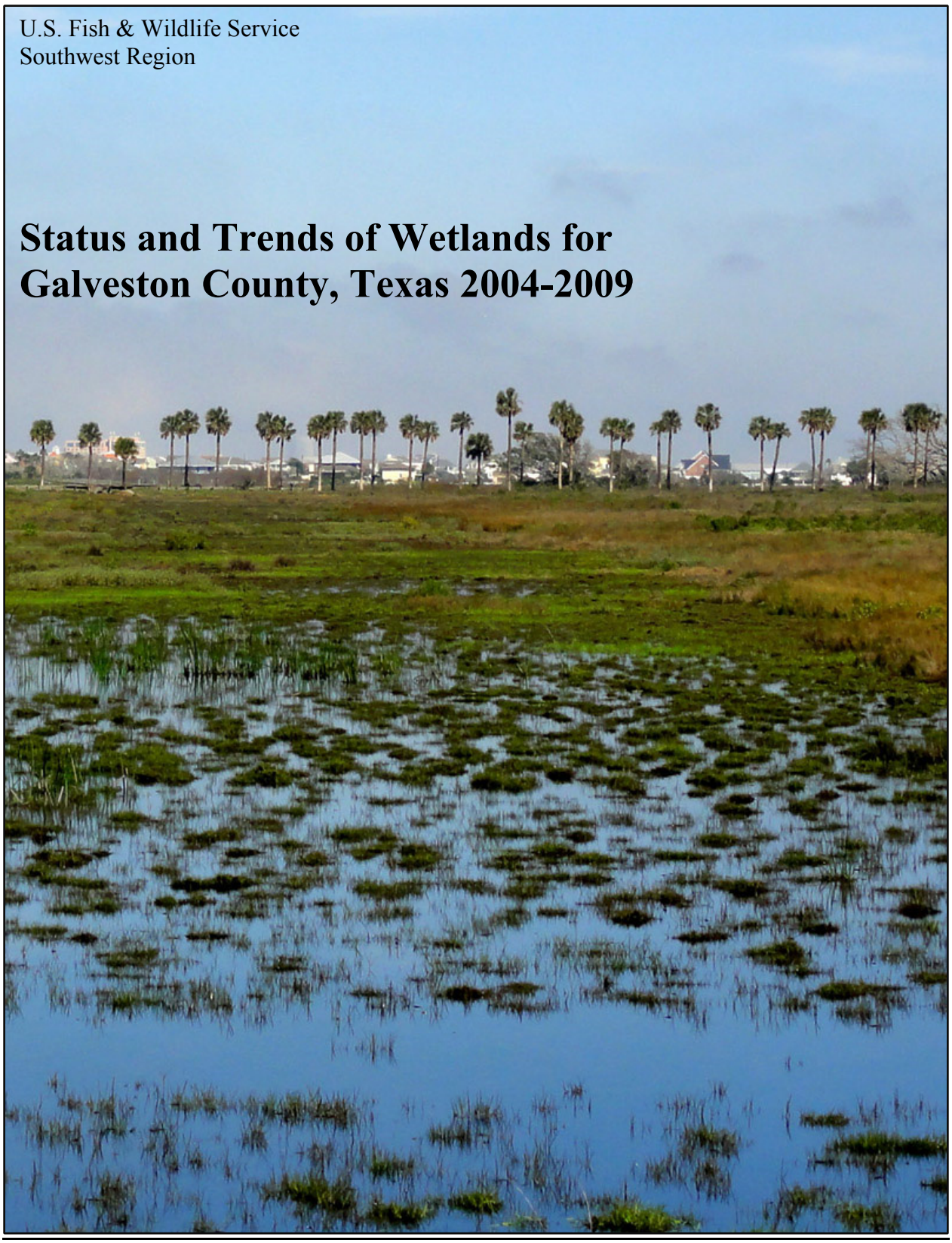
U.S. Fish & Wildlife Service
Southwest Region

Status and Trends of Wetlands for Galveston County, Texas 2004-2009



Status and Trends of Wetlands for Galveston County, Texas 2004-2009

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U.S. Fish and Wildlife Service
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Prairie pothole-type wetland near League City, TX.

Introduction

The U.S. Fish and Wildlife Service's National Wetlands Inventory Program (NWI) is responsible for the mapping of the nation's wetlands and conducting assessments of wetland trends. Galveston County, Texas is experiencing a period of extraordinary change and growth having a substantial impact on wetlands by urban development where information on the current status and recent trends are needed. Consequently, the NWI initiated a local wetland trends study to evaluate the extent of these impacts and to address the status of wetlands in terms of wetland acreage. This report summarizes the study findings and makes government agencies and the public aware of the general status of recent changes the wetlands within Galveston County. Some changes are natural such as storm damage, vegetation succession, and plant colonization of shallow water, while other changes are human-induced including creation of wetlands and loss of wetlands to upland development for a variety of purposes. In addition to increasing public awareness of the status of wetlands, the findings may be used by public agencies and private nonprofit organizations to develop wetland conservation strategies that aid regional and local natural resource planning efforts. Wetlands in the Lower Galveston Bay watershed play several key ecological roles in protecting and maintaining the health and productivity of the estuary.

As the human population grows, society's influences on the physical and ecological components of wetlands become more pronounced. Anthropogenic stresses are placed upon the bay's natural resources and the ecosystem services that they provide (such as clean air and water, flood attenuation, and wildlife habitat). The stressors diminish the health of the estuary and its watershed, as well as the quality of life of residents. The physical and ecological condition of Galveston Bay is a general indicator of the well-being of the regional environment. Most people realize that the bay is an important regional ecosystem, and they have a keen interest in protecting and maintaining its productivity for future generations (Lester and Gonzalez, 2011).

Study Area

Physiographic Form and History

Galveston County (Figure 1.) is located in the southeastern part of Texas along the Gulf of Mexico. The county consists of a mainland area and a barrier island system with Galveston Island and Bolivar Peninsula. The county falls within the Western Gulf Coastal Plain-Bay and Estuary Systems (Omernik, 1987), in the Humid Climate Zone (Thornwaite, 1948). The total jurisdictional acreage of the county (this includes East Bay, West Bay, part of Galveston Bay and an extension into the Gulf of Mexico) is 558,676.8 acres. Of this, 254,996.2 acres are the land area (including wetlands and some deepwater features). Elevation grades from sea level to around 40 feet. Much of the original natural flora was in tall grass and mid-grass prairies and cordgrass marshes. The coastal marsh itself is a narrow belt of low wetlands. The fauna is very diverse, with more than three hundred species of birds relying on this area for food and rest on their spring and fall migrations. Spanish records tell us that there were extensive open prairies of little bluestem, Indian grass, and sedges on the uplands between the many rivers. The bottomland hardwoods were abundant, with sugarberry, pecans, elm, and live oak. The majority of the land currently has been cut and subdivided for urban development, farms and ranches (Bartlett, 1995).

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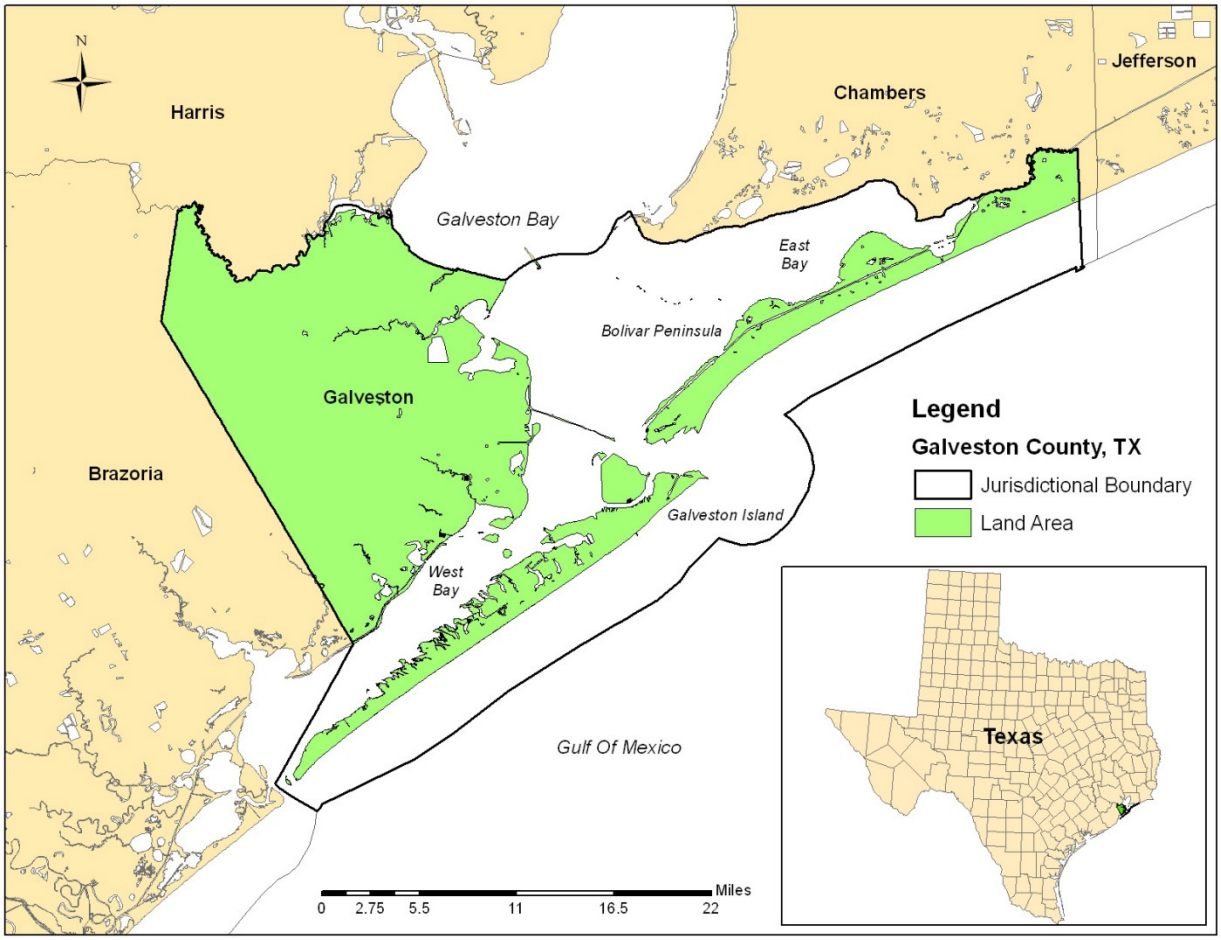

Figure 1. Location of Galveston County, Texas.

European Settlement

The history of Galveston, Texas, began when the first European settlements on the island were constructed around 1816. The Port of Galveston was established in 1825 by the Congress of Mexico following its successful revolution from Spain. The city served as the main port for the Texas Navy during the Texas Revolution. Galveston was founded in 1836 by Michel Menard and served as the capital of the Republic of Texas. During the mid-19th century, Galveston emerged as an international city with immigration and trade from around the U.S. and the world. The city became one of the nation's busiest ports and the world's leading port for cotton exports. Galveston became Texas' largest city and, during that era, was its prime commercial center.

Current Human Activities

Inland areas of the county have been dominated by agriculture, though it has been declining for many years, due to urban development expansion. The main agricultural enterprises in Galveston County are growing beef cattle and crops such as rice and soybeans. The marsh rangeland is used extensively by some larger operators to overwinter cattle. Rice is commonly grown on a field for one or two years; then the field is fallowed, used as pasture or for some other crop for

one or two years. The coastal cities of Texas City and Galveston sustain extensive petrochemical, energy, and shipping industries. Interior towns and cities, such as, League City and Dickinson are seeing urban expansion, as agricultural areas are being sold and converted, and remaining wetlands are constantly under threat. Extensive bays, bayous, and beaches provide ample opportunities for sport and recreation activities. Waterways and beaches attract masses of people to this area throughout the year. Inland, abandoned agricultural areas are often leased for hunting.

Climate

Long summers are hot and humid, with some relief on the coast from sea breezes. Winters are relatively warm with occasional cool spells. The area around Galveston Bay averages 41.8 to 51.5 inches of precipitation annually. This precipitation occurs throughout the year, but 60% falls from April to September. Tropical disturbances in late summer and early fall are common. The hurricane frequency for this area is 12% in any given year (Simpson and Lawrence, 1971).

Soils

Mainland, non-saline soils; major soils are Algoa, Bacliff, Bernard, Edna, Kemah, Lake Charles, Leton, Mocarey, and Verland. These soils are in broad, nearly level areas the are far enough inland that they are not affected by tides or salt from the gulf. The soils in these areas are loamy and clayey, and most are slowly permeable or very slowly permeable. Most of the soils are, or have been, cultivated to rice, grain sorghum, soybeans, and pastureland.

Mainland, saline soils; (about 25% of land area in Galveston County) major soils are in the Francitas, Ijam, Narta, Placedo, Tracosa, and Veston series. These soils are in broad, nearly level areas near the bays and are affected by salt and tides from the gulf. Most of these soils are used as rangeland and as habitat for wildlife. They are poorly suited to or not suited to use as crop or pastureland. The main limitations for urban use are wetness and salinity. In addition, the frequent flooding of some of the soils in this group is a hazard.

Barrier Island, non-saline soils; (about 14% of Galveston County) major soils are in the Galveston and Mustang series. These soils are in nearly level to gently undulating areas on Galveston Island and Bolivar Peninsula. The landscape consists of beaches fronting the gulf, the barrier sand dunes, and the nearly level, wet sands behind the dunes. Most of the soils are non-saline, but salt spray affects the vegetation. Hurricanes and tropical storms flood most of these areas. These soils are sandy and rapidly permeable. A large acreage has been developed for recreation and urban use. The main limitations for urban use are wetness, wind erosion and flood hazard

General Wetland Habitats

The geologic framework of this area of the upper Texas coast is comprised primarily of Pleistocene fluvial systems (Lissie and Beaumont Geological Formations) and Modern-Holocene Formations (no older than 10,000 years), which include sediments adjacent to the coastline and

on river floodplains. This has created a landscape mosaic of ancient/ancestral stream channels and pothole features across the county.

Salt/Brackish Marsh

Figure 2. Salt marsh gradation, Galveston Island State Park.

Salt marsh communities are found in high salinity areas along protected estuarine shorelines. Prevalent species in the salt marsh community include smooth cordgrass (*Spartina alterniflora*), saltwort (*Batis maritima*), saltgrass (*Distichlis spicata*) and glasswort (*Salicornia spp.*) (White and Paine 1992). Smooth cordgrass, which is found in the intertidal zone, dominates the low salt marsh community. This cordgrass while living, is seldom eaten and then by only a few herbivores. Once dead, though, it provides nourishment to the large bay food web as detritus. Edges of the salt marsh serve as refuge and nursery habitat for juveniles of many species, especially brown and white shrimp. These habitats are also important feeding grounds for wading birds, such as herons and egrets. At higher elevations, marsh hay (or saltmeadow cordgrass; *Spartina patens*) and Gulf cordgrass (*Spartina spartinae*) occur, although they are more common in brackish marshes (White and Paine 1992). Brackish marshes inhabit the transitional zone between salt marsh and fresh marsh and are affected by highly variable water levels and salinities. As would be expected, a number of species utilize this habitat, ranging from fresh water to salt-marsh species.

Freshwater Marsh

Freshwater marshes are primarily found in areas where rainfall runoff accumulates, in relic depressions and stream channels. Closer to the coast, they can be found just inland of salt marshes and in interdunal swales on Galveston Island and Bolivar Peninsula.

The water in freshwater marshes is sufficient to maintain a low salinity suitable for such plants as sedges, rushes and coastal arrowhead (*Sagittaria lancifolia*). In low, wet areas, the exotic and invasive water hyacinth (*Eichhornia crassipes*) can be found, while panic grasses (*Rhynchospora spp.*) and spiny aster (*Chloracantha spinosa*) can be found in higher areas.

Many of the freshwater wetlands found in the Lower Galveston Bay watershed exist in complexes on the coastal prairie. The term “pothole” is used to describe these small, well-defined, freshwater wetland depressions. Prairie pothole complexes consist of potholes and one-to-two-feet-tall pimple mounds (sometimes called mima mounds). The hydrology of prairie pothole complexes can be very diverse with deeper potholes being saturated for up to six months at a time. Neighboring pimple mounds may be semi-arid for most of the year (Moulton and Jacob 2000).

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Forested Wetlands

Forested wetlands are found on the floodplains of rivers and streams that cross the Texas coastal plain. In the Galveston County, there are only a few gallery forest areas or mesic woodlands. These are primarily associated with Clear Creek and Dickenson Bayou. In good condition, these forests would be populated with elms (*Ulmus spp.*), willow oak (*Quercus aquatic*) and post oak (*Quercus stellata*). Many of these forests have now been "thickened" with invasive species, such as Chinese tallow (*Sapium sebiferum*) or privet (*Ligustrum spp*.).

Figure 3. Mesic forest near Clear Creek, northern Galveston County.

Historic Wetland Trends

In the Lower Galveston Bay watershed, the majority of wetland losses during the last 50 years can be attributed to the loss of freshwater wetlands (White et al. 1993; Jacob and Lopez 2005; Lester and Gonzalez 2008). White et al. (1993) estimated that of the 35,120 acres of emergent wetlands lost during the 1950 to 1989 time period, 73 percent (25,640 acres) were freshwater wetlands. This equates to a loss of nearly 641 acres per year. White et al. (2004) also found that freshwater wetlands decreased by 1,082 acres on Galveston and Follets Island and Bolivar Peninsula between the 1950s and 2002.

The acreage of forested wetlands increased by 177 percent (3,610 acres) between the 1953 and 1989 (White et al.1993). Almost all of this gain was due to 1) succession, the natural conversion of emergent and scrub/shrub habitats to forest, and 2) the invasion of Chinese tallow, an exotic species of tree with a high tolerance of saturated soil, rapid growth potential and low wildlife value (Lester and Gonzalez, 2011).

Recent Wetland Trends

An analysis of the National Oceanic and Atmospheric Administration, Coastal Change Analysis Program(NOAA C-CAP) land cover data for the five counties surrounding Galveston Bay (Brazoria, Chambers, Galveston, Harris, and Liberty), showed net losses of freshwater wetlands which totaled 25,787 acres, representing a loss of 1,826 acres per year. Of that amount 15,823 acres of freshwater wetlands were lost to development. The other losses were due to the conversion of freshwater wetlands to non-wetland classifications. Some losses were due to changes in hydrology, which converted the wetland to upland vegetation suitable for grazing (Lester and Gonzalez, 2011).

Work by Jacob and Lopez (2005) estimated that the Lower Galveston Bay watershed lost approximately three percent of its freshwater wetlands to development between 1992 and 2002 (9,052 acres of freshwater emergent, forested, and scrub/shrub classes). Most of the loss

occurred in Harris County, which lost at least 13 percent of its freshwater emergent wetlands in the same period, with over half of that loss occurring between 2000 and 2002 (Lester and Gonzalez, 2011).

The estimates document a continued and substantial loss of wetlands in the Lower Galveston Bay watershed. Jacob and Lopez (2005) estimates equate to a 0.3 percent per year loss of classified freshwater wetlands in Lower Galveston Bay watershed from 1992 to 2002. The NOAA C-CAP study (1996-2005) estimates an annual rate of loss of 2,599 acres of freshwater wetlands or 0.3 percent (Lester and Gonzalez, 2011).

Study Methods

Wetland trends involve conducting an area-wide inventory of wetlands covering multiple time periods. This approach is generally used for small geographic areas where more detailed investigations can be carried out. Change detection was done through image interpretation procedure. Aerial imagery was examined to determine wetland trends for the time period 2004-2009.

Wetland Definition and Classification

The Fish and Wildlife Service uses the Cowardin *et al*. (1979) definition of wetland. This definition is the standard for the agency and is the national standard for wetland mapping, monitoring, and data reporting as determined by the Federal Geographic Data Committee. It is a two-part definition as indicated below:

> Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.
>
> For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.

Ephemeral waters, which are not recognized as a wetland type, and certain types of "farmed wetlands" as defined by the Food Security Act that do not coincide with Cowardin *et al.* definition were not included in this study. The definition and classification of wetland types are consistent between every status and trends study conducted by the Fish and Wildlife Service. Habitat category definitions are given in synoptic form in Table 1.

Wetland Classification Applications

The Service has made adaptations to the Cowardin classification system to accommodate the use of remotely sensed imagery as the primary data source. For example, water chemistry, halinity, water depth, substrate size and type and even some differences in vegetative species cannot always be reliably ascertained from imagery. Image analysts must rely primarily on physical or

spectral characteristics evident on high altitude imagery, in conjunction with collateral data, to make decisions regarding wetland classification and deepwater determinations[1].

Deepwater Habitats

Wetlands and deepwater habitats are defined separately by Cowardin *et al.* (1979) because the term wetland does not include deep, permanent water bodies. Deepwater habitats are permanently flooded land lying below the deepwater boundary of wetlands. Deepwater habitats include environments where surface water is permanent and often deep, so that water, rather than air, is the principal medium in which the dominant organisms live, whether or not they were attached to the substrate. For the purposes on conducting status and trends work **all lacustrine and riverine waters** are deepwater habitats.

Upland Habitats

The Wetlands Status and Trends study uses an abbreviated upland classification system with five generalized categories as seen in Table 1. Some habitat monitoring projects may require more specialized upland classification. For these projects, the Service uses the U. S. Geological Survey (USGS) land classification scheme described by Anderson *et al.* (1976). More detailed Level 1 or Level 2 descriptors found in Anderson *et al*. (1976) or other schemes may be used to satisfy specific study applications.

Data Sources

The 2004 NWI digital data served as the foundation for the project. These data were derived by a combination of aerial image analysis and interpreting collateral data sources. Aerial image interpretation was done via onscreen techniques using 2004 color-infrared USDA NAIP imagery. In support of the contemporary period (2009), one-meter resolution true color digital DOQQs were used. These sources allowed an assessment of wetland changes from 2004 to 2009. Other collateral data sources included digital soils data (NRCS SSURGO) and, studies/reports from the University of Texas, Bureau of Economic Geology, and the Texas Coastal Watershed Program.

Interpretation of Trends

Changes in wetlands due to both natural and human-induced actions were detected on the imagery by directly comparing the status of wetlands on each set of imagery. An on-screen, "heads up" process was used for detection and delineation. This method required updating the existing 2004 NWI data using the new 2009 DOQQs. Wetlands were added, deleted, or their boundaries were reconfigured to more accurately represent their status at the applicable time period. Wetlands and deepwater habitats were classified according to the Service's official wetland classification system (Cowardin *et al.* 1979) which is the national standard for wetland classification.

http://www.fgdc.gov/standards/projects/FGDC-standards-projects/wetlands-mapping/index_html

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[1]Analysis of imagery is often supplemented with limited field work and ground observations.

The causes of the changes were determined by consulting the 2009 images. Each change was digitized, with the cause recorded, creating a trends data layer. Conversions of wetlands to non-wetlands were labeled by their respective land use or land cover classification used for national NWI wetland trend studies. The minimum area of change detected was approximately 0.1 acre. Seasonal and tidal variations, which could show as differences when directly comparing these images, are taken into account when comparing two different image sources. Care is taken not to identify these types of natural periodic fluctuations as a change to wetland or wetland system.

Limitations

Certain habitats were excluded from this study because of the limitations of aerial imagery as the primary data source to detect wetlands. These limitations included the inability to accurately monitor certain types of wetlands such as sea grasses found in the intertidal and subtidal zones of estuaries and near shore coastal waters (Orth *et al*. 1990), submerged aquatic vegetation, or submerged reefs (Dahl 2006). The majority of seagrasses are not delineated as part of the status and trends studies. Ephemeral waters not recognized as a wetland type by Cowardin *et al*. (1979), are not included in this study (Dahl and Bergeson, 2009).
It is important to note that some of these changes recorded through photo interpretation with 2009 imagery are subject to change. Currently, storm-damaged areas are being restored, while other scoured areas are showing new growth/reestablishment of wetland vegetation. Future studies could reverse some of these increases/decreases.

Table 1. **Wetland, deepwater, and upland categories used in study**

Salt Water Habitats	**Common Description**
Marine Subtidal*	Open Ocean
Marine Intertidal	Near shore/beaches
Estuarine Subtidal*	Open-water/bay bottoms
Estuarine Intertidal Emergents**	Salt marsh
Estuarine Intertidal Forested/Shrub**	Mangroves or other estuarine shrubs
Estuarine Intertidal Non-Vegetated	Beaches/bars
Riverine* (may be tidal or non-tidal)	River systems
Freshwater Habitats	
Palustrine Forested	Forested swamps
Palustrine Scrub-Shrub	Shrub wetlands
Palustrine Emergents	Inland marshes/wet meadows
Palustrine Non-Vegetated	Shore beaches/bars
Palustrine Unconsolidated Bottom (ponds)	Open-water ponds/aquatic bed
Pond - Natural characteristics	Small bog lakes, vernal pools, kettles, beaver ponds, alligator holes
Pond - Industrial	Mine pits or drainage ponds, highway borrow pits, sewage lagoons, industrial holding ponds
Pond - Urban use	Aesthetic or recreational ponds, golf course

	ponds, residential lakes, ornamental ponds, water retention ponds
Pond - Agriculture	Ponds in proximity to agricultural, farming or silviculture operations such as farm ponds, dug outs for livestock, agricultural waste ponds, irrigation or drainage water retention ponds
Pond - Aquaculture	Ponds singly or in series used for aquaculture including cranberries, fish rearing
Lacustrine*	Lakes and reservoirs
Uplands	
Agriculture	Cropland, pasture, managed rangeland
Urban	Cities and incorporated developments
Residential/Commercial	Non-industrial development; subdivisions/ housing, schools, shopping/small business
Industrial	Heavy industry
Transportation	Major roads and highways, airports, rail
Transitional	Developed areas, but exact use is unclear
Recreational	Parks, playgrounds, dedicated open spaces
Rural Development	Non-urban developed areas and infrastructure
Other Uplands	Uplands not in any other category, barren land or undetermined land use

*Constitutes deepwater habitat
** Combined into Estuarine Vegetated Category

Figure 4. Salt marsh restoration project, Galveston Island State Park.

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Results

Status of Wetlands and Deepwater Habitats, 2009

For Galveston County in 2009, the area of wetlands and deepwater habitats were estimated at 371,292.7 acres. Deepwater habitats accounted for almost 87% of the wetland and deepwater acreage for the county. Intertidal wetlands covered 8% of the area (30561.6 acres). Freshwater wetlands occupied the remaining 5% of wetland and deepwater area (Table 2.).

General Trends

Changes to Wetland and Deepwater Habitats, 2004-2009

Overall, the estimated wetland/deepwater area, for Galveston County, increased slightly from 2004 to 2009 from 370,855.4 acres to 371,292.7 acres. This is an overall gain of 437.3 acres (0.1%). While this report shows a slight gain in wetland acreage, it is important to look at what types of wetland habitats are showing which trend. Table 2 shows the breakout of the overall wetland change, by type.

Table 2: Summary of estimated change in wetland and deepwater area (in acres)

Wetland/Deepwater Category	Estimated Area, 2004	Estimated Area, 2009	Changes, 2004-2009	Change, (In Percent)
Marine Intertidal	1,360.3	1,720.7	360.4	26.5%
Estuarine Intertidal Non-Vegetated	4,113.5	4,625.2	511.7	12.4%
Estuarine Intertidal Vegetated	24,354.5	24,215.1	-139.4	-0.6%
All Intertidal Wetlands	29,828.3	30,561.0	732.7	2.5%
Freshwater Ponds	2,446.0	2,866.2	420.6	17.8%
Freshwater Non-Vegetated	568.6	1,040.0	471.4	82.9%
Freshwater Vegetated	17,293.5	16,264.0	-1,029.5	-5.9%
(Freshwater Emergent)	*(13,321.6)*	*(12,744.7)*	*(-576.9)*	*(-4.3%)*
(Freshwater Scrub-Shrub)	*(2,520.7)*	*(2,281.2)*	*(-239.5)*	*(-9.5%)*
(Freshwater Forested)	*(1,451.2)*	*(1,238.1)*	*(-213.1)*	*(-14.7%)*
All Freshwater Wetlands	20,308.1	20,170.6	-137.5	-0.7%
All Wetlands	50,136.4	50,731.6	595.2	1.2%
Lacustrine (Lakes)	4,732.9	4,804.4	71.5	1.5%
Riverine	505.9	510.0	4.1	0.8%
Estuarine Subtidal	183,344.7	183,029.4	-315.3	-0.2%
Marine Subtidal	132,135.5	132,217.3	81.8	0.06%
All Deepwater	320,719.0	320,561.1	-157.9	-0.05%
All Wetlands/Deepwater	370,855.4	371,292.7	437.3	0.1%

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All Intertidal wetlands saw dramatic gains in coverage. Marine and estuarine wetlands had a total increase of 732.7 acres. Marine intertidal non-vegetated wetlands increased by 26.5% (gain of 360.4 acres) from 2004 to 2009. Estuarine intertidal non-vegetated wetlands increased by 12.4% (gain of 511.7 acres). Though, estuarine intertidal vegetated wetlands actually showed an overall decrease of 139.4 acres.

Freshwater wetlands showed an overall decrease of 137.5 acres (0.7% loss). Freshwater vegetated wetlands showed a 5.9% decrease, with a total loss of 1029.5 acres. Freshwater emergent wetlands experienced a decrease of 4.3%, or 576.9 acres. Forested wetlands saw a total net loss of 213.1 acres. This is a decrease of 14.7% since 2004. Scrub-shrub wetlands saw a net loss of 239.5 acres. Freshwater ponds (predominantly man-made) showed a total net increase of 17.1% (420.6 acres). There were also large increases (471.4 acres) in freshwater non-vegetated wetlands.

Deepwater habitats also showed a decrease of 157.9 acres. Lakes, rivers and marine open water showed modest gains, while estuarine subtidal habitats showed an overall decrease of 315.3 acres.

Gains in Wetlands and Deepwater Habitats from Uplands

Overall, wetland and deepwater habitats saw a gross gain of 1154.4 acres (Table 3, Appendix A.). Of this, 95% (1096.1 acres) were deepwater habitats and non-vegetated wetlands. Creation of man-made features, such as ponds, reservoirs and waterways accounted for 55% of this acreage. The remaining 45% were a result of Hurricane Ike (Table 6, Appendix C). Features such as washovers, blowouts, and beach migration/alteration caused added wetland acreage in the form of estuarine unconsolidated shore or intertidal flats, especially on Bolivar Peninsula (Figure 5).

Loss of Wetlands and Deepwater Habitats to Uplands

Wetlands and deepwater habitats lost to uplands accounted for 717.1 acres of gross loss (Table 3, Appendix A.). Nearly 80% (573.4 acres) of the wetlands and deepwater habitats lost were vegetated wetlands (intertidal and freshwater emergent, scrub-shrub, and forested). Freshwater emergent wetlands, alone, accounted for 48% (273.4 acres) of the loss to uplands (Table 2). Of the total acreage lost to uplands, 63% (454.7 acres) went to urban and rural development categories (Table 5, Appendix B).

Figure 5. Beach damage and flooded blowouts from Hurricane Ike, Bolivar Peninsula.

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Geographic Distribution of Wetland Change

Wetland change occurred throughout Galveston County, though some general patterns can be observed (Figure 6). As development expands south from Houston, northern Galveston County especially around League City, shows more concentrated areas of change resulting mainly from urban development. Likewise, extensive urban development on Galveston Island was observed. The barrier islands show extensive change from coastal processes including Hurricane Ike. No statistical spatial analysis was conducted on distribution of change, in this study.

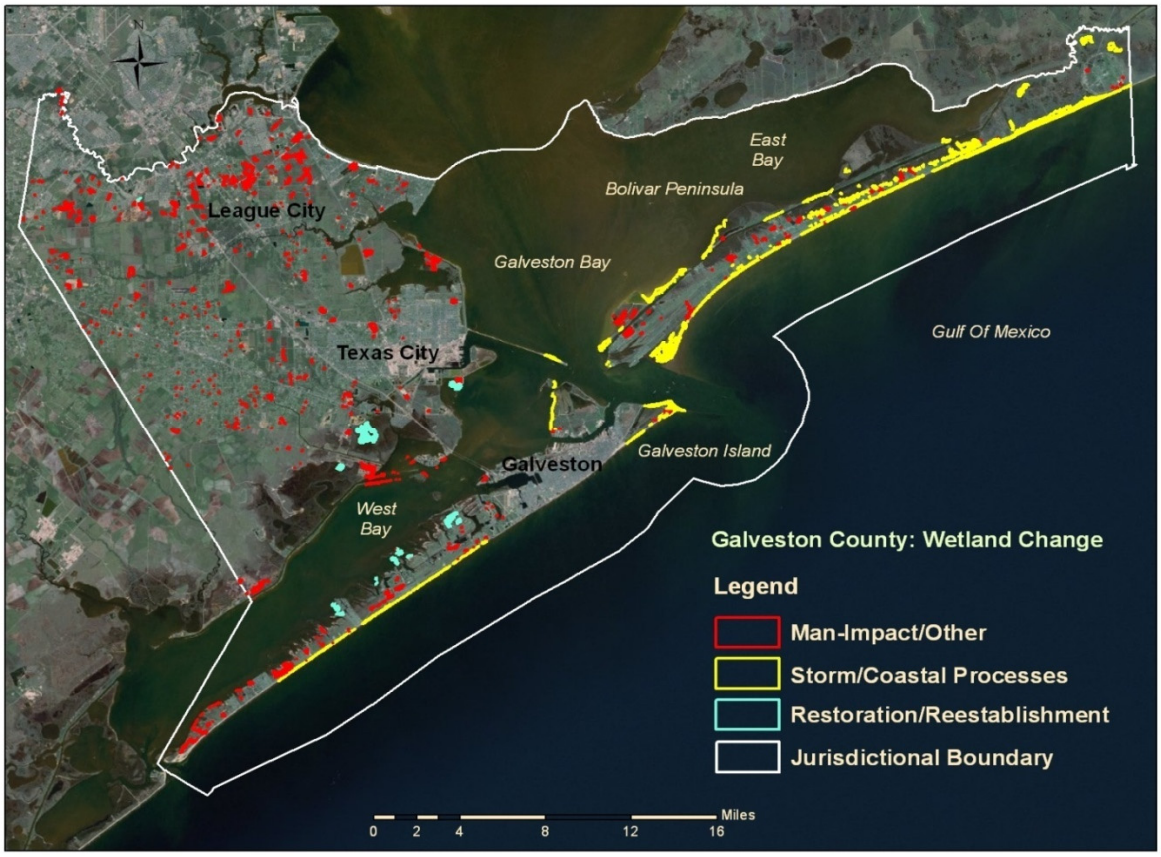

Figure 6. Spatial distribution of wetland change for Galveston County.

Discussion and Analysis

Attribution of Wetland Gains from Uplands

As stated, all wetlands and deepwater habitats saw a gross gain from uplands between 2004 and 2009 that totaled 1154.4 acres (Table 3). A breakout of all wetland gains from selected upland categories is described in Table 4, Appendix B.

Marine intertidal wetlands saw a net increase of 360.4 acres. These habitats had a gross gain of 484.9 acres from areas previously upland (Table 3). Most of this gain occurred on Bolivar peninsula, as Hurricane Ike literally pushed the Gulf beach back into the Island (Figure 9). Of the

484.9 acres, 119.3 of these acres were residential urban development, 364.3 were from the upland other category (Table 4).

Figure 7. Man-made urban pond, League City, TX.

Freshwater ponds saw a net increase of 420.6 acres from 2004 to 2009 (Table 2). With growth in urban development, comes an increase in constructed pond acreage. Pond creation, from uplands, accounted for 363.9 acres (Table 3). Urban ponds are created for a variety of reasons including; storm water retention/flood prevention, borrow pits, and urban esthetics. In Galveston County, ponds for urban and industrial uses accounted for 83% of all ponds created. The highest percentage for urban ponds fell into the residential/commercial categories. Natural pond creation (mostly from the effects of Hurricane Ike) accounted for 9% of new ponds, While, agricultural activities accounted for only 8% of new ponds.

Deepwater features had a gross gain from uplands totaling 160.7 acres. Canals, access waterways for waterfront homes, spoil/retention basins accounted for 145.1 acres. The remaining gain in acreage (15.6 acres) was the result of Hurricane Ike or other natural processes.

Freshwater emergent wetlands showed a modest gross gain from upland of 55.5 acres. Creation of storm water retention ponds, containing freshwater emergent wetland vegetation, accounted for 10.7 acres of this gain.

Attribution of Wetland Loss to Uplands

As stated, all wetlands and deepwater habitats lost to uplands between 2004 and 2009 totaled 717.1 acres (Appendix B). A breakout of all wetland gains from selected upland categories is described in Table 5, Appendix B.

Urban development accounted for 59% (426.1 acres) of the wetland and deepwater habitat loss. Of this, 216.0 acres can be attributed to residential and commercial development. Urban lands in transition accounted for 133.5 acres lost. Miscellaneous urban accounted for 36.3 acres. While remaining urban land uses, such as industrial, transportation and recreation accounted for the remaining 40.1 acres. Rural development (non-agriculture) took 28.6 acres of wetland (Table 5). All freshwater vegetated wetlands saw the largest gross loss to urban development, totaling 521.5 acres. This is 73% of the total gross loss for all wetland types (Table 5). Freshwater emergent wetlands saw the greatest gross loss (273.4 acres) to uplands, predominantly residential and commercial development (Figure 8). Gross losses to freshwater scrub-shrub (130.8 acres) and freshwater forested wetlands (117.3 acres) accounted for the remaining acreage for vegetated wetland loss (Table 5, Appendix B).

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Losses to the upland other category (barren land or undetermined land use) accounted for nearly 31% (216.1 acres) of all wetlands and deepwater habitats lost. Marine and estuarine wetlands and deepwater habitats saw 107.8 acres lost to upland other, freshwater wetlands, 96.2 acres, and freshwater ponds/open water 12.2 acres. Of the total 216.1 acres, 71% (153.7 acres) can be attributed to apparent storm damage from Hurricane Ike.

Agricultural land uses accounted for only 6% (46.2 acres) of wetlands and deepwater habitats lost to upland. Loss of freshwater vegetated wetlands accounted for 99% of this loss, of which more than half was freshwater forest and scrub-shrub habitats.

Figure 8. Wetland change near League City, TX. Green lines indicate existing wetlands, red lines are wetlands lost to upland, black lines are wetlands gained from upland, yellow lines are converted wetland types.

Habitat Restoration; Galveston County

Efforts to restore wetland habitats, especially salt marshes, have made headway in recent years. NOAA currently has 16 wetland/habitat restoration sites throughout the West Bay area. Larger restoration operations were observed in Jones Bay, Jumbilee Cove, and Galveston Island State Park. Salt marsh restoration sites converted 178.2 acres of open water to estuarine vegetated and non-vegetated intertidal wetlands since 2004. Also, Sheldon Ranch, on Galveston Island, had recently converted 77.1 acres of Brazilian pepper, Chinese tallow, and non-native grasses (invasive species) to help re-establish more natural coastal prairie wetlands. Inland, approximately 1.3 acres of freshwater forested wetlands were converted to freshwater emergent wetlands (retention basin). Also, 10.7 acres of freshwater wetlands were gained in the creation of retention basins.

Coastal Processes; Effects of Hurricane Ike on Wetlands

Barrier Island systems are inherently dynamic, constantly subjected to daily wind, wave action and tidal fluctuations. Of course, these areas are also subject to tropical storms and hurricanes. Hurricane Ike, in September of 2008, had catastrophic effects on human development and infrastructure as well as natural systems along the upper Gulf coast. Its effects on wetlands were quite dramatic. Scouring winds and storm surge destroyed wetland vegetation and reshaped tidal flats, beaches and bays. Natural coastal processes, accentuated by Hurricane Ike, accounted for approximately 525.3 acres of gained wetland from previous uplands (Table 6, Appendix C). This accounts for 59% of all gross gains of wetlands. Also, 154.4 acres of wetland were lost to upland (22% of all loss to upland), while 1228.3 acres of wetland were converted from one wetland type to another (59% of all converted wetlands). Most of the wetlands affected by this conversion were estuarine intertidal vegetated and non-vegetated, estuarine subtidal, marine intertidal and freshwater emergent wetlands (Table 3).

Figure 9. Extensive storm damage from Hurricane Ike, Rollover Bay, Bolivar Peninsula. Green lines indicate existing wetlands; red lines are wetlands lost to upland, black lines are wetlands gained from upland, yellow lines are converted wetland types.

Primary Stressors Affecting Wetlands

Wetlands (salt, brackish, and fresh) serve important hydrological and ecological functions in the bay ecosystem. Over the past century these wetlands have experienced significant loss, due to man-influenced and natural processes. Subsidence, tropical storms, freshwater stream flow, changes in climate/weather, as well as human development, all affect quality and quantity of wetland habitats in Galveston County. Natural processes have played a role in affecting coastal salt/brackish wetlands. But, continuing loss of interior freshwater wetlands is of high concern.

The loss is primarily associated with conversion to agriculture and, more recently, suburban and urban development (Lester and Gonzalez, 2011).

Relative Sea Level Rise/Subsidence

In the Galveston Bay area, most of the loss of salt and brackish marsh has been caused by a rise in relative sea level, due in large part to land subsidence from groundwater withdrawals and subsequent conversion to open bay and barren flats. Rates of subsidence in the Galveston Bay area were 8.5 to 9 feet during 1906-1973 (Pasadena-Houston Ship Channel area-White 1985). Creation of subsidence districts and protections under the Clean Water Act has slowed the loss of these estuarine wetlands over the last several decades.

Tropical Storms and Hurricanes

In 2007 The Associated Press compiled a list of the most vulnerable places to hurricanes in the U.S. and Galveston was one of five areas named. These storms threaten human life and property, and can also play a dramatic role in re-shaping the natural environment. Hurricanes have struck the area in 1900, 1915, 1961, 1983, and 2008 causing major damage. The 1900 hurricane is still the deadliest in U.S. history. After that storm, the city decided to shore up its defenses against future storms by constructing a permanent concrete seawall along a large portion of the beach front (1902–1904). The entire grade of the city was raised some 17 feet (5 m) behind the wall to several feet near the Bay (1904–1910).

Hurricane Ike made landfall near Galveston, early morning of September 13, 2008 as a Category 2 hurricane with winds of 110 miles per hour (180 km/h). Ike produced waves and a rising storm surge of about 14 feet (4.3 m), which went around the famous Galveston Seawall, flooding the city via the storm sewers, and the unprotected "bay side" of the island. Damage from this storm is reflected in the results of this report.

Human Development

From 2000 to 2010 the population of the county has experienced modest growth, moving from 250,158 to 291,309 (U.S. Census Bureau). Though the population of League City has increased 84% and is now the largest city in the county. This area has become a distant commuting area for the city of Houston (now the fifth largest city in the nation), exhibiting a boom in residential neighborhoods over this time frame, likewise a higher frequency of freshwater wetland loss and/or conversion, coupled with urban pond creation. A process known as “land-leveling”; where tons of fill is used to raise the level of geographically low areas for construction, is common in this area. Areas where natural vegetation has been removed, and the ground land-leveled, show no indicators of the previous natural condition.

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Summary

Figure 10. Land-leveling in a new subdivision. League City, TX.

This study has examined the recent trends in wetland extent and habitat type within Galveston County, TX, between 2004 and 2009.

Overall, this report closely corroborates the findings of other studies on wetland trends, both nationally and within the same geographic area – continued losses of vegetated wetlands, offset by gross gains in man-made ponds. All wetlands and deepwater habitats showed a net increase of 0.1%.

Most of this increase in wetland acreage was caused by constructed ponds associated with urban development (on the mainland part of the county) and natural coastal processes, including the effects of Hurricane Ike (2008) on the barrier islands.

Hurricane Ike had extensive impacts to wetlands, accounting for 46% of the wetland/deepwater gross gains from uplands, 59% of all converted wetlands/deepwater habitats, and 22% of wetlands/deepwater gross loss to upland. Most of these gross gains and conversions were to non-vegetated wetlands.

Marine and estuarine intertidal non-vegetated wetlands saw a total increase of 872.1 acres, while estuarine intertidal vegetated wetlands saw an overall decrease of 139.4 acres.

Freshwater ponds saw a 17.8% increase over this time period. Freshwater ponds, created from uplands and converted from other wetland types, increased a total of 420.6 acres. Urban and industrial land uses accounted for 83% of freshwater pond creation.

Freshwater vegetated wetlands experienced an overall decline in acreage of 6%. Freshwater emergent wetlands had the highest loss with 576.9 acres. Losses to upland urban development accounted for 47% of the freshwater emergent loss.

Freshwater forested wetlands showed the highest percentage loss at 14.7%. Over half of the acreage lost went to urban land uses, mostly residential and commercial.

Freshwater non-vegetated wetlands saw a total increase of 82%. Much of this was converted freshwater emergent wetlands, scoured by storm tides from Hurricane Ike.

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Appendix A. Acreage Totals for All Wetland/Deepwater Gain & Loss

Table 3. Breakout of change acreage for each wetland and deepwater category

Category	Total Change; Gain	Acres		Total Change: Loss	Acres	Net Change (Acres)
Marine Intertidal	Gain from Upland	484.9		Lost to Upland	19.3	
	Conversion Gain	11.8		Conversion Loss	117	
(MI)		496.7			136.3	360.4
Estuarine Intertidal	Gain from Upland	33.6		Lost to Upland	22.4	
Non-vegetated	Conversion Gain	665		Conversion Loss	164.5	
(EINV)		698.6			186.9	511.7
Estuarine Intertidal	Gain from Upland	2.5		Lost to Upland	51.9	
Vegetated	Conversion Gain	283.8		Conversion Loss	373.8	
(EIV)		286.3			425.7	-139.4
Freshwater	Gain from Upland	55.5		Lost to Upland	273.4	
Emergent	Conversion Gain	186		Conversion Loss	545	
(FE)		241.5			818.4	-576.9
Freshwater	Gain from Upland	0.3		Lost to Upland	130.8	
Scrub-shrub	Conversion Gain	18		Conversion Loss	127	
(FSS)		18.3			257.8	-239.5
Freshwater	Gain from Upland	0		Lost to Upland	117.3	
Forested	Conversion Gain	0		Conversion Loss	95.8	
(FF)		0			213.1	-213.1
Freshwater Ponds	Gain from Upland	363.9		Lost to Upland	62.2	
	Conversion Gain	128.8		Conversion Loss	9.9	
(FP)		492.7			72.1	420.6
Freshwater	Gain from Upland	53		Lost to Upland	2.5	
Non-vegetated	Conversion Gain	464		Conversion Loss	43.1	
(FNV)		517			45.6	471.4

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Appendix A. (Cont.)

Category	Total Change; Gain	Acres		Total Change: Loss	Acres	Net Change (Acres)
Lacustrine	Gain from Upland	49.8		Lost to Upland	18.2	
	Conversion Gain	48		Conversion Loss	8.1	
(L)		97.8			26.3	71.5
Riverine	Gain from Upland	4.1		Lost to Upland	0	
	Conversion Gain	0		Conversion Loss	0	
(R)		4.1			0	4.1
Estuarine Subtidal	Gain from Upland	104		Lost to Upland	19.1	
	Conversion Gain	179.3		Conversion Loss	579.5	
(ES)		283.3			598.6	-315.3
Marine Subtidal	Gain from Upland	2.8		Lost to Upland	0	
	Conversion Gain	82.8		Conversion Loss	3.9	
(MS)		85.8			3.9	81.8
						437.3

	Acres			Acres	Net Change (Acres)
Gross Gain from Uplands	1154.4		Gross Loss to Uplands	717.1	437.3
Conversion Gain	2067.5		Conversion Loss	2067.5	0
Total Gross Gain	3221.9		Total Gross Loss	2784.6	437.3

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Appendix B. Gross Gains and Losses for Wetlands & Deepwater Habitats

Table 4. Gross gains of wetlands and deepwater habitats, by upland category

	Wetland Category												
	MI	EINV	EIV	FE	FSS	FF	FP	FNV	ES	L	R	MS	Total Gain by Upland Category
Built (undetermined)	0	0	0	0	0	0	0.3	0	0	0	0	0	0.3
Built: Residential & Commercial	119.3	0	0	0	0.3	0	5.4	0.3	0	0	0	0	125.3
Upland Category Built: Transitional	0	0	0	8	0	0	19.5	11.2	0	0	0	0	38.7
Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0
Recreational	0	0	0	0	0	0	4	0	0	0	0	0	4
Transportation	0	0	0	0	0	0	0	0	0	0	0	0	0
Rural Development	1.3	0	0	0	0	0	9.5	0	0	0	0	0	10.8
Other	364.3	33.6	2.5	47.5	0	0	288.8	39.1	104	49.8	4.1	2.8	936.5
Agriculture	0	0	0	0	0	0	36.4	2.4	0	0	0	0	38.8
Total Gain by Wetland Category	484.9	33.6	2.5	55.5	0.3	0	363.9	53	104	49.8	4.1	2.8	
													1154.4

Table 5. Gross losses of wetlands and deepwater habitats, by upland category

	Wetland Category												
	MI	EINV	EIV	FE	FSS	FF	FF	FNV	ES	L	R	MS	Total Loss by Upland Category
Built (undetermined)	0	0	0.6	18.2	7.7	8.3	0.6	0.9	0	0	0	0	36.3
Built: Residential & commercial	0	1.4	0.9	102.3	37.1	35.3	38	0.6	0.4	0	0	0	216
Upland Category Built: Transitional	0	0	0.8	28.8	37.7	46.7	1.3	0	0	18.2	0	0	133.5
Industrial	0	0	0	12	0.7	18	8.3	0.6	0	0	0	0	39.6
Recreational	0	0	0	0	0	0	0.3	0	0	0	0	0	0.3
Transportation	0	0	0	0.4	0	0	0	0	0	0	0	0	0.4
Rural Development	0	0	0.8	21	3.5	1.7	1.4	0.2	0	0	0	0	28.6
Other	19.3	21	48.8	71.7	21.4	3.1	12.1	0.2	18.7	0	0	0	216.3
Agriculture	0	0	0	19	22.7	4.2	0.2	0	0	0	0	0	46.1
Total Loss by Wetland Category	19.3	22.4	51.9	273.4	130.8	117.3	62.2	2.5	19.1	18.2	0	0	
													717.1

Appendix C. Primary Causes for Wetland & Deepwater Habitat Change

Table 6. Cause of Wetland and Deepwater Habitat Change (in acres)

	Conversion	Gains	Losses	Net Change
Ike/Coastal Processes	1228.3	525.3	154.4	370.9
Restoration	256.6	10.7	0	10.7
All Other	582.6	618.4	562.7	55.7
	2067.5	1154.4	717.1	437.3

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