Salt Marsh Creation and Coastal Residential Developments: 
Principles and Guidelines for 
Landscape Architecture Practice 

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SALT MARSH CREATION AND COASTAL RESIDENTIAL DEVELOPMENTS:
PRINCIPLES & GUIDELINES FOR LANDSCAPE ARCHITECTURE PRACTICE

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Abstract
Salt marsh creation provides functions and values that are essential to maintain the welfare of people and the integrity of coastal area ecosystems. The literature review provides greater understanding of salt marsh functions and values technical information regarding wetland creation in coastal regions. Interviews and case study analyses identify issues and opportunities regarding salt marsh creation. Products of this study include a model approach, criteria for project evaluation, and principles and guidelines for salt marsh creation and coastal residential development.

Model approach applies the technical information and processes of salt marsh creation provided by scientists and engineers to the landscape architecture design process. The model approach encourages involvement of the client and other professionals throughout the planning and design process. The proposed criteria provide a framework for landscape architects to evaluate the structure and function of created ecosystems and developments. Four salt marsh creation projects around the Chesapeake Bay were selected for review and evaluated according to these criteria. Each project provides evidence that salt marsh creation can benefit residential developments by providing long-term shoreline protection, water purification, wildlife habitat, and amenity of a naturalistic landscape. Design principles and guidelines will help ensure that the model approach is used by developers to attain salt marsh creation that fits the patterns and functions of surrounding ecological systems and increases residents' awareness of both functions and values of salt marsh and the larger.
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"Salt Marsh Creation and Coastal Residential Developments
Principles and Guidelines for Landscape Architecture Practice"

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Introduction

Coastlines provide unique feature where land and water interface. A large proportion of the world's human population is concentrated along coastlines, as well as along rivers which are directly linked or that eventually connect to near-coastal waters. Since humans are attracted to coastlines for aesthetic and economic reasons, the lack of awareness of systems operating in the coastal zone has caused negative impacts on the coastal waters ecosystems (Warren, 1979). There is a need for landscape architects to be involved in management of coastlines in order to protect and restore the integrity of the coastal ecosystem while accommodating developments in coastal areas.

Despite their high productivity, coastal salt marshes have been traditionally considered as worthless waste areas by many people in industrial societies. About half of the nation's wetlands have been destroyed by man's activities since European settlers first arrived in America (EPA, 1992). The most serious threats to these ecosystems have resulted from human activities such as ditching and draining of coastal wetlands for agricultural use and residential development, bulkhead dredging and filling to create developable land, channel dredging for transportation, agriculture and industrial waste disposal, creation of river impoundments and water flow controls, and pesticide use and sewage pollution. These activities have added large amounts of pollutants to coastal waters and disturbed plant and animal habitats in these areas (Reimold, 1977, Queen, 1977, and Knutson and Woodhouse, Jr., 1982). In addition to direct impacts on the wetlands, coastal urbanization has isolated many marshes and fragmented the habitats of larger terrestrial predators, thereby limiting their access to the marshes. Macdonald (1977) indicated that all of the pressures named above are likely to continue reducing the integrity of salt marshes throughout the world.

It is commonly understood that a variety of fauna exists in coastal salt marshes and that many of these animals are found nowhere else (Teal, 1962). Many endangered plant and animal species as well as commercial and recreational species of prime importance to human beings depend upon foods and habitats unique to coastal wetland systems (OTA, 1984) (see appendix A). With human pressures placed upon salt marshes, a number of wildlife species depending upon these ecosystems have lost their actual habitat. Fortunately, because of the concern of scientists, planners and the public for preserving natural environments, most remaining United States coastal wetlands are now legally protected (Chapman, 1977 and Lewis, 1992).
Currently, development along coastal areas is controlled by federal and state laws and regulations. Salt marshes are designated as critical areas in many coastal states (Clark, 1983). Where development involves dredging or filling of salt marshes, federal wetland mitigation policy requires the developer to restore or create salt marshes elsewhere on their property to compensate for the area(s) of marsh that are lost or degraded by project construction. Wetland regulations and mitigation policies certainly have made developers more cautious about dealing with salt marsh habitats. Yet, combined with large areas of salt marsh already lost, developments continue to eliminate or displace the remaining salt marshes (OTA, 1984 and Lewis, 1992). Therefore, the need to protect and restore these ecosystems remains prominent.

The presence of healthy salt marshland contributes to the integrity of the larger landscape of which marsh and humans are part by providing naturally functioning transitions from land to water, as well as by structurally supporting numerous organisms through changes in energy and material flow. In addition, the salt marsh offers visitors a series of experiences created by wind, sunlight and waves, including the open view of an ocean filled with dancing emergents. The smell, touch and taste of tides and heady salt marsh vegetation, the sound of tides rolling in and vegetation rustling, and the glimpse of animals such as gulls, wrens and crabs all add to the delight of the coastal salt marsh systems (Teal and Teal, 1969).

By restoring salt marshes along degraded coastlines and creating them wherever feasible, we can re-establish the functions and values of naturally occurring salt marshes. Therefore, landscape architects should consider incorporating salt marsh creation into their design processes for coastal areas whenever and wherever appropriate.

This thesis discusses "where" and "how" the construction of such salt marsh ecosystems can be accomplished. Ultimately, this thesis seeks to provide an overall framework and specific guidelines for landscape architects and other related professionals who are interested in incorporating salt marsh creation into coastal developments in ways that protect and enhance the welfare of humans while simultaneously retaining the integrity of coastal ecosystems.

**Problem Statement**

Recent ecological research has shown that the functions of a salt marsh ecosystem are an integral part
of the larger coastal ecosystem (Chapman, 1974, Brooks, 1989 and Adam, 1990). This makes the restoration and creation of such ecosystems crucial for our future well-being and for the survival of many species and communities of plants and animals.

Restoration involves recreating both the structural and functional attributes of a damaged ecosystem, while creation traditionally means putting a landscape to a new or altered use to serve various human purposes (Cairns, 1991). Wetland creation should typically be done on a degraded site/landscape or where a newly created system provides artificial structure and function not provided by the existing system (Garbisch, 1986 and Skabelund, 1994).

Recent conservation efforts have raised interest in creating marshes to provide new areas of wildlife habitat critical to the maintenance of larger, intact landscapes, as well as to offset the loss of habitat due to various types of land development (Adam, 1990). However, the dispute over the potential values of coastal salt marshes to our society and the appropriateness of created salt marshes remains prominent. This is due to the different interests and opinions that are held by individuals who have a stake in these places.

Many salt marshes have been restored or created by engineers and scientists in the United States, primarily for shoreline protection or to compensate for lost wetland. Scientists from the fields of soil science, biology, ecology, engineering, and others are involved in both the restoration and creation of salt marshes to demonstrate and/or test the functional values of these "human initiated" salt marshes. The results of their studies provide evidence that created salt marshes can provide functions and values similar to those of natural salt marshes (Teal, 1962, Cammen, et al, 1974 and Cairns, Jr., 1992).

It is the role of landscape architects to apply the findings of engineers and other scientists to their designs for private and public properties, ensuring health, safety and welfare for humans while engendering a respect for land, water and wildlife by humans. This thesis attempts to provide a basis for landscape architects involved in coastal developments to create salt marshes in ways that retain or recreate the integrity of such ecosystems for both wildlife and humans.

Research Goals and Objectives

*Thesis goal: To develop guidelines which incorporate coastal salt marsh creation into coastal area*
developments in ways that protect and enhance the health, safety and welfare of human beings and that ensure the integrity of both the created ecosystem and larger landscape.

The guidelines presented in this thesis will specify ways in which to incorporate salt marsh creation in order to provide appropriate habitats for wildlife, as well as ways to increase human awareness of the value of these ecosystems. Since environmental degradation is a global concern, this thesis is based upon the premise that the creation of salt marshes will protect properties from erosion and flooding while enhancing the aesthetic quality of shorelines, and such endeavors will also provide opportunities for human beings to be a part of, and learn from, these ecological systems. In order to achieve this thesis goal, the following objectives served to guide the work:

**Thesis objectives:**

1) to improve our general knowledge of coastal wetland ecosystems, particularly salt marshes.

2) to identify procedures and techniques for creating structurally and functionally sound coastal salt marshes.

3) to define a role for landscape architects in protecting, restoring and creating salt marsh ecosystems.

4) to provide principles and guidelines for landscape architects to incorporate salt marsh creation into coastal residential developments and the larger landscapes of which these developments are part.

**Thesis Approach**

This thesis consists of three components: 1) a literature review of salt marsh ecosystems and restoration/creation practices, 2) interviews and case study analyses regarding current salt marsh restoration and creation practices from the standpoints of various professionals such as engineers, biologists and soil scientists, and 3) a synthesis of components one and two to formulate principles and guidelines for landscape architects by which they may incorporate salt marsh creation into coastal area developments (Figure 1).
* Thesis Approach

(Figure 1) Thesis Approach

The first section of this thesis seeks to improve our understanding of coastal wetland ecosystems, particularly salt marsh functions and values. The second section discusses the current restoration and creation procedures and techniques related to coastal salt marsh systems. The third section addresses the larger landscape and focuses the reader on the role of the landscape architect in attaining appropriate relationships between created salt marshes and human settlements in the coastal areas.

The series of case study reviews were conducted to help develop an understanding of the various technical and theoretical aspects of salt marsh restoration/creation practices performed by engineers and scientists. Four sites of restored/created salt marshes in the Chesapeake Bay area were selected for
case study review. Although wetland types, ecosystems and regulations among regions may differ, the findings should have relevance for similar ecosystems throughout the world, because fundamental functions and values of salt marsh wetlands are to some degree similar throughout the world (Chapman, 1974).

Case study analysis is an important aid to comprehending the underlying principles that can guide salt marsh creation as a design option for landscape architects. Analysis helps us to recognize some of the attributes of successful salt marsh creation and opportunities to improve future developments. The synthesis of the author's literature review and case study analyses helps establish guidelines for landscape architects to incorporate salt marsh creation into the design processes of coastal residential communities.
I. Salt Marsh and Surrounding Ecosystems

1.1. Coastal Waters Ecosystem

Salt marsh creation involves integral elements of ecosystems; tidal and freshwater, vegetation and soil. Landscape architecture is often involved in altering an existing ecosystem and/or creating a new ecosystem on the land or water. Therefore, landscape architects must understand the operating ecosystems on the site they are working on and the functional attributes of the ecosystems they intend to create.

Clark (1983) defined "ecosystem" as a balanced network of biotic relationships and the "coastal waters ecosystem" as a basic functional geographic unit that embraces all of the biotic and abiotic components within a distinct coastal watershed. The coastal waters ecosystem operates within geologic structures that have been modified over time by dynamic weathering and transport forces such as wind, waves, water flow, erosion and sedimentation. The natural processes of a coastal waters ecosystem are driven by a complex system of energy flows that include water, light and wind. In response to these flows, the biota of a coastal ecosystem consists of a large variety of plants, birds, fish, mammals and invertebrate organisms (Clark, 1983). These are called "elements" of the landscape by Lyle (1985).

Primary Productivity

"The concept of primary productivity refers to the capacity of an ecosystem to produce basic plant material" (Clark, 1983). It indicates the amount of energy that is converted from light, basic nutrients, and carbon dioxide to plant tissues within a certain unit of time in a certain area (Mann, 1982).

Phytoplankton in estuaries are important sources of organic matter both quantitatively and qualitatively. Phytoplankton have high rates of carbon fixation, and initiate the rapid turnover of carbon and ease of utilization by animals (Haines, 1979). Phytoplankton production or primary productivity is enhanced by "upwelling" (any process balancing the spatial separation between the nutrient-rich water at the bottom and the euphotic zone at the surface) (Figure 1.1). This upwelling is a common feature of the shallow water areas such as coastal salt marsh. Therefore, the coastal waters are recognized as a source of much higher primary productivity than open waters, especially in salt marshes where upwelling occurs regularly and macrophytes flourish (Mann, 1982).
(Figure 1.1) Systems of Nutrients in Shallow Waters (adapted from Mann, 1992)
(a) Offshore wind mixes the water and nutrients. (b) Freshwater inputs from river. (c) Tidal regimes mixes the nutrients.
**Marine Macrophytes**

Macrophyte communities of flowering plants and algae are found at the ocean's edge in all climatic zones and along most types of shores (Mann, 1982). Areas with abundant macrophyte communities such as salt marshes, mangals (mangrove communities) and beds of seagrass play a significant role as buffers between the open sea and dry land by creating a plant biomass that traps sediments and absorbs wave energy, thereby protecting shoreline from unchecked coastal erosion (Mann, 1982).

As mentioned earlier, macrophyte converts inorganic compounds (nutrients) and sunlight into energy that is stored in plant tissues. After falling into the water, dead leaves and plant stems are broken down rapidly by bacteria into the small organic particles of detritus. This organic matter feeds lower wetland and estuary species such as fiddler crabs, worms, snails, mussels and a myriad of larval fish and shellfish (Clark, 1983).

Since all animal food begins with plants, there is no doubt that the establishment of marine macrophyte communities plays a significant role in coastal waters ecosystem.

**Coastal Wetlands**

All shoreline areas that are periodically exposed and flooded by salt or brackish water through tidal and normal storm action are considered to be a part of the estuarine shoreline system. When these areas are vegetated with macrophytes, they are referred to as coastal wetlands (Clark, 1983). In general, salt marshes are characteristic of temperate zones, while mangals are mostly found in tropics or subtropics (Figure 1.2). The mechanisms and features of the ecosystems known as mangals and salt marshes are similar in most respects (Chapman, 1977). Chapman (1977) describes the seven factors of the maritime environment that are major determinants of the general distribution of these two ecosystems.

1) **Air temperature**: It determines the northern and southern limits of mangrove species in the Northern and Southern Hemispheres. Northern and southern limits of salt marsh species are related to either winter or summer extreme temperatures in both hemispheres.

2) **Protected coastline**: Neither salt marsh nor mangal can develop on an exposed coast where wave actions prevent the establishment of the seedlings.

3) **Shallow shores**: Where there is little change in shoreline gradient of the shores, the greater the extent of the salt marsh or mangal communities will be. On steeply shelving shores, only fringe
communities develop.

4) Currents: Ocean currents are responsible for the distribution of species along coasts by carrying seeds, seedlings or plants portions.

5) Salt water: Most salt marsh or mangrove species have their optimal growth in the presence of some additional sodium chloride.

6) Tidal range: The greater the tidal range, the greater the vertical range available for the communities, and the wider the more extent on coasts.

7) Substrate: Substrate types vary widely in composition, and can play a part in determining community composition or the total number of species present.

(Figure 1.2) Distributions of Coastal Wetlands (adapted from Chapman, 1977)
Salt marshes and other coastal wetlands occur naturally when all of these factors create a suitable environment in which to grow. Salt marsh restoration and creation efforts need to account for all of the above factors in order to determine types of wetland suitable in a site, and to increase probability of attaining a self-maintaining ecosystem.
1.2 Coastal Salt Marsh

An environment that allows deposition of silt, sand and organic sediments is necessary to develop a salt marsh. According to Chapman (1976), a salt marsh can be established if any one of the following physiographic conditions is met: the presence of estuaries, the shelter of spits, off-shore barrier islands, and large or small protected bays with shallow water (Figure 1.3).

(Figure 1.3) Diagram of Typical Salt Marsh Formation (adapted from Chapman, 1938)
(A) bay, estuary marsh; (B) marsh behind spit; (C) marsh behind bay mouth bar; (D) estuary marsh in narrow valley; (E) marsh behind bay head bar; (F) marsh behind mid-bay bar; (G) marsh behind complex spit; (H) sand beach; and (I) off-shore barrier island and marsh
Marshes are typically formed by the following two processes: (1) a gradual subsidence of the land that either creates a deep layer of silt or of peat, and (2) the rise in substrate level created by the silting up or the accumulation of plant remains in lagoons or areas protected by sand or shingle bars (Chapman, 1938). In the second type of marsh formation, sediments are supplied by wave action, longshore drift or from the upland bank. The sediments stimulate growth of salt marsh plants by supplying important nutrients (Broome, Rogers and Seneca, 1994). Some have posited that the accumulation of organic matter and mineral sediments has the potential to keep pace with the rises in sea levels caused by global warming (Broome, Craft and Seneca, 1993, and Garbisch and Garbisch, 1994).

The major attribute that determines the extent of a salt marsh ecosystem is the slope of the land (Chapman, 1976). Where the land steeply adjoins the sea, the strip of salt marshes will be narrow. On the other hand, the marshes can become very wide where there is gentle slope. In the Pacific Coast of North America, the physiographic features restrict the distribution of coastal salt marshes. Thus, the marshes usually occur as relatively narrow fringes around the few protected bays and lagoons scattered along the coast or in river estuaries with thin veneers (20-180 centimeter thick) of sediments overlying the sandy bay-floor. However, the Atlantic Coast of North America presents extensive and continuous salt marshes covering thousands of acres within protected lagoons between the barrier islands and mainland coast. Sediments in these marshes frequently include thick sequences of peat that extend up to 9 meters in depth (Macdonald and Barbour, 1974).

According to the influence of tides and the period of exposure to inundation, Chapman (1976) divides salt marshes in the United States into four levels: lower low, higher low, lower high, and higher high (Figure 1.4). Plants generally become established at Mean Lower High Water (MLHW), where they tend to be taller, heavier and greener (Barbour and Macdonald, 1974, and Teal and Valiela, 1974).

Because of the physical setting associated with natural processes, the high and low marshes often present quite different features in form, vegetation, and function. For example, low marshes are subject to severe salinity because of frequent coastal flood water. This situation leads to more salt-tolerant species establishing in these areas. The low marshes have capability to store basic minerals and nutrients that are decomposed in the high marshes and the shoreland watershed. Therefore, the low marshes are considered as a primary source in the food chain of the larger ecosystems in the coastal waters (Clark, 1983).
A study of the Georgia Salt Marsh showed that 45% of the biomass within the selected salt marsh was carried out into the estuary by coastal tides before marsh consumers had a chance to utilize it, thus allowing the estuary and larger ocean ecosystems to support an abundance of animals (Teal, 1962).

(Figure 1.4) Typical Section of Coastal Salt Marsh
(adapted from Mann, 1982 and Clark, 1983)

The high marshes are subject to various influences from uplands; these are both natural and human effects, including fresh water run-off, agricultural and urban land uses, and wildlife depredation. As well, the extended period of sun exposure may cause hypersaline conditions. The lower soil water
potentials and hypersaline conditions during the growing season tend to result in selection for plants of low growth potential (Davy, Jefferies and Rudmik, 1977).

Another function of salt marsh ecosystems is in the water purification capacity (Clark, 1983). The study of the Tinicum marshes in Pennsylvania has proven the value of salt marshes as an important pollution filter, indicating 50 to 70 percent reductions in nitrate and phosphate levels several hours after the waters from sewage and effluent passed over a 560-acre tidal marsh (Grant and Patrick, 1970 in Niering, 1983).

**Flora and Fauna of Coastal Salt Marsh**

The colonization and establishment of initial vegetation plays a significant role in the development of coastal salt marsh systems. Vegetation reduces velocities and impacts of tidal currents and accelerates the deposition of silt which increases nutrient levels within these systems (Mann, 1982). Vegetation also provides cover and nest sites for numerous species of fishes and birds, while the death and decay of plants contributes to a greater flow of energy in salt marsh food chain (Teal, 1962 and Chapman, 1976). Vegetation directly affects animal life by protecting animals from predation and by stabilizing nesting areas and their food sources. Vegetation indirectly affects animals by reducing the water actions of ocean tides and upland run-off and by controlling the amount of sunlight and heat within a salt marsh (Daiber, 1977).

The dominant vegetation of coastal salt marshes consists of phanerogamic herbs with occasional shrubs, accompanied by extensive populations of algae, particularly among the Atlantic Coast of the United States (Chapman, 1974). A number of species commonly found in coastal marshes belong to the grass (Poaceae), sedge (Cyperaceae), and rush (Juncaceae) family (Knutson and Woodhouse, Jr., 1982a & b). (See appendix B for a list of plant community associated with salt marsh ecosystems). Numerous studies have shown that an impressive variety of species occurs within individual marshes; much of this diversity in type and habitat is a product of the frequency and duration of tidal activity (Valiela and Teal, 1974, and Davy, Jefferies, Rudmik, 1977).

As the position of salt marshes changes from ocean edge to upland, the frequency of inundation and rates of salinity also change, resulting in plant "succession" (Chapman, 1976). Note that succession here refers to the sequence of species replacement and changes in the biota of the salt marsh.
community, which may take place over a long period of time or quite rapidly according to tidal range and slope of individual shores (Clark, 1983).

It should be stated here that vegetation along Atlantic Coast salt marshes is remarkably uniform (Knutson and Woodhouse, Jr., 1982a). *Spartina alterniflora* (smooth cordgrass) dominates Atlantic Coast salt marshes from Canada to Florida, occupying the intertidal zone from Mean Sea Level to Mean High Water (MHW); several species of *Juncus* grow at the edge or near MHW, and *Distichlis spicata* (saltgrass), *Spartina patens* (saltmeadow hay), and some species of *Salicornia* grow above and near MHW (Reimold, 1977). In the Pacific Coast of North America, where climactic and oceanographic conditions change dramatically, the regional character in sediment types and freshwater runoff becomes a key factor in determining the existence and the distribution of wildlife species (Macdonald, 1969 and 1977).

For more precise lists of local species on the Atlantic and Gulf Coasts, as well as on the Pacific Coast of North America, see Mason (1957), Duncan (1974), Barbour and Macdonald (1974), Pierce (1977), Reimold (1977), and Knutson and Woodhouse (1982 a & b).

In general, animals associated with salt marsh are classified into two groups: 1) animals which are tolerant of a wide range of environmental conditions, and 2) animals which are highly specialized and restricted to specific niches (Heydemann, 1979). The highest distributions of species are generally found under two habitat conditions: 1) in shallow water areas seldom exposed to the sun, and 2) in terrestrial regions seldom inundated even in storm tides.

The aquatic species that feed on detritus and algae, such as fiddler crabs, contribute largely to the biomass occurring within marshes. Most of these marine invertebrates are considered to be algal-detrital feeders and have no impact on halophytes themselves (Teal, 1962 and Chapman, 1976). The primary consumers of halophytes are mostly insect species and larger animals such as birds, rice rats, sparrows, red-winged black birds, etc. (Shanholtzer, 1974 and 1977). Many fish occasionally enter and feed among salt marsh plants at the high tide period.

The marshes along the open ocean areas support a considerable number of migrant shorebirds and waterfowl for their feeding, resting, and protection (Macdonald, 1977 and Reimold, 1977). Mammals
like deer, rabbits, weasels, skunks, or fox mostly use marshes for hunting, but only in high marsh areas (Macdonald, 1977, and Shanholtzer, 1977). As suggested above, not many species are recognized as being characteristic of coastal salt marsh habitats, although large numbers of organisms rely upon them for food, shelter and/or reproduction (Macdonald, 1977).

The distribution of plants and animals in coastal marshes is primarily controlled by the following three factors: salinity gradients, degree of inundation, and the character of the substrate (Daiber, 1974 and 1977). Salinity and inundation determine the distribution of animal species by controlling the kinds of vegetation that can be established.
1.3 Summary of Coastal Salt Marsh Functions and Values

Coastal salt marshes are widely recognized for the following functions and values: shoreline stabilization and protection, wildlife/fisheries habitat, primary productivity, water purification, recreation, education, and aesthetics (Woodhouse, Jr., 1979, Knutson and Woodhouse, Jr., 1982a & b and 1983, Garbisch, 1989, Adam, 1990, and Erwin, 1990). Each functions and/or values are briefly summarized below.

* Shoreline Stabilization and Protection: Marsh plants perform two functions in protecting shoreline areas. Many marsh plants form dense root-rhizome mats which improve the stability of the soil or sediment. Also, plant biomass -- particularly the aerial parts of plants -- forms a flexible mass which dissipates overland sheetflow, wave energy, and storm surges (Knutson and Woodhouse, Jr., 1987, and Erwin, 1990).

* Wildlife/Fisheries Habitat: Coastal salt marshes have high value as nursery grounds for many sport and commercial fishes (Woodhouse, Jr., 1979, Knutson and Woodhouse, Jr., 1982). Many saltwater species of fish spend their juvenile stages in salt marshes, then migrate offshore as they mature (Erwin, 1990). Approximately two-thirds of the commercial finfish harvested on the Atlantic Coast are estuarine dependent species (Adamus, 1983). A large population of animals such as fiddler crabs, mussels, clams, and periwinkles live in or on the mud surface (Woodhouse, Jr., 1979). A large number of resident birds, migrating waterfowl, and mammals such as raccoon and deer utilize marsh habitats (Woodhouse, Jr., 1979, and Erwin, 1990).

* Primary Productivity: Marsh grasses and algae formed on living and dead plants as well as upon the surface of marsh mud are extremely productive, and they are critical components in the food chain (Woodhouse, Jr., 1979). Salt marshes are often referred to as "nutrient sinks," storing an excess of essential minerals and nutrients (Teal and Valiela, 1974 and Davy, Jefferies and Rudmik, 1977).

* Water Purification: Salt marshes, to a certain extent, perform a filtering role in removing potential pollutants such as nitrogen, phosphorus, and metal ions (Woodhouse, Jr., 1979, Knutson and Woodhouse, Jr., 1982a & b, Adam, 1990, and Erwin, 1990).

* Recreation: Salt marshes are not suitable for many recreational uses; however, activities
such as sport fishing and canoeing are major attractions for families and individuals (Erwin, 1990). Also, the variety of animal species attracts specialized interest groups such as bird watchers, hunters and fishermen (Adam, 1990). Nearly 10 billion dollars are spent each year by such specialized interest groups for observing and photographing wetland-dependant wildlife (EPA, 1992).

* **Education:** Salt marshes are viewed as an ideal place for demonstrating and studying zonation patterns of vegetation. This is possible because the relatively low species diversity makes them appropriate places for researchers and classes to carry out exercises in vegetation description and sampling (Adam, 1990).

* **Aesthetics:** The beauty of salt marshes may not be appreciated by everybody; however, the beautiful scene which constantly changes with the ebb and flow of the tide and with the seasonal cycle of the dominant species has been effectively captured by many artists and conservationists (Adam, 1990). Many people view these scenes in the same manner that our society views the fine arts - as entities which are appreciated and protected not for any "practical" reason, but just because they are there and are "somehow special" (Adamus, 1983).
II. Salt Marsh Creation and Residential Development

2.1 Restoration and Creation Overview

The regulation of natural wetlands by the U.S. Army Corps of Engineers (Army Corps), under Section 404 of the Clean Water Act of 1977, requires construction of wetland to compensate for filling existing wetland areas (OTA, 1984). Compensation for lost wetland areas is called "mitigation". Mitigation policies are generally evaluated by federal and state agencies for each project where existing wetlands are or may be affected (Atkinson and Cairns, Jr., 1994)

The term "creation" of a wetland has traditionally meant putting a landscape to a new or altered use - to serve particular human purposes such as shoreline stabilization or water quality enhancement, with less emphasis on wildlife utilization (Cairns, Jr., 1992). The term "restoration" typically describes the effort to return a site to its pre-existing physical and botanical condition by recreating both the structural and functional attributes of the damaged ecosystem (Garbisch, 1989 and Cairns, Jr., 1991).

Much effort has been made toward restoration and creation of the coastal salt marshes in the United States. Salt marsh restoration and creation involve establishing the particular hydrology, soils and plants that would have been naturally found on a site or within its same region and that are necessary to create a functioning wetland.

The Army Corps has worked a great deal with the establishment of salt marshes on dredged materials and existing shorelines (Garbisch, 1989). Recently, other federal and state agencies, private engineers and environmental consultants have also been actively involved with restoration and creation works, chiefly to stabilize shorelines or to recreate habitat for mitigation of effects elsewhere in an area.

Cairns, Jr. argues that "all restoration efforts are exercises in approximation and in the reconstruction of naturalistic, rather than natural, assemblages of organisms and their predisturbance chemical/physical environments" (Cairns, Jr., 1991).

Purpose of Coastal Salt Marsh Creation

Environmental protection and economic welfare for people are two inseparable goals in coastal salt marsh creation. Salt marsh has important values and functions in coastal ecosystems, which, in turn, enhances the economic welfare of human populations living within the coastal community. A healthy
estuarine environment, protected by the maintenance of natural waterflows and vegetation, will help protect waterfront lands from geologic hazard and can greatly enhance their economic value (Clark, 1974).

Most coastal salt marsh restoration/creation work has been done to artificially create similar functions of natural salt marshes. Although it will, in many cases, be impossible to duplicate the quality of the predisturbance condition of the natural wetland, many wetland ecosystem values may be adequately replaced (KuNUla and Kusler, 1990, and Atkinson and Cairns, Jr., 1994). The kind of functions and values restored depends on the type of project undertaken, the plans and techniques developed and used to create the salt marsh, and the larger regional concerns addressed by the project.

This study places emphasis on creating coastal salt marsh for shoreline protection and the provision of natural habitat for wildlife. It is my hypothesis that both functions will eventually provide people with educational, aesthetic, and recreational benefits and will thus enhance the economic status of the area.

**Implementation of Mitigation Policy**

A large number of Federal, State, local, and private programs are involved in the management of coastal salt marshes in the United States. In order to carry out any type of project which has potential impacts on coastal salt marshes, a designer must be aware of the implications of federal and state programs.

The primary program that directs activities proposed for salt marshes is the section 404 of the Clean Water Act (CWA), amended in 1977 from the Federal Water Pollution Control Act (FWPCA), 1972. Section 404 focuses on minimizing or compensating for proposed impacts rather than preventing a development. The program requires anyone who plans to conduct activities that would cause a discharge of dredged and/or fill materials into "waters of the United States" to apply for and obtain a permit from the local district office of the Army Corps (OTA, 1984). Florida Middle District Court, 1974, required the Army Corps to extend its authority on wetland alterations above the Mean High Water (MHW) up to the annual extreme high tide, which in effect authorizes the Army Corps' discretionary review of the permit process over larger landscape contexts (Clark, 1974).

Permit applications are evaluated based on the following two factors; 1) regulations developed by the
Army Corps and the U.S. Environmental Protection Agency (EPA) under the environmental criteria of 404 guidelines, and 2) whether or not the project is in the public interest (Brooks et al., 1989). Section 404 assigns the EPA, the U.S. Fish and Wildlife Services (FWS), and the National Marine Fisheries Service (NMFS) to overview permitting processes (Clark, 1983). The involvement of other Federal agencies (EPA, FWS, and NMFS) encourages the Army Corps to protect the integrity of wetlands, including their habitat values and the quality of water (OTA, 1984).

In addition to the Federal program, many coastal states have their own wetland protection programs. According to the survey conducted by the Office of Technology Assessment, twenty out of thirty coastal states indicated that their individual state programs play a more dominant role than the 404 program; ten states indicated that the 404 program plays the most important role in protecting coastal wetlands. Some states have more comprehensive programs than the Corps' application of the 404 program and may regulate activities occurring outside of a wetland if such activities impact the wetland of interest (OTA, 1984).

**Protection of Property and Creation of Wildlife Habitat**

A vegetative alternative to shore erosion control has been recognized as a viable alternative, and its cost is considerably lower compared to permanent structures (Garbisch, 1994). A major cause of shoreline erosion is the undercutting of upland bank by sufficient wave contact with the shore. Establishment of salt marsh vegetation contributes to the trapping of materials brought by longshore and offshore littoral transport or upland bank erosion. As a result, the elevation along shores increases and frequency of tidal wave contacting with the bank face decreases (Garbisch and Garbisch, 1994).

Planting fast-growing plants like *Spartina alterniflora*, which is commonly found in low salt marshes throughout the Atlantic, and *Spartina foliosa* and *Pickleweed* found along Southern Pacific Coasts in the United States effectively stabilizes both existing shoreline and artificially established shoreline on dredged spoil. These plants have also proved to have high value for wildlife habitat, both as a source of food and of protection from predation. (Broome, Seneca and Woodhouse, Jr., 1974, Woodhouse, Jr., 1979, and Knutson and Woodhouse, Jr., 1984a & b).

A study on artificially established salt marsh with *Spartina alterniflora* on dredge spoil along North Carolina coastline reported successful shoreline protection, as well as dry matter production similar to
natural salt marshes during the second growing season after transplanting. The study indicated that the elevations along the planted slopes increased an average of 0.16 meters about 23 months after planting, while the adjacent unplanted blocks decreased in elevation averaging 0.03 meters (Broome, Seneca and Woodhouse, Jr., 1974).

Some animals are capable of adjusting to a new environment while others are not. A study in a North Carolina salt marsh showed that about half of the animal species found in the natural salt marsh of the region had colonized a created salt marsh on dredge spoil within 9 months after transplanting. Compositions of the fauna of the spoil areas became close to the ones of a true marsh fauna, and succession of higher grade species occurred as sediments developed into the characteristic marsh sediments of that area (Cammea, Copeland and Seneca, 1974).

These studies indicate that created salt marshes can attain similar functions as natural salt marshes in terms of creating a sediment sink, which thus helps filter runoff, trap sediments, and raise elevations according to changes in sea levels.

Plant species, substrate type, and elevation occurring in response to the hydrology of a site are major factors that must be understood to determine the appropriate characteristics of a restored or created salt marsh ecosystem. The focus of salt marsh creation should thus be on the successful establishment of a natural assemblage of substrates and plants and appropriate elevation in response to site hydrology.
2.2 Process of Salt Marsh Creation

Plans and specifications for most coastal wetland restoration and creation projects must account for hydrology as the critical element (Garbisch, 1989). Hydrology on a site determines plant and animal species that can tolerate or adjust to salinity levels, inundation by water, and other frequently changing environmental conditions. The difficulty of salt marsh restoration and creation efforts depends on the degree of the wetland disturbance and ecological change in a landscape (Garbisch, 1989 and Cairns, Jr., 1991). An awareness of these basic factors throughout the process of developing a plan for restoration and/or creation of salt marsh is essential.

The typical process of coastal salt marsh creation involves the following five major events: a) site selection, b) permit application, c) site preparation, d) planting, and e) protection. In discussing these steps, the focus will be on creating salt marsh where the same type of salt marsh did not previously exist.

a) Site Selection and Plan Development

Salt marsh creation typically involves filling in shallow water areas, conversion of upland to intertidal zones, or a combination of both. Filling in shallow water areas is usually not preferred (unless the area is under severe erosion pressures), because shallow water areas along the shoreline are considered to be wetland and may perform critical functions or be highly valued (Perry, 1994). The conversion of high marshes to lower elevation ones is commonly done to improve erosion controls, expand fish and waterfowl habitat, and provide for water and material exchange as a part of mitigation strategy. However, excavating upland area to intertidal zones may increase the potential for tidal flooding in these areas (Garbisch, 1986).

Conversion of upland or subtidal areas or existing shallow water habitats to salt marsh habitats requires an objective determination as to whether the conversion will be ecologically beneficial, compared to existing ecological properties of the subtidal areas (Garbisch, McCallum and Woller, 1975).

It would be most desirable to choose the site which has already been chemically and biologically degraded; areas derived from dredging, mining, or borrow operations; dredged material disposal sites; unvegetated or disturbed shorelines; or areas with low fish and wildlife resources (Garbisch, 1986). Figure 2.1 describes examples that disturbed areas can be converted to created salt marsh.
(Figure 2.1) Converting "disposed", "unvegetated" and "dredged" shorelines into "created" salt marsh (adapted from Garbisch, 1986)
Shiler (1990) recommends either creating a marsh adjacent to functioning salt marshes or using existing salt marsh ecosystems as "reference marshes". To create the marshes that resemble natural ones, it is important to know the characteristics of natural salt marshes within a similar hydrologic region, particularly in terms of their vegetative and substrate compositions and hydrologic systems. If the site historically has contained salt marshes, the causes of degradation, existing characteristics and relationships between these marshes and the surrounding landscape should be identified (Shiler, 1990). If no salt marsh exists on the site, the reasons for this must also be ascertained.

Note that salt marshes are typically lost under the following two circumstances of natural process: 1) when water depths near shore increase, water levels and waves during storms become higher and pass over or break on top of the salt marsh; and 2) when water depths near shore decease or accumulation of sediments and organic matter increase the surface elevation of salt marshes, low tide wave undermines the lower low salt marshes (Broome, Rogers and Seneca, 1994).

The selection of site or landscape planning is one of the critical roles landscape architects should play in helping to create salt marsh. A created salt marsh ecosystem can provide similar functions and values of a natural marsh ecosystem if it is properly located and appropriately designed according to site conditions (Garbisch, 1989). It is suggested that self-sustaining salt marsh, in terms of energy productivity and plant cover, can be created within 2-year period (Broome, Seneca and Woodhouse, 1974, and Garbisch, McCallum and Woller, 1975). Ultimately, a longer duration of monitoring a created wetland is requisite to determining what is self-sustaining (Skabelund, 1994).

To create self-sustaining ecosystems, landscape planning processes must reflect the ecological and cultural needs of the site or community to determine the composition of a proposed marsh. The areas with significant natural and cultural values should be identified so that a proposed marsh construction site would not conflict with such significant areas (Clark, 1974).

The created salt marsh ecosystems can provide improved qualities for fish and wildlife habitat, water and pollution control, and shoreline stabilization, according to the needs of individual sites. Such ecosystems create new patterns and edges in a site and can lead to a more stable and diverse biological community (Garbisch, 1989). Location for salt marsh creation should therefore be determined based upon the potential of a site to establish a wetland ecosystem that provides specific functions and values, in addition to fitting into the surrounding landscape.
Finally, the regulatory and consulting resource agencies must review the proposal and provide input or comment after selection of the salt marsh's location and documentation of the goals and objectives of the salt marsh creation (Garbisch, 1986).

b) Permit Application

Permit requirements for the 404 program regarding coastal salt marsh creation vary from district to district (Woodhouse, Jr., 1979 and OTA, 1984). In general, the 404 permitting process requires detailed wetland construction plans and specifications. Garbisch (1989 and 1990) provides the basic requirements that the plans and specifications must include:

1) Plans on 1" = 100' or larger scale showing one (1) foot contours or less; locations and elevations of all benchmarks on the site; information on slopes; all structures and planting zones; site hydrology (pool elevations, seasonal pool elevation, MHW and MLW); verification of the local hydrology including vegetative zonation of salt marsh.

2) sufficient cross-sections of land and structures; elevations and elevation ranges for the planting and seeding of all plant species shown on the plan with plant spacing and seeding rates.

3) notes and specifications with plant lists, acceptable plant conditions; the suppliers' germination results; fertilization requirements; special conditioning of plants; geographical constraints; names and addresses of all sources of plant materials; kinds and sources of field collected plant materials; construction details and time table for any required controls against wildlife predation; details of landscape guarantees and maintenance programs to be undertaken during and after the guarantee period.

4) information on the land surrounding the created salt marsh, including transition and buffer zones and affects on/by upland areas.
5) a summary of the size and types of the wetland/non-wetland habitats lost and created.
6) a summary of the volume of earthwork and total tonnage of stonework.
7) the construction time table, including: notations of all critical elements for biological success; coordination of earthwork with the installation of certain species of plants; minimization of salt buildup in soils and reduction of damage due to wave action and climatic variation; timing of plant installation or seeding to minimize the impact of waterfowl, drought or floods and to increase likelihood of proper establishment.
8) a reporting timetable and monitoring program.

The plans and specifications are the most important parts of the project. Within these documents, landscape architects and related professionals must account for the larger landscape context, including both ecological and cultural needs of the region and site specific constraints.

c) Site Preparation
The purpose of site preparation is to bring the site to final grades for planting the salt marsh. Planting areas typically require slopes ranging from 15:1 to 5:1 (6.6% to 20% slope) with minimum widths of six (6) meters (Figure 2.2). Such slopes and widths will help prevent erosion and support growth of salt marsh species (Knutson, 1981 in Knutson and Woodhouse, 1982, and Shiler, 1990).

The elevational zone of a potential planting area should be determined relative to the water levels on the nearest natural salt marsh (Broome, Rogers and Seneca, 1994). Site preparation particularly deals with hydrology, soils and plants, and structures.

* hydrology: Local tidal regime can be determined by the following two methods. (1) The standard tide tables from the National Ocean Survey provides the mean highs and lows relative to Mean Lower Low Water (MLLW) at many subordinate tide stations. The information on the tables has to be converted to the National Geodetic Vertical Datum (NGVD) to provide a reference for the construction.
The Office of Oceanographic and Marine Assessment of the National Ocean Service provides the elevations of MLLW relative to NGVD (Coats and Williams, 1990). (2) On-site or near-site wetlands are used as "biological benchmarks" to define the elevational limits of high marsh, low marsh, mudflat, and open water (Garbisch, 1989).

(Figure 2.2) Typical Section of Salt Marsh Creation
(Source: Garbisch and Garbisch, 1994, and Perry, 1994)

Along the Atlantic Coast of the United States, elevation of local Mean High Water is determined by averaging several lowest elevations of on-site or near-site higher marsh species: *Spartina patens* ('Saltmeadow Hay), *Iva frutescens* (Marsh Elder), *Baccharis halimifolia* (Groundsel Bush) and *Panicum virgatum* (Switchgrass). Based upon the estimated elevation of MHW, elevation of Local Mean Low
Water is calculated from the Average Tidal Range Tables of "National Oceanic and Atmospheric Administration Tide Tables" (Garbisch and Garbisch, 1994).

If there are any pockets of poor drainage found on the site, these should be eliminated by grading to avoid accumulation of standing water (Knutson and Woodhouse, Jr., 1982a & b). If there is an existing salt marsh on the site, site grading should conform to the existing topography to maintain the natural hydrology of the marsh (Garbisch, 1986).

* soils and plants: Coastal salt marshes generally grow on a wide variety of substrates on mineral soils ranging from coarse sand to fine clay, and on peats and mucks of varying organic content. Large areas of natural marshes are often found on organic substrates; however, these are considered to be the least desirable soil conditions to use for salt marsh creation because the vegetation in such marshes was generally established before the thick peat formations developed (Woodhouse, Jr., 1990).

Well-sorted medium to fine sand with little silt or clay creates naturalistic substrates for plants and animals to colonize in the Atlantic Coast of the United States (Cammen, Copeland and Seneca, 1974). Toxic concentrations within sediments usually do not occur in the sandy soil marshes (Woodhouse, Jr., 1979). Also, plant productivity of *Spartina alterniflora*, which is common on the Atlantic coast, has proven to be higher in compacted substrates combining fine to very fine sand with a little clay or silt than in fertilized, pure uncompacted sandy substrates (Garbisch, McCallum and Waller, 1975). The appropriate proportions of sand, silt and clay should be determined, based upon the conditions of nearby natural marshes.

The overhead plane of marsh planting areas may have to be partially or fully cleared landward to bring enough sunlight to the created marsh (Knutson and Woodhouse, Jr., 1982a & b). Exposure to sunlight is an essential requirement for the growth of all salt marsh plants. At least six hours of direct sunlight is necessary for vegetation in intertidal zones daily during the growing seasons (Garbisch and Garbisch, 1994).

* structures: Full-size and surface stone structures are sometimes installed to stabilize new sediments within a site (Figure 2.3) (Garbisch, 1994). If the existing shore sediments are too soft for stone structures to be stable, a filter fabric (i.e., MIRAFI-700x and AMICO 1199) is typically placed
underneath the stone structures. The height of these structures should be kept low enough so as not to alter the existing wave vector. Stone containment structures have been effectively established in created salt marshes in the Chesapeake Bay when constructed no greater than 15-23 centimeters above restored shore surface (Garbisch and Garbisch, 1994).

(Figure 2.3) Typical Full-size (top) and Surface (bottom) Stone Containment Structures (adapted from Environmental Construction, Inc., 1991 and 1994)

If wave energy is too strong for salt marsh to be established, an offshore breakwater or sill should be constructed to protect the marsh (Figure 2.4). Wave energy is affected by slope of the shore, orientation of the site, wind speed and duration, depth of water, and "fetch", or the distance the wind blows over water (Broome, Rogers and Seneca, 1994). A site with prevailing wind or steep slopes, or one that is exposed to more than approximately five kilometers of open water, will require wave protection (Knutson and Woodhouse, Jr., 1982a & b and Garbisch, 1994).
The height of these structures are normally slightly higher than local Mean High Water. Breakwaters are typically located at the seaward edge of planting zone less than 0.9-meter deep in water and usually 6 to 30 meters offshore. During storm events, breakwaters will be underwater, and salt marsh will function as shoreline protection (Broome, Rogers and Seneca, 1994 and Perry, 1994). Breakwaters can
be constructed by wood or stones. Both materials work equally well in terms of protecting shore from wave energy. From an ecological standpoint, wooden structures will provide no or very minimal habitat for wildlife. On the other hand, stone structures create new habitat for crabs, snakes, oysters and small mammals (Perry, 1994).

The timing of construction is a very important concern in site preparation. The final grading of planting sites has to be ready well in advance of the growing season for vegetation, as long as climate and other regional situations permit access to the project site (Broome, 1990 and Skisler, 1990). Planting should be done well before or after the area is exposed to annual high-wave stress or seasonal animal appearance (Garbisch, McCallum and Woller, 1975).

d) Planting

Planting in a created shore should be conducted 2 to 4 weeks after fine grading, thus allowing designer to see how stable the shoreline is (Garbisch and Garbisch, 1994). Since newly graded sites in tidal areas are vulnerable to disturbance, it is important to select plant species that would establish maximum ground coverage over the site as quickly as possible. Herbaceous plant species are useful in initial establishment and will provide for fish and wildlife habitat and rapid substrate stabilization (Garbisch, 1986).

Initial planting is usually accomplished by transplanting from pots for most shoreline areas (as opposed to direct seeding). Transplanting ensures higher rates of establishment in the intertidal zones (Broome, Rogers, and Seneca, 1994). It is best to specify perennial plants that are commercially available, that are known to serve marsh functions as designed, and that have proven to be successful under similar site conditions for other salt marsh creation efforts. Transplanted materials (wild or nursery plants) should also be collected within a 100-mile (160 kilo-meters) radius of the project site. Transplanting in the lower salt marsh will generally be successful when planted with peat pot top less than one centimeter below the compacted fine sand substrate surface or as deep as ten centimeters below uncompacted sand substrate surface (Garbisch, McCallum and Woller, 1975). Salinity gradients among higher marsh may develop at toxic levels due to occasional precipitation and tidal flooding in the dry summer period. In the sites where the salinity in the soils causes a toxic condition, freshly prepared sediments should be used. Also, plants should be transplanted 12 to 18 centimeters below the surface substrates where salinity gradients are likely to be lower in the soil profile. Fertilization of plants in such sites should not be allowed (Garbisch, 1989).
If low marsh plant species have been established by planting, the natural process of accretion may occur and result in the establishment of more diverse communities in high marsh over time (Garbisch, 1986). Zonation patterns of vegetation can be created by planting a number of species, particularly when the planting area is manipulated to cover a range of elevations (Adam, 1990). Plant species and zonation should be determined according to regional characteristics of the shoreline and biological requirements of the plants so that a proposed ecosystem be adaptable in the site.

Ideally, created salt marshes will be designed and constructed to function as self-sustaining ecosystems similar to natural systems (Kentula and Kusler, 1990). However, the natural functions of the coastal marshes are too complex to be specified in detail in the construction contract, and the project marsh may not necessarily develop according to its engineering or landscape plan (Weller and Zedler, 1990). Natural processes and functions of a created salt marsh ecosystem such as nutrient cycling, water exchange, and niche availability for micro and macro-organisms change as the organic content of substrates and their chemical and physical characteristics change over time (Garbisch, McCallum and Waller, 1975). After initial planting, it will take time for self-maintaining systems to evolve. It may be necessary to replace plants washed away, eroded, depredated or vandalized (Broome, 1990).

It was reported that subsurface application of fertilizers in uncompacted sand substrate improved survival rate of transplants, while fertilization of compacted fine particle substrate showed high mortality (Garbisch, McCallum and Waller, 1975). The result implies that the application of fertilizer increases root growth, which is important to stabilize shorelines. In any case, surface application of fertilizer must not be allowed in order to prevent chemicals moving into already nutrient-rich estuarine waters. If the establishment of initial plantings is important to control erosion, a subsurface application of fertilizer (Table 2.1) can be done by directly releasing 1/2 oz of recommended fertilizers per plant in the holes created next to the transplants so that fertilizers go into root systems (Broome, Rogers and Seneca, 1994 and Perry, 1994).

Note that all projects should be monitored to manage unexpected problems until the initial plantings are established. The period of establishment should be specified in the landscape contract. At minimum, monthly site inspections should be required for a full growing season and at the beginning of the second full growing season (Garbisch, 1986).
(Table 2.1) Recommended applications of fertilizer

<table>
<thead>
<tr>
<th>Fertilizer Material</th>
<th>Analysis N-P₂O₅-K₂O</th>
<th>Approximate Amount/Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osmocote (8-9 month release)</td>
<td>18-6-12</td>
<td>0.5-1.0 oz.(2-4 tsp.)</td>
</tr>
<tr>
<td>Osmocote (3 month release)</td>
<td>14-14-14</td>
<td>0.5-1.0 oz.(2-4 tsp.)</td>
</tr>
<tr>
<td>Mag Amp Osmocote</td>
<td>7-40-6</td>
<td>0.5 oz.(2 tsp.)</td>
</tr>
<tr>
<td></td>
<td>14-14-14</td>
<td>0.3-0.6 oz.(1-2 tsp.)</td>
</tr>
<tr>
<td>Ammonium sulfate</td>
<td>21-0-0</td>
<td>0.4-0.8 oz.(1-2 tsp.)</td>
</tr>
<tr>
<td>Concentrated superphosphate</td>
<td>0-46-0</td>
<td>0.2-0.4 oz. (0.5-1 tsp.)</td>
</tr>
<tr>
<td>Mixed fertilizer</td>
<td>10-10-10</td>
<td>0.8-1.6 oz.(2-4 tsp.)</td>
</tr>
</tbody>
</table>

(Source: Broome, Rogers and Seneca, 1994)

e) Protection Needs for Created Salt Marshes

Some projects require more site specific adjustments than others. If the problems with animal depredation become a serious concern, trapping of the animals or fencing off the core vegetative zone may be necessary to protect plantings until the second growing season (Broome, 1990). It is a common practice to build a "goose fence" along the seaward edge of salt marsh where Spartina alterniflora is frequently subject to depredation from Canada geese along the northern Atlantic Coast (Figure 2.5) (Garbisch, McCallum and Woller, 1975).

Salt marsh tends to collect litter and debris such as drift wood, twigs and decaying grasses throughout the zone between Mean High Water and annual extreme high tide. The accumulation of debris is considered to be harmless, and it often provides an additional food source for wildlife (Atkinson, 1994 and Perry, 1994). In large-scale salt marsh creation, ditches or tidal channels through the transition zone between salt marsh and upland should be installed to maintain circulation of the debris and water. The channels should have bottom elevations below Mean Low Water to have constant water circulation with open water. Both ditches and channels will serve to control litter, increase nutrient exchange,
create high habitat diversity, and eliminate mosquito breeding (Garbisch, 1986).

(Figure 2.5) Typical Section of Goose Fence
(adapted from Environmental Construction, Inc., 1994)

In summary, landscape architects should note that issues and concerns related to the establishment of salt marsh ecosystems are highly site specific and require a wide range of cooperative efforts with biologists, ecologists, soil scientists and engineers. The major role of landscape architects is to analyze information on living and non-living elements of the site, identify technical, ecological and cultural opportunities and constraints, and account for those opportunities and constraints in design alternatives.
2.3 Principles of Residential Development with Salt Marsh Creation

Development along coasts often results in a struggle with the natural force of "erosion". Shoreline protection has traditionally been provided by hard structures such as seawalls, bulkheads, revetments, groins, jetties and breakwaters. All these practices will protect properties along coasts for a time, but they will not reduce wave energy itself. This wave energy causes erosion along shorelines, which can eventually result in serious damage to shoreline properties. Also, the impacts of residential development may include the generation of pollution, and the loss of wildlife habitat and scenic values. These impacts on the salt marsh ecosystem and surrounding landscape eventually depreciate the property values of the residential communities built to attract people to the coast.

Natural salt marshes have the potential to prevent the erosion process by providing a dense vegetative cover and gentle slope which dissipates wave energy. Studies have shown that created salt marshes can provide similar ecological services to natural marshes, including such services as shoreline anchoring, vegetative screen for wind protection and privacy, and water purification (Broome, Seneca and Woodhouse, Jr., 1974, Cammen, Copeland and Seneca, 1974, Garbisch and Garbisch, 1994).

Since much of the nation's coastal areas have been impacted by human activities, it is our responsibility to recreate areas for wildlife to come back to for resting, feeding, breeding and nesting. Thus, created salt marshes not only ensure the safety of property and filter runoff, they also provide habitat for fish and wildlife. Because laws and regulations chiefly set constraints on development along coastal areas, it is up to landscape architects and other professionals to improve the quality of human and wildlife habitats in coastal zones by incorporating salt marsh creation into the design process.

Residential Developments

As mentioned earlier, a salt marsh is a part of complex system in which environmental attributes (wind, water, sun, soil, etc.) affect numerous species (plant and animal) and functions. Design must account for these based upon the objectives of the project and the ecological and cultural characteristics of the region (USDI, 1993).

The capacity of a development should be determined based on the suitability of site resources to proposed activities; such activities need to be adaptive to existing regional resources, including site
hydrology, sensitive aquatic habitats, and cultural landscapes (USDI, 1993, and DWE and HMD, 1993). Since the critical component to a functioning wetland ecosystem is a site's hydrology, altering variables such as freshwater runoff patterns and tidal regimes can have significant detrimental effects on both existing and created salt marshes.

Clark (1983) describes two fundamental rules in placing development in coastal areas: 1) ensure that water leaves the site in (as nearly as possible) the same quality, volume, and rate of flow as pre-disturbed conditions, and 2) provide an extra buffer strip of native vegetation between residential developments and the marshes to purify urban runoff before it reaches coastal wetlands. A third rule may be added which states that areas of impervious surface must be kept to a minimum.

In order to minimize impacts on hydrologic systems in coastal areas, residential cores should be clustered in upland areas behind the annual extreme high tide and state coastal-setback line. Existing salt marshes must be protected for wildlife to utilize. By clustering the development in upland, vehicular movement can be limited within the clustered area, areas of high runoff can be predicted, and much of the upland vegetation can be preserved.

Access
Creation of roadways can have a significant impact on salt marsh hydrology and ecosystem. Thus, roads should be aligned according to the topography and drainage (surface and subsurface) patterns. Unpaved or permeable roadway surfaces should be used within the property (USDI, 1993). Roadways built parallel to the coastal line usually alter or block natural flows of tidal wave and freshwater runoff from the upland, and may change the period of inundation and degree of salinity in the coastal areas. If the road must go across a created salt marsh or existing wetland, it is advisable to elevate roadbeds using pile supports rather than fill so that circulation of tidal waters and penetration of sunlight to the vegetation underneath can be maintained (Clark, 1983). If elevated roadways are prohibitively expensive, roadways must, at minimum, allow for free flow of water in other ways.

Buffer Strips
Buffer strips between salt marsh boundaries and residential cores serve three purposes. Vegetative buffers allow the marsh plant communities to expand or contract along the shore bank and to respond to changing sea levels. This helps marshes increase their resistance to severe effects related to flooding
and erosion. Secondly, buffers serve as environmental corridors, helping reduce the isolation of marshes and facilitating wildlife movements. Vegetative corridors planted with canopy trees, extensive shrub masses, and continuous ground covers will help many wildlife species to recolonize and utilize adjacent marshes (Hiller and Willard, 1990). Lastly, vegetative buffers create privacy between lots and provide residents with opportunities to encounter wildlife species (Schicker, 1987).

**Interpretation Opportunities**

Residential landscapes should include opportunities for residents to appreciate the ecosystem of created salt marshes. Interpretation is a communication measure that makes people aware of natural and cultural resources of the site through sensory experiences and educational opportunities (USDI, 1993).

Residence should be located in such a way that provide maximum visual access to created salt marshes and other wildlife habitats for increased aesthetic value and opportunities to observe nature. Visual exposure of open spaces increase safety of the residents and visitors using these open spaces, as well (Schicker, 1988). Both visual and physical accesses to the diversity of the ecosystems, including created salt marshes, vegetative buffers, woodlands and open meadows, provide a series of sensory experiences. Location of residential cores should also account for local species-habitat relationships to protect the existing wildlife habitats as much as possible.

Research conducted by Mark Frances (1981) at Village Homes in Davis, California, found that the most heavily used outdoor spaces by children were pedestrian and bicycle paths, greenbelts, open drainage areas, and turf areas. Patios and playground were the least used. The research concluded that the most "sacred" places for children were wild or unfinished spaces (Schicker, 1988). Created salt marshes and vegetative buffer throughout the residential areas provides an ideal playground for children. Pedestrian and bicycle paths should be designed to expose created salt marshes and other wildlife habitats to residents.

Boardwalks and observation decks can be created over created salt marshes to provide residents with environmentally sensitive access and opportunities for play and watching wildlife (Figure 2.6) (Schicker, 1987). All structures created in the water should be set on open-pile and/or floating systems and kept within one-third the distance across the waterway so as to minimize disturbance of the natural flow of the ocean tide (DWE and HMD, 1993). Also, the areas of commercial and particular wildlife
and fishery habitats such as shrimp nursery, oyster bed and nesting/wading areas for birds should be protected to maintain the integrity of the ecosystem.

(Figure 2.6) Boardwalk built on wetland (Virginia, U.S.A.)

Any types of wildlife feeding stations such as bird feeders, rock piles and fruit shrubs allow residents to observe wildlife closely (Schicker, 1988). Featuring native shrubs and small trees at the higher high marshes tends to be more adaptive to the site and attract native birds. These hedgegrowns provide seasonal fruits, flowers and leaf colors and add a "sense of place" in backyards (Cyr, 1988).

A balanced relationship between residential cores, created salt marshes and buffer strips is essential to restore the ecological integrity of a site and provide residents with opportunities for interpretation of nature; therefore, each of these must be clearly identified in the master plan.
III. A Landscape Architecture Approach to Incorporate Salt Marsh Creation into Coastal Area Developments

3.1 Conceptual Approach for Salt Marsh Creation by Landscape Architects

Planning and decision-making for salt marsh creation involves *inter-active environmental management*. Randolph (1991) defines *environmental management* as "the means of controlling or guiding human-environment interactions to protect and enhance human health and welfare and environmental quality," and *inter-active environmental management* as "the means of conserving, developing and/or enhancing land and resources through the integration of environmental considerations during planning and decision-making processes".

The primary role of landscape architects in salt marsh creation is to guide human-environment interactions in ways that protect the integrity of both human and wildlife habitats, as well as to improve the relationship between people, animals and the places they live in. Landscape architects should be able to incorporate available and emerging ecological knowledge and conservation techniques of scientific and engineering fields to create more ideal natural and cultural habitats for both humanity and wildlife.

Landscape architects play an important role in the decision-making processes by analyzing the landscape, evaluating its potential and providing design alternatives to meet certain "program" objectives. In industrial societies, environmental considerations are grounded in human values. In order to integrate environmental considerations into the decision-making process, landscape architects must understand the meaning of "the natural and cultural integrity of an ecosystem" (Regier, 1993).

*Natural Integrity of Ecosystem*

In order to understand the natural integrity of salt marsh ecosystems, a discussion of the larger landscape is necessary. Coastal landscape consists of several different ecological units such as upland (beyond 100-year storm tide), floodplain (between annual extreme high tide to 100-year storm tide), estuarine water area including wetland (from annual extreme high tide to open waters) and open waters (Clark, 1974). All of these ecosystems are interconnected by energy flows of water, wind, light and micro-organisms (see 1.1 & 1.2 in this thesis).

The functions of a salt marsh ecosystem will affect its surrounding ecosystems, while activities in the
surrounding ecosystems will also have a tremendous impact on the salt marsh ecosystem. Therefore, the long-term success of salt marsh creation efforts requires planning with the larger context in mind, as well as specifically accounting for connections with open water, wetland and upland (USDI, 1993).

In order to maintain natural integrity of the ecosystem and maximize opportunities for interpretation of nature, it is essential to maintain and create different types of habitats, including salt marshes, vegetative buffers, open fields and woodlands (Schicker, 1987).

**Cultural Integrity of ecosystem**

As interests among people differ, the land that provides opportunities for these people may differ. The notion of cultural integrity relates to how people view nature. Each individual and society may find a symbolic meaning in the surrounding ecosystem and in events occurring within the ecosystem. The meaning of ecosystem integrity may be symbolic of our personal interpretation of the various phenomena of nature (Ryder, 1990).

The integrity of salt marsh ecosystem is associated with human values of nature grounded in the following four viewpoints, as classified by Regier (1993): exploitist, utilist, integrist and inherentist.

*An Exploitist* is one who views nature as valueless in itself. This is a highly market-oriented perspective common to developers, bankers and business people.

*A Utilist* is one who views some areas of nature as valuable, other areas of no concern, and other areas as harmful. Utilists are often called as "conservationist", and commonly share a consumers' viewpoint (Norton, 1989 in Regier, 1993). This is the most typical perspective shared by people from different regions and all works of life.

*An Integrist* is one who views all natural phenomena as equally important, but holds that not all of our cultural activities are important (Norton, 1989 in Regier, 1993). Integrist interests reflect the importance of "land" as advocated by Leopold (1949). The integrist perspective states that human culture must have respect for the land and be adaptive to natural processes of evolution. This thought is a key one for designers creating anything on the land in order to attain long-lasting landscape.

*An Inherentist* is one who views all living organisms and all non-living phenomena as equally important, as individual human beings. Nature is valued beyond human culture, whether nature brings benefits to our society or not (Reiger, 1993).
All four types of perspectives have historically been used to justify developments associated with salt marsh ecosystems. Exploitists view salt marshes as a wasteland, and have dredged and filled these marshes for market-oriented benefits. Utilist interests share a similar view to exploitists but recognize the productive processes of a salt marsh and utilize it for hunting and fisheries. Integrists try to control and restrict selfish interests of the exploitist and utilist in order to retain the integrity of natural and cultural ecosystems. The interests of inherenists and integrists share common ground in which their decisions toward human-environment interactions are nature-oriented. Inherenists seek to preserve natural landscape for wilderness and protect it from exploitists and utilitists (Regier, 1993).

<table>
<thead>
<tr>
<th>Natural Integrity</th>
<th>Cultural Integrity</th>
</tr>
</thead>
<tbody>
<tr>
<td>* varieties of habitat types (open water, wetland, forest, field and edges)</td>
<td>* symbolic meaning for humans * interpretation of natural phenomena</td>
</tr>
<tr>
<td>* flows of energy (light, nutrients, microorganisms, water and wind)</td>
<td>* compromise between human control over natural processes and successions of natural processes</td>
</tr>
</tbody>
</table>

(Source: Lyle, 1985 and Regier, 1993)

It will be very difficult to satisfy all of the needs of the aforementioned perspectives through design. Designing a place for people with the four different interests will involve some compromises because of the inherent conflict among them.

Landscape architects may find hope by expanding the integrists' viewpoint to make compromises with others and improving human perceptions of salt marshes through design. Design should provide opportunities for residents or visitors to gain personal interpretations of salt marsh ecosystems through sensory experience.

Lyle (1985) discusses the theory of "human ecosystem", where "ecology" is used as a basis for designing human habitats. His theory of the design approach is grounded in compromises between human control over natural processes and the succession of natural processes. This approach for "human ecosystem" provides a basis for landscape architects to attain the integrity of salt marsh
ecosystem.

**Ecological Approach for Design**

Koh (1981) states that the form of an organism (phenotype) is a product or process of interaction between the larger environment (genotype) and its immediate conditions in natural ecological states (Figure 3.1). This theory of ecology is applied to explain architectural or landscape architectural form as "the product of interaction of human evolutionary purpose 'freedom and efficiency' and human ecological context 'adaptability'" (Koh, 1981).

(Figure 3.1) Design Approaches (Source: Koh, 1981, Lyle, 1985, and Booth, 1991)

This concept of form leads us to see an object as related to its larger and immediate ecosystems and a form as a result of processes occurring within the system as well as processes outside the system (Koh, 1981).

Lyle (1985) and Koh (1981) discussed ecological orders and principles of form (Table 3.2). Lyle
(1985) introduced the three modes of order that apply the form of ecology to a landscape design to make human ecosystems work and to fulfill their needs. The order was broken down into "structure", "function" and "location" in order to gather information about the site and effectively integrate it into the design process.

(Table 3.2) Orders/Principles of Ecological Forms

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Three Modes of Orders&quot;</td>
<td>&quot;Three Principles of design&quot;</td>
</tr>
<tr>
<td><em>structure</em></td>
<td><em>inclusive unity</em></td>
</tr>
<tr>
<td>* elements in the ecosystem and relationships of these elements</td>
<td>* unity within the design as well as with the ecosystem</td>
</tr>
<tr>
<td><em>function</em></td>
<td><em>dynamic balance</em></td>
</tr>
<tr>
<td>* conditions required by elements in the ecosystem</td>
<td>* adaptability of the design to change in the ecosystem</td>
</tr>
<tr>
<td><em>location</em></td>
<td><em>complementarity</em></td>
</tr>
<tr>
<td>* suitability of an individual site</td>
<td>* harmonious relationship in seeming contradictions</td>
</tr>
</tbody>
</table>

(Source: Koh, 1981 and Lyle, 1985)

"Structure" refers to elements in the ecosystem and the relationships of these elements (i.e., a particular species and its food web), which is analyzed by their form, density, dominance, relative abundance and trophic structure. "Function" refers to the distributions of energy and materials through the structure (i.e., hydrology, air, light, etc.), which is observed by the patterns and types of flow. "Structure" and "function" of the site indicate the characteristics of the ecosystems and conditions required by plants, animals and people to live. "Location" refers to the conditions of the site (i.e., landform, climate, existing development, etc.), which indicates demand and suitability of a site. All these information are used to create a new order "human ecosystem" complementarily with the existing ecosystems in the landscape (Lyle, 1985).

Koh (1981) derived three design principles from ecological forms: "ecological unity", "evolutionary balance", and "complementarity". "Ecological unity" refers to "unity of itself as well as with
environment and function", in which design must fit a local ecosystem and a human ecosystem to fulfill its need and maintain the "sense of place". "Evolutionary balance" refers to the adaptability of the design to change and grow in the ecosystem, which is attained by understanding natural processes. "Complementarity" refers to harmonious relationship in seeming contradictions (i.e., between efficiency and freedom, thought and feeling, and building and garden) (Koh, 1981 & 1988).

Lyle (1985) identifies orders to an ecosystem, and Koh (1981) provides keys to attain these orders of the new ecosystem. The structure of the designed ecosystem must have a unity within itself and with the surrounding ecosystems. The function of the designed ecosystem should be adaptive to the ecosystems and natural processes. The location of the elements of new ecosystem must be complementary to the existing conditions.

If a salt marsh and surrounding environment are created according to these principles and orders of ecology, "function" of the created salt marsh will follow its "form" (Koh, 1981, and Franklin, 1991 in McCormick, 1991). In other words, a created salt marsh will fit in the pattern of natural landscape and function with the surrounding ecosystems. Through an approach based upon the understanding of both natural processes and cultural values of the landscape, residential developments with created salt marshes can attain the ecological integrity of potential niches for both people and wildlife. It should be noted that, in some cases such as barrier islands where the dynamic natural forces constantly change their physiographic characters and ecosystems, it would be wise to stay away from these sites to avoid natural hazards.
3.2 The Planning/Design Approach for Salt Marsh Creation and Coastal Area Development

Salt marsh creation typically involves planting of certain species. Landscape architects have traditionally used plant materials in the same manner as they have treated other design elements such as landform, buildings, pavement and water to achieve design goals. Plant materials are very important in landscape architecture to meet the objectives of the designer and to solve environmental problems (Booth, 1983).

McCormick quoted from Franklin (McCormick, 1991): "Because of the global environmental crisis, 'water, soil and vegetation will be everything'. Landscape architects will be forced to adopt 'an organic aesthetic that reveals the process of the place'." Incorporation of salt marsh creation into residential development is a way to reveal the ecological processes of the place and increase residents' awareness of nature.

In order for landscape architects to incorporate salt marsh creation into the design process, the model approach must account for the largest possible context to deal with natural processes and cultural needs in the site (Lyle, 1985). The approach should respond to the primary environment within the broad landscape context and the immediate ecosystem to ensure the created salt marsh fits in the landscape both functionally and visually (Koh, 1981 and Booth, 1991).

Lyle (1985) defines a systems approach as "a logical structure for problem solving that emphasizes interrelatedness" and describes several different approaches. Although these approaches imply linear-sequential steps, human modes of thinking repeat the creative side of "proposing" and the analytical side of "disposing" throughout design processes. The process should be interactive so that planners/designers are open to new information on issues, objectives, impacts and alternatives throughout the process (Lyle, 1985 and Randolph, 1991).

Lyle (1985) divides design process into three stages advocated by Whitehead (1929); "stage of romance", "stage of precision" and "stage of generalization" (refer to Figure 3.1 in 3.1). "The stage of romance" involves in understanding the implications of the landscape and establishing the foundations for the entire design process. "The stage of precision" requires detailed analysis of the implication for design purposes. "The stage of generalization" represents the final stages of the systematic approach and involves the development of a plan, as well as its implementation and management (Lyle, 1985).
Application of systems approach with salt marsh creation requires specific considerations on environmental attributes such as hydrology, soils and vegetation in order to attain the functions and values that a created salt marsh is intended to provide. Coats and Williams (1990) summarized four basic steps for designing a wetland restoration; 1) define the objectives, 2) determine the topography and tidal regime at a site, 3) analyze the opportunities and constraints imposed by local biological and physical conditions, and 4) develop design alternatives. Weller and Zedler (1990) discuss the importance of regulatory and permitting processes, design criteria, and post-construction monitoring plans. The model approach emphasizes these important processes of wetland restoration and creation for landscape architects to incorporate salt marsh creation into coastal area residential developments (Figure 3.2).

**Goals and Objectives**

The primary goals of salt marsh creation have already been defined as shoreline protection and wildlife habitat creation. The initial proposal should discuss the principal functions of the created salt marsh and wildlife species that the design is intended to provide and the benefits associated with them (Weller and Zedler, 1990). Landscape architects must make sure that the design will maximize those benefits of the salt marsh creation and will provide the opportunities for residents to interpret the ecosystem.

**Site Inventory and Analysis**

The base plan for salt marsh creation should be 1" = 100' or larger, including property lines, topography (one-foot contour intervals), vegetation, bodies of water, built structures, access, utilities and immediate off-site conditions. This information can be supplied by the client or obtained from on-site survey and aerial photographs (Booth, 1983, and Garbisch, 1989 and 1990).

Inventory refers to the data collection which is involved in the identification and recording of "elements" in the landscape. Analysis involves decision-making about the importance of the "elements" and their "structures" and "functions" in the landscape (Booth, 1983 and Lyle, 1985). This is where "stage of precision" takes the place of the "stage of romance," in Lyle’s terminology.
Salt Marsh Creation and Resedential Development

Clients/Public

Goals and Objectives
- marsh functions
- target species
- economic welfare

Site Inventory & Analysis
- identification of elements/structure
- existing landscape
- analysis of landscape function

Large-scale analysis
- hydraulic systems
- habitat/species analysis
- natural/cultural resources (Ecological/Cultural Characteristics)

Small-scale analysis
- local tidal regimes
- suitability of the site
- regulatory requirements (Opportunities and Constraints)

Detail Program & Design Criteria
- identification of elements and their functioning structure in the design
- identification of specific marsh functions and their benefits to the property

Design Alternative
- application of Design Criteria to the site design
- integration with ecological and cultural characteristics of the site
- consideration of opportunities & constraints of the site

Final Design & Monitoring Plan
- detail site plan with construction details
- evaluation period and hierarchy in evaluation criteria

Determines - location of developments, salt marsh creation and wildlife habitats
- habitat types and wildlife utilization

Specify - form (special pattern) of designed environments
- access and interpretation opportunities
- economic welfare to the property

Review - evaluation criteria

Related Professionals
- biologists, ecologists, economists, engineers, soil scientists, etc.

Notes: ——— indicates inputs
- indicates decision points

(Figure 3.2) Model Approach for Landscape Architecture
This process should improve our broad knowledge of regional concerns such as micro-/macro-climate, local flood protection needs, local run-off, potential shoreline erosion, local sediment transport and deposition rates, accumulation of floating debris, soil or substrate characteristics, water quality, presence of buried debris or toxic wastes, local plants and animal species that may utilize the site, regional pattern of bird movement, potential vector (mosquito) problems, control of exotic species, and local land use (Coats and Williams, 1990 and Weller and Zedler, 1990).

There are at least three basic conditions to be inventoried and analyzed for salt marsh creation: a) site hydrology and topographic information, b) habitat-species relationships, and c) significant natural and cultural resources. Inventory and analysis can be as large as a watershed or city district to make sure the design fits in the larger ecological and cultural contexts.

a) Site Hydrology and Topographic Information

Hydrology is a source of the energy flow and nutrient exchange and determines the type of ecosystem created. Inventory must identify information on tidal regime, including timing and duration of inundation, in relation to topography. The elevation of the land related to the tidal regime indicates types of vegetation and animals colonizing and utilizing the site. Landform indicates the direction and duration of sun exposure, directions of prevailing wind, and natural drainage system. Hydrology and topography provide landscape architects with an idea of what the created salt marshes would look like.

It is essential to predict and control tidal flushing and freshwater input at the construction site in order to support the establishment of salt marsh species and to prevent negative impacts of the construction on the coastal waters ecosystem (Zedler, 1988). Hydroperiod of the site should be taken from the site and existing marshes on/near site by actual site survey to restore the historic patterns and quality of natural waterflows. Restoration of the natural hydrologic system is essential to ensure the safety of the land from storm or erosion, to support sport and commercial fisheries, to maintain natural vegetative covers and wildlife habitats, and to retain "a sense of a place" (Clark, 1974).

b) Habitat-species Relationships

A series of biotic inventories must be made to gain the information on the local species, species composition, and patterns of their distributions (Shonman, 1990). All animals except insects should be identified to species, and insects should be identified by family. Information on these specific species-habitat relationships around the site should be inventoried in order to restore wildlife habitats and
protect them from development impacts (Cammen, Cope and Seneca, 1974).

Presence of local wildlife and their niches are essential components of a "sense of place". Potentials of each site to accommodate these species should be evaluated to create the detail program (Zedler, 1988).

c) Natural and Cultural Resources

Natural features that are rare, unique, or with significant economic value are important resources to be inventoried. Low marsh areas that provide nursery grounds for shrimp and other sport and commercial fisheries are of significant importance. The significance of a cultural resource is usually evaluated on the basis of artistic or scientific merit, and importance as a part of landscape or as "viewshed", often associated with historic, local or cultural events or people (USDI, 1993).

Inventory should also include land use conditions within and around the site. Land use patterns and conditions around the site indicate characteristics of the neighborhood, including architectural style, vegetation, significant natural and cultural features, and views and vistas (Booth, 1983).

The larger the project scale or plan unit, the more complex information and technique become. Matrix and map overlays methods advocated by Ian McHarg (1969) are convenient to identify the land suitability for different uses. Since not all information is apparent or static, Lyle (1985) suggests to use several types of "graphic models" to manage the complexities and uncertainties in the landscape. Modeling of landscape provides means to visually present the linkages between forms and invisible processes of energy flows underneath the landscape (Lyle, 1991).

Identification and analysis of these variables require interdisciplinary co-operation in any scale of landscape design from backyard to community-scale (Lyle, 1985). Related professionals such as biologists, hydrologists, geomorphologists, soil scientists, economists, and engineers will be beneficial sources of information for landscape architects to create inventory of the regional landscape and to identify specific opportunities and constraints of individual sites (Coats and Williams, 1990).

Opportunities and constraints of the site indicate the capability of the site to create salt marsh ecosystems and wildlife habitats, as well as providing opportunities for interpretation that meet ecological and cultural needs of the region within the context of residential developments. Table 3.3 describes the attributes of salt marsh creation and basic land use requirements to determine the
capability of the site.

Finally, most coastal states and counties have regulations controlling development along coastal areas. Salt marshes are registered as "critical areas" in many states (Clark, 1983 and Garbisch, 1994). Regulatory requirements must be reflected in the opportunities and constraints of the site.

**Detail Program and Design Criteria**

Based on the findings from the site inventory and analysis process, landscape architects must refine the program and develop the detail design criteria. It is in this stage to clearly indicate the principal functions and values of the created salt marsh and target wildlife species, including plants and animals, and their benefits to the property (Weller and Zedler, 1990).

Design criteria specify ways to implement the proposed program. Design criteria must reflect ecological and cultural needs of the region and basic land use requirements associated with the immediate conditions of the site. The client's needs and wishes should be reflected in the design criteria. All the people who will be using and maintaining the site should be interviewed by the designer so that the design accommodate their needs (Booth, 1983). Any types of the structural aid to help establish salt marsh ecosystems must be described in detail. Design criteria should also specify ways to maximize interpretation of the ecosystem and sensory experience of the residents.

The design intention and implication of salt marsh creation such as shoreline protection, wildlife habitat creation and interpretation opportunities should be understood by the clients. Involvement with residents throughout design and monitoring processes will help them understand, enjoy and protect their investments (Tregay, 1986).

**Design Alternatives**

The purpose of providing alternatives is to search for the potential of the site to attain the proposed "structure" of the landscape. The alternatives should provide ways to maximize the principal functions and values of the created salt marsh and opportunities for interpretation of nature proposed in the detail program and design criteria.
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYDROPERIOD</td>
<td>the average daily submergence period, the longest period of continuous submergence</td>
</tr>
<tr>
<td>ELEVATION AND SLOPE</td>
<td>the potential location and width of a marsh in relation to the tidal range</td>
</tr>
<tr>
<td>WAVE CLIMATE</td>
<td>severity of waves indicated by slope of the shore, orientation of the site, wind speed and duration, depth of water and &quot;fetch&quot; (distance the wind blows over water)</td>
</tr>
<tr>
<td>SALINITY</td>
<td>salinity in the regularly flooded area, hypersaline conditions over a dry period in the irregularly flooded area</td>
</tr>
<tr>
<td>SUBSTRATE</td>
<td>types of substrate (mineral soils from coarse sand to fine clay, and peats and mucks of organic contents) and toxic concentrations</td>
</tr>
<tr>
<td>SUNLIGHT</td>
<td>exposure to sunlight (at least six hours of direct sunlight for marsh plants)</td>
</tr>
<tr>
<td>PRODUCTIVITY</td>
<td>biological use of a site</td>
</tr>
<tr>
<td>SAFETY</td>
<td>safety from loss of life, property damage, etc.</td>
</tr>
<tr>
<td>STABILITY</td>
<td>substrate stability, protection from slope hazards, etc.</td>
</tr>
<tr>
<td>HEALTH</td>
<td>protection from deleterious hazards, diseases, infection, etc.</td>
</tr>
<tr>
<td>COMFORT</td>
<td>micro-climatic influences upon humans</td>
</tr>
<tr>
<td>ACCESSIBILITY</td>
<td>ease of circulation with minimum adverse impact on the ecosystem (vehicular and pedestrian movement)</td>
</tr>
<tr>
<td>UTILITY</td>
<td>ability to service a site as necessary</td>
</tr>
<tr>
<td>Wildlife Habitat</td>
<td>existing distributions of wildlife in and around a site, availability of food, protection and corridors</td>
</tr>
<tr>
<td>AMENITY</td>
<td>enjoyment of a site</td>
</tr>
<tr>
<td>SPATIAL PATTERN</td>
<td>relationship to adjacent land uses or land pattern</td>
</tr>
</tbody>
</table>

As a design should recognize a distinction between the general design that respond to the broad ecological and cultural contexts and the specific design that respond to the immediate ecosystems, design alternatives should seek the ideal "structure" to meet the requirements of the coastal ecosystems and specific opportunities and constraints of the site (Koh, 1981 and Booth, 1983). These alternatives must specify the alteration of the topography, the tidal regimes for the created salt marshes, and the volume of the cut and fill materials.

**Final Design and Monitoring Plan**

The final design should be selected and refined after the regulatory agencies, other professionals and user groups involved in the project have a chance to review the design alternatives and comment on them. The final landscape architecture and engineering plans should be presented with a site grading plan, detail plans for any proposed structures, and specifications for planting strategies (see 2.3 in this thesis).

The monitoring plan must be presented to see how well the project matches its goals, including biological and hydrological functions of the created salt marsh (Garbisch, 1986, Erwin, 1989, D'Avanzo, 1989, Weller and Zedler, 1990, and Coats and Williams, 1990). Scientific research has shown that self-sustaining salt marsh, in terms of energy productivity and plant cover, can be created within two-year period (Broome, Seneca and Woodhouse, 1974, and Garbisch, McCallum and Woller, 1975).

When a wetland is restored or created for mitigation policy, the monitoring plan typically includes annual report of the created wetland to evaluate its performance at least for three years after the construction. Annual reports include documentation of any vegetation changes in percent survival and cover of planted species, several photos describing each vegetative communities, and plan view (Erwin, 1989).

When a salt marsh is created for shoreline protection by engineering or environmental planning firms, maintenance and replacement of the initial planting is generally guaranteed by the responsible firms until one year after the construction (Garbisch, 1994). Landscape architects should be responsible for monitoring the designed ecosystem at least three years to see if the design can actually function as a part of natural ecosystems and how well it meets the detail program.
Methods and criteria for evaluation of wetlands are discussed by numerous sources in the literature. Atkinson, et al (1993) discusses vegetation as a primary parameter for monitoring plan to calculate percentage wetland and upland. Erwin (1989) describes several quantitative parameters to evaluate plant conditions of artificial wetlands, and he presents a generalized qualitative evaluation technique referred to as "vegetation mapping". Vegetation mapping identifies different types and communities of vegetation on plan drawings with information on topography, water depth, and wildlife utilization for each vegetation type.

For such a short-term monitoring period as three years, using vegetation as a key parameter seems a reasonable solution. Sediment composition such as proportions of sand, silt, clay and organic contents and salinity gradients are major determinant factors for distribution and establishment of marsh flora and fauna; however, development of these organic matters may take four to twenty-six years and salinity gradients change according to fluctuating hydrologic regimes over seasons and years (D'Avanzo, 1989, LaSalle, 1991, Levin and Mey, 1991, and Atkinson et al, 1993). Conditions of sediments, hydrology and salinity of the site can be interpolated by the distribution and establishment of vegetation. The potential for wildlife utilization can also interpreted by the type and density of vegetative communities. Since salt marsh creation is a part of the overall design, conditions of buffer zones and upland vegetation should also be monitored (Erwin, 1989 and Lyle, 1991).
3.3 Criteria for Project Evaluation

Quantitative and scientific approaches to the evaluation of artificial wetlands have been attempted by several scientists. D'Avanzo (1989) and Erwin (1989) have extensively discussed criteria to evaluate restored and created wetlands. Table 3.4 summarizes the essence of evaluation criteria. These criteria focus on evaluating a created salt marsh in a broad landscape context including the relationship of existing, proposed and potential development in adjacent uplands. Criteria help to determine performance of elements in the landscape and their structure, how they are experienced by visitors, and how the structures reflect natural ones.

(Table 3.4) Summary of Evaluation Criteria

<table>
<thead>
<tr>
<th>Location</th>
<th>* conditions of the site (hydrology, landform, biodiversity, etc.)</th>
<th>* patterns of natural and cultural landscape</th>
<th>* suitability of the land for salt marsh creation, wildlife species and developments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form</td>
<td>* structure and scale of the designed ecosystems</td>
<td>* adaptability to the natural processes</td>
<td></td>
</tr>
<tr>
<td>Access</td>
<td>* sensitivity to the ecosystem both visually and physically</td>
<td>* exposure and enclosure of the ecosystem</td>
<td></td>
</tr>
<tr>
<td>Habitat Type</td>
<td>* compositions and distributions of wildlife habitats</td>
<td>* potential niches for animal species</td>
<td></td>
</tr>
<tr>
<td>Vegetation</td>
<td>* growth and density of vegetative community</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wildlife Utilization</td>
<td>* food source, protection and nesting area</td>
<td>* circulation corridor</td>
<td></td>
</tr>
<tr>
<td>Shoreline Protection</td>
<td>* adequate planting zone and slope range</td>
<td>* selection of desirable plants</td>
<td></td>
</tr>
<tr>
<td>Interpretation</td>
<td>* sensory experience</td>
<td>* educational opportunity</td>
<td></td>
</tr>
<tr>
<td>Economic Welfare</td>
<td>* longevity and self-sustainability</td>
<td>* amenity of clean water and naturalistic or pleasant landscape for recreation</td>
<td></td>
</tr>
</tbody>
</table>
Each of the criteria should be evaluated according to the natural and cultural characteristics of the sites. Hierarchy in the criteria should vary in each project depending upon its goals and objectives. The criteria will also provide a framework for landscape architects to incorporate salt marsh creation into coastal area residential developments.

a) Location: Location of created salt marshes, other wildlife habitats, and residence in relation to natural and cultural conditions of the site is an essential factor to determine if a project can simulate natural ecosystems. Suitability of the site to accommodate salt marsh ecosystems depends on hydrology of the site. Elevation of created salt marsh in relation to tidal regime controls establishment of plants and utilization by animals.

Natural salt marsh typically develops in shallow water areas protected from excessive wind and wave. The location of the created marsh must resemble the area of natural marsh. The plan must make sure that the elevation of the created salt marsh will support intended plant and animal species. If a shoreline is located under exposure to the excessive forces of wave and wind, protection must be provided. If excavation of subtidal areas or filling in shallow water areas has been done to create salt marshes, the created marshes should improve safety, aesthetics and biodiversity of shorelakes.

Location of upland development in relation to created salt marshes and other open spaces should also be evaluated to see how it maximizes wildlife utilization and opportunities for interpretation of the ecosystem, as well as how it minimizes the negative impacts of developments on coastal waters. Developments in upland must provide enough transition zones from created salt marshes to allow enough sunlight over vegetative areas, slow down urban runoff, and provide vegetative corridors for terrestrial wildlife. Wildlife habitats in upland, including vegetative buffers, should be planned to maximize the circulation of wildlife throughout the property as well as opportunities for residents to encounter wildlife.

b) Form: Form indicates a spacial pattern of the landscape. In designing a landscape, the essential concept of the ecological design is "form follows function, function follows form, and form also follows environment" (Koh, 1981). The spacial pattern of the designed landscape has to be adaptive to the natural processes as well as the cultural context of the site complementarily.
In natural state, form consists of vegetation, soil and water. Compositions of these elements differ according to the natural processes of the site. Each landscape has developed the characteristic forms through years of natural processes.

The form of designed landscape includes slope and width of created salt marshes and other habitat types, as well as built structures and their relationships. These influence hydrology, energy flows, vegetative zonation, wildlife utilization, human experiences, safety and visual quality of the site.

c) Access: Site access includes various types of travel for various people. The most desirable type is the one with least polluting, least intrusive and most quiet aspects to protect the integrity of the ecosystem.

Access within residential development or to wildlife habitats, including created salt marshes, should be limited to pedestrians. Walkways should avoid environmentally sensitive areas such as designated wildlife habitats and existing coastal wetlands. Boardwalks can be presented in created salt marshes to provide sensory experience and educational opportunities while preventing pedestrians from getting into the marshes. Layout of these access should be made to form views and direct attention to natural and cultural landscape features around the site (USDI, 1993). An adequate access to created salt marshes and the natural wetlands is important to provide residents with opportunities for interpretation of nature.

d) Habitat Type: Types of habitats provided in a project will give us a clue to determine what kind of wildlife will be utilizing the site. Habitat type includes both natural and created low/high salt marshes, other water bodies, buffer strips, open fields, piled sand and stones and woodland areas. Vegetative composition within these habitat types is an important factor to evaluate the diversity of wildlife habitats.

Habitat types should be mapped to identify compositions and distributions of each habitat and potential niches for various wildlife species.

e) Vegetation: Vegetative growth and density are influenced by salinity and chemical conditions of substrates, freshwater runoff and available nutrients in the site, and disturbance from animal and human activities. Dense vegetative cover along a created salt marsh allows the marsh to expand landward according to the rises in sea levels and provides the marshes protection from prevailing wind and
increased runoff from development. Establishment of vegetation in and around a created salt marsh indicates conditions of site hydrology and substrates, and potential for shoreline protection (D'Avanzo, 1985, Kentula et al, 1992, Atkinson et al, 1993 and Garbisch, 1994).

Density of vegetative areas can be measured quantitatively by stem density and morphometric measurements which measure the height of stem and number of leaves in each stem for several areas within the site and compares these quantified data to these in reference marshes (Atkinson, 1994).

f) Wildlife Utilization: Surface utilization of created salt marshes by local wildlife species indicates that the marshes are contributing to the ecosystem. It can be analyzed by the actual site visit tracking footprints of the animals and observing birds and fishes visiting the marshes. Density of certain vegetative community ensures food sources and resting areas. Native plant species provides food sources and nesting areas for endemic wildlife. In the Atlantic Coast of the United States, *Spartina alterniflora* provides food sources for small animals, birds and insects and becomes an important source of food web in the estuarine species. Also, native shrubs such as *Baccharis hamifolia* and *Iva frutescens* provide nesting and perching sites for birds.

g) Shoreline Protection: A major purpose of salt marsh creation is to protect shoreline from erosion and flooding. Salt marsh should cover at minimum six meters wide within a slope range of 5:1 to 15:1 in order to effectively dissipate wave energy and trap sediments (Knutson and Woodhouse, Jr., 1983 and Shiler, 1990). If created salt marshes are resistant to erosion and flooding, initial vegetation will grow and expand both seaward and landward up to the limit of tidal influence. In the Atlantic Coast of the United States, native species of *Spartina alterniflora* in low marsh and *S. patens* at high marsh are commonly used for shoreline protection.

h) Interpretation: Interpretation is a communication measure that makes people aware of natural and cultural resources of the site through sensory experiences and educational opportunities (USDI, 1993). Sensory experience includes views, sounds and smells of vegetation, tide and wildlife. Design must tie nature to daily life and provide a comfortable space for residents to enjoy such sensory experiences.

The design with created salt marshes must provide ways to make the value of the ecosystem and beauty of the resources apparent to user groups. On a day-to-day basis, experimentally or regularly, contact
with nature instills in residents an awareness of and symbolic meaning of the ecosystem (Schicker, 1988).

i) Economic Welfare: The property value is dependant upon a wide range of attributes including structural characteristics, socio-economics, neighborhood characteristics, and environmental characteristics (Garrod and Willis, 1992). Since monetary units are widely accepted as a means to equate the value of natural resources destroyed and those developed, it is important to account for the benefits associated with salt marsh creation (Westman, 1978).

The concept of economic welfare and the effects of salt marsh creation is mutually exclusive. Functions of created salt marsh can have effects on humans directly and indirectly through values associated with salt marsh (see 1.3 in this thesis). Meanwhile, values that individuals place on the functions of salt marsh determine the degree of economic welfare or "benefits" of salt marsh creation to their property.

Freeman III (1979) discusses "benefit" in relation to "cost". Coastal area developments often involves the "cost of creating wetland" vs. "cost of losing wetland", "cost of controlling erosion" vs. "cost of erosion", and "cost of protecting wildlife habitats" vs. "cost of destroying wildlife habitats". "Willingness to pay" for salt marsh creation is, to some degree, based upon preferences of people. Therefore, landscape architects must make it apparent that salt marsh creation provides benefits in terms of economic welfare as well.

The economic welfare of a created salt marsh is evaluated in terms of its longevity, self-sustainability and amenity. Longevity indicates the resistance of a created salt marsh to wave actions, freshwater runoff and upland pressure for long term. Self-sustainability indicates low maintenance and ability to re-generate plants and substrates to maintain its functions. Amenity includes clean water and naturalistic or pleasant landscape. The provision of amenity associated with salt marsh creation can provide an economic gain since it increases individual or social welfare through preventing erosion, pollution and health damages (Shechter, 1991). If salt marsh creation provides these economic welfare, salt marsh creation can shift the demand for coastal area residential developments.
IV. Case Study Analysis

Four sites were selected for case study analysis after visiting nine different sites around the Chesapeake Bay (Figure 4.1). Each project indicates common issues of salt marsh creation and future opportunities for salt marsh creation as a part of coastal area developments. Each project will be evaluated in light of the forementioned criteria (see 3.3 in this thesis). Hierarchy in the evaluation criteria is determined according to the goals and objectives of each project.

(Figure 4.1) Location of Case Study Sites
4.1 Created salt marsh as compensation for urban development

*Project A: a tributary to the York River, Gloucester Point, the Chesapeake Bay*

Wetland Mitigation Policy associated with Section 404 of the Federal Clean Water Act requires creating wetland to compensate for the wetland lost due to a proposed development. Creating wetlands on dredge spoil and converting upland areas into intertidal zones have become common practices to meet mitigation policy; however, few studies have been conducted to compare these created wetlands with adjacent natural marshes (Bradshaw, Havens and Varnell, 1992). The following project presents a case where a new salt marsh has been created as compensation for a natural salt marsh lost due to urban development pressures.

**Background and Site Analysis:**

The site is located in a tributary to the York River near the mouth of the Chesapeake Bay (Figure 4.2). The existing salt marsh was filled to create a shopping center complex and parking lot. As compensation, the developer created 1.66 acres of salt marsh habitat. This project was conducted in 1985 by converting some upland area into intertidal zones. It has been ten years since the salt marsh was constructed. The created salt marsh is now covered by dense salt marsh vegetation. If the establishment of vegetative cover is the sole measurement of the success of salt marsh creation, this project may well be considered successful; however, biologists and ecologists are raising questions about the performance of this salt marsh creation project (Perry, 1994).

**Program and Design Analysis:**

The salt marsh was designed as an enclosed shape consisting of a large low marsh and narrow high marsh to fit between the shopping center and a tributary river (Figure 4.2). A channel was created throughout the marsh to bring tidal water into the created salt marsh from a tributary of the York River.

The large portion of the created salt marsh was low marsh designed to accommodate *Spartina alterniflora*. Surrounding the low marsh, a fringe of high marsh was designed for *Spartina patens* and *Distichlis spicata*.

In order to make an enough intertidal zone for salt marsh creation, the transition zone between upland
and intertidal zone was made narrow and steep. Drainage from the shopping center parking lot was directed to the created salt marsh through drainage pipes to protect natural marshes from negative impacts of the development.

(Figure 4.2) Relative Location of Created Salt Marsh
(adapted from Bradshaw, Havens and Varnell, 1992)

Implementation and Management:
The salt marsh was created by bringing a channel from a tributary of the York River and excavating upland forest to create intertidal zone where salt marsh macrophytes can grow. Site preparation involved a large amount of excavation to bring the site to necessary intertidal elevations, grading according to the elevations of flow and ebb tides from York River. The channel was excavated to a depth of 3 feet (0.9 meters) from local Mean Low Water to maintain a constant water supply to the created salt marsh.
After the site had prepared, three different species of plants, *Spartina alterniflora*, *Spartina patens* and *Distichlis spicata*, were transplanted into the site with spacing of 24- to 36-inch on-center (roughly 0.6- to 0.9-meter apart). All transplants were greenhouse grown and were one-year old.

**Project Evaluation:**

Table 4.1 describes the evaluation of this project according to the hierarch in the forementioned criteria.

(Table 4.1) Evaluation of Project (A)

| OBJECTIVE                                                                 | *
|---|---
| to compensate for the salt marsh lost due to a proposed shopping center development |
| LOCATION | *
| forested upland along the tributary of the York River |
| right behind the parking lot for the shopping center |
| FORM | *
| enclosed shape with the smaller opening at the river and larger end at the northern edge |
| wide low marsh with narrow and steep high marsh |
| ACCESS | *
| no physical access and poor visibility to the created salt marsh |
| HABITAT TYPE | *
| mostly low marsh habitats |
| VEGETATION | *
| covered by dense and mature low marsh plants |
| WILDLIFE UTILIZATION | *
| restricted opportunities for aquatic species due to the small water access at the river |
| restricted opportunities for terrestrial animals and birds from adjacent forest due to the narrow and steep high marsh |
| SHORELINE PROTECTION | *
| not applicable |
| INTERPRETATION OPPORTUNITY | *
| limited sensory experience |
| no educational opportunities |
| ECONOMIC WELFARE | *
| not applicable |

The detailed study of comparison of these two salt marshes found significant differences between them. The adjacent natural salt marsh has shorter period of inundation, which attributes to the wide inlet and
narrow low marsh, as opposed to the created salt marsh with the narrow inlet and large low marsh. Also, a significant amount of urban runoff coming into the created salt marsh will be trapped in low marsh for a long period because of the enclosed shape and little transition area from upland. That resulted in a completely different hydrologic system, plant growth, and wildlife utilization between the two marshes (Bradshaw, Havens and Varnell, 1992, and Perry, 1994).

The data also showed that primarily production, organic carbon content and salinity in the created marsh was lower than the adjacent marsh and may remain lower because of the difference in the physical environments. In addition to these facts, the adjacent marsh contained 70 percent cover of saltbush species such as Baccharis halimifolia and Iva frutescens, offering valuable habitats for small birds. In the created salt marsh, these saltbush species were absent (Bradshaw, Havens and Varnell, 1992).

**Implication:** In this case, a product of mitigation policy and a development interest resulted in destroying a natural salt marsh and introducing an "ecological landscape" that would not occur in that region. The created salt marsh does not provide much variety in the habitat types, and the unique form of the marsh habitats created a different ecosystem from the adjacent natural marsh. Hydrologic systems of the outside of the created salt marsh allow the excessive amount of freshwater runoff coming in the system, and the form of the marsh does not allow adequate water circulation, resulting in lower primarily production, organic carbon content and salinity than the adjacent natural marshes. This project indicates the importance of hydrologic systems.

The key to creating a salt marsh that has similar function to the ones naturally found in the region and are beneficial to local wildlife species is to create a landscape pattern that simulates natural hydrologic systems. Salt marsh creation must only be considered appropriate when the natural hydrologic system is restored, especially when the purpose of creating salt marsh is to provide wildlife habitats. Landscape architects should emphasize protecting and re-creating the natural hydrologic systems to create salt marshes that have similar characteristics to natural ones, thus attaining the natural integrity of the site.
4.2 Salt marsh creation as substitute for bulkhead

Project B: Virginia Institute of Marine Science, Gloucester Point, the Chesapeake Bay

The major purpose of development on coasts is usually to provide access to open water. There are several engineering practices traditionally used to support residential facilities in coastal areas. These practices primarily use hard structures such as bulkheads and seawalls. However, the longevity of such structural methods and the impacts of these structures on the ecosystem are of significant concern. An alternative method, if it is to be suggested, must last longer, have less impact on the environment and cost less to implement and maintain. The following project was implemented as an attempt to satisfy these requirements, and it may provide an example for re-developments of coastal areas.

Background and Site Analysis:

The study site is located in Gloucester Point, Virginia side of the Chesapeake Bay (Figure 4.3). The entire site used to be covered by salt marsh vegetation. The natural marsh was dredged and filled to accommodate a research complex for Virginia Institute of Marine Science in 1920. The site provides several research facilities, a marina and parking lot. The site is surrounded by beaches which are constantly under the erosive pressures. Of particular interest in this site is a fringe of salt marsh, created parallel to the wooden bulkhead in order to bring a canal into the marina.

The pre-existing bulkheads at the both sides of the canal were deteriorating because of impacts from constantly changing tidal regimes, pressure from upland, and boat traffic in the marina. Both the wooden bulkhead and the salt marsh were constructed at the same time to replace the aging structures. Both the bulkhead and salt marsh have the same length under the same environmental conditions. This provides an opportunity to compare the feasibility and benefits of a created salt marsh with these of a bulkhead.

Program and Design Analysis:

A fringe of salt marsh was designed and created by an ecologist Dr. James E. Perry to provide the same function as a bulkhead. The site hydrology was taken from the data on the demolished bulkhead and maintained at the same levels. Average daily tidal ranges on the site were approximately one foot.
The salt marsh planting area was graded according to the existing tidal regimes to accommodate primarily *Spartina alterniflora*. A fringe of high marsh is designed to accommodate *Spartina patens* by the parking lot. The offshore stone breakwater was designed to create a planting area, stabilize substrates and protect salt marsh vegetation along the canal. The height of offshore stone structure was designed as high as the elevation of the local Mean High Water (Figure 4.4).
The stone structure was also extended to the mouth of the bay by standing alone as a groin structure. The size and shape of the stone structure was calculated by structural engineers to ensure its stability. The recommended base-height ratio ranged from 4:1 to 5:1 to have a pyramid base. The typical size of the structure was designed as 10 feet bottom width and 2 to 3 feet high depending upon the bottom elevation of the canal. The structure was located exactly where the bulkhead used to be. The area behind it was graded to provide minimum 6 meters wide planting area and topsoiled with fine straight sandy soil.

(Figure 4.4) Typical Section of Stone Breakwater

A fringe of salt marsh was designed between the stone structure and the existing unpaved parking lot. The channel was designed approximately two-third from the entrance of the canal to provide water circulation and increase nutrient exchange within the marsh (Figure 4.5).

Implementation and Management:
The construction of the site was accomplished by the Virginia Institute of Marine Science led by Dr. Perry in 1985. The construction involved excavation of the bank from the edge of the existing parking lot to the canal in order to achieve proper elevations and slope for low marsh species to grow.
*Spartina alterniflora* was transplanted by his students on 45-centimeter center. A fringe of *Spartina patens* was transplanted at the transition zone between the parking lot and low marsh. Total cost of this project was $20,000, while the newly constructed wooden bulkhead at the opposite side of the canal costed $120,000.

![Channel within the Created Salt Marsh](image)

(Figure 4.5) Channel within the Created Salt Marsh

**Project Evaluation:**

Table 4.2 describes the evaluation of this project according to the hierarch in the forementioned criteria. The design has created a whole "ecosystem", consisting of water, marsh land, and upland (Perry, 1994). Algae floating along the stones indicates that micro-organisms within the created salt marsh is functioning. The created salt marsh provides an environment much more aesthetically pleasing than the one with wooden bulkhead.

Ten years after the construction, the bulkhead has started deteriorating. There are some holes behind the bulkhead caused by pressure from the upland. The reconstruction of the bulkhead will be necessary in the near future. On the other hand, the created salt marsh, costing much less provides full coverage of vegetation, shoreline protection, wildlife habitats, water purification, and amenity. This project indicates the feasibility of salt marsh creation as an alternative design to bulkhead.
Implication:
This project can be viewed to showcase the creation of a fringe of salt marsh as an alternative design along a highly disturbed shoreline. Salt marsh creation requires more land than the construction of bulkhead does; however, regulations along the Chesapeake Bay and other coastal areas require setbacks for placing development near waterfront. When a salt marsh is created within the setbacks, the area of developable lands will not decrease (Perry, 1994).

(\textit{Table 4.2}) Evaluation of Project (B)

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>* to replace bulkhead and maintain water access to the existing marina facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHORELINE PROTECTION</td>
<td>* effective for flood and erosion control</td>
</tr>
<tr>
<td>ECONOMIC WELFARE</td>
<td>* construction cost significantly less than bulkhead</td>
</tr>
<tr>
<td></td>
<td>* self-sustainable and no maintenance</td>
</tr>
<tr>
<td></td>
<td>* improved amenity (salt marsh plants)</td>
</tr>
<tr>
<td>ACCESS</td>
<td>* direct but limited access to the created salt marsh by a stone structure</td>
</tr>
<tr>
<td>INTERPRETATION OPPORTUNITIES</td>
<td>* close sensory experience of the created ecosystem from stone structure</td>
</tr>
<tr>
<td></td>
<td>* educational opportunities led by the college for students and public</td>
</tr>
<tr>
<td>LOCATION</td>
<td>* filled salt marsh along a canal</td>
</tr>
<tr>
<td>FORM</td>
<td>* linear salt marsh with a little channel</td>
</tr>
<tr>
<td></td>
<td>* roughly 6 meters wide from stone structure to the parking lot with 5:1 slope at maximum</td>
</tr>
<tr>
<td></td>
<td>* mostly low marsh sustained by a stone structure along a canal</td>
</tr>
<tr>
<td></td>
<td>* very little high marsh along the landward edge</td>
</tr>
<tr>
<td>HABITAT TYPE</td>
<td>* mostly low marsh habitats with very little high marsh</td>
</tr>
<tr>
<td></td>
<td>* a pile of stones along a canal</td>
</tr>
<tr>
<td>VEGETATION</td>
<td>* covered by dense and mature low marsh plants</td>
</tr>
<tr>
<td>WILDLIFE UTILIZATION</td>
<td>* colonized benthic animals (blue crabs &amp; oysters)</td>
</tr>
<tr>
<td></td>
<td>* visiting small mammals (muskrats, salt marsh snakes, and raccoons)</td>
</tr>
</tbody>
</table>
The little ecosystem created on this site is a very effective teaching tool for science and engineering students and for the wide range of the public to learn about the ecosystem and ways to live with it. Stone structures created to protect the salt marsh provide a physical access for people to walk along and have a close and intimate look at the created ecosystem. A fringe of created salt marsh provides a sensory experience and educational opportunity of nature in urbanized shorelines.

The success of this project provides landscape architects with an opportunity to incorporate salt marsh creation in re-development of coastal areas. Salt marsh creation in urbanized situation can restore the integrity of ecosystem and attain the safety and welfare of human life.
4.3 Salt marsh creation in the backyard

There are some cases where property protection is accomplished by creating salt marshes. Along the Atlantic shoreline, the state of Maryland takes a lead in terms of creating salt marshes for shoreline protection. The state provides property owners with financial aid paying the half of construction costs to create a fringe of salt marsh for erosion control (Garbisch, 1994).

Project C(1): Cove View Condominiums, St. Michaels, MD

Background and Site Analysis:
The private condominium complex, located on Spencer Cove, St Michaels, Maryland, contains approximately 300 feet (90 meters) long shorelines in the eastern shore of Chesapeake Bay (Figure 4.6). Three condominiums are located in the property approximately 100 feet away from the edge of the created salt marsh.

Before the salt marsh was constructed, the lawns over the top of upland bank had been subject to the influence of spring high tide. The shoreline used to consist of upland bank without any vegetation in the intertidal zone. Although wave energy was not high, the foot of upland bank had been subject to erosion from daily tidal waves. Permit for salt marsh creation was obtained from both Maryland Department of Natural Resources and U.S. Army Engineer District of Baltimore by Environmental Construction, Inc. in 1991.

Program and Design Analysis:
The project was accomplished by Environmental Construction, Inc., 1991. The purpose of this salt marsh creation was primarily to protect their property from erosion.

The site hydrology was estimated by using adjacent salt marsh as a "reference marsh". The reference marsh was analyzed to locate the elevation of the existing Spartina patens as a biological benchmark. The average elevation of Spartina patens at the seaward edge was calculated to estimate the approximate elevation of Mean High Water (MHW) on the site. Average tidal range was taken from "Tidal Table" of National Ocean and Atmospheric Administration.
(Figure 4.6) Engineering Plan of Salt Marsh Creation
(Source: Environmental Concern, Inc., 1991)
In this case the average tidal range of this area was 1.2 feet (36 centimeters). The estimated elevation of MHW was indicated as elevation 1.2 feet. The elevation of Mean Low Water was determined to be 1.2 feet lower from MHW and indicated as elevation 0.0 feet (0.0 centimeter). All the existing spot elevation was taken from site survey.

A fringe of salt marsh was designed along the entire shoreline within the property. The width of planting area was roughly 20 feet (6 meters). The average slope across the created salt marsh was 5:1. Only two species of plants were specified; Spartina alterniflora from the elevation of mid-tide to MHW, and Spartina patens from MHW to top of the bank.

Five full-size stone containment structures were designed approximately every 50 feet (18 meters) perpendicular to the shoreline within the planting zone in order to increase stability of introduced substrate. A Stone-swale was designed across the created salt marsh from upland to the limit of filling to direct upland runoff to the bay (Figure 4.7). All stone structures were designed so as not to exceed 0.5 feet (15 centimeters) above top of fill so that it would not affect natural wave vector.

(Figure 4.7) Stone Swale
(Source: Environmental Concern, Inc., 1991)
Implementation and Management:
No clearing or excavation was conducted on the site. The salt marsh was created entirely by filling sandy soils on the foot of the eroding upland bank. The area of fill was determined to be approximately 20 feet (6 meters) seaward from the top of the bank. All the fill materials were limited to 2 feet below the elevation of MLW, where the depth of water typically prevents colonization of *Spartina alterniflora*.

Full-size stone structures were built prior to filling. Stone Swale was installed after filling. The existing dock was decided to be left remaining. Ground surface of the existing dock was also graded the same levels as surrounding areas. Since the wave energy of the area under the dock was not expected to be very high, the sand substrate was left alone without any stone containment or planting.

After all the site preparation efforts had been completed, 15-week old *Spartina alterniflora* and *Spartina patens* were transplanted with peat pots every 1.5 feet (45 centimeters) spacing. All the seedlings were taken from nearby salt marsh in the Chesapeake Bay and propagated by Environmental Concern, Inc..

As many coastal habitats along the Chesapeake Bay, this property was within the habitat of Canadian geese. Goose fence was installed approximately one foot shoreward of the limit of planting to prevent them coming in at the high tide until the second growing season.

During the one-year monitoring period, it was found that the wave energy at the eastern edge of the property was too high for salt marsh vegetation to be established, and the stone containment structure built initially did not stabilize the shoreline. Therefore, they reconstructed the stone containment structure as the offshore breakwater and created a salt marsh behind it.

Project Evaluation:
It has been three years since this site was constructed. The establishment of new growth cordgrass and hay indicates that the created salt marsh has been effective for stabilizing the new shoreline. The condition of upland lawn areas indicates very little salt or brackish water influence, which proves that the salt marsh is also effective as flood protection (Garbisch, 1994). The created salt marsh has been effective to dissipate wave energy and protect the upland from erosion. The primary objective of this project, shoreline protection, is to be said accomplished (Table 4.3).
(Table 4.3) Evaluation of Project (C.1)

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>* to stop shoreline erosion and prevent flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHORELINE PROTECTION</td>
<td>* effective for flood and erosion control</td>
</tr>
<tr>
<td>ECONOMIC WELFARE</td>
<td>* half construction cost aided by the state</td>
</tr>
<tr>
<td></td>
<td>* self-sustainable and no maintenance</td>
</tr>
<tr>
<td></td>
<td>* improved amenity (salt marsh plants)</td>
</tr>
<tr>
<td>LOCATION</td>
<td>* along a toe of the eroding upland bank</td>
</tr>
<tr>
<td>VEGETATION</td>
<td>* covered by dense and mature low and high marsh plants</td>
</tr>
<tr>
<td></td>
<td>* naturally emerging native shrubs along landward edge of the created salt marsh</td>
</tr>
<tr>
<td>ACCESS</td>
<td>* visual access over lawns from the condominiums</td>
</tr>
<tr>
<td></td>
<td>* small dock extended to the deep water</td>
</tr>
<tr>
<td>INTERPRETATION OPPORTUNITIES</td>
<td>* sensory experiences provided in the private lawn areas and dock</td>
</tr>
<tr>
<td></td>
<td>* flowering native shrubs that provide foods and habitats for wildlife</td>
</tr>
<tr>
<td>FORM</td>
<td>* linear salt marsh along upland lawn</td>
</tr>
<tr>
<td></td>
<td>* roughly 6 meters wide low/high marsh</td>
</tr>
<tr>
<td></td>
<td>* average slope 5:1 from limit of fill line to upland bank</td>
</tr>
<tr>
<td>HABITAT TYPE</td>
<td>* low and high marsh habitats</td>
</tr>
<tr>
<td></td>
<td>* a pile of stones across the marsh</td>
</tr>
<tr>
<td>WILDLIFE UTILIZATION</td>
<td>* migratory birds and waterfowls (great blue herons &amp; Canada geese)</td>
</tr>
<tr>
<td></td>
<td>* visiting small mammals and insects (muskrats, crickets and grasshoppers)</td>
</tr>
</tbody>
</table>

Five full-size stone containments are covered by plants and are no longer visible from a distance. The created salt marsh has encouraged a few volunteer plants at the high marsh. These volunteer species include *Panicum virgatum* (Switchgrass), *Baccharis hamifolia* (Groundsel Bush) and *Phragmites australis* (Common reed).

*Panicum virgatum* has high wildlife value as a source of food and protection. *Panicum virgatum* also creates buffers along the upland edge, filters urban runoff and prevent flooding. *Baccharis hamifolia*
provides habitats for diversity of wildlife, particularly for small birds, and aesthetically pleasing white flowers for property owners. *Phragmites australis* has very little wildlife value and may eventually displace more important salt marsh species at high marsh areas. *Phragmites australis* should be cleared from the site (Atkinson, 1994, Garbisch, 1994 and DWE, 1993). These volunteer species associated with the created salt marsh have added diversity at the shore that once was eroding unvegetated upland bank.

Property owners were pleased about volunteer species and wildlife coming into their property. Three years after construction, the created salt marsh now provides protection to the property, habitats for wildlife and amenity for humanity.

On the other hand, protection of water quality in the bay becomes a question. The stone swale directs runoff without passing through the marsh areas. One of the important values of salt marsh is its capability for water purification. As a potential design alternative, stone piles can be installed behind *Spartina parrs* with additional vegetative buffers to help dissipate upland stormwater runoff (Perry, 1994). Also, it is possible to excavate a portion of upland area to extend the high marsh, thus allowing wider planting area (Figure 4.8).

**Implication:**

This project indicates that even a small-scale salt marsh creation has a potential to attract animals and birds to visit and utilize the ecosystem. The lawn area behind the marsh allows additional spaces for native species to settle in. If a dense cover of hedge growth is included in the initial design, a variety of habitat types will be established and the invasion of undesirable species can be controlled.

Use of native species that have wildlife value and seasonal character will enhance the aesthetic quality and sense of place in backyards. The existing dock and private lawn area provide residents with opportunities to encounter wildlife. The setting, as a backyard, creates a private and quiet atmosphere where residents can relax and interpret nature through day-to-day sensory experience.
(Figure 4.8) Proposed Section of Salt Marsh Creation

Project C(2): Barrett Cove Residence, St. Michaels, MD

Background and Site Analysis:

A private residence, called Barrett Cove Residence for this study, is also located in St. Michaels on the eastern shore of the Chesapeake Bay. The site is located in the pocket of the bay where intensive wave energy has been eroding upland areas. Salt marsh creation was conducted prior to the construction of the residence, while the design of the residence was still in the planning stage.

The property is located between natural and restored salt marshes. The area beyond the northern boundary of this property provides natural salt marshes. The salt marsh located at the southern end of the property was constructed five years ago by the company constructing the previous site.
(Figure 4.9) Engineering Plan of Salt Marsh Creation
(Source: Environmental Concern, Inc., 1994)
The property contains a shoreline approximately 400 feet (120 meters) long. This project was conducted by Environmental Construction, Inc. in 1994 (Figure 4.9). The property contained an upland bank ranging from 0 to 4 feet (0-1.2 meters) high. The trees standing at the edge of the upland were in danger of falling down due to erosion.

The condition of the adjacent created salt marsh indicated a significant decrease in transplanted *Spartina alterniflora* due to the strong wave activities caused by the prevailing northern winter wind. Compared to the site previously studied, the significant wave energy made this site a much more difficult one in which to create salt marsh. This project provides an example of the latest techniques used for salt marsh creation in the Chesapeake Bay.

**Program and Design Analysis:**

The primary goal of this project was to protect shoreline from erosion. The site hydrology was determined based on the vegetative zonation of near-site natural salt marsh as a biological benchmark. Average tidal range was taken from "Tidal Table" of National Ocean and Atmospheric Administration.

In this case the average tidal range of this region was 1.4 feet (42 centimeters). The elevation of MHW was estimated from the location of Spartina patens in the adjacent natural marsh. The elevation of 1.4 feet below MHW was determined to be MLW and indicated as elevation 0.0 feet. The limit of planting area was designed to be approximately 20 feet (6 meters) seaward from the top of the bank to achieve the minimum recommended width for shoreline protection.

Most of the eroding shoreline was filled to create slope ranges from 5:1 to 10:1 and an enforced seaward edge by stone sills. The substrates of the existing marsh were left undisturbed, but enforced at the seaward with stone edging. A total of six stone containment structures were designed with stone edging approximately every 40 feet. All stone structures were designed so as not to exceed 0.5 feet (15 centimeters) above the top of fill or the top of existing bank.

Several sections were drawn to indicate proposed and existing conditions, amount of fill, elevations of MHW, MLW and mid tide, and location of transplants. Only two species of plants were specified for transplanting, *Spartina alterniflora* from the elevation of mid-tide to MHW, and Spartina patens from 0.5 feet (15 centimeters) above MHW to the upper end of fill.
Implementation and Management:
Since the client wished to preserve as many upland trees as possible, the alteration beyond the upland bank was kept at a minimum except for the access for the construction.

The area of filling was limited within the area of 2.0 feet (60 centimeters) below MLW, which was the lowest elevation where Spartina alterniflora could possibly grow (Garbisch, 1994). All the plants were transplanted with peat pots, spacing 1.5 feet (45 centimeters) on center after site preparation had been completed in late August. As in the site previously studied, it was necessary to design goose fences between the seaward end of planting area and stone edging and sill.

In order to increase the stability of introduced sandy substrates, six stone surface containments were built perpendicular to the shoreline after fine grading had been completed. Full-size stone containment structures were not considered necessary because the proposed stone edging and stone sill provided protection from severe wave energy at the site. The same stones were used to stabilize the toe of upland banks where the root systems of upland trees had been exposed to shore erosion.

Project Evaluation:
This project was completed just 10 weeks prior to the study. It was too early to determine if this project was successful or not; however, the site already indicated some opportunities and constraints associated with this project (Table 4.4).

A number of Spartina patens transplants had been lost or washed away. Planting late at growing season had probably led to this consequences (Garbisch, 1994). Some of the lowest portions of goose fences were broken, which might indicate that the area had been exposed to the higher wave energy than the rest of the area (Garbisch, 1994). Also, there were some litter materials coming into the site, which might infringe growth of the transplants.

The upland of the site has not been developed. The impact to the natural salt marsh has kept at a minimum by confirming to the existing grade and restoring natural hydrologic systems. Since the salt marsh was created on the fill, habitats for terrestrial animals has not been disturbed. Dense upland forest and natural marshes provide good habitats for wildlife. The created salt marsh, if established, will protect upland trees from erosion and add diversity to the habitat types.
### Table 4.4 Evaluation of Project (C.2)

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>* to stop shoreline erosion and protect upland forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHORELINE PROTECTION</td>
<td>* effective for erosion control and stabilizing the root mat for upland forest</td>
</tr>
</tbody>
</table>
| ECONOMIC WELFARE              | * half construction cost aided by the state  
                                 | * no more loss of upland forest from erosion  
                                 | * improved amenity (salt marsh plants) |
| LOCATION                      | * along a toe of the eroding upland forest |
| VEGETATION                    | * not established yet  
                                 | * naturally emerging native shrubs along landward edge of the created salt marsh |
| ACCESS                        | * no physical access planned  
                                 | * limited visual access through forest |
| INTERPRETATION OPPORTUNITIES  | * not planned |
| FORM                          | * linear salt marsh along upland forest  
                                 | * roughly 6 meters wide low/high marsh with stone sill  
                                 | * average slope range from 5:1 to 10:1 between upland bank and stone sill |
| HABITAT TYPE                  | * low and high marsh habitats  
                                 | * a pile of stones across the marsh and along the seaward edge |
| WILDLIFE UTILIZATION         | * migratory birds and waterfowls (great blue herons and Canada geese)  
                                 | * visiting terrestrial mammals from the forest (deer and raccoon) |

**Implication:**

The conditions of nearby natural marshes suggest the potential for volunteer species to enter this site, making for a more natural-looking marsh in the long run. Higher species diversity is expected after a couple of growing seasons. A major concern is *Phragmites australis* (Common reed), commonly found at disturbed sites. Common reed, which grows vigorously in disturbed areas, is less desirable for salt marsh creation due to its lack of wildlife value and reduced effectiveness as a shoreline stabilizer, compared to *Spartina alterniflora* or *Spartina patens*.
In order to stabilize the shoreline, control invasion of undesirable species, and to prevent negative impacts from future upland developments, it is essential to establish dense cover of high marsh species. Transplanting of preferred species must have been done before the growing season to allow them enough time to establish.

Finally, potential for interpretation of nature is very high on the site. The site is isolated from other urban developments and provides a wide range of ecological units. Residential developments occurring upland should maintain the natural hydrologic systems and wildlife circulation between the forested upland and the marshes as much as possible.
4.4 Summary of Case Study Reviews

The series of salt marsh creation projects reviewed in this chapter are all considered to be successful in terms of establishing mature and dense salt marsh vegetative cover. However, each project presents some concerns that were also seen in the other five sites visited (but not described in this thesis). The major failure in salt marsh creation is generally attributed to inappropriate planting zones. This concern relates to creating an environment where salt marsh plants can adapt and establish themselves, which is related to the concerns described in Tables 4.5a and 4.5b: wave/wind energy, adaptability, water quality and human/animal impacts. Table 4.5a presents concerns directly related to salt marsh creation efforts. Table 4.6b describes indirect concerns. All of these should be considered in the process of salt marsh creation.

(Table 4.5a) Direct Concerns on Salt Marsh Creation

<table>
<thead>
<tr>
<th>CONCERNS</th>
<th>FEASIBILITY</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>wave/wind energy</td>
<td>* create a shallow water area for planting zone according to the local tidal regimes</td>
<td>* locate breakwater along the seaward edges of salt marsh at the MLW lines. (The height of breakwater should be lower than the MHW levels.)</td>
</tr>
<tr>
<td></td>
<td>* provide an adequate protection according to the vertical changes in daily sea levels (MLW &amp; MHW)</td>
<td>* install stone containment structure should be installed with introduced substrates</td>
</tr>
<tr>
<td></td>
<td>* provide an adequate protection against wind induced wave energy (direction and intensity of wave)</td>
<td></td>
</tr>
<tr>
<td>adaptability</td>
<td>* attain natural assemblage of substrates and indigenous plants</td>
<td>* maintain or restore natural hydrologic systems (including freshwater run-off and tidal inundation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* transplant indigenous plants over appropriate elevations in response to the site hydrology</td>
</tr>
</tbody>
</table>

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(Table 4.5b) Indirect Concerns on Salt Marsh Creation

<table>
<thead>
<tr>
<th>CONCERNS</th>
<th>FEASIBILITY</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>water quality</td>
<td>* control runoff from upland</td>
<td>* provide vegetative buffer strips with dense shrubberies or stone piles behind created salt marsh.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* maintain natural hydrologic systems on upland</td>
</tr>
<tr>
<td></td>
<td></td>
<td>* direct runoff water through buffer strips and created salt marsh to filter runoff</td>
</tr>
<tr>
<td>human/animal</td>
<td>* prevent people and animals coming into the site at least until the second growing season</td>
<td>* provide enclosure fence and signage at landward edges of created salt marsh to prevent people from entering</td>
</tr>
<tr>
<td>impacts</td>
<td></td>
<td>* provide goose fence at seaward edge of the planting zone to prevent waterfowls from entering</td>
</tr>
</tbody>
</table>

Note that Tables 4.5a and 4.5b describe common concerns regarding salt marsh creation on the nine sites visited in the Chesapeake Bay area while appendix C presents summary evaluation of the four case study reviews discussed in the body of this thesis.
V. Guidelines for Salt Marsh Creation and Coastal Residential Developments

The findings from the case study analyses and interviews enable us to see opportunities for improving, salt marsh creation. Successful salt marsh creation has a potential to prevent erosion process itself, reduce flooding, filter urban runoff and provide wildlife habitats by accumulating organic matter, providing a dense vegetative cover and offering gentler slopes along shorelines. Salt marsh creation is usually less expensive than other hard structures such as bulkheads and salt marsh can become self-sustaining, thus requiring little or no maintenance. Naturalistic landscapes consisting of created salt marsh and tidal waters will also add other benefits such as visual amenity and educational opportunities. Principles and guidelines help ensure that created salt marsh is beneficial to both people and wildlife.

The following guidelines are based upon the synthesis of information provided by engineers, scientists and landscape architects. Guidelines for salt marsh creation are framed to lead landscape architects in improving the safety and value of human settlements and restoring the integrity of coastal ecosystems.

Principles of Salt Marsh Creation and Coastal Residential Developments

1. A net gain of salt marsh ecosystems is desired for coastal areas.

Salt marsh creation must not replace natural salt marshes but expand ecosystem functions and values. Natural salt marshes will help naturalize a created salt marsh by wildlife circulation and energy flows such as hydrology and wind movement throughout the ecosystem.

2. Salt marsh creation must account for the broader landscape context.

Coastal ecosystems include various ecological units such as open water, wetland, field, forest and residential development. Each of these ecological units has its own "structure," and together they create a unifying pattern in the landscape. Created salt marshes must be adaptive to the overall pattern of the landscape, both functionally and visually retaining landscape integrity. Salt marsh creation and residential development must account for the ecological and cultural characteristics of the region as well as the basic land use requirements of the site.
(3) Incorporation of created salt marsh into coastal area developments must maintain a balance between human needs and natural processes.

The primary purpose of incorporating salt marsh creation into coastal residential developments is to create a place where both humanity and wildlife can co-exist and benefit from the created ecosystems. Salt marsh creation must protect the shoreline, enhance wildlife habitat and serve as an amenity for people. To achieve these goals, created salt marsh must attain its functions and values as discussed earlier in this document.

(4) Design must provide residents with opportunities for "interpretation" of nature during their day-to-day experience.

Interpretation is a communication measure that makes people aware of natural and cultural resources of a site through sensory experience. Interpretation of natural and cultural resources through sensory experience is an essential aspect to "value-based" awareness on learning (USDI, 1993). A design with created salt marsh must provide opportunities to enjoy the values and beauty of the place, to instill in residents an awareness of salt marsh functions, and to interpret the symbolic meaning of both (Schicker, 1988).

**Planning Guidelines**

1. Nearby natural marshes should be analyzed as references to determine the functional attributes desired for a created salt marsh.

   * In order to design a salt marsh that has similar visual and functional characteristics to natural ones, landscape architects should analyze the structure and function of the reference marshes, including hydrology, substrate, landform, vegetative composition and wildlife utilization.

2. Spatial pattern of the landscape, including topography, habitat types and significant natural resources, must be inventoried and analyzed at the regional scale so that the created salt marshes can be adaptive to the natural processes of the landscape.

   * Wildlife species that are rare, unique or have economic importance should be identified as target species to protect them from development impacts (Cannen, Copeland and Seneca, 1974).
Potentials of the site to accommodate these species should be analyzed to create the detailed program for the project (Zedler, 1988).

* Natural features and resources that are rare, unique or have economic importance must also be protected to increase an awareness of nature and/or utilized to enhance the benefits of the society.

3. Involvement of the client and other professionals throughout a planning/design process and monitoring period should be encouraged.

* Involvement of residents will help incorporate their wishes and needs in the design and increase their awareness, understanding and enjoyment of the created ecosystem (Booth, 1983 and Tregay, 1986).

* Related professionals such as biologists, ecologists, engineers, geomorphologists, hydrologists, and soil scientists will be beneficial sources of information for landscape architects to create an inventory of the broad landscape and to identify specific opportunities and constraints of individual sites (Coats and Williams, 1990).

4. Monitoring plans should be prepared for at least three years to observe how the designed ecosystem functions as a part of the ecosystems and how it matches the goals and objectives of shoreline protection, wildlife utilization and interpretation opportunities.

* Hierarchy in evaluation criteria (see 3.3) needs to be determined according to the goals and objectives of the project.

* Conditions related to sediment types, hydrology and salinity of the site can be interpreted by distribution and establishment of vegetation. Establishment of dense vegetative cover provides shoreline protection, wildlife utilization and opportunities for interpretation of nature. Thus, Vegetative composition and density throughout the property should be mapped to identify different types of vegetative communities on the plan drawing. The map should include information on topography, water depth, and wildlife utilization for each vegetation type (Erwin, 1989 and Atkinson, et al, 1993).
**Salt Marsh Creation Design Guidelines**

1. Salt marsh creation typically involves filling in shallow water and/or excavation of upland (Figure 5.1). Salt marshes should be created on sites where the functions and values of the proposed ecosystems can improve the existing conditions.

* Estuarine and shallow water areas along shoreline are ecologically sensitive. Filling these areas may degrade existing ecological integrity and increase erosion off-site or upstream. Converting upland into intertidal zones create habitats and refuges for small fishes and shrimps; however, it may increase the potential for tidal flooding (Zedler, 1988 and Perry, 1994).

* It is desirable for a salt marsh to be created in degraded areas such as areas derived from dredging material, filled wetlands, waste disposal sites, unvegetated or disturbed shorelines, or areas with low fish and wildlife resources utilization as a way to improve the safety, aesthetics and biodiversity of shorelines.

* Whenever a bulkhead has been (or will be) installed to protect shoreline property or to provide water access, the possibility of creating salt marshes associated with the breakwater should be examined.

2. A created salt marsh should be at least 20 feet (6 meters) wide, preferably as wide as 40 feet (12 meters), and within a slope range of 15:1 to 5:1 (Figure 5.2).

* The minimum of a 20-foot planting zone is necessary in many cases to establish dense vegetative covers, dissipate wave actions, trap sediments, and filter stormwater runoff. Vegetation is unlikely to colonize and erosion may occur in the intertidal zones steeper than slope of 5:1 ratio. The slope must be at least a 15:1 ratio to dissipate wave energy within a 20-foot planting zone (Knutson, 1981 in Knutson and Woodhouse, 1982a & b, Garbisch, 1986 and Shiler, 1990).
1) Naturally Occurring Salt Marsh

2) Salt Marsh Creation by Filling

3) Salt Marsh Creation by Combination of Excavation and Filling

4) Bulkhead

(Figure 5.1) Typical Created Salt Marsh and Bulkhead
3. Substrate materials should be fine to medium pure sandy soil or a mixture of sandy soil with some clay or loam.

* Sandy soils provide easier surface to work with and prevent hypersaline conditions to occur (Woodhouse, Jr., 1979, and Broome, 1990). Stone containment structures can be installed across the introduced substrates to stabilize the new sediments. A portion of fine clay or loam combined with sandy soil simulates natural conditions of marsh substrates, enhances productivity of salt marsh macrophytes and encourages wildlife species to colonize and/or utilize the site (Cammen, Copeland and Seneca, 1974).

4. Natural salt marshes typically develop in shallow water areas protected from excessive wind and wave energy. If a shoreline is located where there are excessive forces, protection must be provided (Figure 5.3).

* Stone containment structures should be installed across the created salt marsh to stabilize introduced substrates.
* Sites facing prevailing winds, having steep slope or that are exposed to more than five kilometers of open water require wave protection. Under these circumstances, an offshore stone breakwater or sill must be built along the MLW line (Knutson and Woodhouse, Jr., 1982a & b and Garbisch, 1994). The height of these structures should be slightly lower than the Mean High Water, allowing the annual extreme storm tide to go over the structures. These stone structures also provide habitats for benthic animals and small mammals.

(Figure 5.3) Section with Wave Protection

5. Channels should be installed at larger sites to ensure water circulation throughout the salt marsh. (Figure 5.4).

* Channels that simulate natural creeks will enhance nutrient exchange, provide access to fauna, and decrease mosquito breeding (Garbisch, 1986 and Perry, 1994).
6. The location of a planting area should be determined relative to the water levels of the nearest natural salt marsh and aspects of the site being worked on (Figure 5.5).

* The plan sections must make sure that the elevation of the created salt marsh will support the target plant/animal species and that the location of the marsh resembles the reference marshes (Broome, Rogers and Seneca, 1994).

* Planting areas for salt marsh species must receive at least six hours of direct sunlight daily (Garbish and Garbish, 1994). A transition between trees and salt marsh may thus be required.

* Native mature shrub growth should be established at the landward edge of marshes. Mature shrub growth works as additional protection for flooding, slows down runoff, presents seasonal variation, and provides nesting and perching sites for birds. Dense planting of these species prevents less desirable species from invading the site (Atkinson, 1994).
(Figure 5.5) Planting Zone According to Sea Levels and Sun

**Upland Design Guidelines**

1. The residential area should be clustered beyond the state (or other mandated) setback line and surrounded by vegetative cover to minimize the negative impacts of upland developments on sensitive wildlife habitats and the coastal waters ecosystem (Figure 5.6). Clustered townhouse and condominiums are thus preferred over single-family-lots along shorelines.
(Figure 5.6) Concept Layout of Residential developments with Created Salt Marsh
*Location of development should avoid disruption of wildlife travel or nesting patterns.

* The area of impervious surface should be kept at a minimum in order to avoid adversely impacting the existing hydrologic systems of the site (Clark, 1983). Direct input from drainage ditches must be evaluated and regulated to maintain the salinity of salt marshes. Finished grades at the construction site should be designed so that waterflows remain in natural drainage courses or flow over natural terrain so that vegetation, roots and soils can cleanse runoff water.

2. Vehicular access should be kept to a minimum in upland areas. Access to wildlife habitats, including created salt marshes, should be limited to pedestrians (Figure 5.7).

* Access to wetland areas should be built to minimum dimensions on the existing grades or on open pile supports higher than 10-year storm flood lines on the existing grade.

* Walkways should avoid environmentally sensitive areas such as designated wildlife habitats and existing coastal wetlands. Areas of commercial value and/or particular wildlife and fishery habitats such as shrimp nurseries, oyster beds and nesting/wading areas for birds should be avoided.

3. Vegetative buffer zones with canopy trees, shrub masses and ground covers should be spread throughout the property to attain wildlife circulation and increase residents' awareness of nature (refer back to Figure 5.6).

* Surface utilization by local species is important to increase residents' awareness of nature. Vegetative buffers also provide privacy between the lots (Schicker, 1987). Native shrubs and trees that change leaf colors and produce fruits attract birds and other wildlife and provide a "sense of season" (Cyr, 1988).

* Presence of local wildlife and their niches are crucial components of a "sense of place". Previous research has found that the most "sacred" places for children were wild or unfinished spaces (Schicker, 1988).
(Figure 5.7) Access to Created Salt Marsh
**Interpretation Opportunity**

1. Layout of created salt marshes and residential facilities should be arranged to tie nature to residents' daily life. The design should include safe and quiet spaces where residents can share relaxation and sensory experience. Observation areas, vistas and lawn spaces can provide such places (refer back to Figures 5.6 & 5.7).

   * Sensory experience includes views, sounds and smells of tide and wildlife. The design associated with created salt marshes must provide ways to make the value of the ecosystem and beauty of the resources apparent to user groups.

   * An adequate access to created salt marshes and visual access to the natural wetlands are important to provide residents with opportunities for interpretation of nature. Layout and location of pedestrian paths should be made in order to maximize opportunities for residents to encounter wildlife and to encourage children to explore wildlife habitats.

   * Boardwalks and observation decks over created salt marshes are environmentally sensitive and provide residents with opportunities for play, watching wildlife, sensory experience, and educational opportunities while preventing pedestrians from getting into and damaging marsh vegetation and soils (Schicker, 1987).

   * Stone breakwaters may provide a secondary level of physical access to the created marshes and water. Since stones create habitats for salt marsh fauna, they provide visitors with an intimate view of the ecosystems and reveal the ecological processes occurring within the marshes.

2. Recreational activities should be provided in or around created salt marshes. These potential activities include fishing, scenic enjoyment, bird watching, nature enjoyment and study, boating, and hiking.

   * A small dock with boardwalk can provide opportunities for these activities. All structures built in water should be set on open-pile or floating systems and be kept within one-third of the distance across the waterway to maintain the natural flow of the ocean tide (CWE and HMD, 1993). The areas of commercial and particular wildlife and fishery habitats should be protected.
Conclusion

The lack of awareness of natural systems operating in the coastal salt marsh and of values provided by such systems has allowed a huge loss of these wetlands and negative impacts on the coastal ecosystems (Warren, 1979). As the population continues to grow, development pressures on coastal areas are likely to continue reducing the integrity of salt marsh ecosystems throughout the world (Macdonald, 1977). The cost of losing the remaining salt marsh habitats to our future is not entirely measurable. There is a need for landscape architects to be involved in salt marsh creation to restore the integrity of the coastal ecosystem while accommodating residential developments in coastal areas.

Current scientific knowledge and restoration techniques indicate that salt marsh creation can provide the functions and values that naturally occur in salt marshes by providing dense and diverse vegetative communities along the shoreline. These functions and values include shoreline protection from erosion and flooding, water purification, fishery and wildlife habitat, and aesthetics. The creation of such ecosystems is crucial for our future well-being and for the survival of many species and communities of plants and animals in coastal areas and beyond.

Salt marsh creation for erosion control has proven to be a viable option in terms of its performance, longevity and feasibility (Garbsch, 1989 and 1994, and Perry, 1994). Typically, the cost of salt marsh construction is much less than other structural erosion control measures. Created salt marsh should be adaptive to natural processes and can become self-sustaining, thus requiring less maintenance over the long term life of a project or area.

Salt marsh creation has mostly been conducted because of mitigation policies or for research purposes. Despite evidences of the functions and values salt marsh restoration/creation efforts can provide, it is still rare for landscape architects to create salt marsh ecosystems either on private properties or as a part of residential developments (Perry, 1994). Coastal area residential developments should move from the traditional idea of "putting a landscape to a new or altered use to serve particular human purposes" towards creating coastal ecosystems in order to improve the integrity of both humanity and wildlife habitats (Cairns, Jr., 1992).

Of critical importance to salt marsh creation is the hydrologic systems of a site. The difficulty associated with salt marsh creation lies in the ways in which a created ecosystem can function and attain
values that benefit both people and wildlife. A created salt marsh ecosystem can be self-sustainable and provide salt marsh functions and values if it is properly located and appropriately designed. This includes meeting ecological needs and patterns of the surrounding landscape as well as the hydrologic systems of a site (Broome, Seneca and Woodhouse, Jr., 1974, Cammen, Copeland and Seneca, 1974, Garbisch, 1989, Kentula and Kusler, 1990, Broome, Craft and Seneca, 1993, Atkinson and Cairns, Jr., 1994, and Garbisch and Garbisch, 1994).

The primary role of landscape architects designing created salt marsh is to set in place an ecosystem that fits the "structures" and "functions" of the local landscape. Landscape architects must apply the technical information and processes of salt marsh restoration and creation provided by scientists and engineers to their coastal zone planning and design efforts. Also, landscape architects must find ways to make people aware of the values of salt marsh ecosystems and to improve quality of human settlements and wildlife habitats. Residential landscapes should include opportunities for residents to gain an appreciation of the created salt marsh ecosystems. In order to fulfill this role, the landscape architect must recognize the values of salt marsh in nature and human society and integrate these values into the decision-making process.

The integrity of an ecosystem which includes human settlements and wildlife habitats can be attained through understanding of both natural processes and cultural values of the landscape. A balanced relationship between development, salt marsh creation and other wildlife habitats is essential to provide residents with opportunities for interpretation of nature, as well as to create the integrity of an ecosystem and a sense of place.

This thesis expands the integrists' desire to protect the integrity of salt marsh ecosystems by changing how people view these systems in a positive way. The model approach for salt marsh creation and residential development presents a way to incorporate salt marshes into coastal developments, combining human settlements with wildlife habitats. This approach responds to the primary environmental conditions of a landscape as well as to specific ecosystem types within a specific project site. This approach thus allows for designed salt marshes to adapt to existing ecosystem dynamics and to future changes in the coastal landscape (Koh, 1981 and Booth, 1991).

The model approach recognizes that involvement of the client and other professionals throughout a planning/design process is critical. The involvement of residents in both planning and design is
necessary for landscape architects to accommodate their wishes and needs, and it provides opportunities to increase their awareness, understanding and enjoyment of the created ecosystem (Booth, 1983 and Tregay, 1986). Related professionals, such as biologists, ecologists, economists, engineers, geomorphologists, hydrologists, and soil scientists, provide beneficial information during the site inventory and analysis phase by identifying the ecological and cultural needs of the regional landscape and the specific opportunities and constraints of an individual site (Coats and Williams, 1990).

Design principles and guidelines are formulated to help create salt marsh ecosystems within the context of coastal residential developments so that both people and wildlife can co-exist and benefit from the created ecosystems. If a salt marsh and the surrounding environment are created using these principles and guidelines, the marsh should fit into existing natural patterns, function with surrounding ecological systems, and increase resident opportunities to more fully appreciate natural processes of salt marshes and their surrounding landscapes.

Proposed criteria provide a framework for landscape architects to evaluate the structure of created ecosystems, how people and wildlife benefit from them and how visitors experience them. Case study reviews provide evidence that salt marsh creation does benefit residential developments by providing long-term shoreline protection, water purification, and the amenity of naturalistic landscapes and wildlife habitat.

Created salt marshes within the residential communities can help engender a respect for land, water and wildlife by humans. The key is to make the values associated with salt marsh creation evident to residents. Designs should tie residents' daily activities to natural phenomena occurring around the created marsh thus increasing opportunities for personal interpretation of these systems. Day-to-day contact with natural phenomena occurring in created salt marsh ecosystems instills in residents a fuller appreciation and understanding of these habitats (Schicker, 1987 and Ryder, 1990).

Presence of local wildlife and their niches are crucial components of the "sense of place". Wildlife conservation areas within residential communities have been shown to increase market demand for such areas (The ULI, 1983). Vegetative buffer zones throughout the property will help maintain wildlife circulation and utilization of created ecosystems by migrant and resident species, also increasing resident awareness of nature. Vegetative buffers also provide edges between lots and create a private place where residents can relax and enjoy multiple sensory experiences (Schicker, 1988).
Interpretation of within salt marsh ecosystems may eventually create incentives for residents to engage in scientific research, preservation of rare or endemic species, restoration of other wetlands and protection of culturally and environmentally sensitive sites (Adamus and Stockwell, 1983). Interpretation opportunities should be provided in created ecosystems so that the integrity of natural ecosystems can be appreciated and protected for present and future generations. It is believed that the quality of human experiences occurring within a created salt marsh depends upon the integrity of ecosystem attained by the project.

Finally, salt marsh creation is still an exercise in approximation of naturalistic assemblages of organisms. Due to the complexity within ecosystems and the different values of people, the "success" of salt marsh creations are still difficult to measure. Thus, more research needs to be done to compare functions and values between naturally occurring and created salt marshes to determine the most appropriate shoreline protection techniques, to further, understand the relationship between created salt marsh and wildlife/fishery habitat, primary productivity and water purification. Aesthetic values of created salt marsh ecosystems within the context of land development projects also deserves further exploration.

In order to increase the incentive for incorporating salt marsh creation into coastal residential developments, detailed studies of long-term economic impacts, including non-monetary based values of created salt marsh (such as amenity, related to these project types) are needed.
Appendices

Appendix A: Endangered Species in Coastal Wetlands of the United States

Appendix B: Plant Description for Salt Marsh Creation/Restoration

Appendix C: Summary of Case Study Review
Appendix A  Endangered Species in Coastal Wetlands of the United States
<table>
<thead>
<tr>
<th>Range</th>
<th>Species (including subspecies, groups of similar species, and genera)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alaska, Northwest California ..............</td>
<td>Aleutian Canada goose</td>
</tr>
<tr>
<td>California</td>
<td>Saltmarsh harvest mouse</td>
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<tr>
<td></td>
<td>California clapper rail</td>
</tr>
<tr>
<td></td>
<td>Light-footed clapper rail</td>
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<tr>
<td></td>
<td>San Francisco garter snake</td>
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<td></td>
<td>Saltmarsh Bird's beak (a snapdragon)</td>
</tr>
<tr>
<td>California, Arizona</td>
<td>Yuma clapper rail</td>
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<tr>
<td>Carolinas to Texas, California ...........</td>
<td>Brown pelican</td>
</tr>
<tr>
<td>Rocky Mountains east to Carolinas.........</td>
<td>Whooping crane</td>
</tr>
<tr>
<td>Southeast</td>
<td>American alligator</td>
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<tr>
<td></td>
<td>Houston toad</td>
</tr>
<tr>
<td></td>
<td>Pine barrens tree frog</td>
</tr>
<tr>
<td>Carolinas</td>
<td>Bunched arrowhead</td>
</tr>
<tr>
<td>Florida</td>
<td>Everglades kite</td>
</tr>
<tr>
<td></td>
<td>Cape Sable seaside sparrow</td>
</tr>
<tr>
<td></td>
<td>Dusky seaside sparrow</td>
</tr>
<tr>
<td></td>
<td>American crocodile</td>
</tr>
<tr>
<td></td>
<td>Atlantic saltmarsh snake</td>
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<tr>
<td>Massachusetts</td>
<td>Plymouth red-bellied turtle</td>
</tr>
<tr>
<td>Main</td>
<td>Furbish lousewort</td>
</tr>
<tr>
<td>Hawaii</td>
<td>Hawaiian coot</td>
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<tr>
<td></td>
<td>Hawaiian duck</td>
</tr>
<tr>
<td></td>
<td>Laysan duck</td>
</tr>
<tr>
<td></td>
<td>Hawaiian gallinule</td>
</tr>
<tr>
<td></td>
<td>Hawaiian stilt</td>
</tr>
<tr>
<td>Guam, Marianas Island</td>
<td>Marianas mallard</td>
</tr>
</tbody>
</table>

Appendix B  Plant Description for Salt Marsh
Creation/Restoration
PLANT MATERIALS FOR COASTAL SALT MARSH RESTORATION/CREATION IN NORTH AMERICA

For marsh-planting purposes, the coastal salt marshes of the continental United States are divided into the Atlantic, Peninsular Florida, Gulf of Mexico, North Pacific, and South Pacific (Woodhouse, Jr., 1979). This study only focuses on the Atlantic, North and South Pacific Coasts. The Atlantic Coast extends from the Canadian border to south of Daytona Beach, Florida where the marsh species are largely replaced by mangrove trees (Knutson and Woodhouse, Jr., 1982). The North Pacific ranges from about northern California to the Canadian border; the South Pacific from north of San Francisco southward to Mexico (Woodhouse, Jr., 1979).

This section describes the plants that have proven successful for the restoration and creation of coastal salt marshes in North America. The plant information presented here is primarily based on the findings of Woodhouse, Jr. (1979) and Knutson and Woodhouse, Jr. (1982a & b).

A: Plant Materials in the Atlantic Coast

This region covers a wide range of climatic zones and a variety of secondary marsh species; however, the plant material used in this region is highly uniform (Woodhouse, Jr., 1979, and Knutson and Woodhouse, Jr., 1982a and 1983).

1) *Spartina alterniflora* (Smooth Cordgrass)

Smooth cordgrass is the dominant flowering plant in the regularly flooded intertidal zone throughout this region. Smooth cordgrass is native to the east coast of the United States; it is tolerant of inundation, well-adapted to sea strength salinity, and found essentially in pure stands. It can grow in a wide range of substrate from coarse sand to silty clay (Woodhouse, Jr., 1979). The height of smooth cordgrass tend to increase as elevation changes from mean high water to near mean low water (Garbisch, McCallum and Woller, 1975). Smooth cordgrass is easy to propagate, quick to establish and spread, and valuable in protecting the lower slope of spoil disposal areas or the eroding shorelines (Woodhouse, Jr., 1979). Plant productivity of this species will be maximized around the elevation of mean tide level when transplanted spacing 0.9 meters. Smooth cordgrass will naturally cover the lower elevation from mean tide level over time (Garbisch, McCallum and Woller, 1975).

2) *Spartina patens* (Saltmeadow Hay)
Saltmeadow hay is a fine-leaved grass (15 to 80 centimeters height) that occurs extensively all along the Atlantic Coast, replacing smooth cordgrass at about MHW; it tends to be dense from MHW to the Annual Extreme High Tide. Saltmeadow hay generally forms a narrow band along the marsh edge, but on the gently sloping topography it may cover a wide expanse, mixed with saltgrass, patches of needle rush, and other high marsh species. Saltmeadow hay tolerates either extended periods of flooding or drought and often occurs in the poor surface drainage areas; however, it doesn't tolerate the daily flooding of the intertidal zone. This species is also easy to multiply and transplant and is useful for the stabilization. The productivity of this plant can be high, although it doesn't contribute to the detrital food chain as much as smooth cordgrass does.

3) *Juncus roemerianus* (Black Needle Rush)
Black needle rush occurs along the northern Atlantic Coast just above MHW where it is only flooded by the wind-driven tides. The height ranges from 0.5 to 1.5 m. The characteristics of this rush are stems and leaves with sharp-pointed tips. It also grows with smooth cordgrass and saltmeadow hay near the edge of upland. Since black needle rush usually grows and spreads slowly, it will be best to let it volunteer naturally.

4) *Distichlis spicata* (Saltgrass)
Saltgrass is a low-growing grass widely distributed in the high marshes. The species usually occurs associated with saltmeadow hay and rushes, except in the small, poorly drained, and more saline patches where saltgrass becomes dominant. Although saltgrass can be an effective stabilizer, it will also be best to let it volunteer naturally.

B: Plant Materials in the Pacific Coast (North)
The species composition in this region is more diverse than those in other regions in the United States, and the elevational zonation of vegetative communities is less discrete (Woodhouse, Jr., 1979). Such diversity in the species is caused by the great influence of freshwater (Knutson and Woodhouse, Jr., 1982b).

1) *Salicornia* spp. (Pickleweed)
Pickleweed is a frequent colonizer of the irregularly flooded intertidal flats. It forms a dense mat, but is not a very effective stabilizer
because of its shallow roots. Since Pickleweed is the most salt-tolerate species in this region, it should be planted at slightly below Mean Lower High Water and supplemented with other species at the higher elevations.

2) Carex lyngbyei (Lyngbye's Sedge)  
Lyngbye's sedge is a major component of this region and usually occurs from about Mean Lower High Water to mean higher high water on silty substrates. Since lyngbye's sedge is relatively tall and a good stabilizer, it is recommended as the best choice for planting in the intermediate zone where the salinity is not too high.

3) Triglochin maritima (Seaside Arrowgrass)  
Seaside arrowgrass, plentiful in this region, is usually found lower in the intertidal zone and occasionally at the higher elevations; also, its ability to trap sediments and debris helps other plants to colonize. When planted with sedge, seaside arrowgrass extends lower than sedge.

4) Deschampsia caespitosa (Turfed Hairgrass)  
The elevation range of Turfed Hairgrass is similar to that of sedge. Turfed hairgrass is the most prevalent plant in high marshes where it is only flooded by the extreme high tide. This species is also a good stabilizer and sediment accumulator and easy to transplant.

C: Plant Materials in the Pacific Coast (South)  
Most of the coastal salt marshes in this region are substantially altered by man (Woodhouse, Jr., 1979). As opposed to the North Pacific region, the salinity in this region limits plant diversity, and the plant communities are relatively uniform (Knutson and Woodhouse, Jr., 1979).

1) Spartina foliosa (Pacific Cordgrass)  
Pacific cordgrass is similar in appearance to the smooth cordgrass found in the Atlantic Coast; however, it is not as tall and as vigorous as the smooth cordgrass. Still, Pacific cordgrass is the dominant flowering plant at the lower elevation of intertidal marshes throughout this region. This is recommended as the most useful plant for downslope protection and as an energy source of the estuary. This species can be established in either sand or fine-grained sediments. For successful establishment Pacific cordgrass should be planted from mean water level
or slightly below to about Mean Higher High Water.

2) Salicornia spp. (Pickleweed)
Pickleweed is often dominant in the high marshes in this region. This species is not as effective a stabilizer as Pacific cordgrass, but it is easy to plant, tolerant to the salinity, and the best to use up-slope of the Pacific cordgrass planting.

In general, the genus Spartina and the species Juncus and Salicornia are widely recognized plants in coastal salt marshes across North America (CTA, 1984). Salt marsh plants are usually propagated either by seeds or vegetatively. Transplanting with peat pot is common in order to stabilize shoreline; however, in protected sites, seedlings are more preferred because they require much less cost, labor, and time (Woodhouse, Jr., 1979). The average planting space of these materials is suggested to be one meter spacing for average conditions and a half meter for the exposed sites, although the difference would not matter after the first growing season (Knutson and Woodhouse, Jr., 1982). Normally full cover and near-maximum primary productivity of the newly established marsh vegetation will be attained in two to three years (Woodhouse, Jr., 1979). For more species and description of the marsh plants in these regions, see Woodhouse, Jr. (1979), and Knutson and Woodhouse, Jr. (1982a & b and 1983).
BIBLIOGRAPHY


Skabelund, R. Lee. 1994. Assistant Professor, Virginia Polytechnic and State University. personal communication.


Appendix C  Summary of Case Study Reviews
<table>
<thead>
<tr>
<th>Project</th>
<th><strong>CASE STUDY A</strong></th>
<th><strong>CASE STUDY B</strong></th>
<th><strong>CASE STUDY C (1)</strong></th>
<th><strong>CASE STUDY C (2)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Background</strong></td>
<td>compensation for lost salt marsh</td>
<td>waterway creation to the marina</td>
<td>shoreline protection</td>
<td>shoreline protection</td>
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<tr>
<td><strong>OBJECTIVE</strong></td>
<td>excavation</td>
<td>excavation</td>
<td>filling</td>
<td>filling</td>
</tr>
<tr>
<td><strong>IMPLEMENTATION</strong></td>
<td>created</td>
<td>restored</td>
<td>natural</td>
<td>natural</td>
</tr>
<tr>
<td><strong>TIDAL REGIMES</strong></td>
<td>dredged material</td>
<td>fine sand</td>
<td>fine sand</td>
<td>fine sand</td>
</tr>
<tr>
<td><strong>SUBSTRATE</strong></td>
<td>installed</td>
<td>installed</td>
<td>not installed</td>
<td>not installed</td>
</tr>
<tr>
<td><strong>CHANNEL</strong></td>
<td><em>S. alterniflora</em></td>
<td><em>S. alterniflora</em></td>
<td><em>S. alterniflora</em></td>
<td><em>S. alterniflora</em></td>
</tr>
<tr>
<td><strong>INITIAL PLANTING</strong></td>
<td><em>S. patens</em></td>
<td><em>S. patens</em></td>
<td><em>S. patens</em></td>
<td><em>S. patens</em></td>
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<td><strong>S. spicata</strong></td>
<td><em>S. spicata</em></td>
<td><em>S. spicata</em></td>
<td><em>S. spicata</em></td>
<td><em>S. spicata</em></td>
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<tr>
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<td>filled wetland</td>
<td>eroding bank</td>
<td>eroding bank</td>
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<tr>
<td><strong>LOCATION</strong></td>
<td>large low marsh &amp; steep high marsh</td>
<td>linear marsh with stone breakwater</td>
<td>fringe marsh along lawn</td>
<td>fringe marsh along forest</td>
</tr>
<tr>
<td><strong>FORM</strong></td>
<td>poor physical/visual access</td>
<td>stone breakwater</td>
<td>lawn area &amp; small dock</td>
<td>not planned</td>
</tr>
<tr>
<td><strong>ACCESS</strong></td>
<td>Low marsh &amp; aquatic habitats</td>
<td>low/high marsh &amp; stone piles</td>
<td>low/high marsh &amp; upland lawn</td>
<td>low/high marsh &amp; upland forest</td>
</tr>
<tr>
<td><strong>HABITAT TYPE</strong></td>
<td>dense initial planting with few volunteers</td>
<td>dense initial planting</td>
<td>dense initial planting with few volunteers</td>
<td>not established yet</td>
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<tr>
<td><strong>VEGETATION</strong></td>
<td>not adequate for indigenous wildlife</td>
<td>Benthic animals, small mammals</td>
<td>small mammals, birds, etc.</td>
<td>territorial, animals, etc.</td>
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<tr>
<td><strong>WILDLIFE UTILIZATION</strong></td>
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<td>effective</td>
<td>effective</td>
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<tr>
<td><strong>SHORE PROTECTION</strong></td>
<td>limited opportunities</td>
<td>educational opportunities</td>
<td>sensory experience</td>
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<td><strong>INTERPRETATION OPPORTUNITY</strong></td>
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<td><strong>ECONOMIC WELFARE</strong></td>
<td>not applicable</td>
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<td>significant</td>
<td>likely</td>
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</table>
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