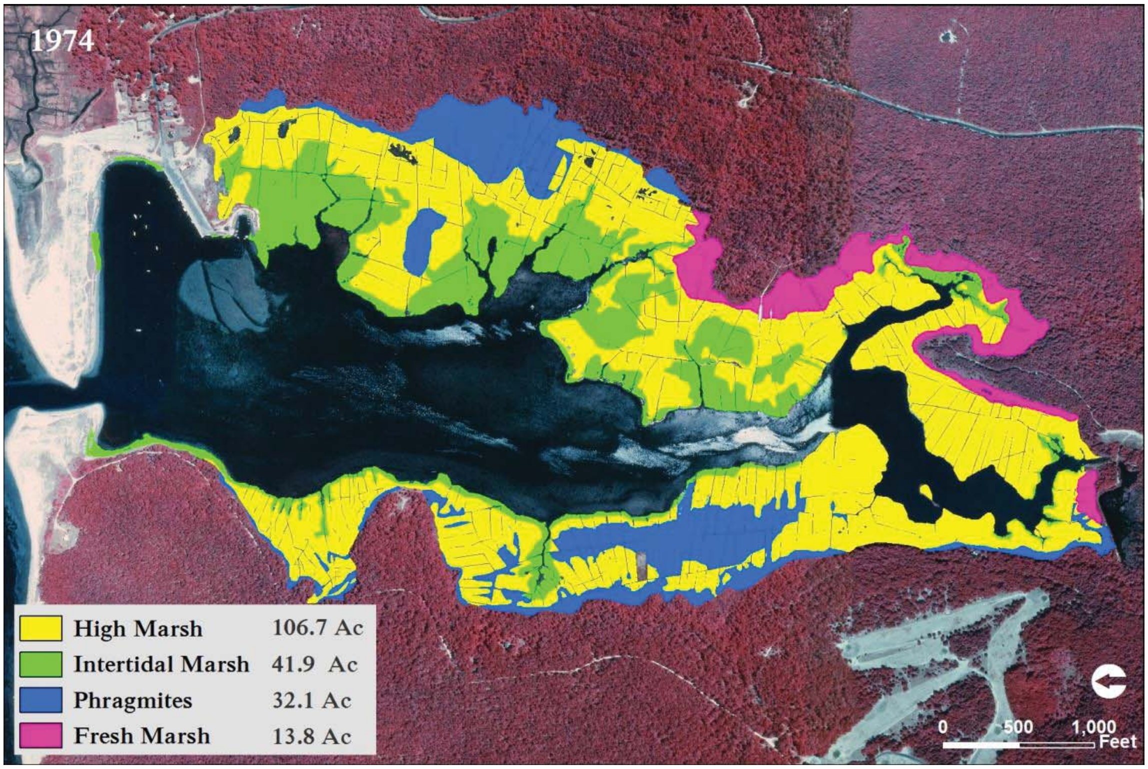


Figure 50: Northwest Creek (Complex ID #165)
[See Page C9, Appendix I for Locator Map]



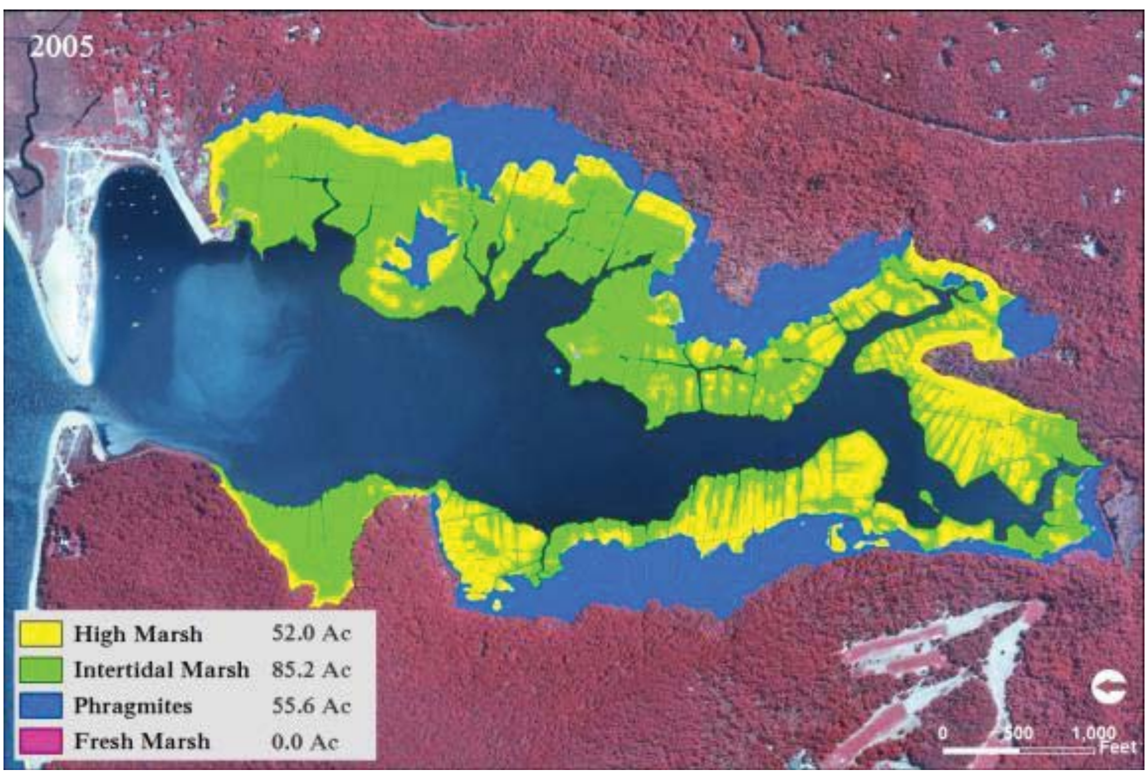


Figure 51: West Neck Creek (Complex ID #196)
[See Page D8, Appendix I for Locator Map]

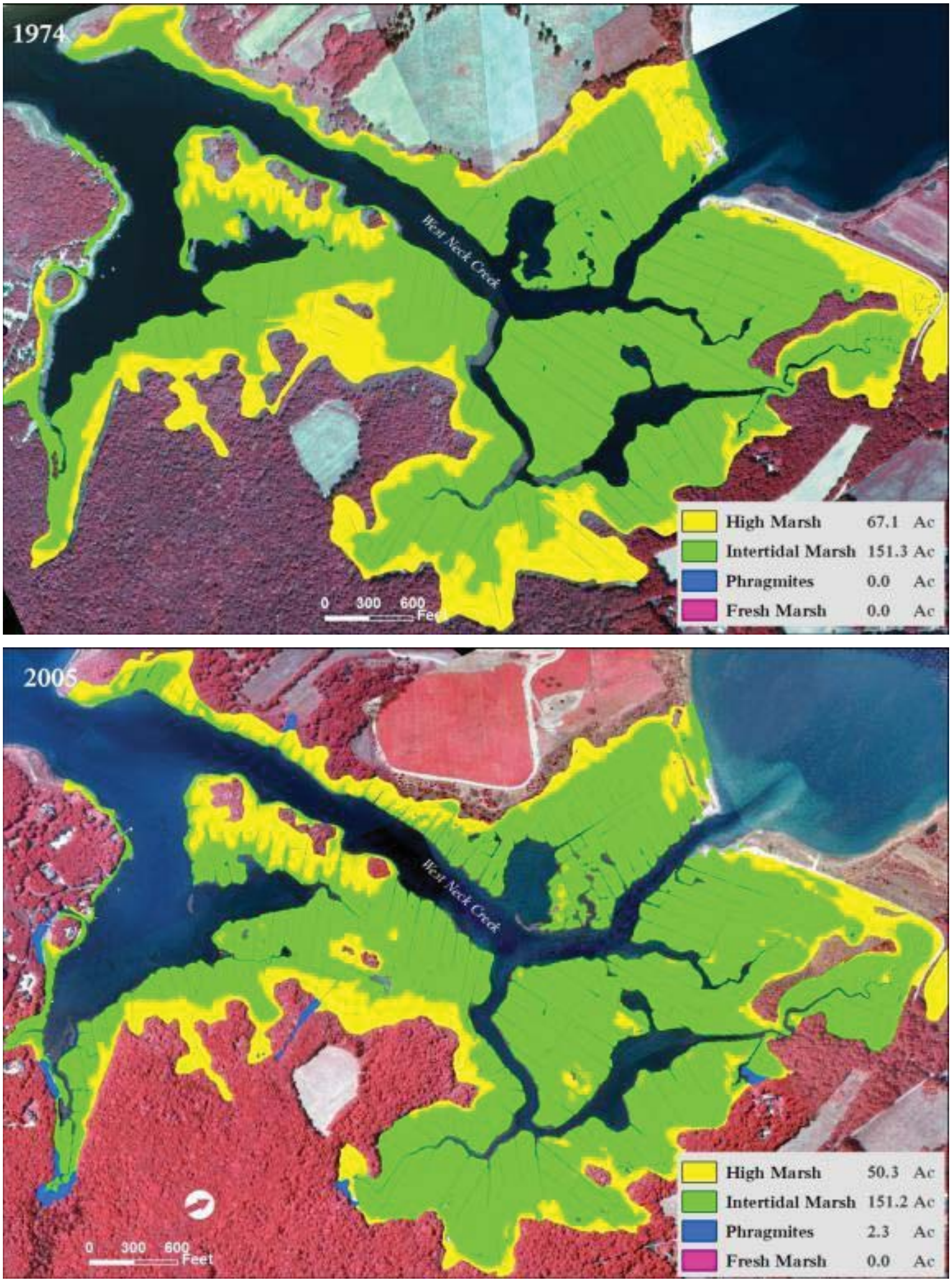
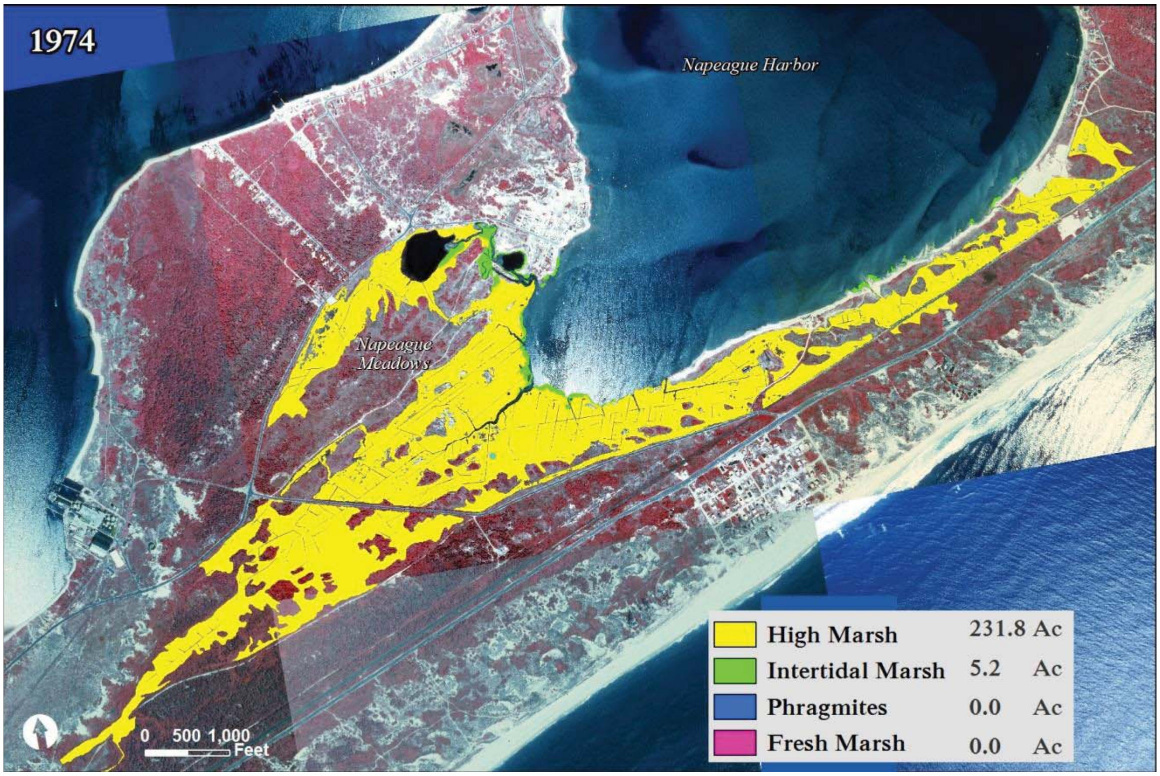


Figure 52: Napeague Meadows (Complex ID #154)
[See Page C10, Appendix I for Locator Map]



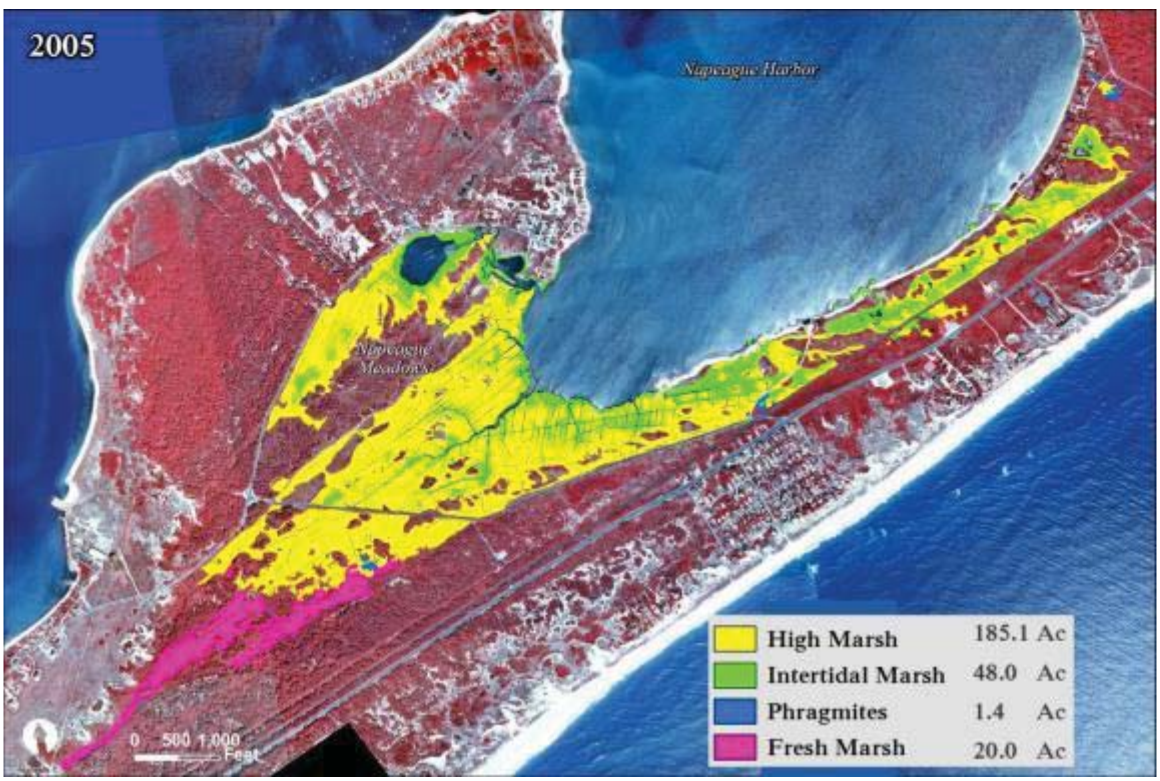
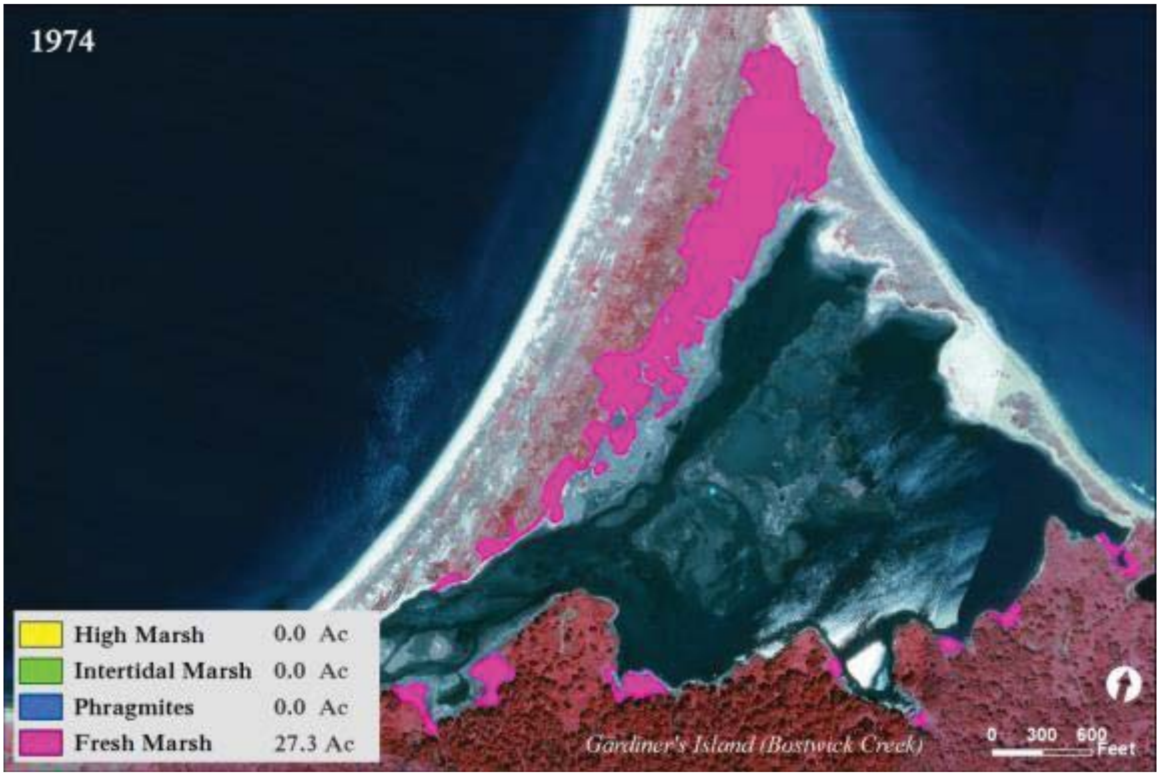


Figure 53: Gardiner's Island Bostwick Creek (Complex ID #109)
[See Page C10, Appendix I for Locator Map]



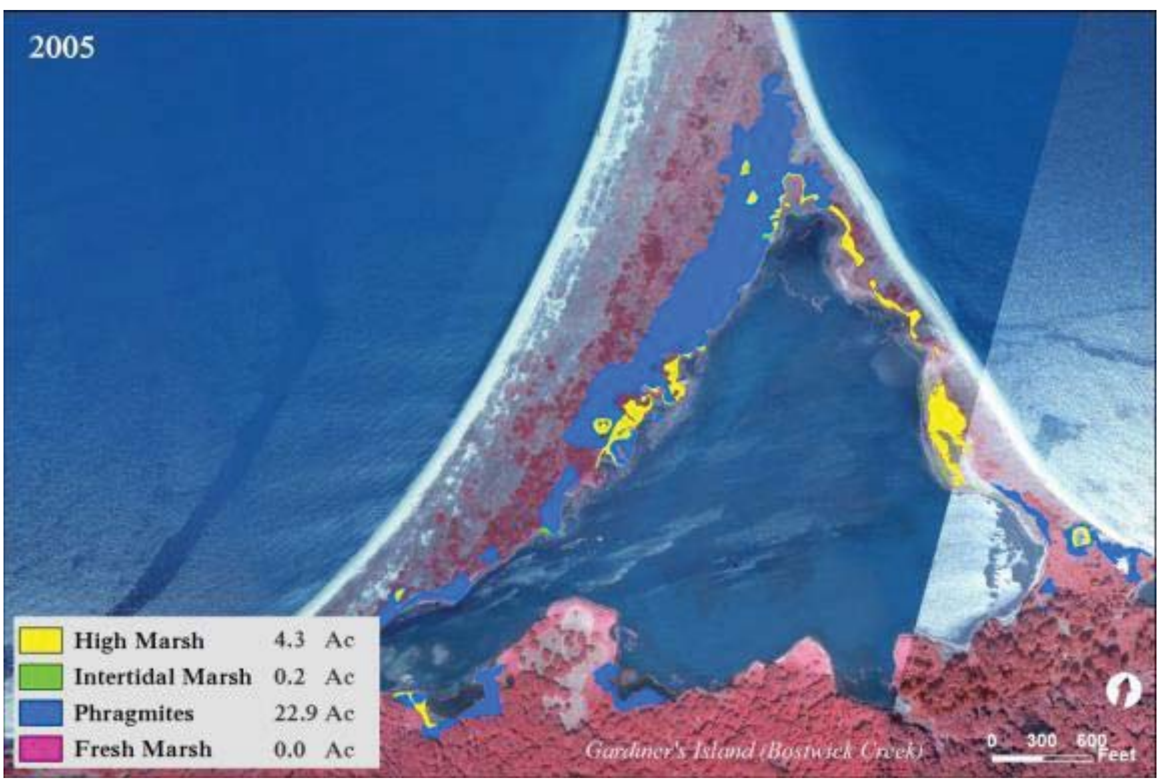
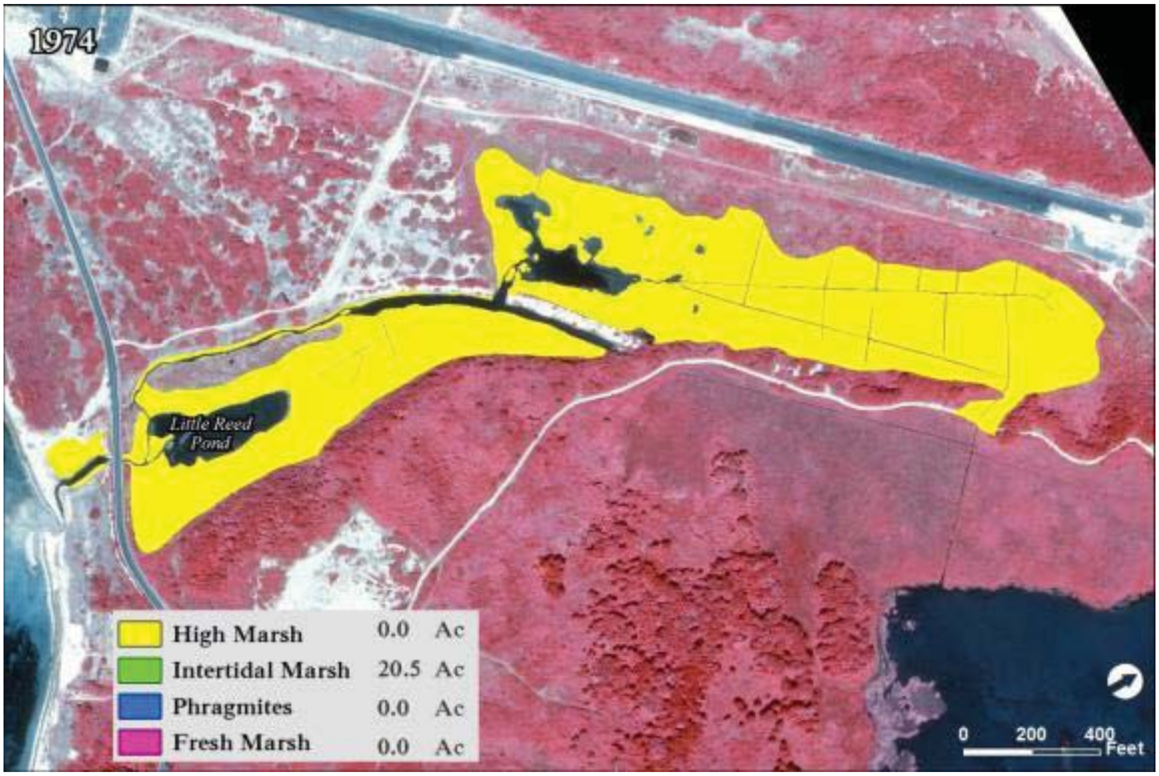


Figure 54: Little Reed Pond (Complex ID #150)
[See Page C11, Appendix I for Locator Map]



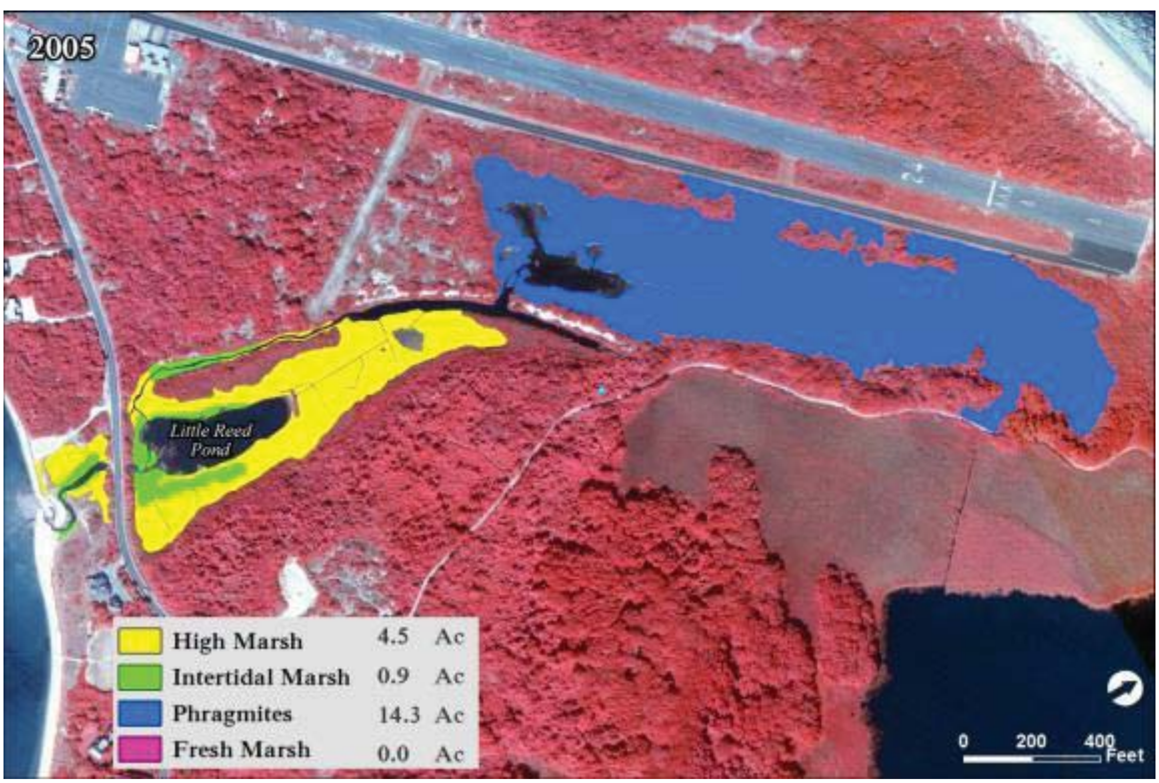
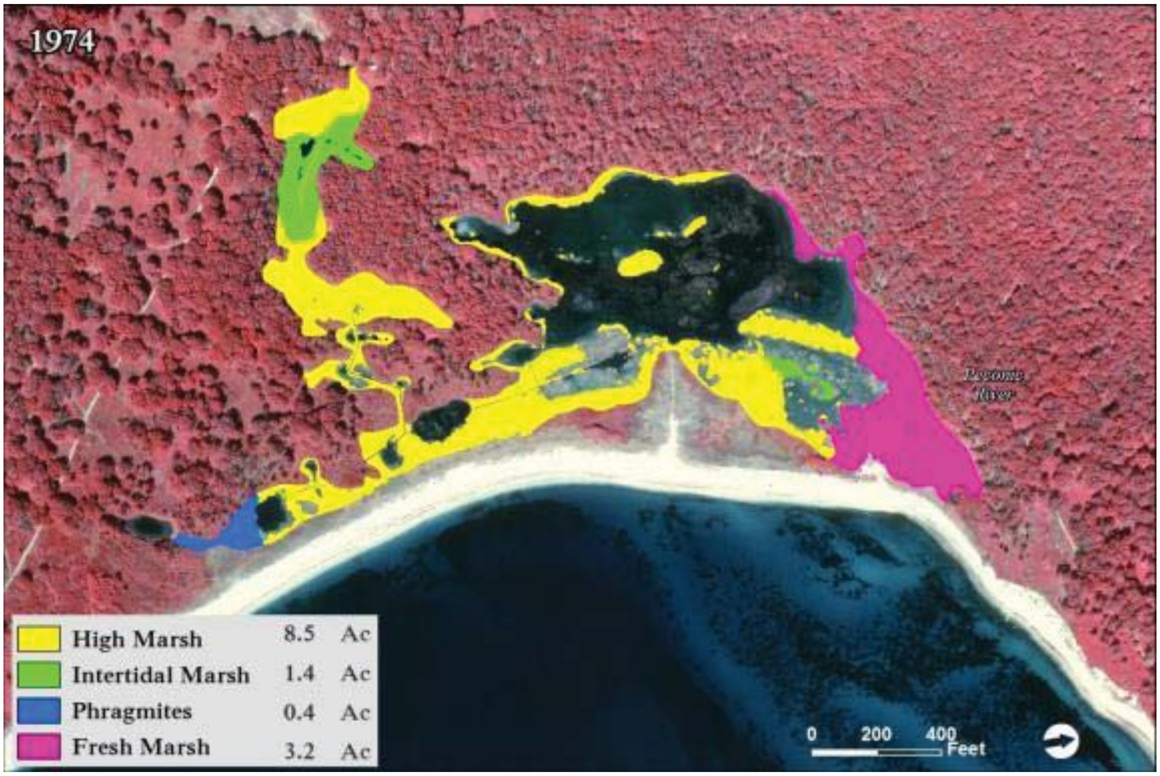


Figure 55: Plum Pond (Complex ID #126)
[See Page C9, Appendix I for Locator Map]



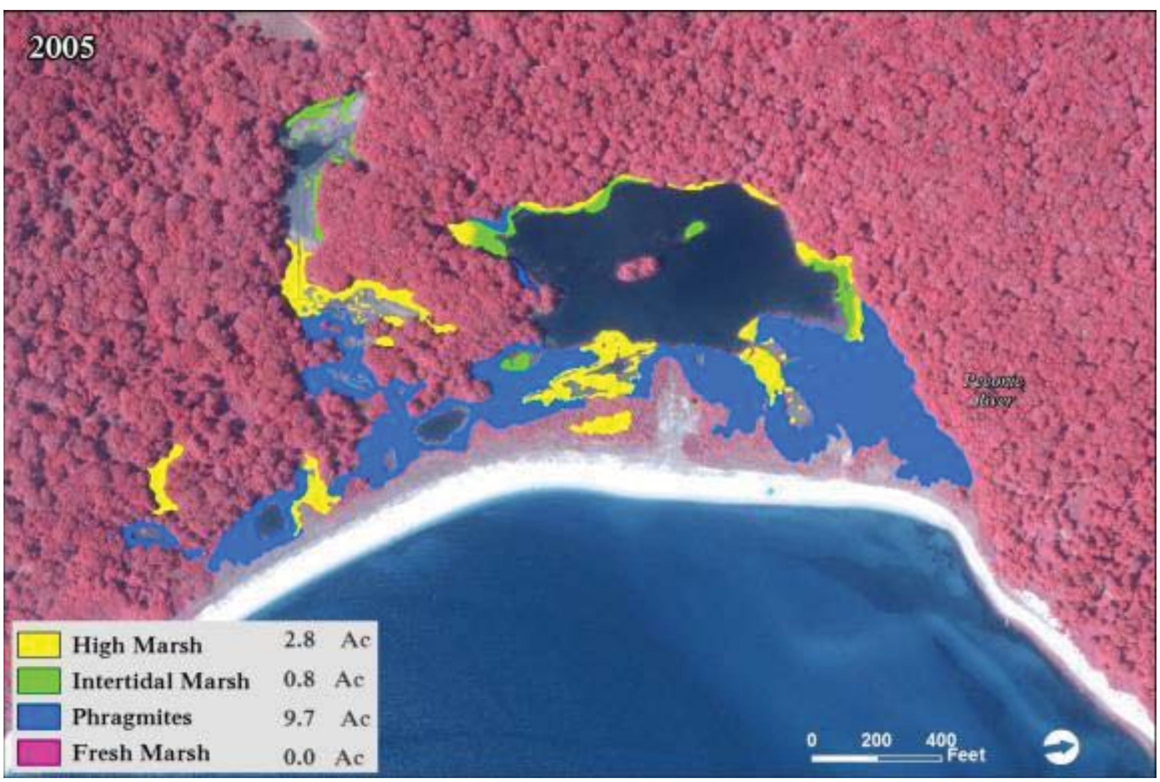
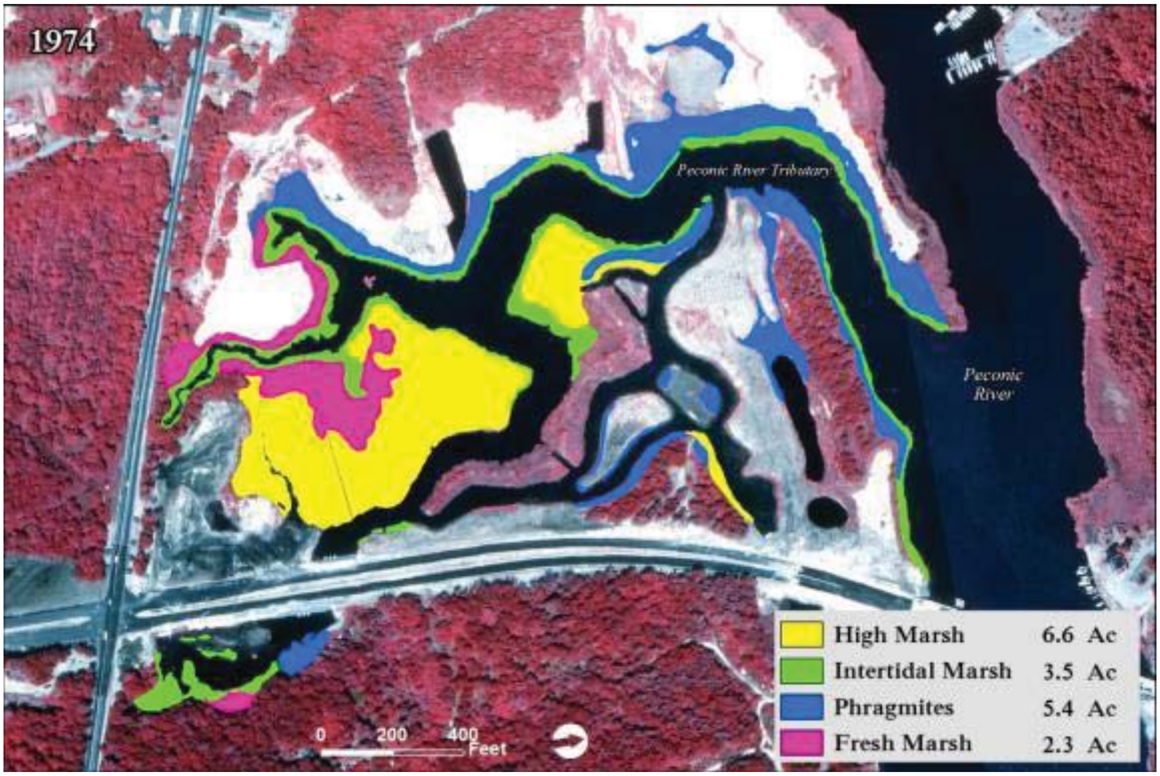


Figure 56: Peconic River Tributary (Complex ID #2)
[See Page D7, Appendix I for Locator Map]



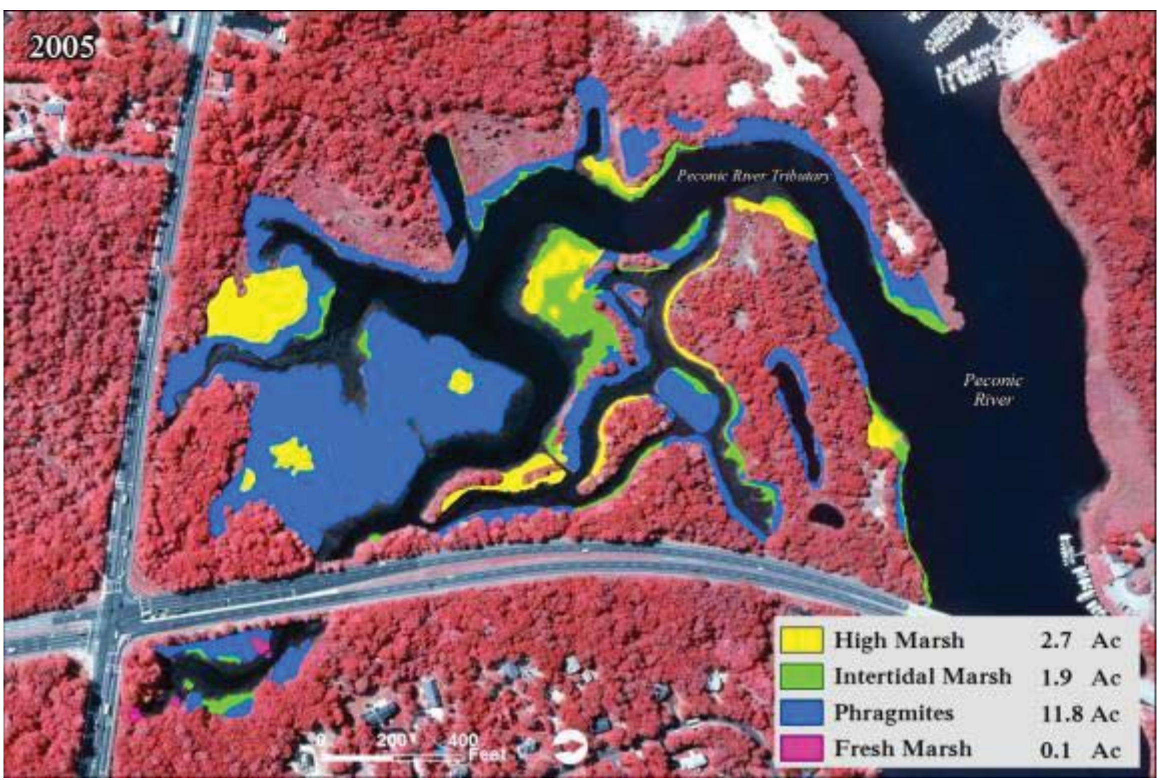
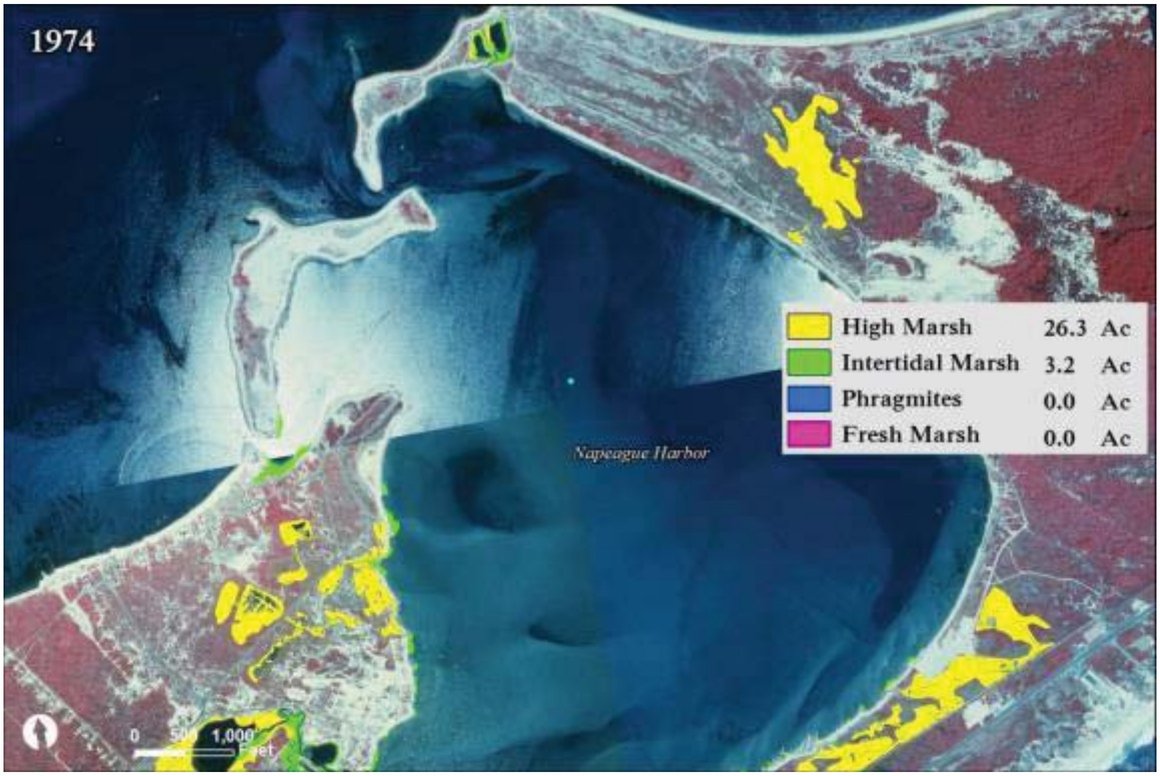


Figure 57: Napeague Harbor (Complex ID #153)
[See Page C10, Appendix I for Locator Map]



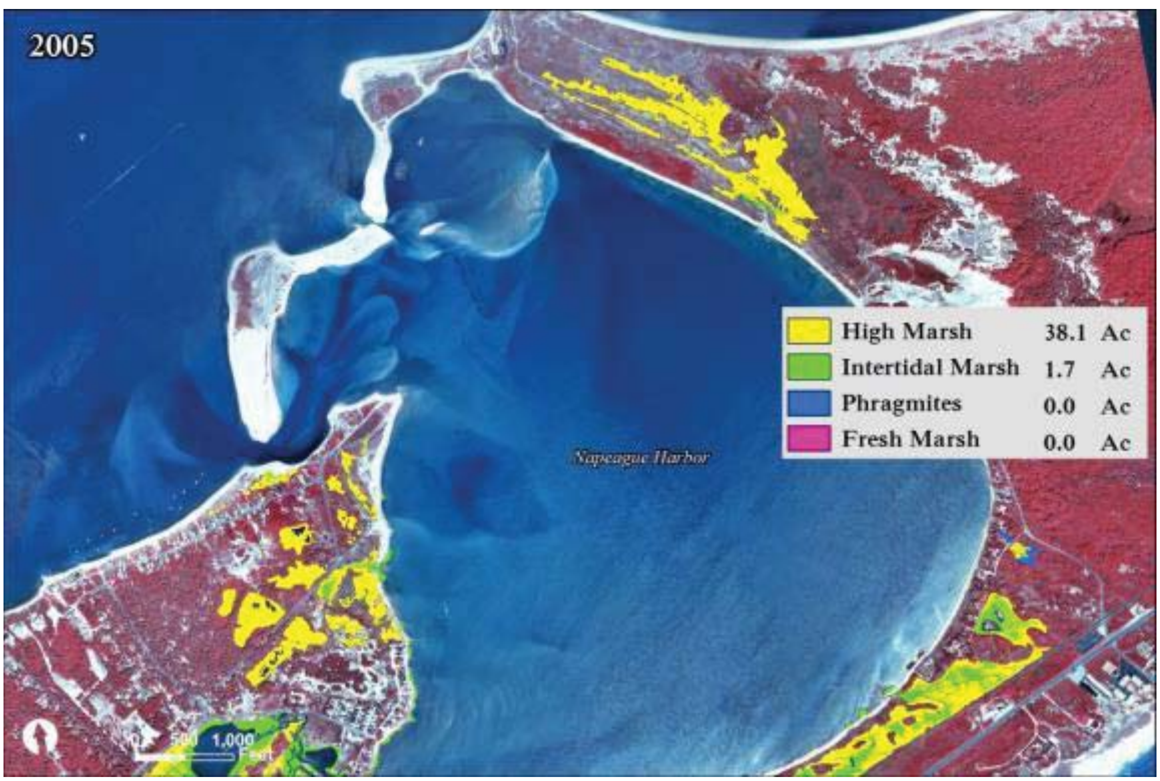


Figure 58: Cold Spring Pond West (Complex ID #204)
[See Page D8, Appendix I for Locator Map]

Table 43 summarizes the At-Risk marshes by town in the Peconic Estuary. An „At-Risk" marsh was defined as one in which the change in vegetated marsh area exceeded 10 percent loss between 1974 to 2005. The trends analysis identified 86 „At-Risk" marshes complexes – out of a total of 159 – in the Peconic Estuary. Figure 59 provides the spatial distribution of „At-Risk" marshes in the Peconic Estuary. Two data ranges were employed for the percent change in marsh area, i.e., „10 to 30 percent" and „greater than 30%", for the „At-Risk" marshes. The locations of „Stable Marshes", i.e., those that sustained less than 10 percent loss in wetlands, are also mapped. „Stable Marshes" appear to be situated in the lesser developed areas of the estuary. „At-Risk" marshes are located throughout the estuary; however, clustering is apparent in the western portions of the estuary, particularly adjacent to more developed areas around Riverhead, Sag Harbor and along the north shore of Peconic Bay.

Figure 59: Peconic Estuary Wetland Complexes by Percent Change in Vegetated Marsh Area (1974-2005)

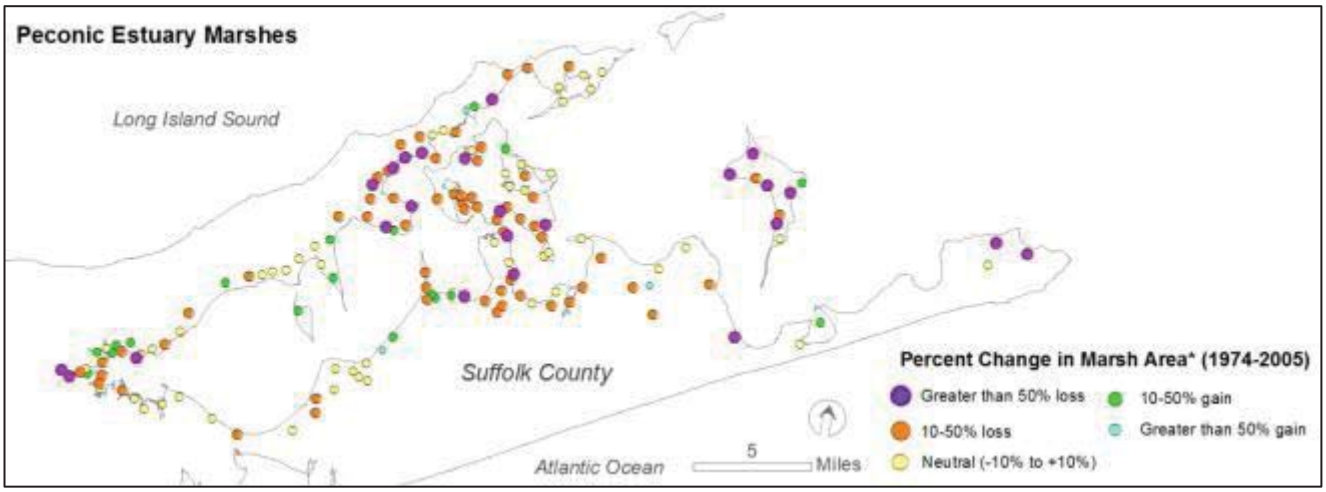


Table 43: At-Risk Wetland Complexes in the Peconic Estuary by Town

ID #	Wetland Complex	Town	1974 IM+HM (Acres)	2005 IM + HM (Acres)	Change in IM+HM (Acres)	Change in IM+HM (%)
114	Gardiner's Island Gales Pond	East Hampton	0.3	0.0	-0.3	-99.7
109	Gardiner's Island Bostwick Creek	East Hampton	27.3	4.4	-22.9	-83.8
150	Little Reed Pond	East Hampton	20.5	5.4	-15.1	-73.8
149	Oyster Pond	East Hampton	9.2	3.1	-6.1	-66.6
112	Gardiner's Island Boat Basin FC	East Hampton	1.7	0.6	-1.1	-65.7
155	Fresh Pond EH	East Hampton	7.3	3.1	-4.2	-57.3
110	Gardiner's Island Cherry Hill Pond	East Hampton	2.8	1.2	-1.6	-57.0
116	Gardiner's Island Tobaccolot Pond	East Hampton	19.0	9.4	-9.6	-50.4
113	Gardiner's Island Little Pond	East Hampton	10.1	5.6	-4.5	-44.2
111	Gardiner's Island Home Pond	East Hampton	20.0	13.7	-6.3	-31.4
163	Alewife Brook & Pond	East Hampton	32.3	22.2	-10.1	-31.3
167	Little Northwest Creek	East Hampton	47.0	33.3	-13.7	-29.1
160	Three Mile Harbor Hands Creek	East Hampton	9.1	6.8	-2.3	-25.1
156	Accabonac Harbor	East Hampton	260.9	214.4	-46.5	-17.8
164	NW Creek State Tidal Wetlands	East Hampton	28.8	24.3	-4.5	-15.6
165	Northwest Creek	East Hampton	162.4	137.2	-25.2	-15.5
161	Three Mile Harbor Inner Harbor	East Hampton	11.1	9.8	-1.3	-11.6
		Subtotal	669.8	494.6	-175.2	-26.2
76	Simmons Point	Riverhead	1.9	0.7	-1.2	-63.7
2	Peconic River Tributary	Riverhead	12.3	4.7	-7.7	-62.1
1	Peconic River	Riverhead	2.4	1.0	-1.4	-59.4
5	Colonel Island	Riverhead	3.2	2.1	-1.1	-33.8
82	Indian Island County Park	Riverhead	3.9	3.4	-0.6	-14.7
72	State Boat Marina	Riverhead	1.6	1.4	-0.2	-12.0
77	Bay Woods Drive	Riverhead	0.8	0.7	-0.1	-11.0
		Subtotal	26.1	13.9	-12.2	-46.8
148	Hay Beach Point	Shelter Island	1.9	0.0	-1.9	-100.0
126	Plum Pond	Shelter Island	13.1	3.7	-9.4	-71.9
133	Smith Cove Creek	Shelter Island	0.6	0.3	-0.3	-55.4
143	Chase Creek	Shelter Island	3.6	1.7	-1.9	-52.9
145	Gardiner's Creek	Shelter Island	9.8	5.2	-4.6	-47.2
119	Cedar Island Cove Marsh	Shelter Island	9.9	6.3	-3.6	-36.4
135	Dickerson Creek	Shelter Island	11.3	8.3	-3.0	-26.9
141	West Neck Creek Fred's Lane Tributary	Shelter Island	3.5	2.6	-0.9	-25.3
146	Dering Harbor Creek	Shelter Island	4.3	3.2	-1.0	-24.3
137	Montclair Colony Shoreline	Shelter Island	1.3	1.0	-0.3	-23.2
127	Bass Creek	Shelter Island	25.1	19.4	-5.7	-22.7
140	West Neck Creek Simpson Lane Tributary	Shelter Island	2.5	2.0	-0.5	-20.4
118	Coecles Harbor Shoreline IM	Shelter Island	15.7	12.8	-2.9	-18.6
136	Menantic Creek	Shelter Island	5.2	4.2	-0.9	-18.1
139	West Neck Creek Shoreline IM	Shelter Island	19.5	16.1	-3.4	-17.3
132	Miss Annie's Creek	Shelter Island	15.1	12.7	-2.4	-15.7
131	Log Cabin Creek	Shelter Island	3.8	3.2	-0.6	-15.1
147	Crab Creek	Shelter Island	12.8	10.9	-1.9	-14.6
128	Majors Harbor Marshes	Shelter Island	4.7	4.1	-0.6	-13.4

ID #	Wetland Complex	Town	1974 IM+HM (Acres)	2005 IM + HM (Acres)	Change in IM+HM (Acres)	Change in IM+HM (%)
134	South Ferry Marsh	Shelter Island	9.6	8.3	-1.3	-13.1
		Subtotal	173.1	126.0	-47.1	-27.2
181	Cedar Lane FC Wetland	Southampton	1.3	0.5	-0.8	-64.8
178	Actors Colony Road Marsh	Southampton	0.8	0.4	-0.4	-52.7
176	Fresh Pond (Sag Harbor)	Southampton	5.4	2.7	-2.7	-50.1
48	Noyack Jessup Neck North	Southampton	4.1	2.4	-1.7	-41.6
171	Middle Sag Harbor Cove	Southampton	13.0	8.8	-4.2	-32.3
179	Tyndal Point	Southampton	2.5	1.8	-0.7	-28.4
174	Upper Sag Harbor Cove	Southampton	7.7	5.6	-2.1	-26.8
9	Reeves Bay Islands	Southampton	4.4	3.3	-1.1	-25.7
8	Iron Point	Southampton	28.0	20.9	-7.1	-25.3
205	Shinnecock Canal (North of locks)	Southampton	0.1	0.1	0.0	-24.0
170	Lower Sag Harbor Cove	Southampton	15.7	12.2	-3.5	-22.5
173	Ligonee Brook	Southampton	2.9	2.3	-0.6	-20.3
175	Great Pond Creek	Southampton	15.1	12.3	-2.8	-18.7
11	Goose Creek (Flanders Bay)	Southampton	72.8	59.3	-13.4	-18.5
185	Noyack Morton NWR	Southampton	6.5	5.3	-1.1	-17.6
197	Little Sebonac Creek/Sebonac Island	Southampton	79.9	66.8	-13.1	-16.4
201	Bullhead Bay	Southampton	29.8	25.9	-4.0	-13.3
186	Noyack Jessup Neck	Southampton	7.1	6.2	-0.9	-12.7
169	Sag Harbor Shoreline	Southampton	1.0	0.8	-0.1	-12.1
		Subtotal	298.2	237.6	-60.6	-20.3
52	Paradise Point FC Wetland	Southold	0.5	0.0	-0.5	-95.9
56	Rambler Road Marsh	Southold	4.2	0.3	-3.9	-93.2
46	Debexidon Road Pond	Southold	1.3	0.4	-0.9	-65.8
43	Sage Blvd Boat Basins	Southold	1.5	0.5	-1.0	-65.3
49	Jockey Creek	Southold	3.9	1.6	-2.3	-60.1
35	Spring Pond	Southold	0.9	0.4	-0.5	-51.8
44	Mill Creek & Budd's Pond	Southold	3.5	1.7	-1.8	-51.5
48	Town Creek	Southold	2.9	1.5	-1.4	-47.8
38	Fanning Point	Southold	0.7	0.4	-0.3	-47.2
70	Brushs Creek	Southold	10.4	6.7	-3.7	-35.6
34	Dam Pond	Southold	15.6	10.1	-5.5	-35.1
67	Deep Hole Creek	Southold	13.3	8.9	-4.4	-33.1
58	Richmond Creek	Southold	36.5	24.7	-11.8	-32.4
47	Hippodrome Pond	Southold	5.2	3.9	-1.3	-25.3
50	Goose Creek (Southold)	Southold	23.8	17.9	-6.0	-25.1
53	Cedar Beach Point	Southold	36.7	27.9	-8.8	-24.0
57	Corey Creek	Southold	33.3	25.5	-7.9	-23.6
41	Arshomonaque Wetlands	Southold	22.2	17.0	-5.2	-23.3
42	Conkling Point	Southold	8.8	6.9	-1.9	-21.2
51	Harbor Lights Drive Wetland	Southold	3.0	2.4	-0.6	-20.4
31	Narrow River	Southold	17.8	14.8	-3.0	-16.9
33	Orient Harbor	Southold	36.3	30.6	-5.7	-15.6
45	Hashamomuck Pond	Southold	46.7	42.0	-4.7	-10.1
		Subtotal	328.8	246.0	-82.8	-25.2

South Fork Ponds: Mecox Bay, Sagaponack Pond, and Georgica Pond

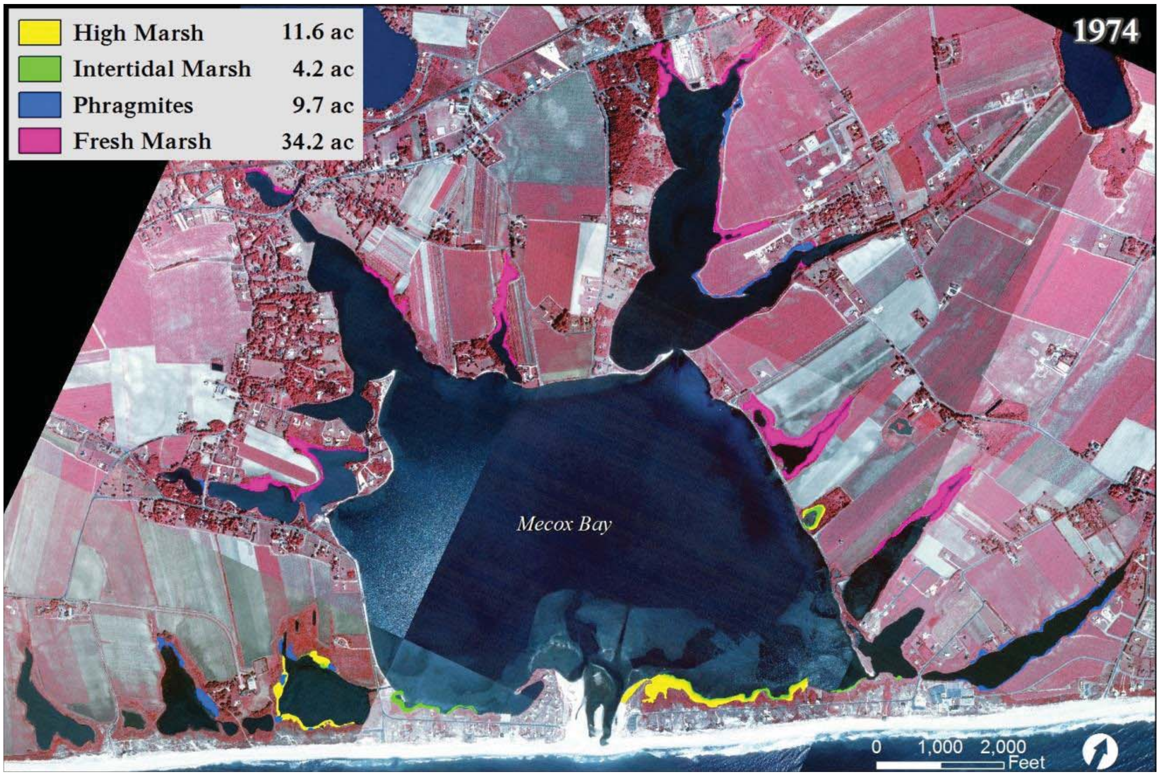
Mecox Bay (ID # 540), Sagaponack Pond (ID #541), and Georgica Pond (# 542) exhibited very large losses in native tidal wetlands between 1974 and 2008 as shown in Table 44. In 1974, these permanently flooded tidal ponds had 43.2 acres of coastal fresh marsh habitats located in their northern headwaters and small areas of intertidal and high marsh typically adjacent or proximal to the barrier beach. Due to extensive clearing, disturbance, and nutrient loading in the adjacent uplands, *Phragmites australis* stands in these coastal ponds have increased from 21.5 to 106.5 acres (395.7%) resulting in the near complete eradication of native coastal fresh marsh communities, as shown in Figure 60. The few areas of intertidal and high marshes present in these coastal ponds in 1974 have also been invaded by *Phragmites australis* resulting in -71.8 to -75.9% declines in these habitats. Percent loss of intertidal, high, and coastal fresh marsh between 1974 and 2005 was -98.7% for Mecox Bay, -59.6% for Georgica Pond, and -100.0% for Sagaponack Pond.

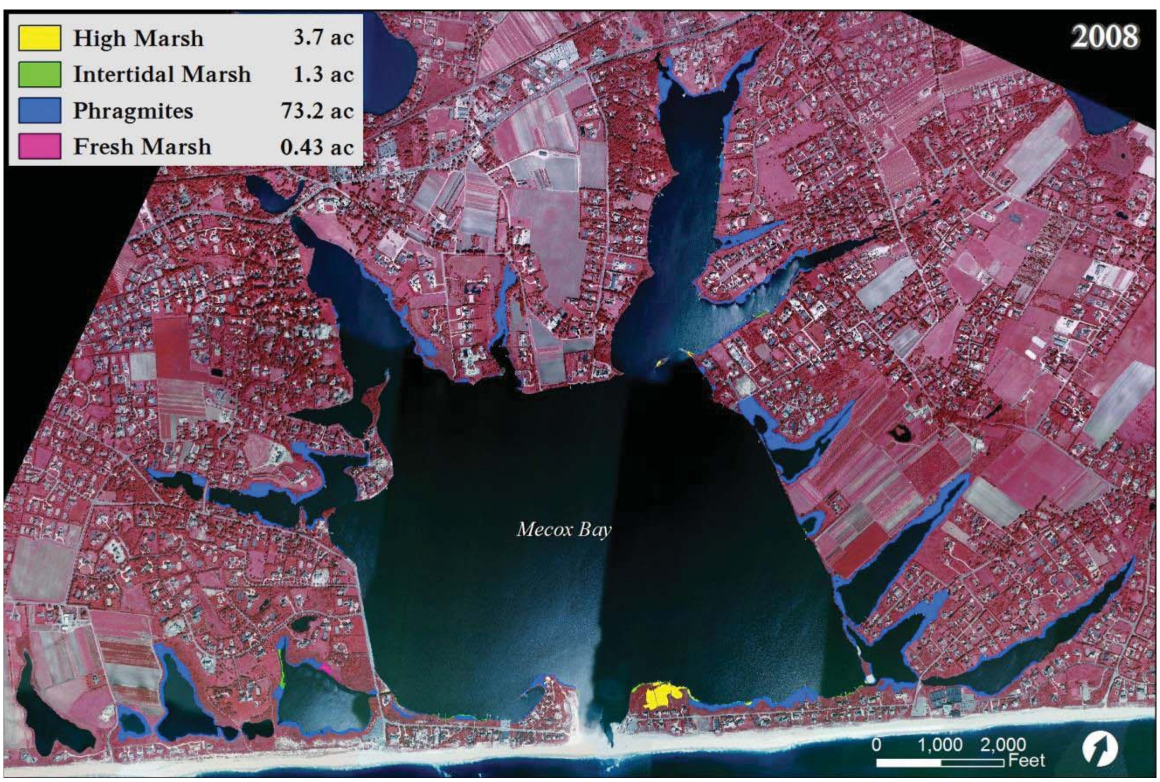
Table 44: Tidal Wetland Area Change (1974-2008) in Mecox Bay, Sagaponack Pond, and Georgica Pond

Wetland Type	1974 Wetland Area (acres)	2008 Wetland Area (acres)	Change (%)
Intertidal Marsh	5.8	1.4	-75.9
High Marsh	13.6	3.8	-71.8
Coastal Fresh Marsh	43.3	2.0	-95.3
Marsh Subtotal	62.7	7.2	-88.5
Phragmites australis	21.5	106.5	+395.7
Vegetated Area Total	84.2	113.8	+35.1

Figure 60: Mecox Bay (Complex ID #540)

[See Page D9, Appendix I for Locator Map]





Error Analysis

Two types of error were calculated for the tidal wetlands delineation. The first is classification error, which measures the initial mapping error with respect to groundtruthed „test" points, and the second is relative error, which calculates the difference in wetland areas between the 1974 manual, photo-interpretation methodology and the computer-assisted classification approach applied to a set of 1974 color-infrared images.

Classification Error

Table 45 below summarizes the classification accuracy of the various species and feature types and for their tidal wetland classes. The classification accuracy provided in Table 45 is for the initial classification of the color-infrared images for the current year delineation, i.e., Year 2005 and Year 2008. Following the initial classification and vectorization of the classified imagery, the tidal wetland delineation were meticulously checked and manually corrected, where necessary, against high-resolution color-infrared imagery.

It is noted that the classification accuracy that was achieved for the Year 2005 and 2008 color-infrared images is exceptionally high for supervised classification, i.e., as compared with that typically reported in peer-reviewed literature. The relatively high classification accuracy is attributed to the project"s extensive collection of ground-truthed training and test points which, in turn, resulted in a well-defined spectral library. The classification accuracy by class ranges from approximately 66% for the salt scrub class to 92.8% for intertidal marsh. The initial classification accuracy for both the native high marsh and intertidal marsh are relatively high for an image classification project owing to the numerous training points collected in the field and the relative ease with which these features can be extracted from color-infrared imagery. This is fortunate as the native high marsh and intertidal marsh comprise a large majority of the area of the tidal wetlands.

As expected given the complexity of the salt scrub, i.e., intermixing of species and variations in physical conditions in the uppermost reaches of the high marsh, its class classification accuracy is relatively low, i.e., only 66.9%. Accordingly, the largest share of manual tidal wetland boundary corrections was required for this class. Large areas of salt scrub are more likely to be found in wetland complexes of the South Shore and Peconic Estuaries compared to those in the Long Island Sound due to the less steep topography of the South Shore and Peconic Estuaries. As a result, the relatively low classification accuracy of salt scrub habitats disproportionately affects wetland complexes of the South Shore and Peconic Estuaries.

Table 45: Summary of initial classification accuracy for tidal wetland features and classes

Type	Correct	Incorrect	Total	% Accuracy
Native High Marsh				
Sp.pat/D.spic Sp. Dominant	6	0	6	100.0%
Spart. pat/Distic.spic 50/50	12	1	13	92.3%
Spartina patens	16	3	19	84.2%
Distichlis spicata	14	2	16	84.2%
Total	48	6	54	87.5%
Salt Scrub				
Juncus gerardii	8	2	10	80.0%
lva frutescens	17	6	23	73.9%
Phrag low-vigor	4	7	11	36.4%
Total	29	15	44	65.9%
Intertidal Marsh				
Spartina alt-short form	35	2	37	94.6%
Spartina alt w/rockweed	1	0	1	100.0%
Spartina alt-tall form	22	2	24	91.7%
Spartina alt/Distich spic 50/50	7	1	8	87.5%
	65	5	70	92.8%
Phragmites australis				
Phrag high-vigor	9	2	11	81.8%
Fresh Marsh				
Schoenoplectus sp.	4	1	5	80.0%
Typha angustifolia	1	0	1	100.0%
Total	5	1	6	83.3%
Unvegetated				
Salt panne	11	1	12	91.7%
Upland				
Ammophila breviligul	4	0	4	100.0%
Baccharis haliminfolia	13	2	15	86.7%
Morella pensylvanica	9	0	9	100.0%
Toxicondenron radica	3	1	4	75.0%
Panicum virgatum	6	0	6	100.0%
Total	35	3	38	92.1%

Relative Error

The discrepancy, or relative error, in wetland delineations is a comparison of the tidal wetland areas derived via the two methodologies for 25 randomly-chosen tiles as shown (Table 46).

This estimate – which is based on a random sample with probabilities proportional to size – depends on the variation of the newer measurement divided by its sampling probability. If the individual area measurements delineated by the previous, or older, 1974 methodology are denoted by A_{74old}, with a total acreage of T_{74old}, and if the measurements made using the newer, automated methodology are denoted as A_{74new}, then T_{74new} would be the total new wetland area.

Table 46: Summary of the area differences for the automated and manual delineation methodologies

	1974 Automated			1974 Manual			% Difference	
TW Tile	IM	HM	Total	IM	HM	Total	IM	HM
606-522	9.89	4.55	14.44	9.41	5.04	14.45	-5.11%	9.64%
610-494	239.87	20.33	260.20	237.64	22.92	260.57	-0.94%	11.31%
614-526	20.38	0.00	20.38	20.38	0.00	20.38	0.00%	0.00%
618-528	53.74	30.89	84.63	50.54	34.18	84.71	-6.34%	9.61%
620-492	20.36	4.68	25.04	20.16	4.89	25.04	-1.00%	4.24%
624-496	227.77	19.59	247.36	205.58	42.55	248.13	-10.79%	53.96%
624-528	20.12	9.76	29.88	18.84	11.19	30.03	-6.82%	12.84%
636-532	15.62	3.95	19.57	15.46	4.11	19.57	-1.07%	3.94%
638-500	60.74	171.38	232.12	47.67	185.12	232.79	-27.41%	7.42%
648-528	54.39	2.10	56.48	54.85	2.26	57.10	0.84%	7.11%
660-508	8.90	39.77	48.67	7.70	40.97	48.67	-15.50%	2.92%
672-508	15.20	43.33	58.54	13.60	45.20	58.79	-11.81%	4.12%
686-514	73.39	106.43	179.83	63.00	117.17	180.16	-16.50%	9.16%
690-516	37.22	11.59	48.81	38.68	10.13	48.81	3.78%	-14.35%
696-520	11.95	6.51	18.46	11.50	7.11	18.61	-3.94%	8.46%
704-530	38.96	41.25	80.21	36.43	44.26	80.69	-6.95%	6.80%
708-522	76.77	43.37	120.14	74.37	45.83	120.20	-3.23%	5.38%
708-530	4.99	21.97	26.96	5.02	16.94	21.96	0.70%	-29.67%
712-524	8.10	6.40	14.50	8.02	6.49	14.51	-0.99%	1.44%
716-550	5.98	9.26	15.24	5.72	9.70	15.42	-4.57%	4.56%
720-552	7.37	6.15	13.52	6.84	6.68	13.52	-7.79%	7.93%
724-548	19.11	4.61	23.72	18.55	5.18	23.72	-3.05%	10.95%
728-542	13.75	23.74	37.49	13.85	23.82	37.66	0.72%	0.32%
744-548	9.61	16.12	25.73	10.00	15.73	25.73	3.89%	-2.46%
748-572	2.21	1.40	3.61	2.23	1.42	3.65	0.80%	1.75%
Acreage	1056.40	649.12	1705.52	996.02	708.89	1704.90		
						Relative Error	-6.06%	8.43%

The sampling probabilities are A_{74old}/T_{74old}, so the estimate is simply the average of $[A_{74new}/(A_{74old}/T_{74old})]$, which is the same as T_{74old} × average $[A_{74new}/A_{74old}]$ for the tiles sampled. Therefore, the discrepancy, or relative error, of the estimate depends on the variation in (A_{74new}/A_{74old}). This factor will be calculated for each tidal wetland class; the relative error will be calculated by subtracting this value from "1", or mathematically, 1 - (A_{74new}/A_{74old}).

There is a wide range of differences in high and low marsh area between the manual, photo-interpretation approach and the computer-assisted image classification, i.e., from -27.41% to +3.89 % for Intertidal Marsh delineations and from -29.67% to +53.96% for High Marsh delineations. However, a majority of percent difference values range from approximately +3% and -7% for the intertidal marsh comparison and from 0% to 8% for the high marsh. The relative error, as given by 1 - (A_{74new}/A_{74old}), is -6.06% for the intertidal marsh and +8.43% for the high marsh. These relative error values indicate that 1974 manual photo-interpretation approach underrepresented the intertidal marsh areas and overrepresented the high marsh. This finding is understandable given the inability of the photo-interpreters to delineate the relatively small intertidal marsh areas inside larger high marsh areas. This would result in a slightly larger intertidal marsh area and slightly smaller area for the high marsh for the computer-automated approach as compared with the photo-interpretation approach. There were no statistically significant differences in the percent difference values between the three major estuary systems (Long Island Sound, South Shore Estuary, and Peconic Estuary) for either intertidal marsh and high marsh classifications according to two tailed *t*-tests (i.e., all P values were greater than 0.05).

Future Approaches for Mapping Tidal Wetlands

This section considers potential approaches for future mapping of the tidal wetlands of Long Island that exceed the technical limitations of the multi-spectral (3-band) imagery and supervised classification methodology employed in this study. It is important to note, however, that despite many advances in data collection and image processing techniques, regional-scale wetland mapping remains one of the most problematic of all vegetation mapping exercises. In particular, variations in hydrologic regime, topography, nutrient loading and other stressors, induce significant variations in the spectral responses (i.e., differences in reflectance across the electromagnetic spectrum) of individual wetland species. Such variations are present at the local scale (i.e., individual marsh complex), but are magnified when mapping is required at regional levels wherein the potential for variations in the physical environment are even greater. For example, even a geographically limited area such as Long Island, sustains a varied array of marsh habitats, i.e., from the low-lying, predominantly intertidal marsh islands south of Hempstead, New York to the diverse intertidal, high and coastal fresh marshes of the Peconic Estuary. As a result of variations in physical parameters, the spectral signatures of different wetland species often overlap, in turn generating confusion and/or errors when attempting to differentiate between species (Tuxen et al., 2010).

As a response to the challenges of wetland mapping (i.e., in particular, computer-driven approaches at the regional scale), researchers have developed a variety of techniques to enhance mapping accuracy. These include hyper-spectral image acquisition and classification, object-oriented analysis, artificial neural networks and decision trees, to name a few. The following discussion briefly examines how such methods may be used either singularly or in combination to facilitate more accurate and rapid tidal wetland mapping for Long Island.

Historically, the first method used to map tidal wetlands at a regional scale entailed the manual, photo-interpretation of aerial imagery. To this end, the use of false color-infrared imagery was particularly advantageous. It was found that the red and infrared bands of the electromagnetic spectrum were particularly suited for effectively differentiating between a number of tidal wetland species. When combined with the visible green band of the electromagnetic spectrum, the red and near-infrared bands produced a 3-band, false-color image useful for readily distinguishing between the different marsh classes (i.e., inter tidal, high, salt scrub and coastal fresh marshes), upland species and non-vegetated areas (i.e., water, mud flats and salt pannes.) The manual photo-interpretation of such color-infrared imagery produced the official 1974 Tidal Wetland Maps of New York State.

The manual photo-interpretation approach can produce wetland mapping sufficient for defining the broader wetland classes and marsh extent. The limitations of this method are realized, for example, where tidal wetlands are comprised of multiple, intermixed patches of high and low marsh species and/or non-vegetated features (e.g., salt pannes) within a relatively small area. In such instances, manual photo-interpretation, or digitizing, of numerous polygons would be impractical while the resulting wetland area calculations would be underestimated or overestimated, depending on the wetland features.

At a minimum, the multi-spectral imagery and supervised classification methodology employed in this study provided higher resolution of marsh features compared with the previous 1974 manual delineations.(Indeed, image classification methods were applied to the 1974 imagery in order to extract pannes and water features from the 1974 tidal wetland mapping.) However, like the previous (1974) manual, photo-interpreted delineation, the computer-assisted classification performed under this project was also a time-consuming endeavor. This was owed primarily to the required processing of hundreds of color-infrared image tiles which covered the breadth of the Long Island study area. These images were comprised of 9-inch-by-9-inch color-infrared film frames on a roll which, as of necessity for digital image processing and classification, needed to be scanned and orthorectified. The orthorectified images were then normalized in order to apply a common spectral library of wetland and other species. Any future mapping efforts should, ideally, employ a digital camera or other digital sensors on either a satellite or airborne platform as opposed to color-infrared film. There are a number of reasons for this choice such as the following. Firstly, digital imagery would eliminate the need for scanning of film; the conversion from film (analog) to digital format always sustains some loss of information. Secondly, the use of digital imagery would prevent the edge effects, e.g., darkening, inherent in color-infrared image frames. In addition, the digital sensors that would be employed for future tidal wetland data acquisition would instead capture – for advantages described below.

Hyperspectral Data

The multi-spectral, color-infrared imagery employed in this project comprised only three spectral bands, i.e., one green, one red and one near-infrared. The reflectance values for these bands are, in effect, an average of the spectral responses across the approximate 0.4 to 2.5 nanometer (wavelength) portion of the electromagnetic spectrum. In reality, though, wetland species exhibit considerable variation in reflectance across even this small portion of the electromagnetic spectrum. The averaging of spectral reflectances – and thus the loss of spectral response information – was a primary reason for confusion between species when applying image classification to the multi-spectral imagery of this project.

Alternatively, hyperspectral imagery utilizes subdivisions of the 0.4 to 2.5 nanometer portion of the spectrum (i.e., several or more bands), thus allowing greater definition of a given species spectral fingerprint. In fact, hyper spectral imagery can record reflectances across dozens or even hundreds of narrow, continuous bands throughout the electromagnetic spectrum. Researchers have found, though, that reflectances across only several bands in the visible, near-infrared and short-wave infrared were optimal for mapping tidal wetland species (Adam et al., 2010). In particular, subdivisions of the red-edge and near-infrared portions of the spectrum were particularly useful for tidal wetland mapping as they demonstrated the greatest variation in spectral response among saltwater marsh species. For these reasons, it is recommended that future tidal wetland mapping initiative consider use of hyperspectral data acquisition and analysis techniques.

Secondary Landscape Attributes

Image classification techniques – which utilize either multi-spectral or hyperspectral data – may be enhanced through the use of secondary landscape attributes. Such data can serve as an overlay to aid the image classification algorithm in assigning the appropriate class or species to a given image pixel. Secondary landscape attributes may comprise, for example, the height of vegetation or soil type.

Data on vegetation height, in particular, would be highly useful in differentiating between certain wetland species on Long Island. For example, it was found that *Phragmites australis* and *Spartina alterniflora*, which although vary substantially in height, produce similar spectral responses under certain conditions. Specifically, the short form of *Spartina alterniflora* is spectrally confused with low-vigor *Phragmites australis* while the tall form of *Spartina* *alterniflora* is spectrally similar to the highest vigor form of *Phragmites*, i.e., within the context of multispectral imagery. However, in both of these situations, *Phragmites australis* is always taller than *Spartina alterniflora*. High-resolution elevation data for wetland species can be used in concert with multispectral imagery to improve classification accuracy. For example, a Connecticut River study conducted by Gilmore et al (2006) utilized LiDAR elevation data and multispectral imagery to map a marsh that was comprised primarily of *Spartina patens*, *Typha spp*. and *Spartina patens;* these plant species have distinct height differences which were used to more accurately differentiate between the wetland species. Such data, if available in the future, particularly for differentiating between certain life stages or environmental conditions of *Phragmites australis* and *Spartina alterniflora*, would help improve classification accuracy.

Other Methods

In addition to the use of hyperspectral data acquisition and analysis and secondary attributes for image classification, there are various other means to efficiently and accurately map tidal wetlands. These techniques include object-oriented analysis, artificial neural networks, fuzzy logic and decision tree analysis. Object-oriented analysis takes advantage of variations in plant texture and tone to identify wetland species; this approach has potential merit given the obvious textural variations wetland species in Long Island marshes. For example, *Phragmites australis* stands exhibit a fine, almost feathery texture while *Iva frutescens* patches appear clumpy with significant variations in one, i.e., light to dark pixels within a cluster. Artificial neural networks and fuzzy logic methods would potentially be useful for solving identification issues related to complex vegetation. Complex vegetation in Long Island marshes include mixed-class areas such as that which occur with *Iva frutescens* and low-vigor *Phragmites australis* near the upper limit of the high marsh. Decision tree analysis is a rule-based classifier for processing data at different scales; it would be especially useful in the future for integrating secondary attributes such as vegetation height, slope and soil type, provided such data were made available at sufficient resolution and geographic extent.

Summary

Given the wide range of tidal wetland mapping techniques presently available and for whose potential applicability and effectiveness to mapping Long Island‟s marshes is not fully known, it is recommended that a feasibility study be conducted prior to initiating any new tidal wetland mapping. Such a feasibility study would acquire pilot data sets and test the merit of various mapping approaches, especially those mentioned above. The development and testing of innovative wetland mapping techniques has historically been a pursuit of academic institutions and their researchers. Thus, the recommended feasibility study would necessarily be obliged to include experts in the field of remote sensing.

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