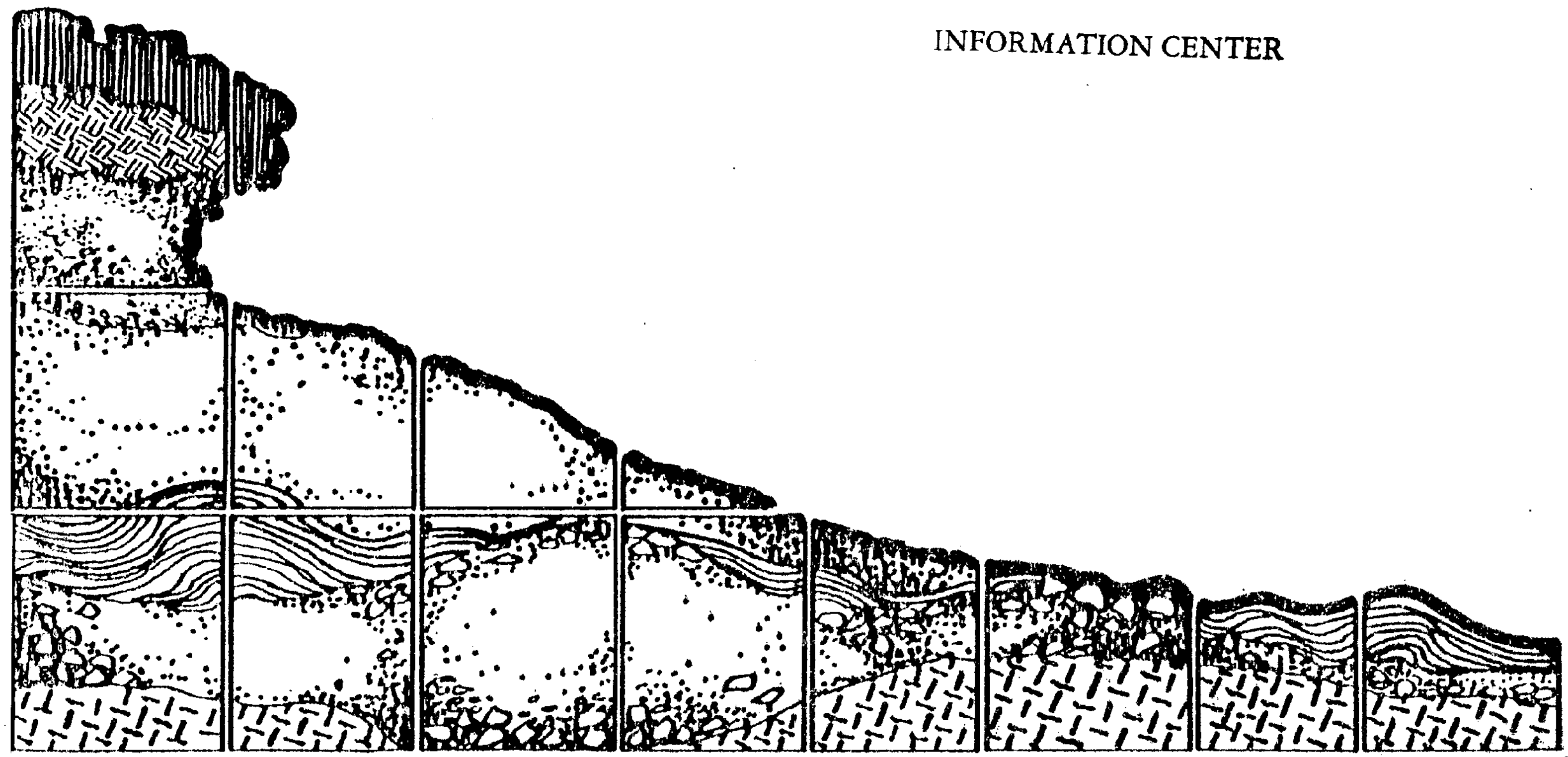
COASTAL EROSION
control handbook for... Rhode Island

COASTAL ZONE
INFORMATION CENTER



COASTAL EROSION control handbook for... Rhode Island

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Prepared for the Rhode Island
Coastal Resources Management Council

May 1981

CREDITS

Credit is given to the Landscape Architecture Department at the Rhode Island School of Design, for helping to develop the skills necessary for the preparation of this project.

As a faculty advisor, Michael Everett has offered guidance and criticism that has led to the format of this project. Lee Whitaker, of the Division of Coastal Resources, has provided his knowledge of Coastal Zone Management and has lent support throughout this project. Donald Greenough and Nicholas Pisani, have, in part, allowed the field work to be possible, and have provided their suggestions and knowledge of Engineering. Other persons within the Coastal Resources office have generously provided their assistance and use of office facilities for the preparation of this project. Linda Steere and James Parkhurst, Biologists for the Division of Fish and Wildlife, have shared their knowledge.

Special attention is given to the outstanding efforts that Donald Greenough, James Parkhurst, Nicholas Pisani, and Linda Steere have afforded in support of Coastal Conservation and Restoration.

CONTENTS

PREFACE

The State of Rhode Island's Coastal Resources Management Council's (CRMC) guiding principal is to "preserve, protect, develop, and where possible restore coastal ecological systems, and to measure, judge, and regulate any environmental alteration of the coastal resources." Since ecological systems are the basic functional units of nature, it is necessary to design plans and programs for the protection of each resource. The adopted policies and regulations of the CRMC state that the Council shall favor non-structural erosion controls.

The intention of this publication is to evaluate and provide an understanding of Rhode Island's coastal systems, determine past and present impacts of structural erosion controls, and to provide a range of options for the use of non-structural erosion controls that will best simulate natural processes and reduce impacts to the coastal zone. The premise of this handbook is that structural erosion controls generally are visually and physically degrading to ecologically and environmentally important coastal systems locally and within a broader scale. The overriding design goal is to make erosion control measures visually and physically subordinate within the coastal zone landscape.

There are erosion conditions along isolated sections of the Rhode Island shoreline where non-structual controls are not wholly appropriate nor effective. In such cases, structural controls must be designed for site specific conditions and evaluated by the CRMC and its staff to ensure that the proposed structure will effectively control the erosion without causing adverse impacts on adjoining and nearby shoreline property or the environment.

THE PROBLEM

It has been proven that wind, water, and gravity are the primary factors that encourage erosion within coastal areas. The rate varies according to the slope, soil composition, vegetative cover, meteorological conditions, and wave and current velocities. It is a fact that within these coastal areas property is threatened by erosion, and people invariably consider structural solutions. People do so without realizing non-structural methods are less expensive, and in the long run, more effective both physically and visually .

In Rhode Island human activity close to the shoreline will weaken its' capacity to withstand erosional forces. In certain cases where people clear house lots along the coast, the loss of vegetation intensifies the velocity and rate of fresh water runoff, causing the erosion and sedimentation to the shoreline and adjacent area, and a loss of property will result. Another example can be seen along the beach where a jetty has been constructed. Here sand accumulates and restores the immediate area although, the downdrift zone has been deprived. Therefore, cummulative effects should be considered before any alteration to the coastal zone has been initiated.

All shoreline systems are dynamic and change their shape and character in response to storms, currents, unnecessary human modifications, and the gradual rise in sea level, therefore, these are unstable sites for permanent structures.

CRMC field experience has demonstrated that a portion of the public sector is not aware of the fact that any alteration to the coastline could impact upon that area. The people that should be totally aware of this (i.e.,homeowners,contractors,and developers) are not and often times fail to file an application with the CRMC for shoreline alteration. Normally, if non-structural methods of erosion abatement are used the owner can begin work with a letter of assent from the Council instead of having to go through the application procedure. Failure to receive CRMC approval prior to commencement of shoreline alteration work or the installation of shoreline protection facilities will result in delays, possibly legal action, and otherwise avoidable problems had the party correctly sought Council approval.

It is the intention of this handbook to inform the public of shoreline treatments most acceptable to the state, based on existing natural conditions.

SOLUTION

In 1972, the Coastal Zone Management Act was passed by the federal government because of an awareness for potentially adverse effects of intense pressures upon the national coastal zone. It is on the state level of government that specific policies and regulations have been designed to manage the coastal zone (illus.1). Theoretically the planning and management processes continue to evolve from basic standards and criteria. Concurrently, the Science Of Ecological Planning and the Art Of Landscape Architecture will be used to evaluate and design solutions for non-structural erosion controls. The Ecological Planning Process will establish a framework that is broad enough to study entire ecosystems as well as examine individual environments within that ecosystem.

METHOD

THE SCIENCE OF ECOLOGICAL PLANNING involves two stages:

1. Inventory of natural and cultural conditions.
2. Synthesis of natural and cultural conditions.

THE ART OF LANDSCAPE ARCHITECTURE includes:

1. Evaluation of aesthetic environment based on aesthetic criteria.
2. Selection and adaptation of preferred design solutions.

The preferred design solutions are based on the idea of ecosystem management and are clearly cognizant of cultural needs.

NON STRUCTURAL CRITERIA

A survey of Narragansett Bays' shoreline in 1979, revealed that along a quarter of the shoreline natural features had been replaced by man-made structures. Most of the construction on the shoreline that has taken place in the last two decades is an attempt at "erosion prevention", undertaken at great cost by private owners. Unfortunately, many of the people who have built bulkheads or rip-rapped their shorefront with fitted stone or concrete do not realize that most of the erosion in the Bay takes place during major storms and hurricanes and that their structures will not withstand even a "ten year storm" of high intensity. These same structures, however, are usually more elaborate than what is necessary to check the small scale erosion that takes place between major storms (1).

Vegetation as a means of erosion abatement is more efficient than structural methods and is by far <u>less expensive</u>.

If a comparitive cost analysis was done for constructing a bulkhead or rip-rapping as opposed to planting and maintaining vegetation the results would be totally in favor of planting vegetation. While doing so, the cost of reconstruction after a major storm should be kept in mind.

Not only is the use of vegetation as a means for erosion control less expensive, but it also provides for wildlife needs. With the proper selection of plant species, food, shelter, and breeding habitats can be provided for local species.

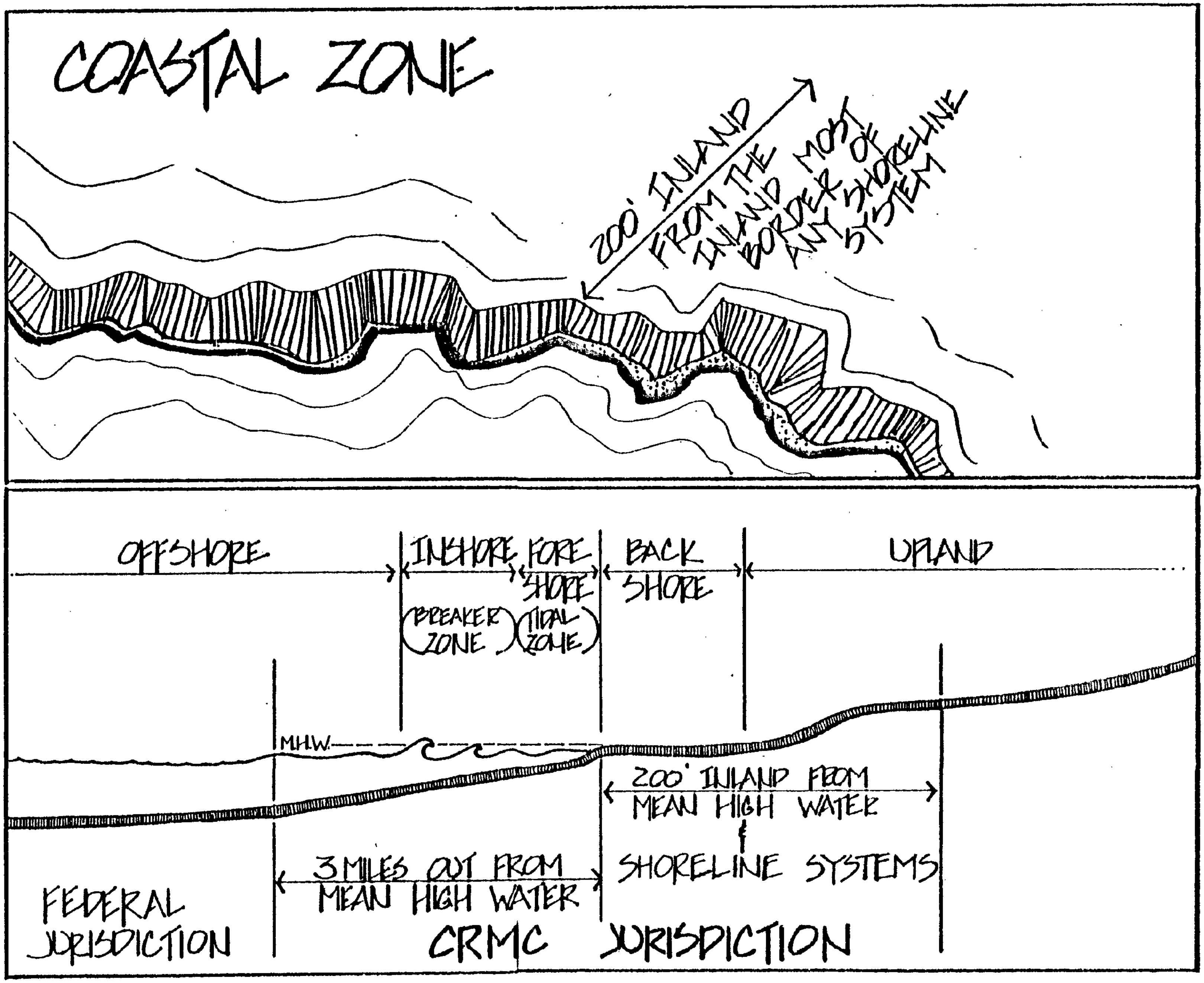
AESTHETIC CRITERIA

"AESTHETICS" is defined as a branch of philosophy concerned with that which is beautiful in art and nature.

The aesthetic quality of Rhode Island's coastal systems is based on and characterized by landform, water, and vegetation. Each coastal system offers unique variety and vividness. Variety is seen and vividness is perceived as a strong, clear impression on the senses. Variety and vividness is derived from terrain patterns, presence of water, weather characteristics, vegetational pattern, and cultural land use patterns. Uniqueness is determined by the composition of space, form, texture, and color of any given coastal unit.

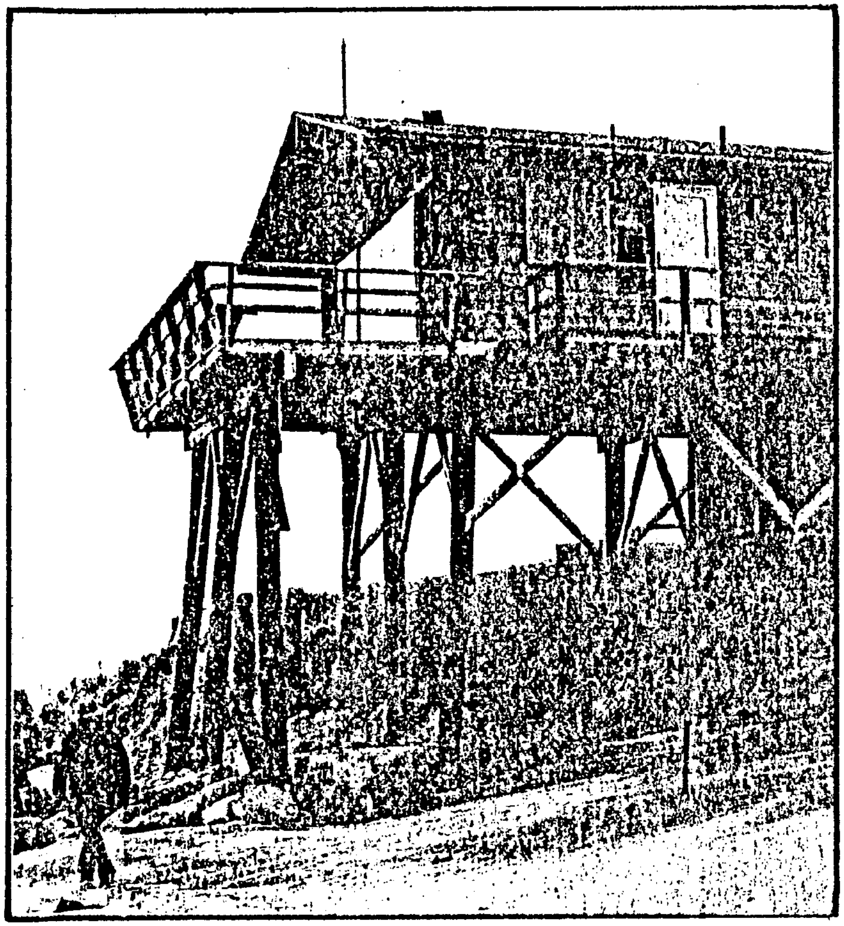
Since coastal systems are considered aesthetic resources they are visual or sensory attributes of a landscape, and have a value distinct from that of the practical utility of ecological functions of the resource. The protection of aesthetic resources, along the coastline, would reinforce the wise management of biological and ecological resources, and would maintain and enhance the visual and perceptive qualities that these resources provide. Management of the environment for its aesthetic and ecological attributes is a valid concern for everyone.

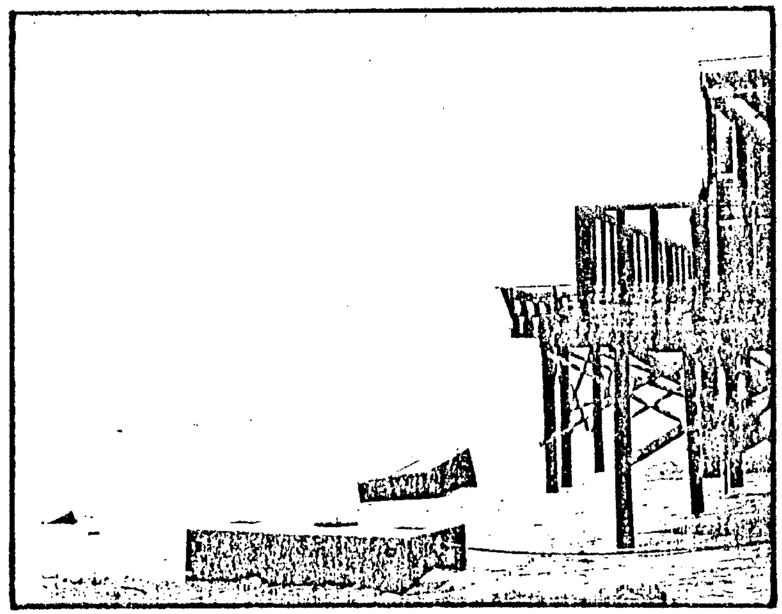
Any physically placed cultural influence prevalent within a, or along a coastal system forms a basis for aesthetic judgement. Cultural influences alter the unique quality, and unity of a particular landscape unit. Unity alteration is degrading to Rhode Island's coastal landscape.

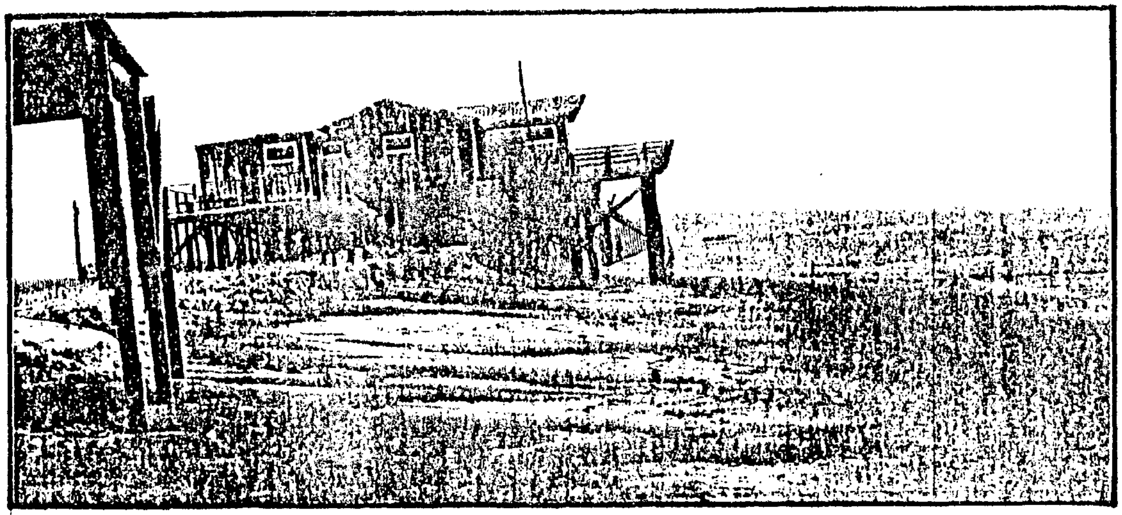

COASTAL ZONE
200' INLAND FROM THE INLAND MOST BORDER OF ANY SHORELINE SYSTEM
OFFSHORE
INSHORE
FORE SHORE
BACK SHORE
UPLAND
(BREAKER ZONE)
(TIDAL ZONE)
M.H.W.
200' INLAND FROM MEAN HIGH WATER & SHORELINE SYSTEMS
3 MILES OUT FROM MEAN HIGH WATER
FEDERAL JURISDICTION
CRMC JURISDICTION

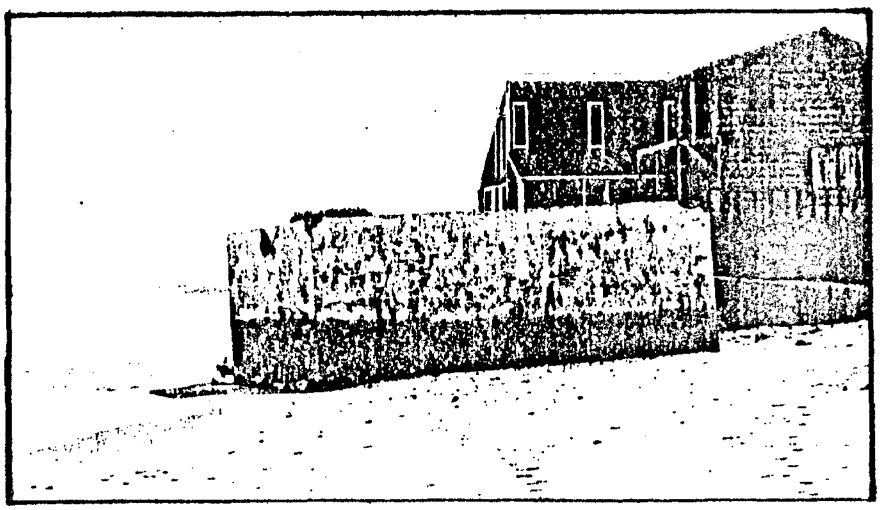
1.

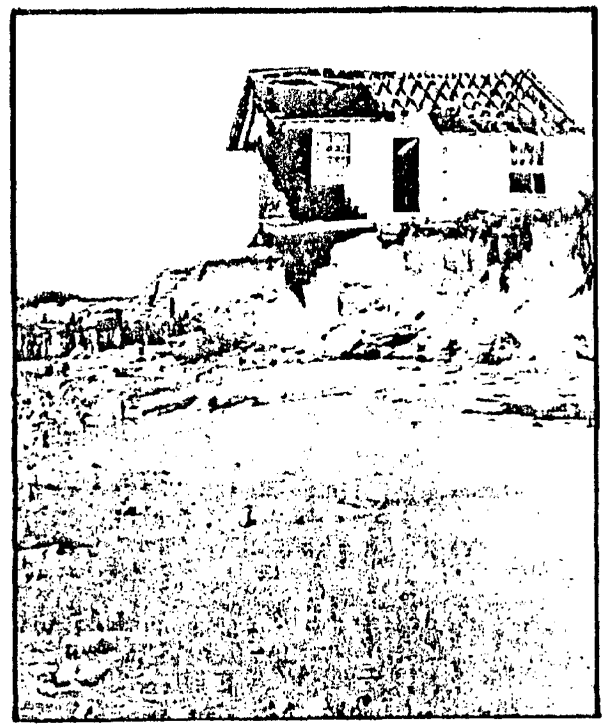
STORM EROSION . . R.I.









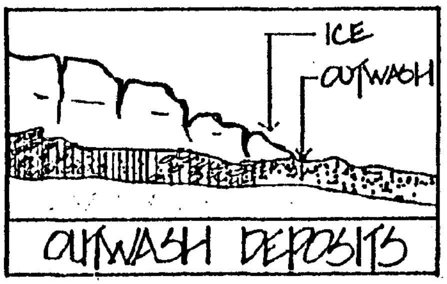


NATURAL ENVIRONMENT

GEOLOGY

Approximately 12,000 yrs. ago during the last ice age, in the Tertiary and Pleistocene Periods, R.I. was a series of hills and valleys with rivers flowing toward a sea whose shore lay off what is now Block Island. As the glacier moved southward, it covered the land with ice as much as a mile thick, scouring and scraping the land to create the gentle contours characteristic to the R.I. landscape. As the glacier retreated, vast quantities of boulders, sands, and sediments where deposited over the land and into the river valley that now underlies Narragansett Bay (2).

A large variety of shoreline types can be found along the coastal edge of Rhode Island. Sandy barrier beaches can be found along the southern shorelines. These landforms act as natural buffers that protect the coastal wetlands directly inland. This southwestern shoreline is generally composed of glacial outwash. (illus.2).



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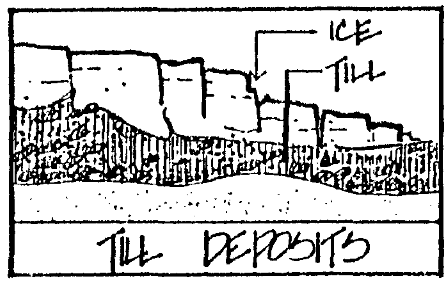


3.

Along the southeastern coastline starting in Newport, large cliffs of bedrock prevail forming a jagged shoreline, and in places sandy beaches have formed from eroded bedrock and other sediments. East along Little Compton, and in Tiverton, easily erodeable shorelines of glacial till exist (illus.3). Wide sandy beaches are found along the ocean shore at Bonnet Shores, and between the southern headlands of Middletown. There are a few sandy beaches inside Narragansett Bay where longshore currents have built small barrier spits across shallow embayments and cuspate beaches such as Conimicut Point. The most common shoreline in the state is a narrow shoreline of till backed by a scarp. The scarp is often unvegetated. The shorelines of Beavertail and Common Fence Point are made of soft rock that is easily erodible. Brenton Pt., is made of a hard granite and metamorphic rock that is by far the most resistant to erosion. Another category of shoreline is common in sheltered waters, where sediments are likely to accumulate. Here salt marshes flourish. If undisturbed salt marshes are capable of laying down a layer of peat, composed of dead plant material, that permits the living marsh to grow upward and keep pace with the rising sea level. In some old and well-established marshes, the peat may be several feet thick.

HYDROLOGY

Glaciers have dramatic effects on sea level. When New England's surface water was in the form of ice, the oceans were much smaller. During the last glacier, the Wisconson, sea level in this region was about 300 ft. lower than it is today. As the ice melted sea level rose and advanced inland. The rise due to both a slow increase in the volume of water in the ocean and to a gradual sinking in the New England land mass. The present rate of rise in sea level may seem insignificant, but it should be kept in mind that much of the shoreline is low-lying and that a vertical rise of 1 ft. may account for an inland advance of thirty or more feet.

Rainfall in R.I. averages 3 ft. per yr., and river discharge peaks in March and April. With the increasing development of paved upland surfaces discharge into rivers and streams is greatly accelerated and can contribute to the rise in sea level.

Some scientists conclude that the increase in carbon dioxide in the worlds' atmosphere caused by the rapid burning of fossil fuels in this century may cause a warming trend. This could melt more ice at the poles and rapidly accelerate the rise in sea level worldwide. Others argue that the carbon dioxide levels are not great enough, or it may only serve to forestall the period of climatic cooling that will precede the next era of glaciation (3).

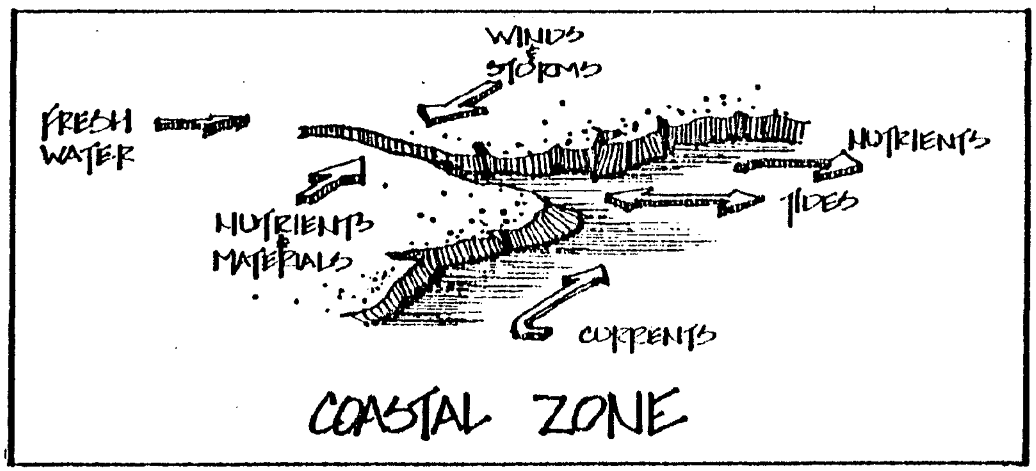
RHODE ISLAND COASTLINE

The Rhode Island coastline, like others, is never still. To the casual observer this seems obvious since the water conditions are ever changing. Tide and waves, storm and calm are the dynamics that can go unnoticed. But there are other actions revealed to a slightly more perceptive observer. Certainly, this does not make the coast different in kind from all other places on earth, but the rate of change is always faster. Since the coastal zone is only a narrow band at the junction of land and sea, it makes the relative importance of change a serious matter, not only to man, but to the survival of the intricate and productive systems of plants and animals that are found there. Like man, these organisms have contihuously adapted to the coastal dynamics. The balance between the organized biological arrangements and the changing face of the coast are often delicate when seen against the extremes of energy released through storms, sweeping ocean currents, and large tidal increases.

To better appreciate the conditions of coastal existence, it is helpful to think of the coast as the meeting and mixing place where fundamental forces and substances from both land and sea are joined. Every day of every year materials are blown or washed from the land's surface and carried down to the water's edge. The constant renewal of the meteorological and hydrological systems powered by solar energy and gravitational forces guarantee the transport of the earths' materials to the oceans will continue. Contained in the flows of waters and winds are sands, silts, clays, and organic particles along with dissolved chemical compounds from the land. These substances may accumulate in higher concentrations as they are transported to coastal waters thus increasing the load for eventual deposition to the oceans. This land to sea movement contributes basic material for the building of coastal forms, and is the source of salts and chemical nutrients necessary to the health of coastal and oceanic ecosystems.

Unfortunately, not all materials transported from land to coastal waters are benign and beneficial. The same forces that carry chemical nutrients such as nitrogen, phosphorous, calcium, iron, potassium, and others also move the waste products of human endeavor to the coast. These waste substances are often harmful either because they are over-concentrations of otherwise useful and needed materials or because they are directly toxic to living things. When the land-derived materials enter the coastal areas, the currents, tides, and waves of the coastal waters provide the transport system for distribution and dilution. This action of transport from places of origin or concentration to places richly endowed with nutrients and food sources spreads the chemical basis for biological productivity along the coastal zone and outward to the ocean.

River outfalls, coastal wetlands, and estuaries are singularly important areas for which nutrients and food are removed. Many of the currents transporting materials from the outfalls carry them long distances. Less dramatic, but equally important are the local currents and daily tides (illus.4).



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In many ways, it is the effects of day-to-day stresses of winds, waves,tides, and currents rather than major storms that are the physical factors which determine the biologic systems occupying different locations along the coast and from coast to open sea. It is the high and low levels of tide that determine the zonation of plant and animal species on all shores. It is the depth of disturbance of waves coupled with turbidity that limits the growth of subtidal organisms on the floor of the sea. It is the shape and composition of the water's floor, in combination with coastal currents and tides that influence species of fish in their choice of habitats. It is the patterns of flow, the circulations, and mixing of fresh and saline waters in the estuaries and coastal ponds, that fix the locations of shellfish beds or the spawning areas of other mollusks (clams and scallops), crustaceans (crabs and lobsters), and fish. And it is the transport and dilution of both benificial and harmful chemicals and sediments by coastal and ocean currents that in large part determine the level of productivity of coastal ecosystems (4).

The dynamics of a coastal area are therefore, essential to its' ecological well-being.

TIDES & WIND

The forces of the sea originate in the sun and the moon. The sun causes air movements, winds, and helps the moon create the tidal rise and fall of the ocean surface. Air movements originate with temperature changes. The sun heats the earth, the waters of the earth, and the air around the earth, but this heating is not uniform. The air in some parts of the earth is heated more than that in other places. The warmer, lighter air rises, causing a zone of reduced pressure; winds result as colder, denser air moves into this zone (5).

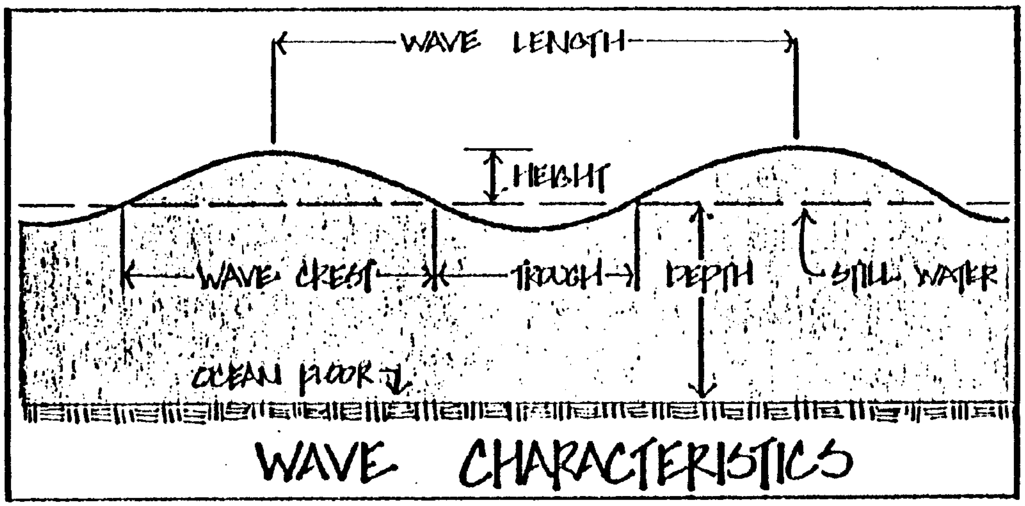
The moon and to a lesser extent the sun, creates the tides of the sea. During full moon days and two days thereafter the tide averages its highest provided there is no meteorologic influences. This is also true during new moon periods. This tide level is referred to as "Mean High Water Spring",MHWS. On other days the highest limit line is, MHW. The low tide limits are just the opposite with "Mean Low Water Spring", MLWS, and MLW. The mean tide level is generally that of mean sea level.

In Rhode Island tidal fluctuations vary from a height of 3.6 ft. at the southern portions of the state, where the Narragansett Bay and the Sakonnet Rivers meet the ocean, to 4.6 in the upper, northern, zones of these areas. Although, when high energy storms are present the water level can exceed the height of an average high tide in places by 10-12 feet (1).

Together, the sun and moon generate the tides because they attract the water masses in the same way that the earth attracts objects near its surface. Because of this gravitational force and the fact that the sun, moon, and earth are always in motion with relation to each other, the waters of the ocean basins are set in motion. Once the water masses of the oceans have been set in motion, they create the tides and currents (5).

WAVES

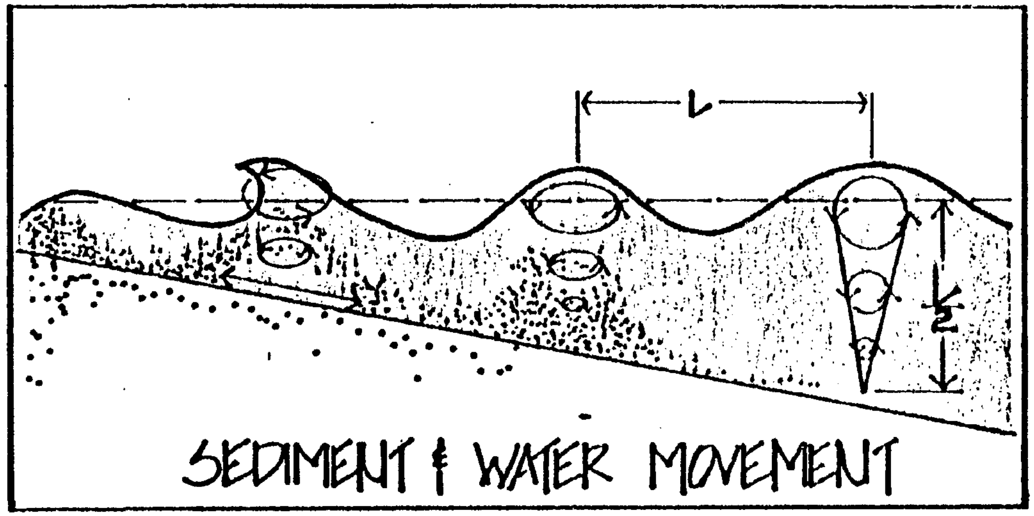
The familiar waves of the sea are "wind waves" generated by winds blowing over the water. They may vary in size from ripples on a coastal pond to large ocean waves. Wind waves cause most of the damage to shorelines. Another type of wave ,the tsunami, is created by earthquakes or other large disturbances on the ocean bottom, but fortunately they do not occur frequently along the Rhode Island coastline. Wind waves, known as oscillatory waves, are usually defined by height, length, and period (illus.5).Wave period is the time between successive crests passing over a given point.



5.

When waves move over the water, only the form and energy of the waves move forward. Advance of the wave form causes oscillatory motions of the individual water particles. These particles describe circular orbits in deep water with each particle returning to its original position after passage of the wave. The diameters of the circles decrease with depth from a diameter at the surface equal to the wave height.

In shallow water the orbital movements become flattened, and at the bottom, if the water depth is shallow, sediments begin to shift (illus.6).



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The height, length, and period of waves are determined by the distance the generating wind blows over the water, and the length that it blows. The fetch is therefore, the determining factor for wave development. Generally, the longer the fetch, the stronger the wind, and the longer the time that the wind blows over the water, the larger the waves will be. If winds of a local storm blow toward the coast, the generated waves will reach the local shore in essentially the form in which they are generated. If the waves are generated by a distant storm, they may travel through many miles of calm water and decay as a result. Waves that have under-gone this type of change will reach the shore as relatively long, low waves (5).

CURRENTS & SURGES

Currents are created in the oceans, adjacent bays, and tidal marshes when the water in one area becomes higher than the other. Water in the higher zone flows toward the other and a current begins. Causes of differential movement are tides, wind, waves, and stream and river flow into the ocean. Changes in water temperature also cause changes in water density and produce currents such as the Gulf Stream.

As the wind blows over the water it creates stress, and the water particles move in the same direction as the wind. Thus, a surf ce current is created. When the water hits a barrier, such as land, a storm" surge"is experienced. Its velocity depends on wind speed, direction, fetch, and water depth. "Storm surges" on the north Atlantic coast rise to a lesser degree than than that on the shallower southern Gulf coast.

Waves create a current known as the "longshore current" when they approach the beach at an angle. These currents are responsible for the transport of sediments along the littoral zone (6).

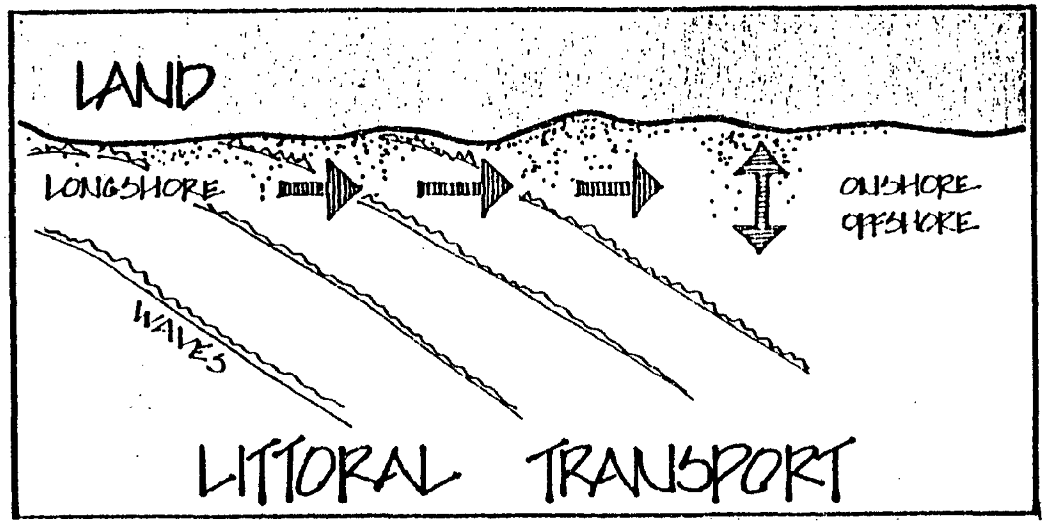
LITTORAL TRANSPORT

Littoral transport is defined as the movement of sediments in the nearshore zone by waves and currents and is divided into two general classes: transport parallel to the shore, longshore transport, and transport perpendicular to the shore, onshore-offshore transport. This transport is distinguished from the material moved, which is called "littoral drift" (illus.7).

Onshore -offshore transport is determined primarily by wave steepneds, sediment size, and beach slope. In general, high steep waves move material offshore, and low waves of long period, move material onshore. Longshore transport results from the stirring up of sediment by the breaking wave, and the movement of this sediment by the component of the wave in an alongshore direction, and by the longshore current generated by the breaking wave. The direction of longshore transport is directly related to the direction of wave approach, and the angle of the wave to the shore. The average annual net rate of littoral transport at a given place is fairly regular from year to year unless the shoreline has been altered by some sort of structure that eliminates or reduces the supply of sand. Obviously, the rate depends on local shore conditions and alignment as well as the energy and direction of wave action in the area (6).

NATURAL STABILIZERS

Despite the potential for shoreline erosion along the R. I. coastline, the growth of biological communities on shore and in the intertidal zones help to stabilize the shifting coastline. The successful establishment of living communities of plants and animals is very important to these areas. Beach grasses and shrub communities protect against wind and water induced erosion along barrier beaches and beachs. Salt marsh communities cushion some of the intertidal areas against the full forces of storm-driven water. In all instances, the presence of healthy vegetation is a natural mechanism providing a more stable base for the plants themselves, fostering a physically stronger biologic community, and allowing for the expansion



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of the community along its margins. The dynamic mix of natural forces along the coast slows the development of large, highly productive and relatively permanent coastal ecosystems. Some R.I. salt marshes, for instance, have taken thousands of years to grow to their present size. All the while, they are subject to the physical stresses of changing weather, water movement, and dramatic changes in sea level. Yet they survive and grow. In addition to their value as habitat and sources of primary productivity, natural landforms, barrier beaches, dunes, beaches, and salt marshes, in the coastal zone provide significant protection from coastal storms, flooding, and erosion. Beaches and marshes also, dissipate destructive storm waves over their gradual slopes. Dune systems, if stabilized by beach grasses and other binding vegetation, prevent direct wave attack against inland areas. Barrier beaches protect both mainland development and the salt marshes and productive habitat between them and the mainland.

In order to function effectively as natural buffers, however, these landforms and the natural processes which link them together must remain relatively free from alterations which would disturb their natural state of "dynamic" equilibrium. For example if natural erosion of one beach is providing sediment material via littoral transport that is eventually deposited on another beach farther downcoast, it will be important to prevent any action to retard erosion of the upcoast beach from impeding the flow of sand to the downcoast beach. As another example, barrier beaches migrate slowly inland and downcoast, but this movement allows them to maintain their elevation and protective capability relative to rising sea level and storm forces. Only monumental climatic alteration or geologic change would be sufficient to destroy or damage the natural resiliance of the coastal ecosystems were it not for the presence of man.

Pressure for development of sensitive buffer areas for residential, commercial or recreational uses has been significant in the past, resulting in substantial losses of property during major northeast storms and hurricanes, and impairing the ability of these buffers to protect inland development and other unique aspects of the coastal zone. These man-induced stresses, however, are not simply occasional; they are widespread and becoming more frequent.

ECOSYSYTEM MANAGEMENT

The concept that ecosystems recognizes that all life is interconnected and interdependent. It rests on the understanding that there is an organization among plants and animals in response to their physical environment that promotes optimal efficiency in capturing, storing, and transforming the energy and chemical elements essential for life and growth within the group of organisms living in a given area. Since this process occurs both worldwide and locally, it is possible to think of something as large as one global ecosystem or as small as the group of plants and animals livingon one type of rock in the intertidal zone. The fundamental physical and chemical conditions in the environment make it possible or impossible for particular organisms to survive in a particular place. It is for this reason that the living world exhibits such variety; species occupying any one place are only those that are adapted to functioning together in their local conditions of sunlight, physical forces, and chemicals (4).

Modern coastal management depends on growing knowledge of ecosystems as the basis for decision making. Such knowledge is also essential to all levels of private and public planning for land and resource use, unlike earlier management techniques that focused efforts on whole ecosystems. Changes in any one part of the ecosystem, however small or remote,cause alterations in all other parts, and sets the pace for management.

The coastal zone of Rhode Island has several types of coastal ecosystems, barrier beaches, sand dunes, beaches, salt marshes, barrier wetlands,and cliffs, ledges, and bluffs. While the major elements of each ecosystem are known, and the principals that govern the physical and biological interactions of each are understood, there is still a need for the physical protection of these vitally important natural resources. Ultimately, it will be the degree to which improved knowledge of the coastal systems can be disseminated to, and consistently applied by, all coastal zone users and decision makers that will preserve Rhode Island's coastal resources in the future.

VEGETATION .. EROSION ABATEMENT

There are two methods by which erosion can be controlled, either permanent or temporary. Temporary erosion controls are those that are implemented until permanent control has become established.

Nature has provided itself with the most efficient means of erosion control, that being vegetation. Where there is a fairly good cover of surface vegetation, along R.I.'s shoreline and adjacent slopes, the ground is stable. Where there is little or no surface vegetation, these areas are unstable and prone to erosion. The foliage and branches intercept rain that would otherwise fall directly on a slope, their roots bound and stabilize soil, and their fallen leaves and dead twigs reduce the rate of overland water flow. Since indigenous plant species are the most adapted to these areas their chance of survival is far greater than those introduced from foreign places. It is a fact that indigenous plant species require little to no maintenance after they have become established.

Planting vegetation on highly erodeable steep slopes is hard to acheive, therefore it is here where vegetation should be left in its natural state. Eventhough planting on steep slopes is difficult, with the proper knowledge and procedures it is highly possible to acheive with good results. With the availability of water becoming a problem more and more people are using indigenous plants that are more adapted to coastal soils and the climatic conditions that prevail.

A setting of native shrubs and trees grown naturally and informally can look very neat and appealing without demanding care. In fact, limiting maintenance is important to the plants survival. Leaf cover, for example, should be left on the ground under the plants to decompose and build up organic content within the soil. This aids water retention, recycles nutrients, and reduces the risk of erosion. Indigenous plant species require virtually no pesticides. Chemical insecticides can be counter-productive and deprive the landscape of its natural vitality. Bugs are important to nature and all are not at odds with landscape objectives. If no hard chemical pesticides are used, temporary inconveniences in the landscape may result but that is the way nature operates and it is best accepted.

Landscaping with plants that would grow naturally without care or energy subsidy will support the design and function of the landscape requiring a minimum of supplemental care. This practice not only helps to fight the forces of erosion, but also conserves energy by limiting the need for pesticides, fertilizers, and water, all of which require fossil fuels for processing and delivery. The balance of natural systems and all the creatures of nature who depend on a quality functioning natural environment are also protected. A well designed native landscape can help to stop erosion, require limited maintenance, and look the way it is naturally supposed to, once established.

SELECTION

The usual method for introducing shrubs and trees is by planting. Seeding is undesireable because of establishment time, cost, and difficulty of germination. Planting has the advantage of allowing the plant to be placed in the exact position required to give both physical and visual protection immediately. The rapid drying, especially of steep slopes, makes these sites even more unfavourable for direct seeding. Therefore, the selection of appropriate plant material is necessary.

Plant material can be obtained as seed, bare-root, balled and burlapped, or container grown.

Direct seeding, is most often done with grasses in spring and late summer or early in the fall. Seeding is difficult on slopes because of the lack of water. When Seeding is done during periods of rain the chance of erosion is greatly increased. For a comprehensive procedure and listing of grass types refer to the state of Rhode Island's, Soil Conservation Service,"Sediment Control Handbook".

Bare-root plants, are those that have no soil under their roots. Great care must be taken to be sure that the roots do not dry during planting. Bare root plants should be dug and re-planted only when they are dormant.

Balled and burlapped plants, are those that are dug in a nursery with a ball of soil around their roots that is held in place with a burlap wrapping.

Container grown plants, are those that are produced in the nursery in a container and sold in that form.

The selection of plant species should be governed by the selection of materials appropriate to the site. All plant material chosen should be of normal health and vigor, there survival depends on it.Listed are standards set forth by the, American Nurserymen's Association:

1. The general condition of plant material should be:

a. Uniformity of leaf coloration.
b. Dormant plants should exhibit firm,moist,and uniformly placed buds.
c. Plants should have uniform twig and leaf growth on top and sides,including their base.
d. Generally,plants of the same species should exhibit the same growth habit.
e. Balled and burlapped plants should have a firm root ball of relatively good size.

2. Check individual plants for for freedom of defects.

a. Decay. Look for spots of rotten tissue on the main stem and branches.
b. Sunscald. Look for areas on bark that is differing in color,usually on the south or west side.
c. Abrasions of the bark.
d. Girdling roots that are close to the surface and circling the trunk or main stem.
e. Improper pruning. Stubs left are point of entry for insects and disease.If cuts are made they should be flush with trunk, or if on branch it should be back to the bud.
f. Frost cracks. Long vertical splits in the bark on south and southwest side. Entry for fungi and bacteria.
g. Signs of injury. Dead leaves,and flower buds,die back of twigs and branches;blackened sapwood; sunken patches of discolored bark,sunscald,on trunk or limbs.

3. Check individual plants for freedom of diseases and insects.

a. Diseases. Will appear in many forms such as abnormal growth of leaves,twigs,fruits,discoloration of leaves and bark,unusual discharge of sap through the bark,etc. Any plants showing these signs reject.
b. Insects. Look for eggs, evidence of leaf feeding,and twig,bark and trunk feeding. Look for bore holes in trunk and bark. Trees showing any of these signs reject.

3. Check all container grown plants for healthy root systems. Plants that are found to be pot bound, wrapped around the interior of the container,and plants that have insufficiently developed root systems, will not hold the soil together when removed from the container and should be rejected. Healthy roots should be able to hold the soil mass together yet not be crowded around the outside. They will appear whitish in color.

DELIVERY

In spite of the desirability of ordering trees and shrubs from a nursery close at hand in order to minimize delivery time and to obtain stock acclimatised as possible to the site, it is often necessary to order from more distant and larger nurseries with a wider range of species and cheaper stock. Speed of delivery has always been recognised as an essential, the more so on difficult sites where the good condition of delivered stock may be a very important factor in the success of the operation. Most large nurseries deliver by road whenever possible. All possible steps must be taken to minimise the time during which the plants are out of the ground. As soon as the plants are received, care should be taken to ensure that the roots are kept covered with a material to keep them moist. Balled and burlapped material should be protected from drying damage and should also be kept moist by watering and covering the root ball (7).

SITE PREP

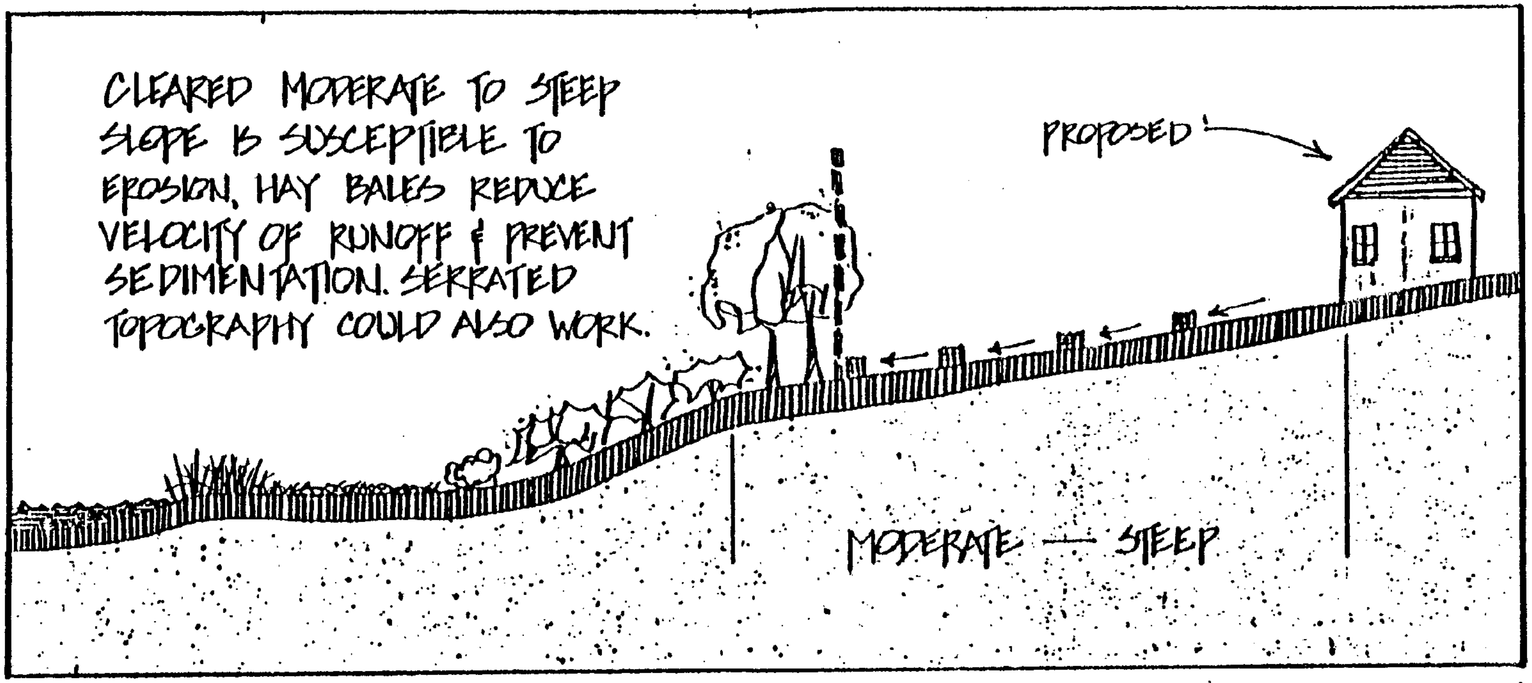
Grading and earth moulding operations however necessary for erosion control or land use, may often be detrimental to the growth of trees and shrubs planted shortly afterwards. The heavy machinery or heavy foot traffic can cause compaction of the soil with loss of structure and reduction in soil aeration. This happens particularly in areas of high clay content. Apart from compaction and air loss, grading disturbs the natural contours of landforms, causing soils to lose moisture, and increases the velocity of runoff. Site preparation should be done with regard to:

- Natural contours of the land should remain unless proven otherwise.
- Proper site preparation is important to insure the successful establishment of newly implemented plants.
- Site prep and planting should be backed to minimize moisture loss in soil.
- Large sites should be prepared and planted in sections to limit exposure of slope.
- Remove and disturb only what is necessary.
- Vehicular and foot traffic should be localized to maintain slope stability.
- All materials to be disposed of should be removed from the site vicinity.
- Hay bales or approved equal should be used on the toe,top,and back of slope to reduce runoff velocity (illus.8).

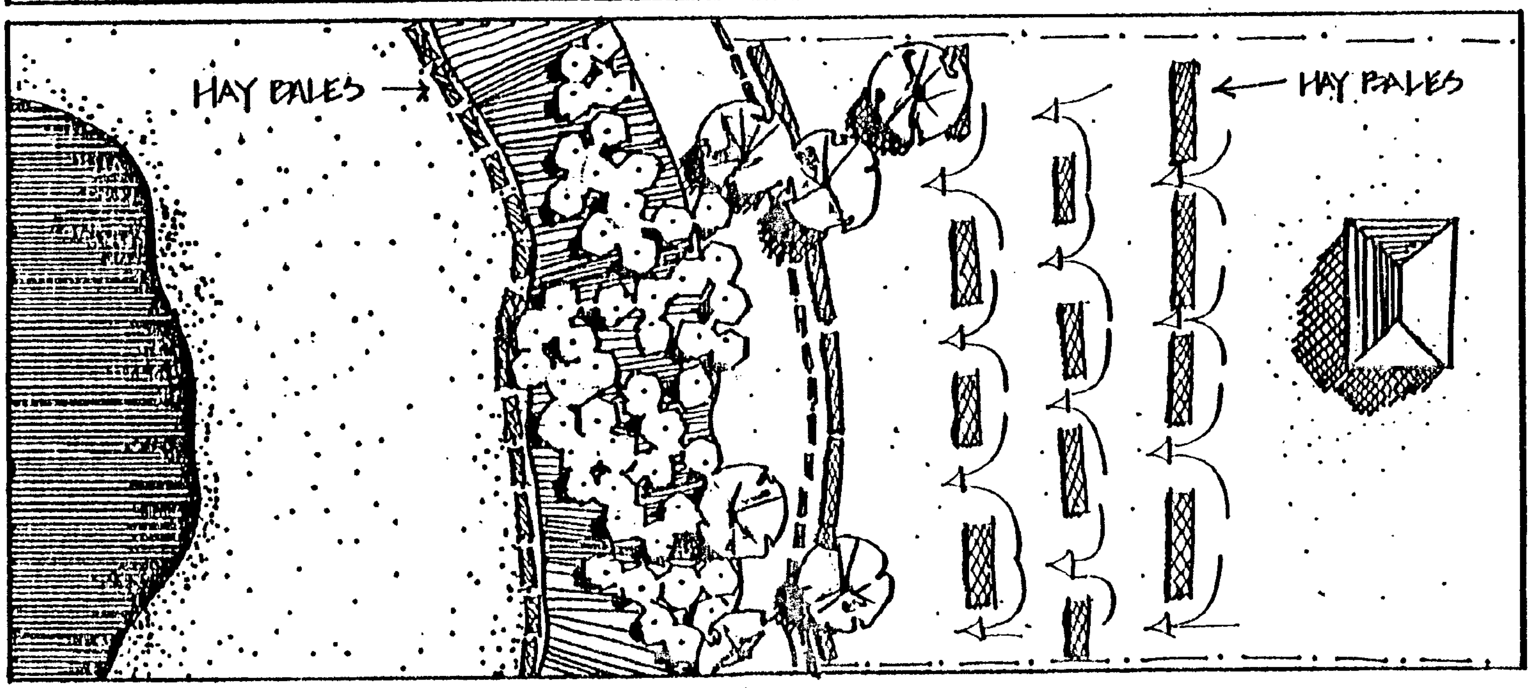
PLANTING

Ideally planting takes place while the plant is dormant, after the plant has hardened off after the last years growth, this being the period during the end of October to the beginning of April. Provided periods of cold winds and frost are avoided, planting can go on throughout the winter and spring with reasonable success. If new plantings go into the winter, when the humidity is low and winds are high, the mortality rate of new plants is most likely to be high. Therefore, it is important to supply new plantings with adequate moisture so that they do not become dehydrated during the winter months. Hot dry summer months are also critical (7).

Plants growing naturally spread by underground runners, rhizomes, and by seeds. When they spread and grow naturally they often form dense clusters. The feasibility to produce this type of appearance is not economical and can not always be done. If plants are spaced closely they have the ability to obtain surface stabilization by the root network sooner. This is not to say that plants cannot be placed in such a way they take on a natural character. Too often plants are placed in the landscape in neat straight lines, and in order to maintain their appearance they must be maintained. Maintenance is often difficult on slopes. The placing of plants so they take on natural character will contribute to the visual quality of the coastal zone landscape (illus.9).



CLEARED MODERATE TO STEEP SLOPE IS SUSCEPTIBLE TO EROSION. HAY BALES REDUCE VELOCITY OF RUNOFF & PREVENT SEDIMENTATION. SERRATED TOPOGRAPHY COULD ALSO WORK.
PROPOSED
MODERATE — STEEP

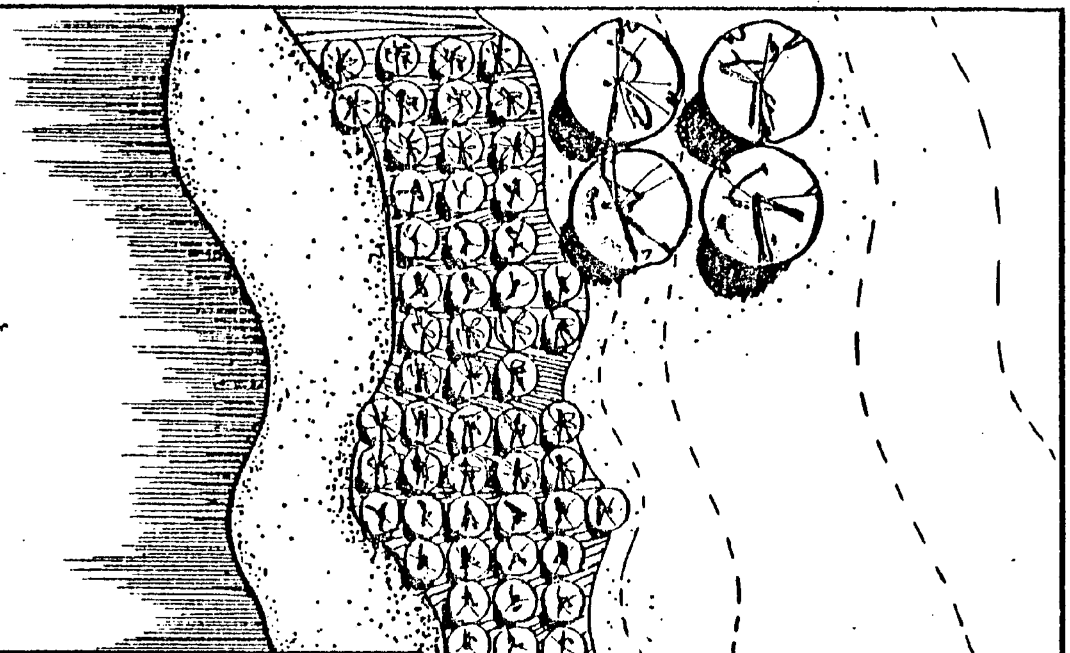


HAY BALES
HAY BALES

8.

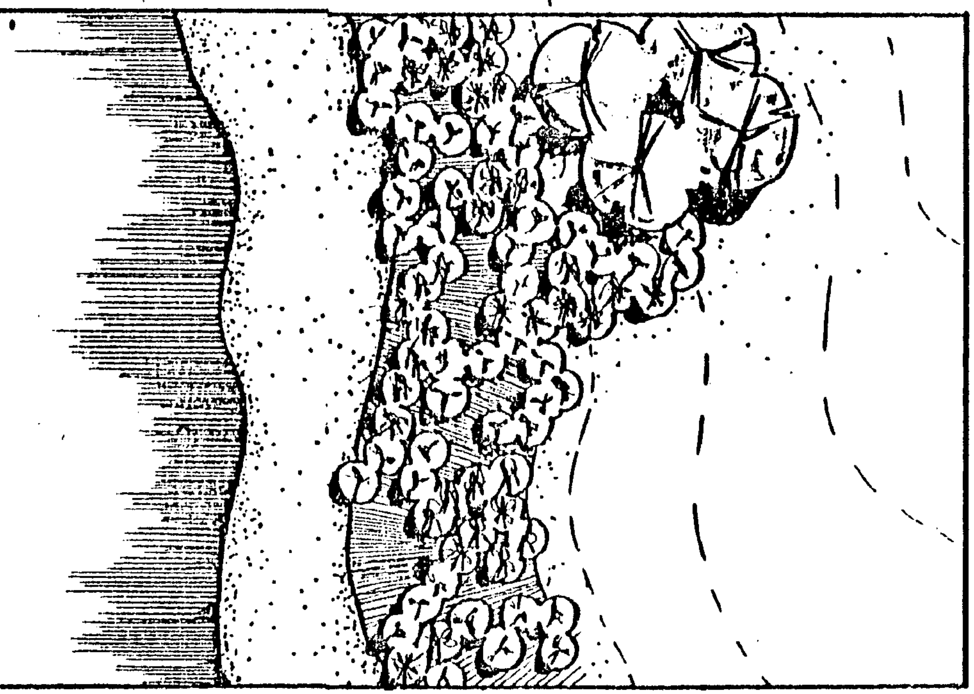
PLANNED CHARACTER

TENDS TO LOOK ARTIFICIALLY IMPOSED ON THE COASTAL EDGE.



NATURAL CHARACTER

LOOKS NATURAL ON THE COASTAL EDGE.



Plants should be spaced according to their growth habit and size. On slopes plants can be spaced closer on slopes if desired because each plant receives a higher percentage of light from all sides, especially on southern facing slopes. Reccomendations for planting are:

-Slope should be saturated with water to a depth of 4-6inches prior to planting.
-All planting should be done from top of slope to base whenever possible.
-Ground cover should be used on slope for water retention and slope protection.
-Hay bales or approved equal should be used at toe, top, and back of slope for runoff protection and sedimentation (illus.8).

SOIL PREP

The soil's ability to retain moisture and provide chemical nutrients is essential for the establishment of newly planted plants. The soil pH indicates, to a certain extent, the nature of the internal chemical processes of soils which determine the state or condition of soil fertility. Every kind of plant is believed to have a most suitable soil reaction or pH range for its best growth. The average range for soil pH is from 4.5 - 9.0. The minimum pH limit designates the strongest acidity, and the maximum pH limit indicates the strongest alkalinity the plant will tolerate without the possibility of serious injury (8).

Since moisture is of main concern for enabling plants to become established the preparation of existing soil is recommended. Loam is a good moisture retainer, peat is a moisture retainer and provides acid, and manure is a good source for organic material. It is recommended that the soils for planting pits be prepared since they are generally well drained along Rhode Island's coastline. For optimum success of new plants soil preparation is essential. Further information can be acquired from a professional or from the R.I. Soil Conservation Service (9).

G. COVER

Low growing ground cover in close proximity will prevent surface erosion more effectively than trees and shrubs which are necessarily spaced further apart. Ground cover plantings have been used extensively throughout the U.S. along highway cuts for soil stabilization and have proven effective. They can be used along with tree and shrub planting for extra soil protection, design feature, or for steep slopes where tree and shrub planting is difficult.

Procedure for planting GROUND COVER

1-Cover watered area of slope for planting with an even layer of mulch approx. 2 - 3 inches.
2-Plant at previous planting depth and space according to effect desired keeping in mind the closer the better protection.
3-Water after planting is complete to help bind mulch.
4-When handling ground cover remember never to let root system to dry out. Keep moist.

Maintenance

-Water for first growing season.
-Check mulch to make sure it remains in tact, and control competing weeds.

MULCH

Mulches protect exposed soils, retain moisture necessary for plant establishment, and some decompose with time and provide organic material to the soil. Mulches can be either temporary, like jute netting, or or permanent, like shredded bark. Recommended mulches are as follow:

Hay or Straw

75-100lbs. per acre.
Good for steep slopes and other critical areas.
Keep moist, they are subject to wind blowing.
Salt marsh hay can be used where applicable.

Manure

1 inch cover.
Introduces weeds.
Adds fertility.
Subject to odor.

Peg and Twine

Used to anchor hay or straw from wind.
Stretch twine between driven pegs in criss-cross manner.
Pegs 8-10" long, 3'-4' on center.

Jute Netting-Burlap

Used in critical areas of concentrated water flow.
Best for steep slope.
Must be anchored with pins etc., refer to manufacturer or professionals recommendation.

Brush

Cut brush can be scattered on slope.
Introduces weeds and other plants.
Not recommended for under new plants.

Shredded Bark

Apply moist.
3" minimum depth.
Water after installation for stability.

SHRUBS

Shrub planting is most effective on low - moderate slopes. Existing shrubs should be saved whenever possible.

Procedure for planting SHRUBS

1-Choose plant species best suited to site.
2-Dig planting pit 6"wider and 12"deeper than roots.
3-Fill bottom 12" of pit with prepared soil and place in plant.
4-Add prepared soil to fill pit 1/2 full,add water and allow to settle.
5-Never allow soil level to go above previous mark on main stem.
6-If present, fold burlap from top of ball and fill pit with soil.
7-Form saucer around plant and thoroughly water.
8-Place mulch on top of planted surface for maximum moisture retention.

TREES

Tree planting is most effective and easily acheived on low and moderate slopes.Existing trees should be saved whenever possible.

Procedure for planting TREES

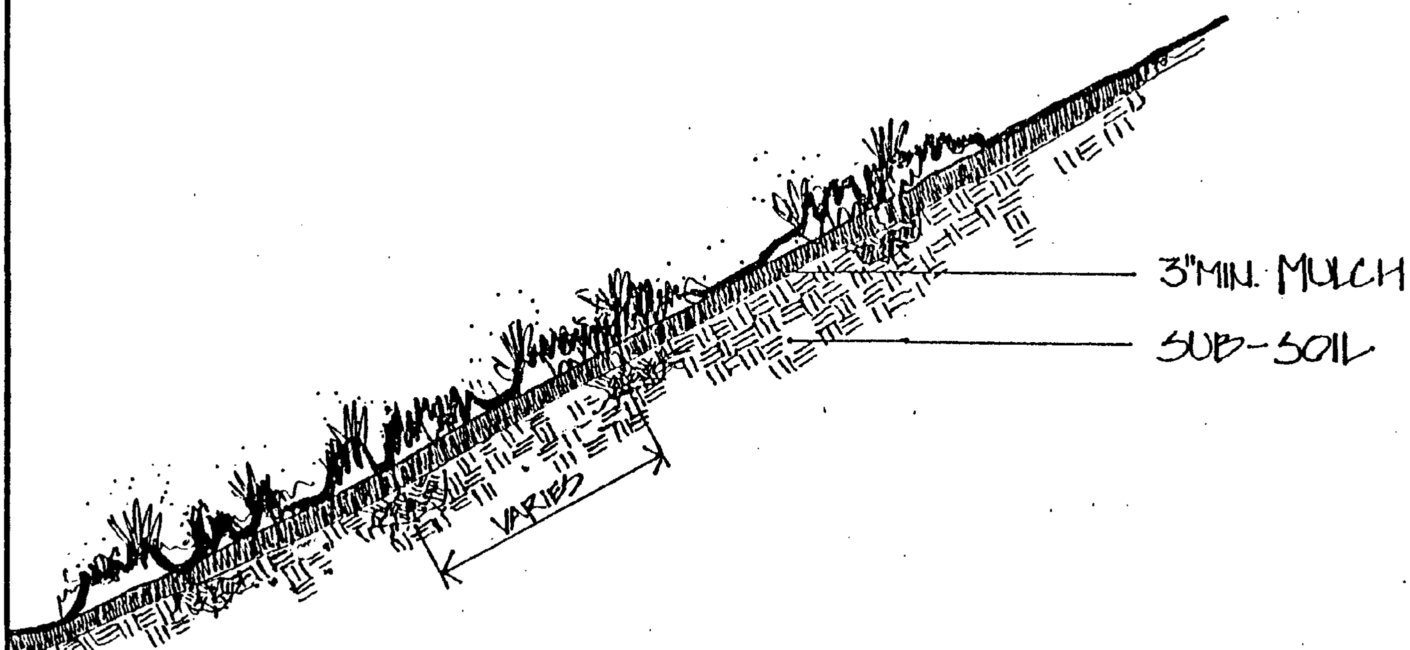
1-Same as shrub.
2-Stake trees with 3-stakes approx. 120 degrees apart.
3-Stakes can be away from root ball or firm against it for added support.
4-Ties to be placed directly above first limb,use protective material between wire and bark.
5-For maximum support drive stakes a standard of 2-3'.

MAINTENANCE

-Trees and Shrubs require water for first growing season.
-Control competing weeds until plants become established.
-Check mulch for stability.

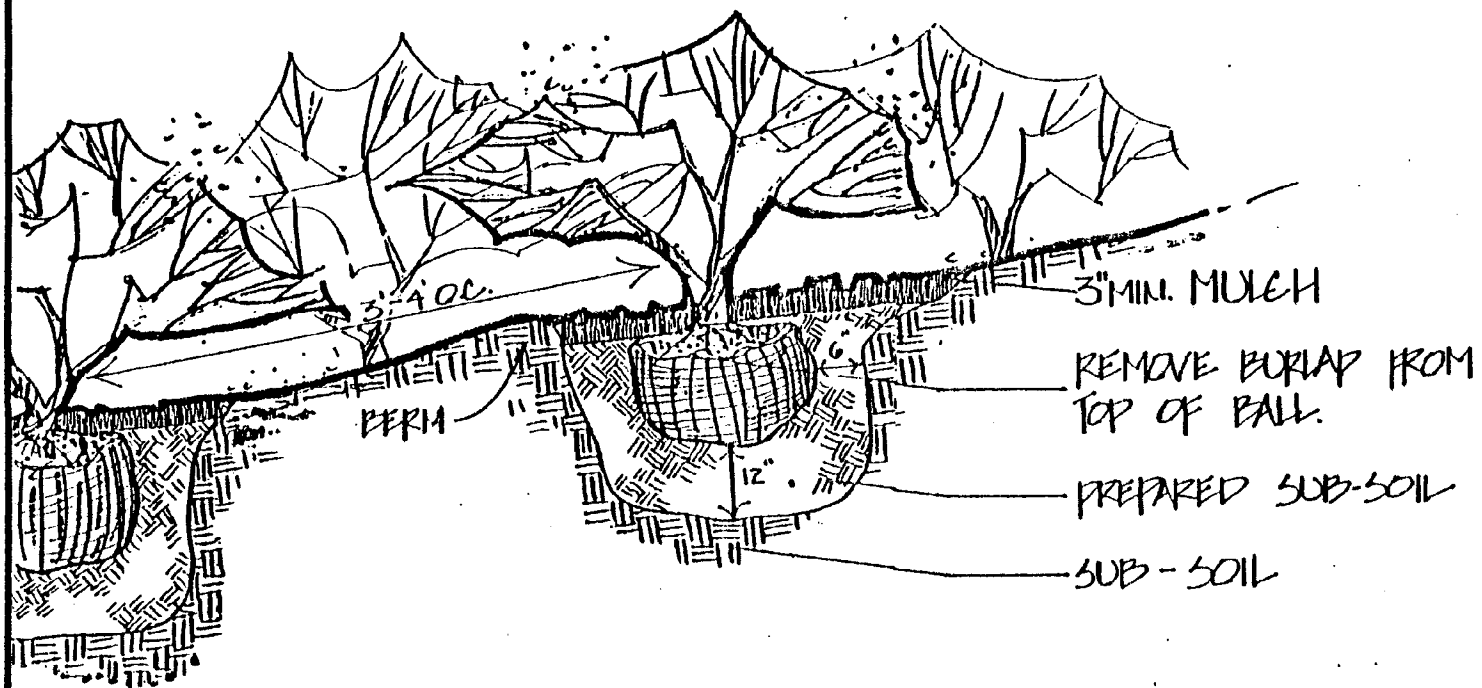
Sources: (9,10,11,12)

GROUND COVER PLANTING DETAIL



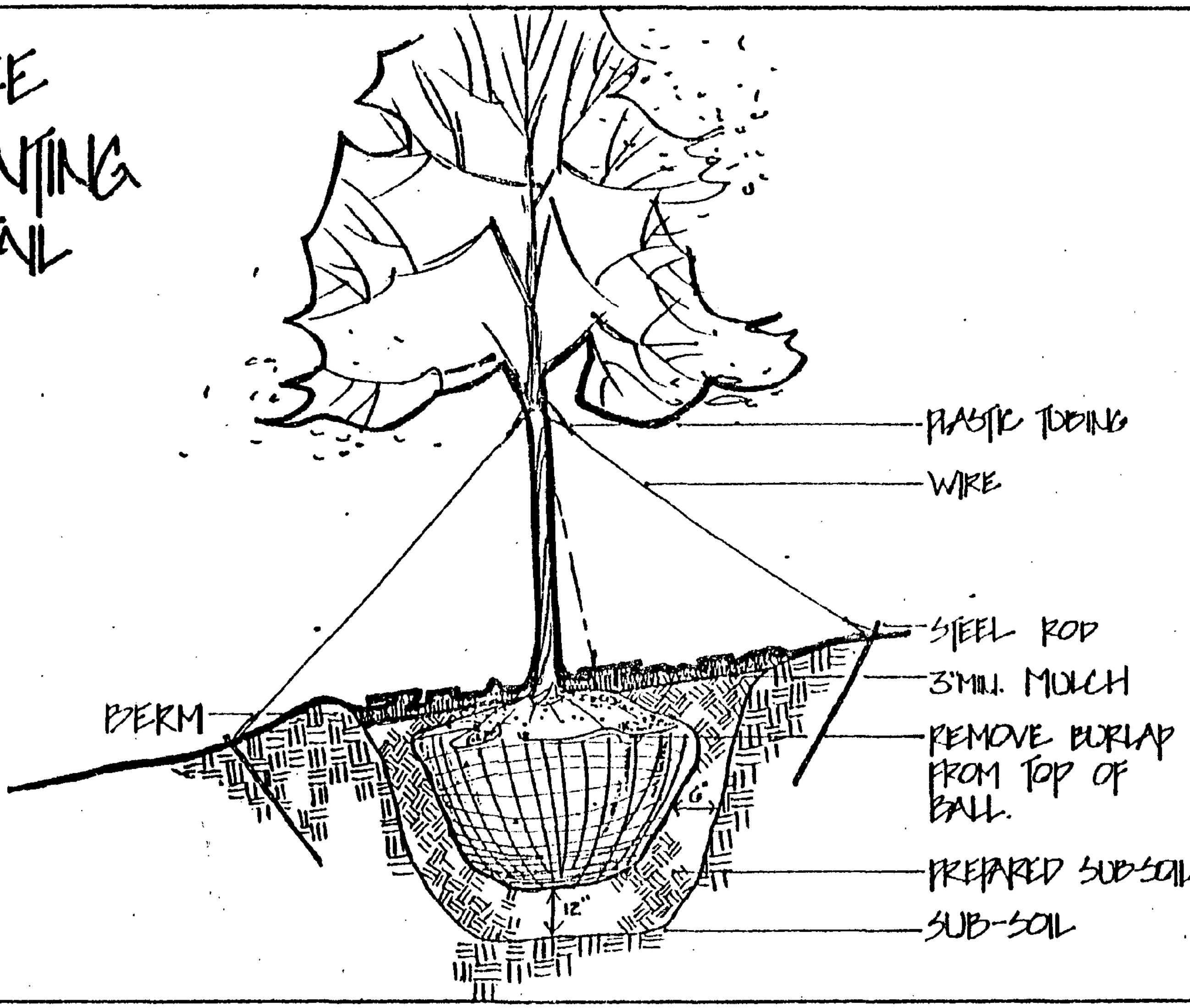
SLOPE
STEEP

SHRUB PLANTING DETAIL



SLOPE LOW-MODERATE

TREE PLANTING DETAIL



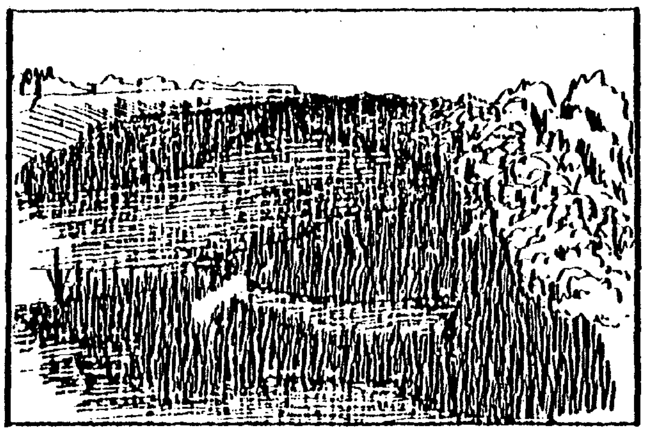
SLOPE
LOW - MODERATE

COASTAL WETLANDS

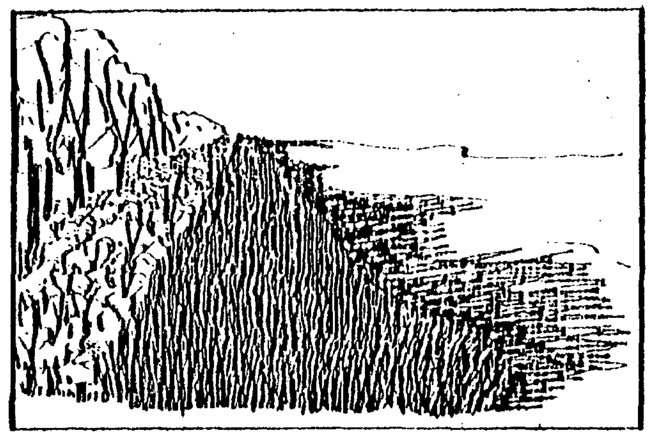
COASTAL WETLANDS

In Rhode Island, coastal wetlands are inundated with saline water semi diurnally. Technically these coastal systems are classified as salt marshes, based on the plant species that exist and the tidal influence. These salt marshes are flexible features that can change in shape as sea level rises and as sediments erode and are carried into these areas via water. R.I. has a total of 3,668 acres of salt marsh and 76 acres of fringe marsh that are generally less than ten yards wide (13).

According to Rhode Island State Law, a coastal wetland shall mean any salt marsh bordering on the tidal waters of this state, whether or not the tidal waters reach the littoral areas through natural or artificial water courses, and such uplands directly associated and contiguous thereto which are necessary to preserve the integrity of such marsh. Marshes shall include those areas upon which grow one or more of the following: smooth cordgrass (Spartina alterniflora), salt meadow grass (Spartina patens), spike grass (Distichlis spicata), black rush (Juncus gerardi), saltwort (Salicornia spp.), sea lavender (Limonium carolinianum), salt marsh bullrush (Scirpus spp.), high-tide bush (Iva frutescens), tall reed (Phragmites communis), tall cordgrass (Spartina pectinata), broadleaf cattail (Typha latifolia), narrowleaf cattail (Typha angustifolia), spike rush (Eleocharis rostellata), chairmaker's rush (Scirpus amercana), creeping bentgrass (Agrostis palustris), sweet grass (Hierochloe odorata), wild rye (Elymus virginicus).



SALT MARSH



FRINGE MARSH

Salt marshes are found along the Narragansett Bay and Sakonnet River shorelines and outside their proper limits. They occur in sheltered waters that are protected from ocean waves and strong currents. Those that exist outside the properlimits are generally found along the southern shore of R.I..These are sheltered from the ocean by barrier beaches, termed barrier spits. The term given to these marshes is "Barrier Wetlands".

Salt marshes in R.I. range from highly altered ponds like Point Judith, to small undeveloped ponds like Trustom which is in a rural setting. Wherever they exist they are all beginning to feel the pressures of development.

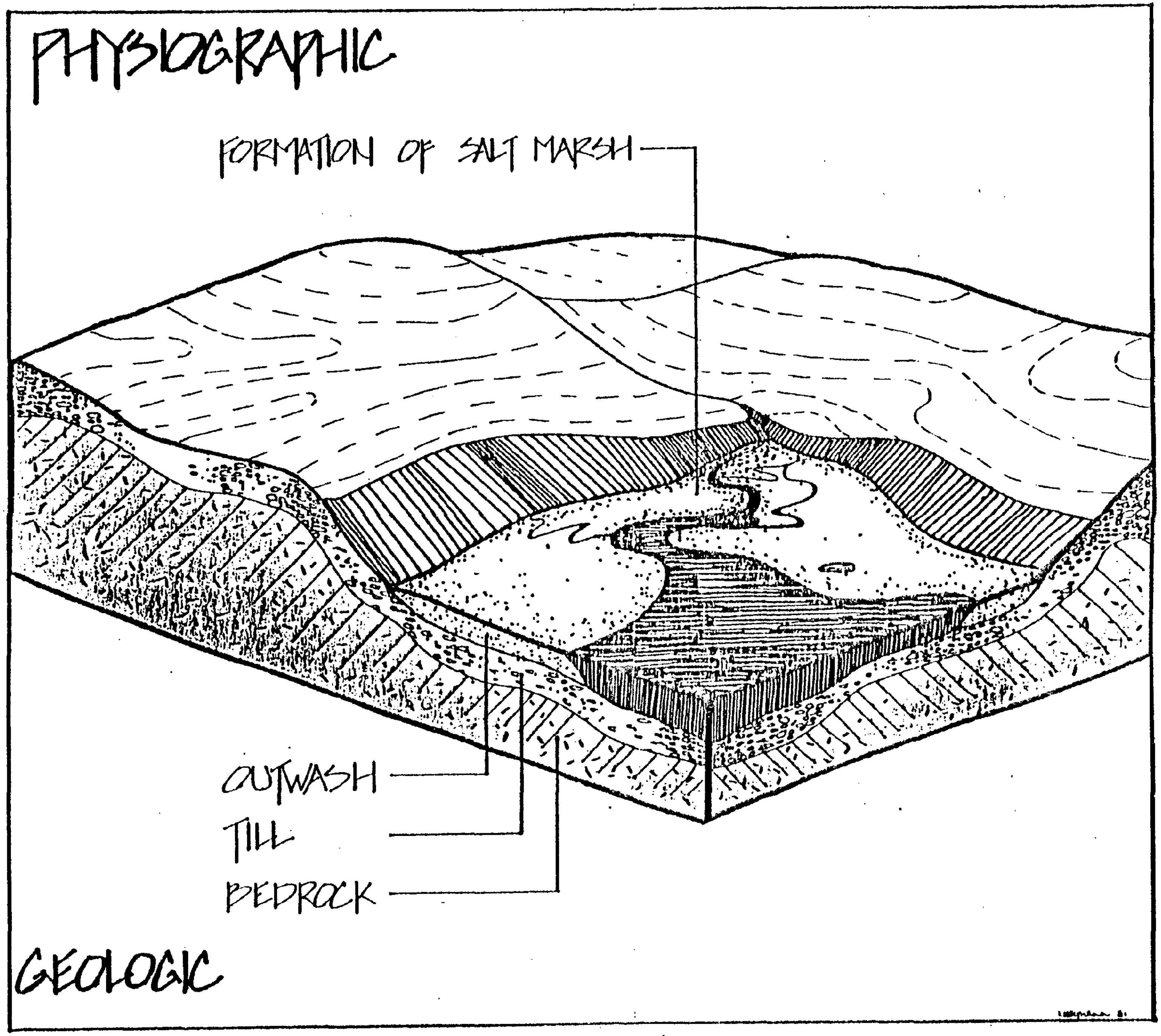
The salt marsh is one of the most important ecosystems along the R.I.coastline with its' net primary productivity far surpassing that of any other environmental ecosystem. The salt marsh can be viewed as a self sustaining life support unit, transferring food and chemicals back and forth between the productive land system and the open ocean. As such, it fills a vital role in maintaining the physical-biological character of the near shore coastal area as well as supporting life in both terrestrial and aquatic zones (14).

NATURAL INVENTORY

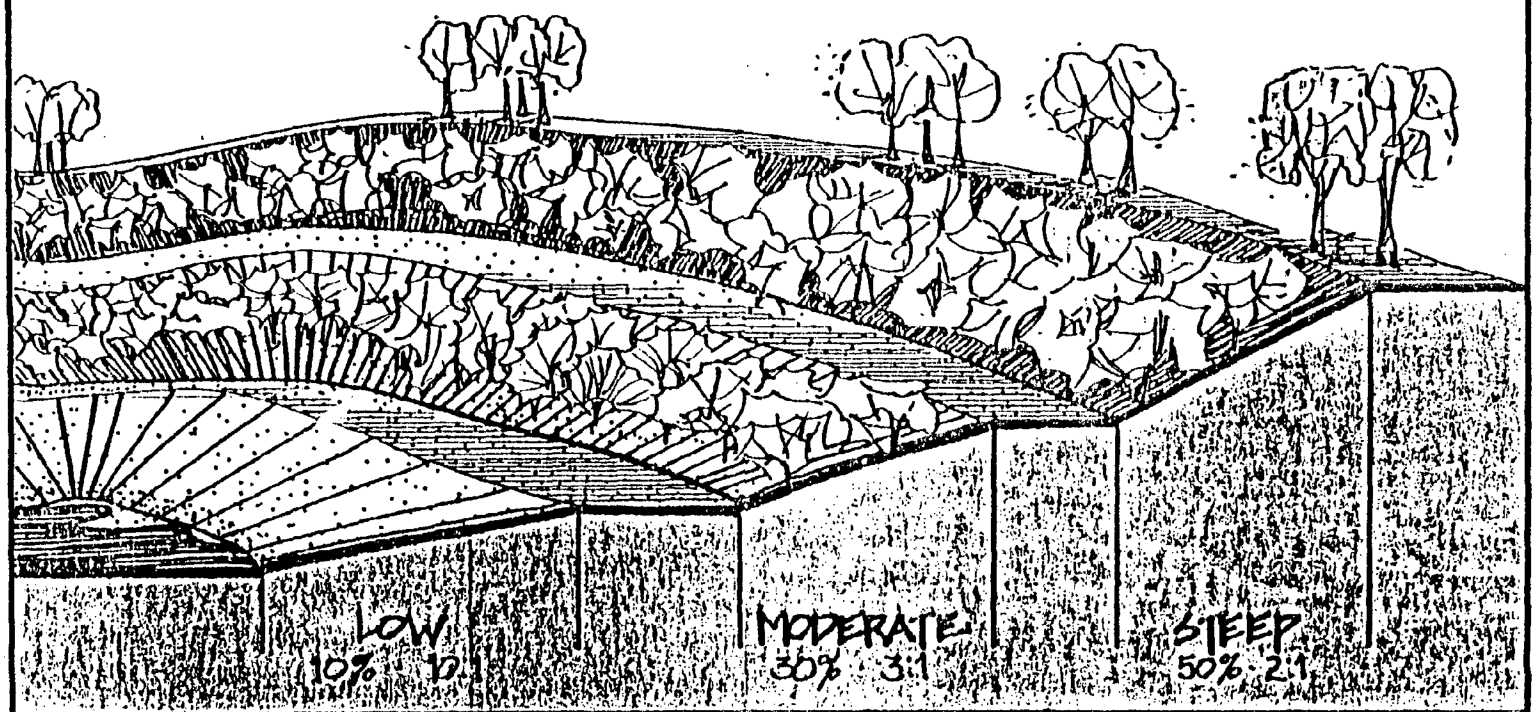
PHYSIOGRAPHY .. GEOLOGY

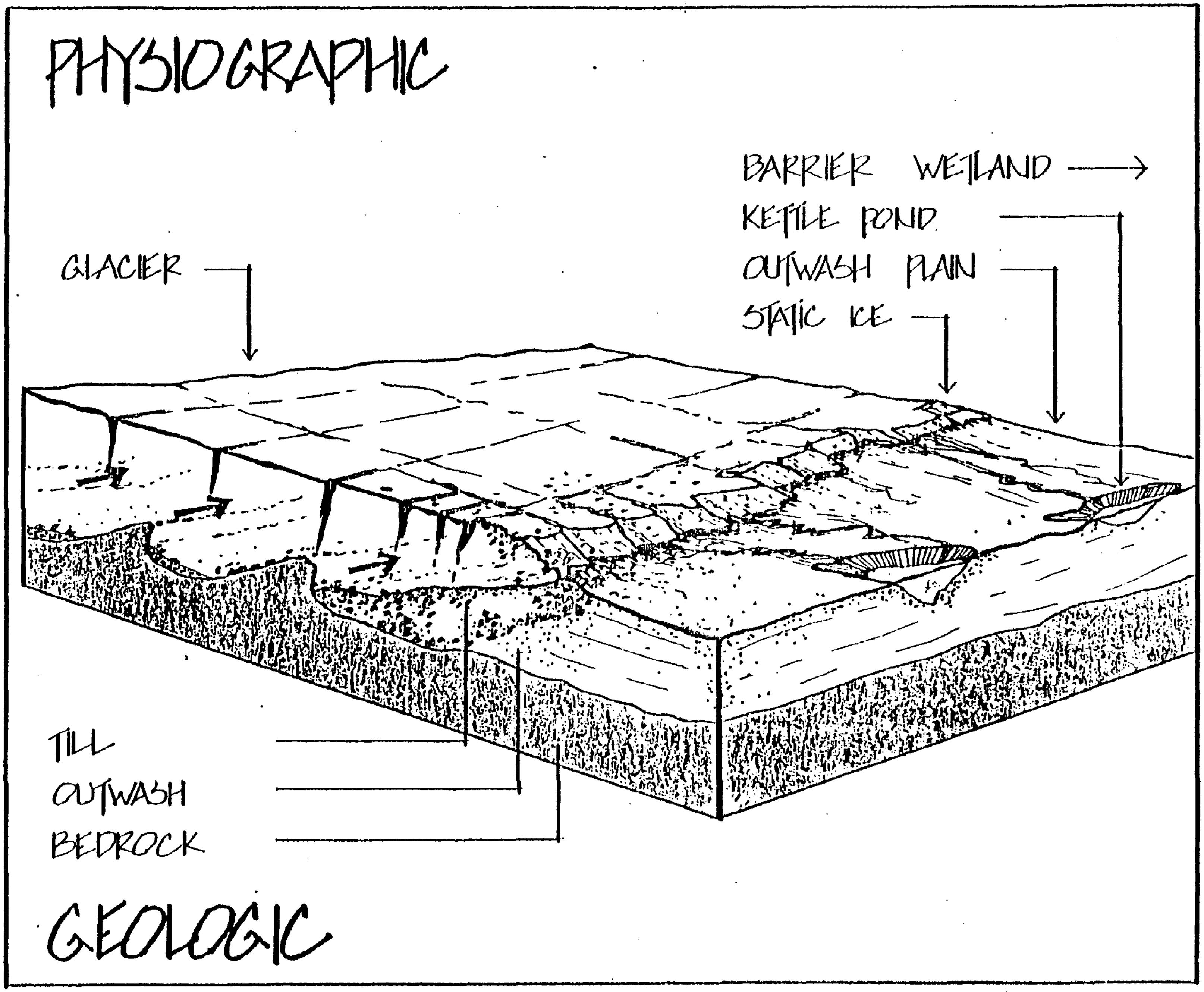
The original physical form of Rhode Island's salt marshes was created by geologic and glacial processes primarily during the last ice age roughly 12,000yrs. ago. Each salt marsh has its own identity, primarily based on physiographic form. As the glacier melted heavy till was layed down and the meltwaters carried finer outwash to lower lying areas. As sea level rose the low lying land was covered by salt water and was first colonized by algae, and where the water was shallow aquatic grasses became established. The grasses trapped fine sediments and as the elevation increased terrestrial vegetation took over. The vegetation then trapped more sediments that were suspended in fresh water stream and river outlets and in tidal waters (illus.13). Two conspicuous physiographic features of the salt marsh are meandering creeks, that carry fresh and tidal waters during high and low tides. If shallow enough, the water may evaporate leaving a concentration of salt. Meandering creeks are formed by a complex process dependent on surface irregularities and the deflection of water. These aforementioned salt marsh characteristics are delineated by a rise in topography inland ranging from several feet to 35ft. (illus.14).

Barrier wetland formation has been a result of glaciation also but in a different way. The southern shoreline is the result of later modification of glacial action caused by marine erosion and deposition. Along this area the Charlestown Moraine exists. Here the glacier maintained a stationary front long enough to allow outwash to flow out with the meltwater. This outwash formed a low relatively flat plain (illus.15). After sea level rose however, a large portion of the outwash plain was covered. As currents began to form barrier spits the salt marshes started to establish themselves in much the same way as other initially more protected coastal wetlands began (2).


PHYSIOGRAPHIC
FORMATION OF SALT MARSH
OUTWASH
TILL
BEDROCK
GEOLOGIC

SLOPE




PHYSIOGRAPHIC
BARRIER WETLAND
KETTLE POND
GLACIER
OUTWASH PLAIN
STATIC ICE
TILL
OUTWASH
BEDROCK
GEOLOGIC

15.

SOILS

Within Rhode Island's salt marshes peat and muck is found atop glacial outwash, till, or both. Peat is formed by decaying matter which is in excess. This peat is highly acid due to a complete lack of oxygen caused by both chemical processes and constant waterlogging. Some of the more pristine salt marshes have a peat layer several feet thick. The adjacent upland slopes consist of a thin layer of organic material, where vegetation is or was once prevelent, underlayed by outwash or till over bedrock. The till and,or outwash vary in thickness depending upon location (2,15).

HYDROLOGY

Salt marshes are the meeting and mixing grounds for fresh land based water and saline tidal waters. The fresh water content of a salt marsh is dependent upon rainfall and and that which is derived from surface flow, channeled flow, or subsurface flow from the land. Surface flow is intermittent and normally follows rainfall or melting snow. Channeled flow includes all permanent and temporary rivers, streams and creeks, along with all intermittently flooded drainageways, swales, and so forth-which convey land runoff toward coastal wetlands. Subsurface flow is derived from soil that has a large capacity for water storage when its surface is open. This water however, moves through the soil at a rate much slower than the others, although this time allows for removal of pollutants by natural filtration.

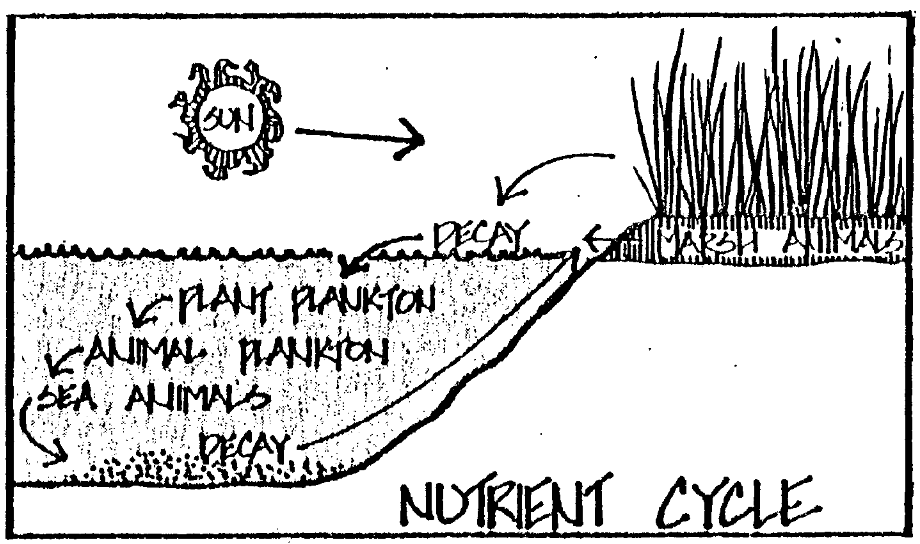
Salt water influence varies according to wind, tide, and current amounts and velocities. The influx of salt water is essential to the survival of a salt marsh. The flushing action of tides seems to take away and bring in sediments and nutrients necessary for life support both in the marsh and adjacent waters. The natural drainage pattern must be presumed to be beneficial, both in the manner by which waterborne nutrients and sediments are delivered to the marsh and the rate of delivery (4,16). Sedimentation from cleared upland areas would prove to be detrimental to the life of salt marshes.

VEGETATION

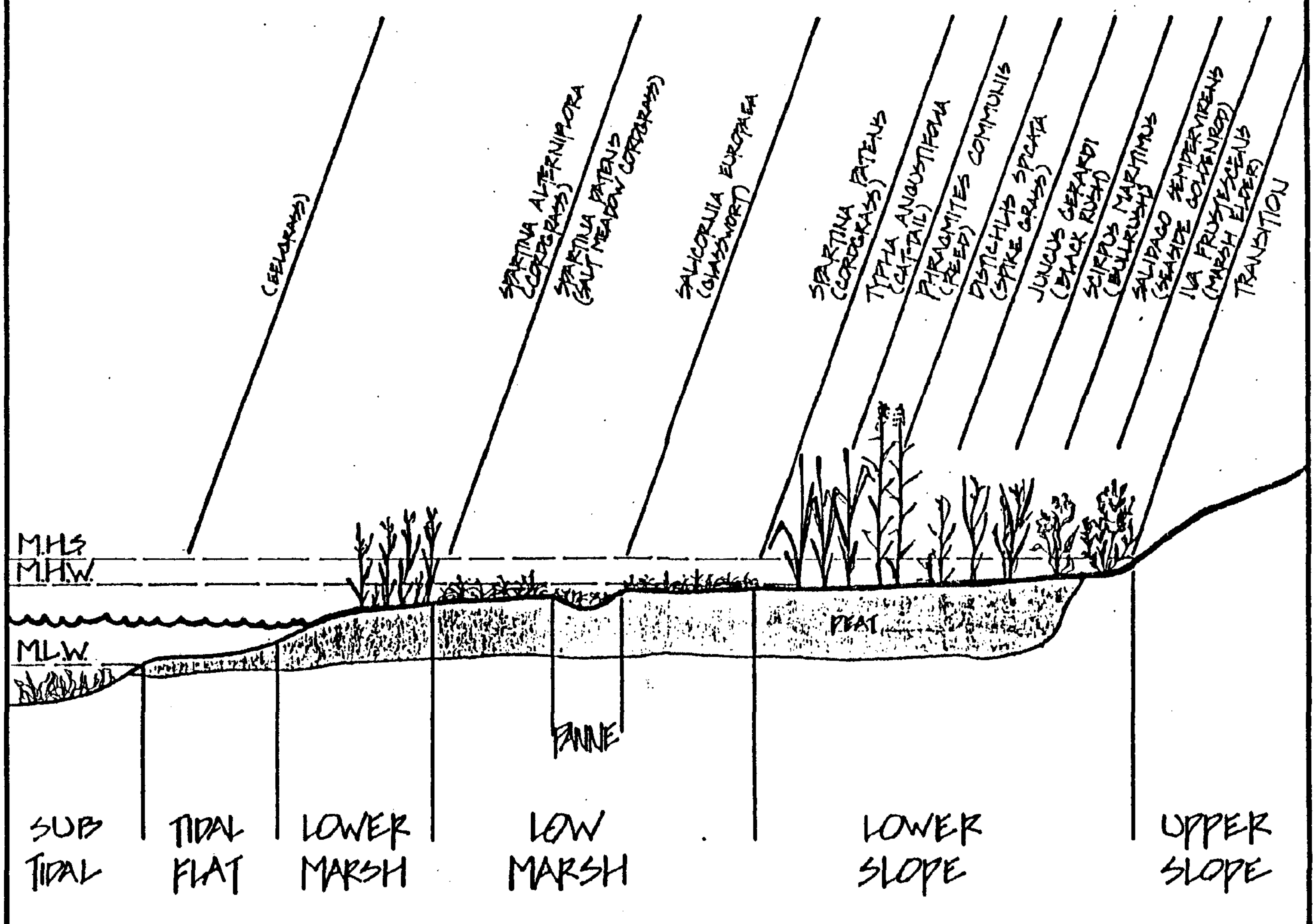
As in all biological systems, vegetation serves a variety of roles in the marsh. It is able to use solar radiation and nutrients to produce food; it reduces extreme temperatures, it transfers moisture from the soil to the air by means of transpiration, and it adds organic material to the marsh soil. While marsh plants use a large amount of food they produce in order to survive in their rigorous environment, the remainder is available to be used as a source or nutrients by other plants and animals. This contribution can be substantial considering that each year, anywhere from five to ten tons of organic matter may be produced by each acre of salt marsh. Wheat fields, by comparison, yield one and one-half tons per acre per year, hay fields, four tons per acre per year, and deserts and oceans, one-third of a ton per year, making the salt marsh one of the most productive of all ecosystems (17).

Similar to most intertidal biotic communities, Rhode Island's salt marshes generally show clear patterns of zonation (illus.16). In general the variety and complexity of plant communities are greater in the larger marshes. In some marshes the zonation pattern is broken into a mosaic pattern; in other usually smaller marshes, one or more of the zones may be present. Fringe marsh is frequently composed almost exclusively of Spartina alternifolia (cordgrass). Along the bordering slopes plant communities differ from site to site also.

Besides marsh and bordering plants contributing to the productivity of the marsh, microscopic algae covering the muddy surfaces also contribute. They are essential food sources for small invertebrate animals. After the plant and algae have produced a seasons growth, they die back and become detritus. Decomposers, which are primarily aquatic bacteria, fungi, and protozoans, break down the detritus into minerals, gasses, and water. These by-products of detritus form the basis for aquatic life in and outside the limits of the salt marshes aquatic realm, as seen in the following illustration (15,17).



VEGETATION



(EELGRASS)
SPARTINA ALTERNIFLORA (CORDGRASS)
SPARTINA PATENS (SALT MEADOW CORDGRASS)
SALICORNIA EUROPAEA (GLASSWORT)
SPARTINA PATENS (CORDGRASS)
TYPHA ANGUSTIFOLIA (CAT-TAIL)
PHRAGMITES COMMUNIS (REED)
DISTICHLIS SPICATA (SPIKE GRASS)
JUNCUS GERARDI (BLACK RUSH)
SCIRPUS MARITIMUS (BULRUSH)
SOLIDAGO SEMPERVIRENS (SEASIDE GOLDENROD)
IVA FRUTESCENS (MARSH ELDER)
TRANSITION
M.H.S.
M.H.W.
M.L.W.
PEAT
PANNE
SUB TIDAL
TIDAL FLAT
LOWER MARSH
LOW MARSH
LOWER SLOPE
UPPER SLOPE

BIOTIC COMMUNITY

The salt regime of the marsh community has been a major factor in restricting the number of animal and marine species that inhabitat the marsh. Among marine animals only a relatively few can adjust to the rapid salinity changes that occur with the tides. Those few that do adjust can endure tidal marsh conditions. These few aquatic species are relatively free of the kinds of competitors and enimies that harass related species in nearby waters.Usually only a few species are prominent but upward of 60 species of fishes have been found in tidal streams (17).

The marsh vegetation supports not only a resident population of marine life but "migrants" as well, including mammals such as the raccoon and the opossum, and several species of song birds. The raccoon, visits the water's edge at low tide where it digs and eats mussels and crabs. The meadow mouse moves into the lower slope from the fringing upland. There it feeds upon the vegetation; it is preyed upon by owls and hawks. The muskrat is a permanent resident in the less saline parts of the marsh where it feeds on an abundance of bulrushes and cat-tails.

While most species of eastern U.S. birds may be found in the marshes, only a few species are characteristic of the salt marsh and either breed there or closely frequent it. The more common species include certain rails and sparrows, the black duck, blue-winged teal, certain shorebirds, the marsh hawk, short - eared owl, red-wing blackbird, meadowlark, and marsh wren. Herons also frequent salt marshes. Salt marshes also play a role to certain migratory birds like the canadian goose. Many of the birds support their diets by eating small fishes, aquatic insects, snails, and plants (15,18).

It is the adjacent upland environments where these associated marsh species seek shelter when not feeding on the marsh.Here is where efforts must be made to provide suitable habitats for these important marsh creatures.

AESTHETIC ENVIRONMENT

The aesthetic quality of Rhode Island's salt marshes is based on the unity of landform, water, and vegetation. The aesthetic environment offers unique variety and vividness. Variety is seen and vividness is perceived as a strong, clear impression on the senses. Variety and vividness is derived from terrain patterns, presence of water, weather characteristics, vegetation patterns, and cultural land use patterns. Uniqueness is derived from the composition of form, space, color, and texrure.

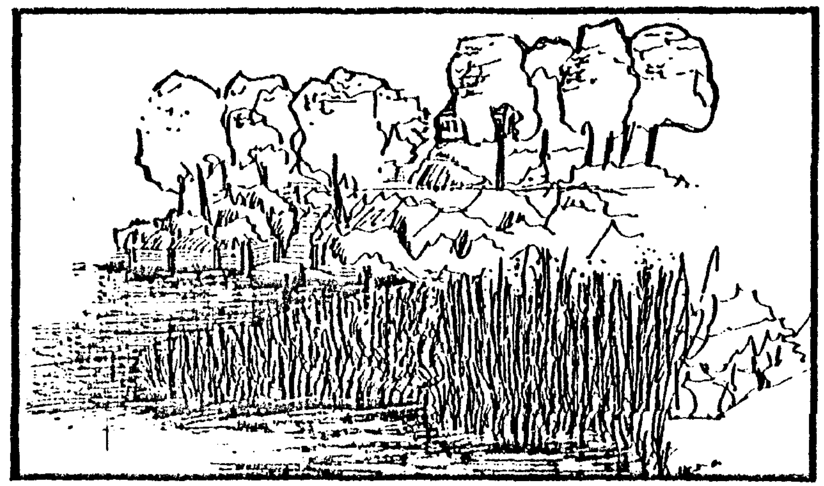
Views in and around salt marshes are contained by the bordering landforms. Generally, the densely vegetated hill and valley topography has become disturbed by cultural development. Development along the marsh perimeters has, in most cases, drastically altered their natural unity. In places where vegetation has become re-established the built and altered landscape has become subordinate and unified once again.

It is on the edges, where marsh meets land, that strong focal points exist. Alteration of unity at this point goes unnoticed and becomes visually degrading if not handled properly. The following illustration was done of an edge condition in Rhode Island.

Three different coastal edges exist. Two are visually degrading. These dominate hard lined edges their textures,and their colors are visually degrading,not to mention their physical degradation. They totally alter the marsh unity. The natural edge has variety in its' own right. It gives the viewer the perception and feeling of salt marsh. It also reduces the dominance of the adjacent house.and it supports life in the marsh,and acts as a natural buffer to waves and currents. The choice to save the vegetation also saved the natural character of the slope and landform.

On the following page the next illustration was drawn several hundred yards downshore from the above illustration.

Here the altered coastal edge is less dominate. Instead of altering the total edge terracing was used;it enabled the landform to maintain its natural form. Wood as a material in this case helps to maintain the composition and becomes subordinate. There is a certain quality to this setting that gives the marsh a pleasing vitality. If alteration to the coastal edge is to be done it should add to the visual and sensory resource.



EXISTING.. PROPOSED SOLUTIONS

Erosion occurs on the surface of slopes bordering Rhode Island salt marshes. Surface instability leading to erosion can occur on otherwise stable slopes because of the breakdown or stripping of vegetation. This breakdown and stripping of vegetation generally occurs during construction of property adjacent to salt marshes (illus.17). The exposed soil is able to erode and cause sedimentation to occur on the slope and marsh. Further activity can cause channeling of water. This is when water collects in a footprint, tire track, and etc..This channeling accelerates the flow of water that gradually cuts down through the soil and forms rills which can form into gullies. Channeling, rills, and gullies should be avoided hence, they are capable of transporting large quantities of sediment.

The aforementioned activity can be avoided by minimizing activity on and near the slope (illus.18) by instituting a setback line to:

-Insure conservation of landform and vegetation.
-Maintain visual,biological,and ecological quality.
-Reduce risk of erosion and sedimentation.
-Prevent bulldozing of soil and vegetation over slope.

If the land and slope is classified as severe then (illus.8,page22) should be followed to:

-Reduce velocity of runoff.
-Reduce sediment transport onto slope and into marsh.
-Maintain visual quality of landscape after construction.

Another common unaccepted activity along the coastline of salt marshes is to construct revetments. Revetments are in the form of seawalls and stone rip-rap (illus.19). The procedure here, prior to the Coastal Zone Act, was to build a seawall and to dump fill to extend property or the fill was dumped and the rip-rapwas used to hold it in place and prevent toe erosion. Rip-Rap is still being used to date and it causes impact to the salt marsh:

-Alters natural runoff patterns
-Reduces subsurface water flow
-Holds back chemical nutrients
-Restricts vegetation from encroaching intomarsh.
-Alters aesthetic environment.

The practice of constructing seawalls was not unnoticed by the CRMC, and is no longer allowed unless absolutely necessary. However, existing seawalls are being undermined and repair is often requested. This should no longer be accepted as the norm since it has been proven they cause severe impacts. They should be removed and what is necessary should be done to allow salt marsh vegetation to flourish once again.

The seawall can be removed and the land sloped to its natural angle of repose. If insufficient space is provided then the filling of marsh for vegetation establishment may be considered worthwhile. This would eliminate the typical procedure of filling toe of seawall with stone (illus.20).

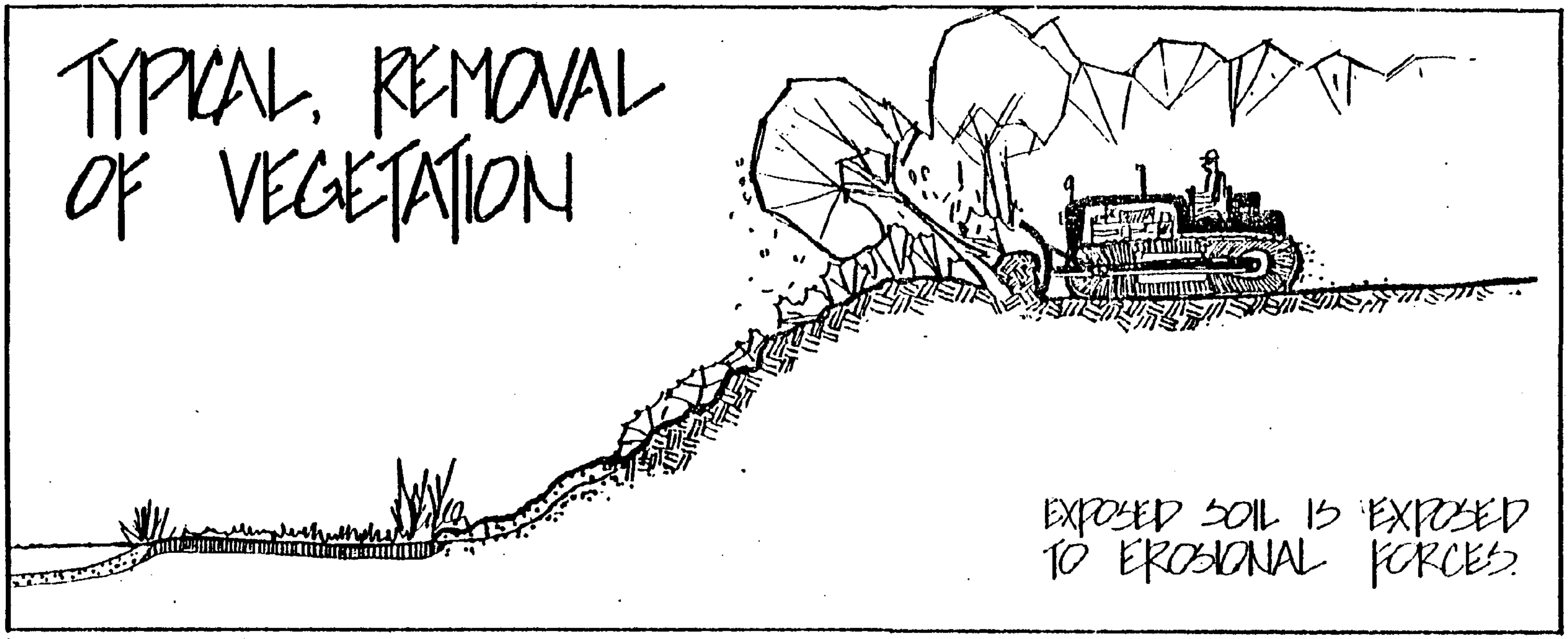
Access to the waters edge through salt marshes is often required, although methods to protect the salt marsh vegetation become visually degrading when it is not necessary. The best accepted method would be to lower the boardwalk to the point where it doesn't become dominate within the landscape and so it does not rest on the marsh vegetation (illus.21).

Keep in mind:

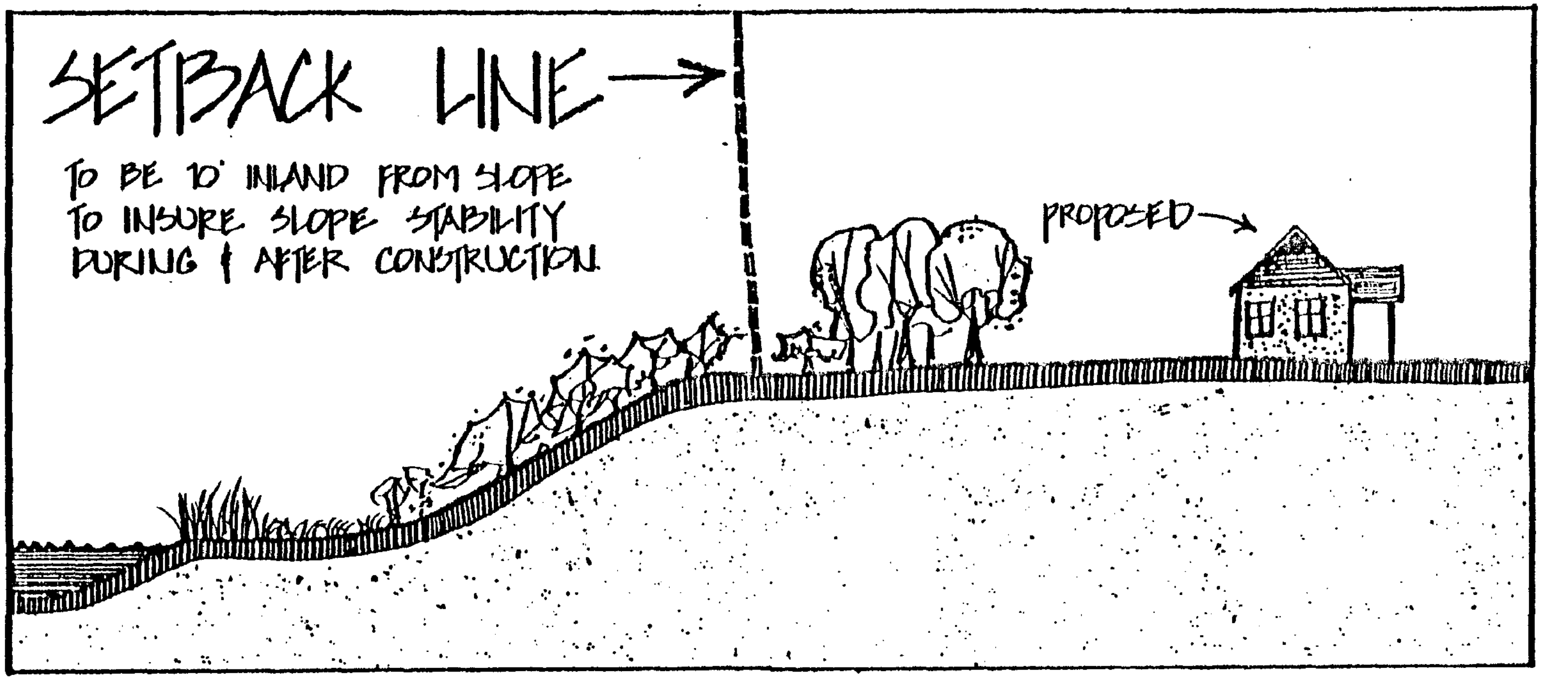
-Low level boardwalks should be used when necessary.
-They become subordinate and do not visually and physically degrade salt marshes to a large degree.
-Wood is best material-it holds up to weather,and tends to blend with the environment.
-Boardwalks save marshes by localizing access.
-Allow access to waters edge during high and low tides.
-Save vegetation from foot traffic.

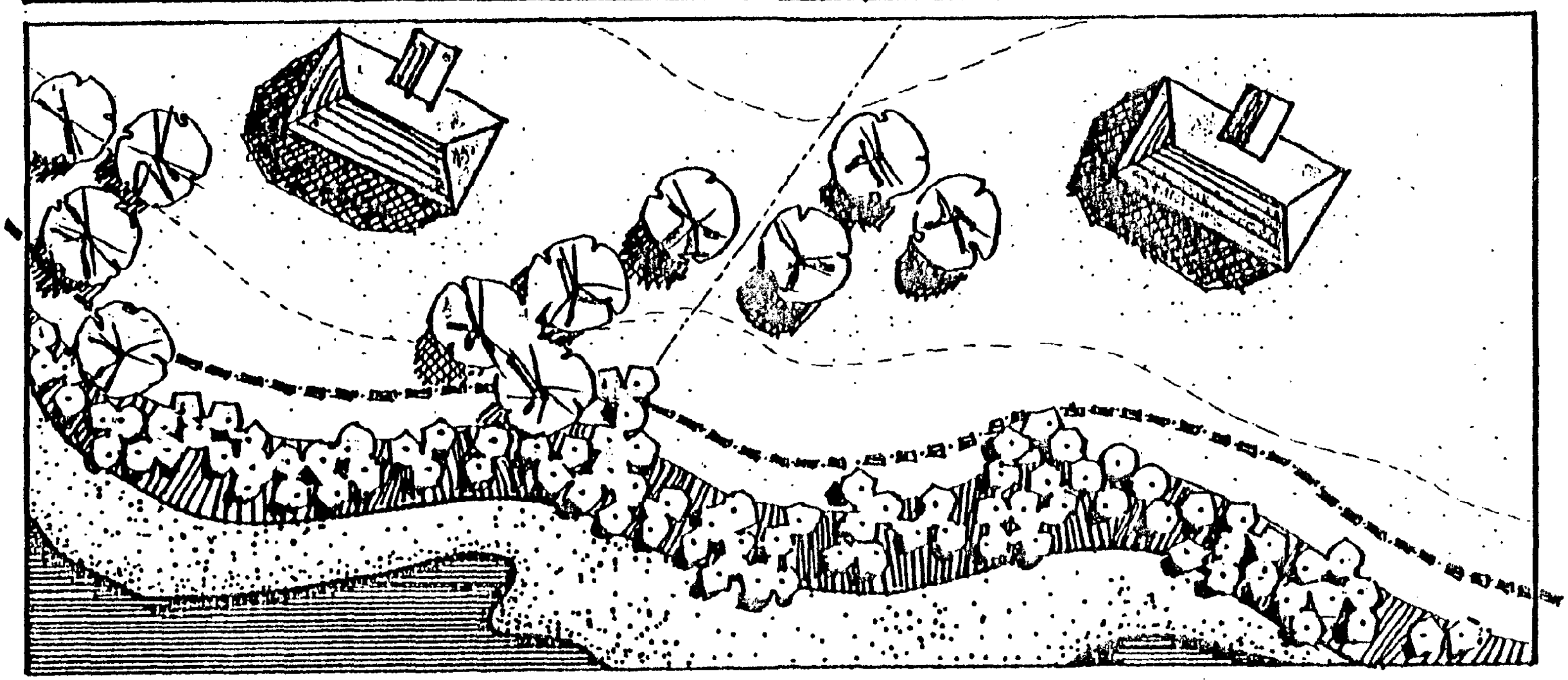
At certain locations where slope erosion has begun to threaten property the first step toward solving the problem is to define the erosional forces effecting the slope. After the problem has been defined, then choose from the range of proposed controls outlined in the barrier beach and beach sections. It is possible to use one or a combination of solutions to solve the specific problem.

For a listing of plant species best adapted for coastal use refer to pages(104-108).

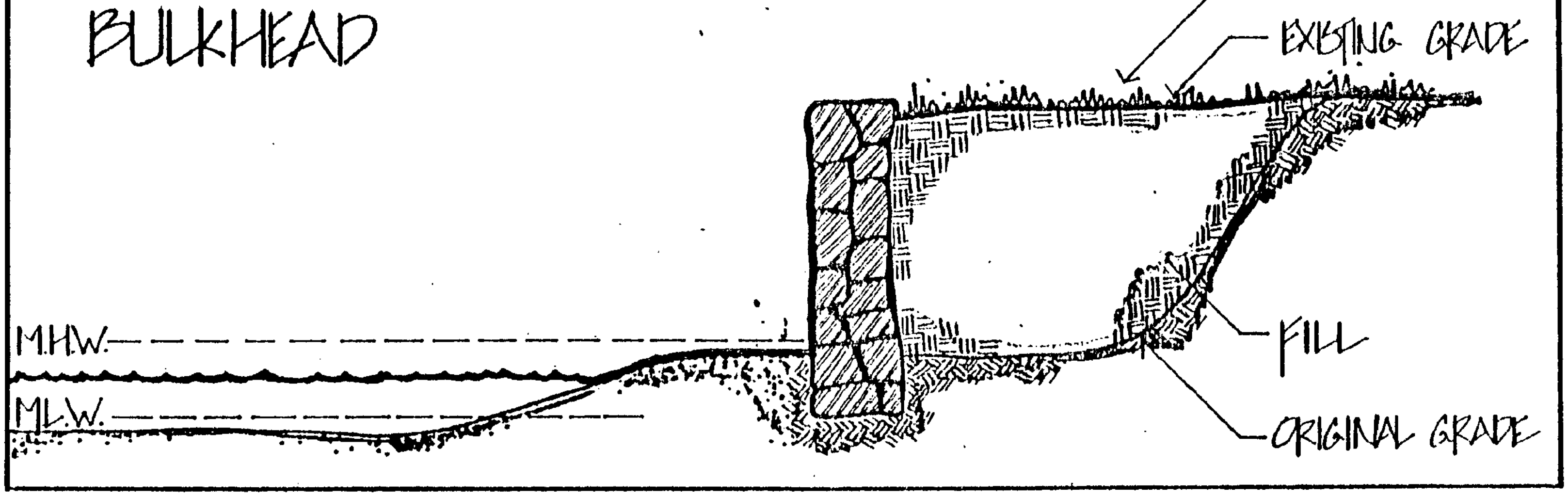

TYPICAL, REMOVAL OF VEGETATION
EXPOSED SOIL IS EXPOSED TO EROSIONAL FORCES.

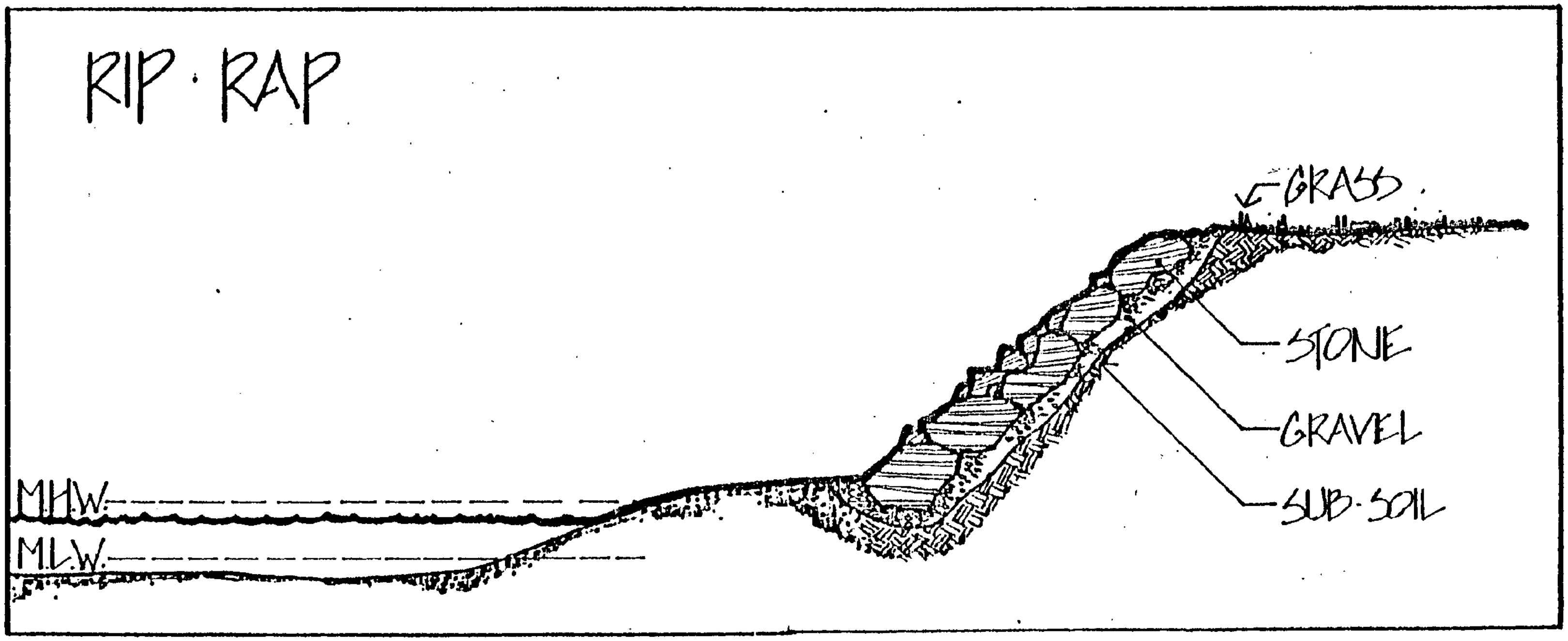

SOIL HAS ERODED & SEDIMENTATION ON MARSH HAS OCCURED.

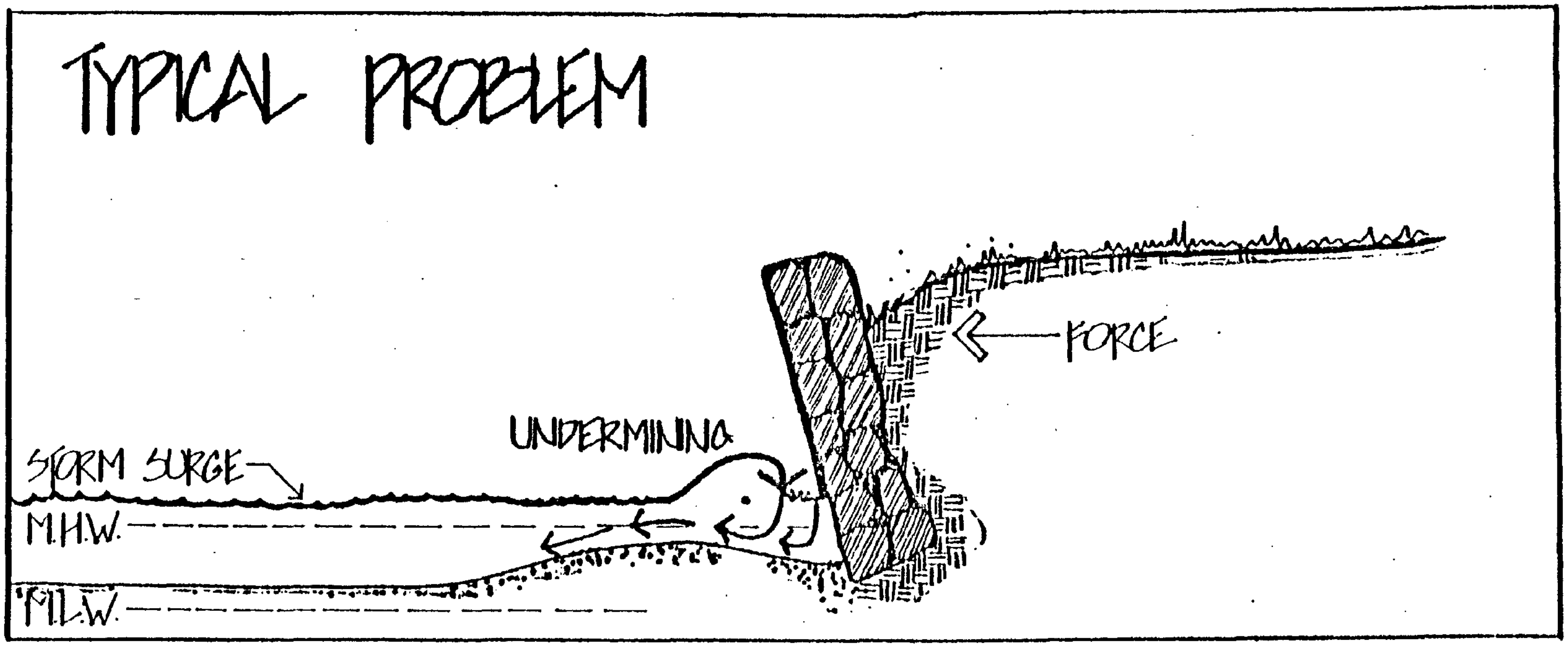

SETBACK LINE
TO BE 10' INLAND FROM SLOPE
TO INSURE SLOPE STABILITY
DURING & AFTER CONSTRUCTION
PROPOSED

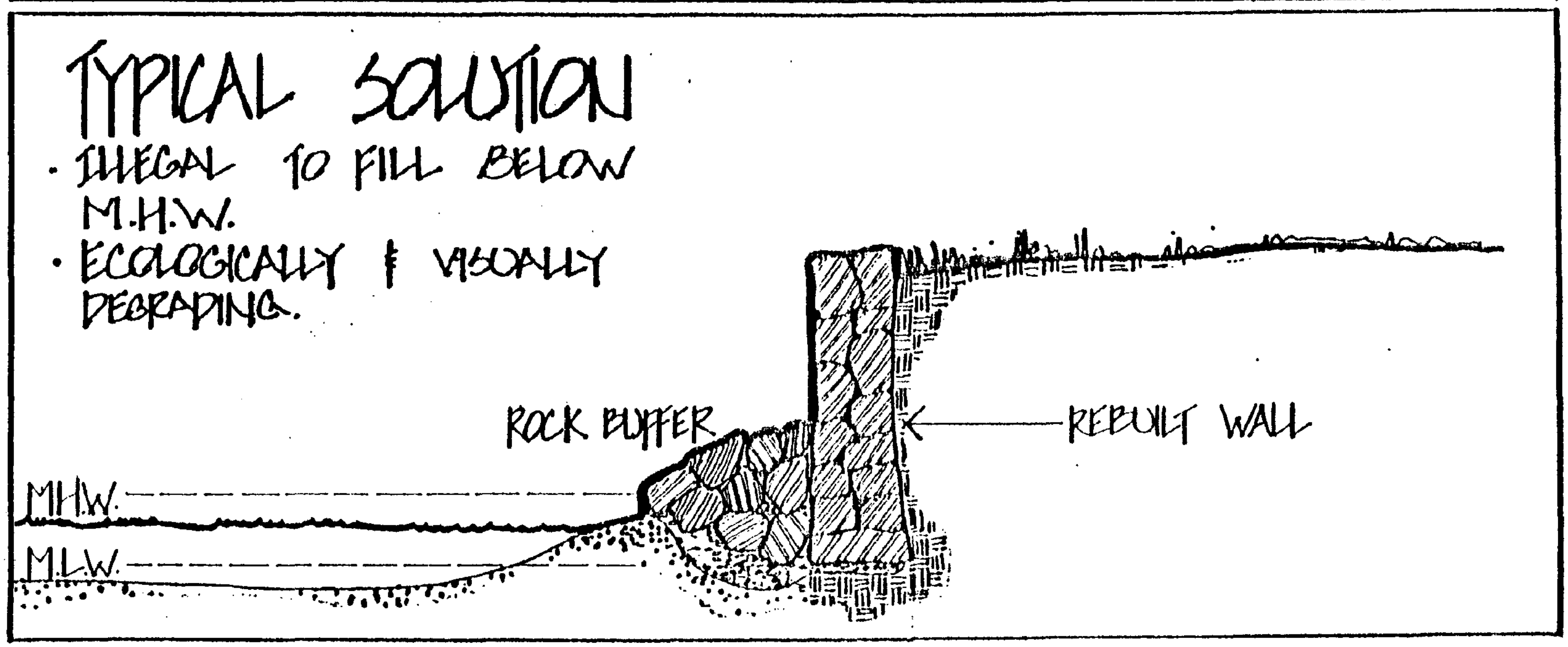


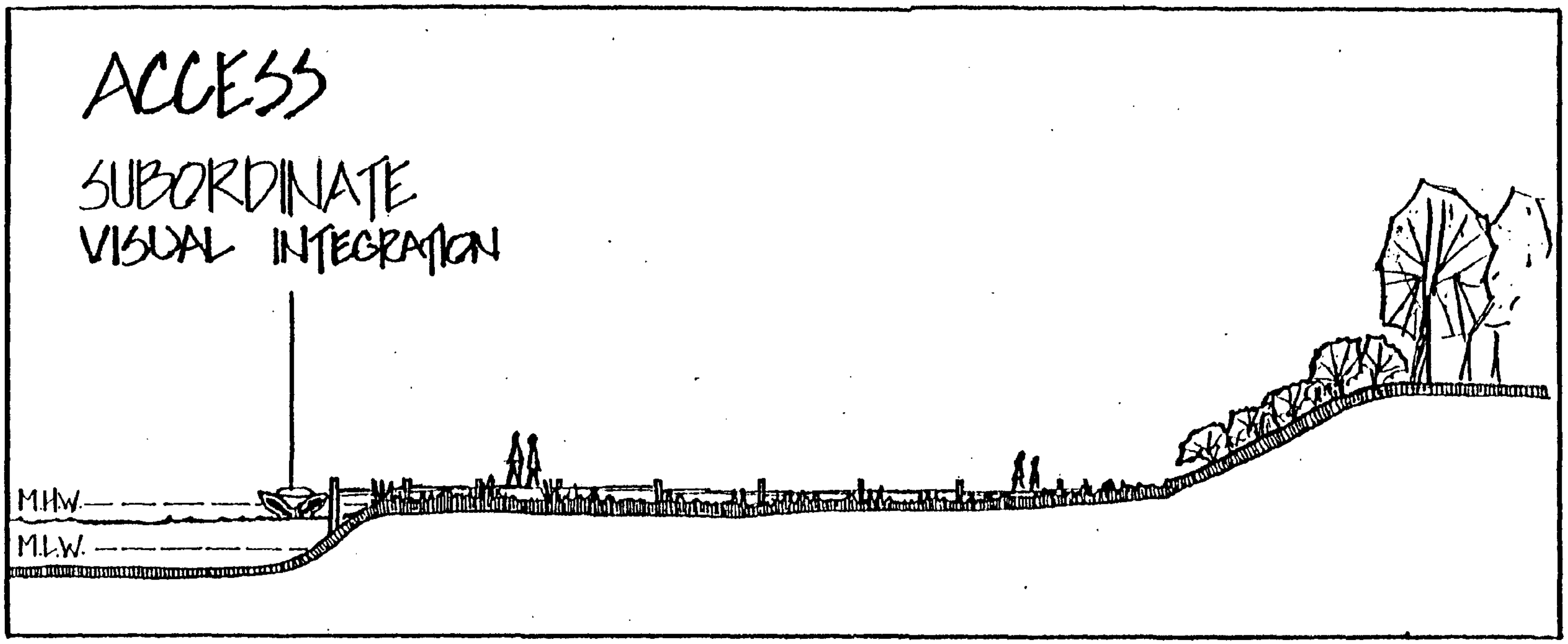
TYPICAL REVETMENTS

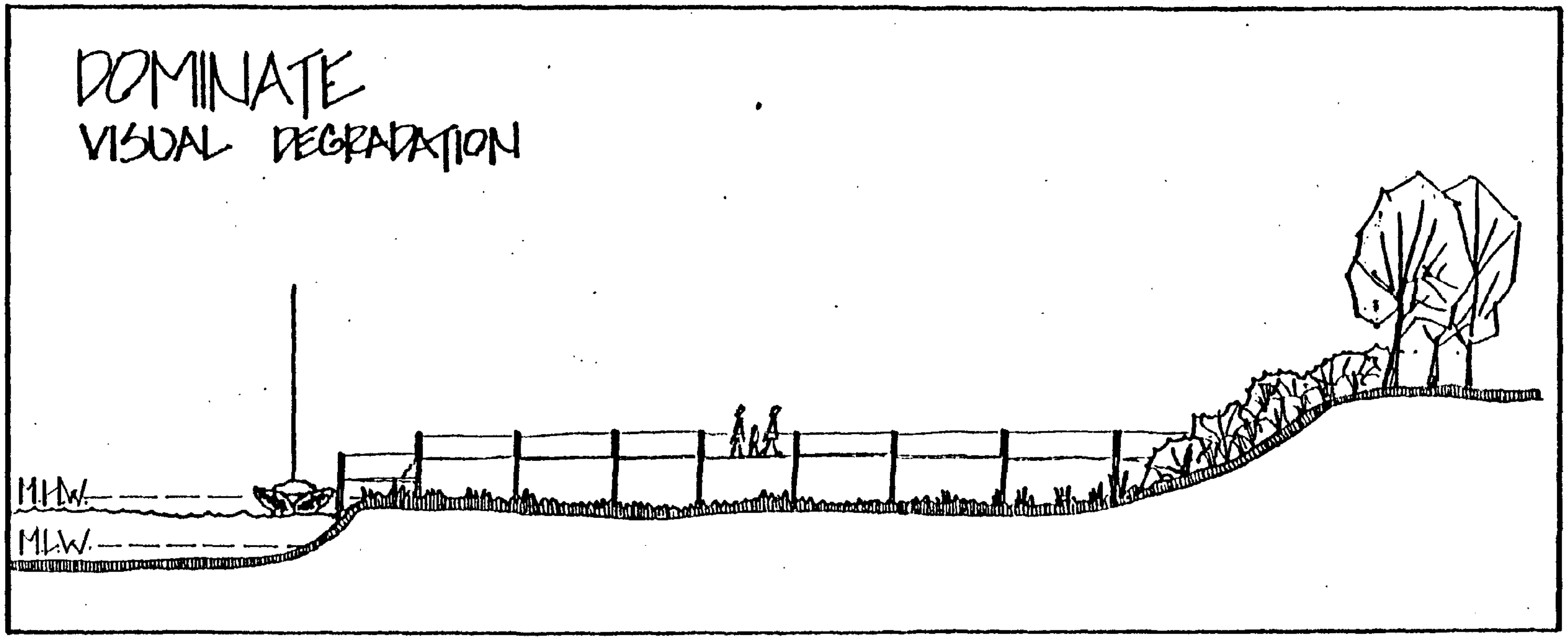





TYPICAL PROBLEM
FORCE
UNDERMINING
STORM SURGE
M.H.W.
M.L.W.


TYPICAL SOLUTION
• ILLEGAL TO FILL BELOW M.H.W.
• ECOLOGICALLY & VISUALLY DEGRADING.
ROCK BUFFER
REBUILT WALL
M.H.W.
M.L.W.


ACCESS
SUBORDINATE
VISUAL INTEGRATION
M.H.W.
M.L.W.

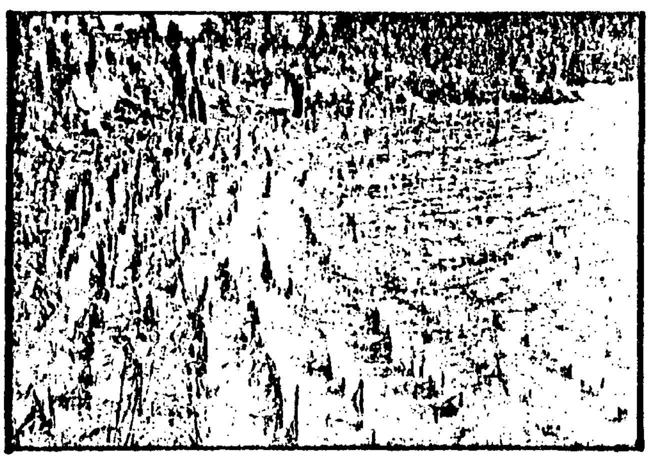

DOMINATE
VISUAL DEGRADATION
M.H.W.
M.L.W.

SALT MARSH ESTABLISHMENT

Salt marsh development, improvement, and management was initially done to provide water fowl habitats at the turn of the century. During the last decade the technology of tidal marsh establishment has evolved considerably. There have been extensive projects ranging from Virginia to the northern Chesapeake, and throughout other parts of the U.S.. The gentleman responsible for the majority of norhtern east coast work is, Edward Garbisch Jr. from, Maryland.

SHORE EROSION ABATEMENT

Marsh establishment along eroding shoreline banks may provide effective erosion control. The established marsh functions as a biological buffer, absorbing wave and current energy as they pass through. Sediment from alongshore drift and from bank and slope erosion is trapped within the stand of marsh grass and the shore increases in elevation. As the shore elevation increases, the contact time of tidal water with the eroding bank decreases. The contact time may only occur with periods of storm tides. Generally, the wider the band of marsh that can be developed seaward of the eroding bank, the more effective will be the erosion abatement. A six to ten foot wide band is the narrowest that can be expected to provide meaningful erosion abatement.(19).



May planting

2 months later

GUIDELINES FOR SITE SUITABILITIES

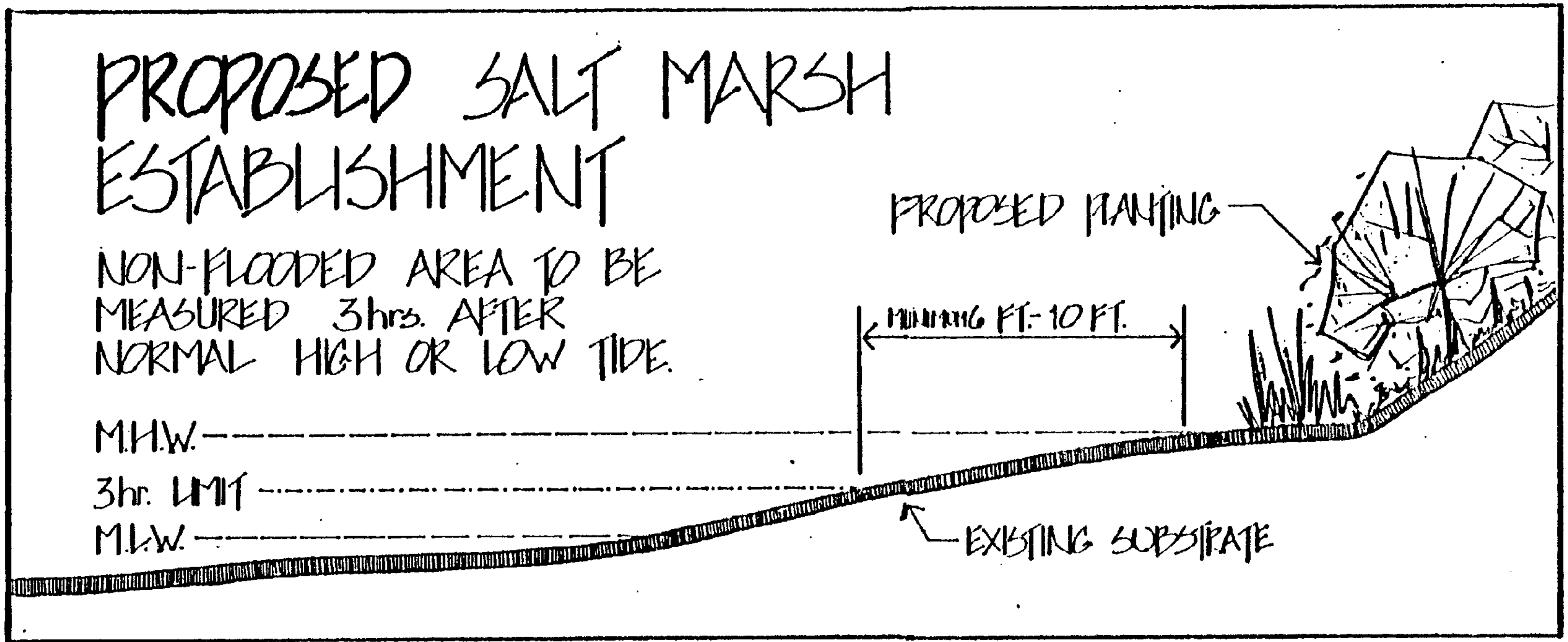
Tidal amplitudes, currents, wave dynamics, water salinities, and directions and volumes of sediment transport are variable throughout the coastal zone. It is improbable that any two locations will have the same variables replicated. Consequently, the designs and specifications for marsh establishment must be site specific. The application of guidelines should be tempered with judgement based on local conditions.

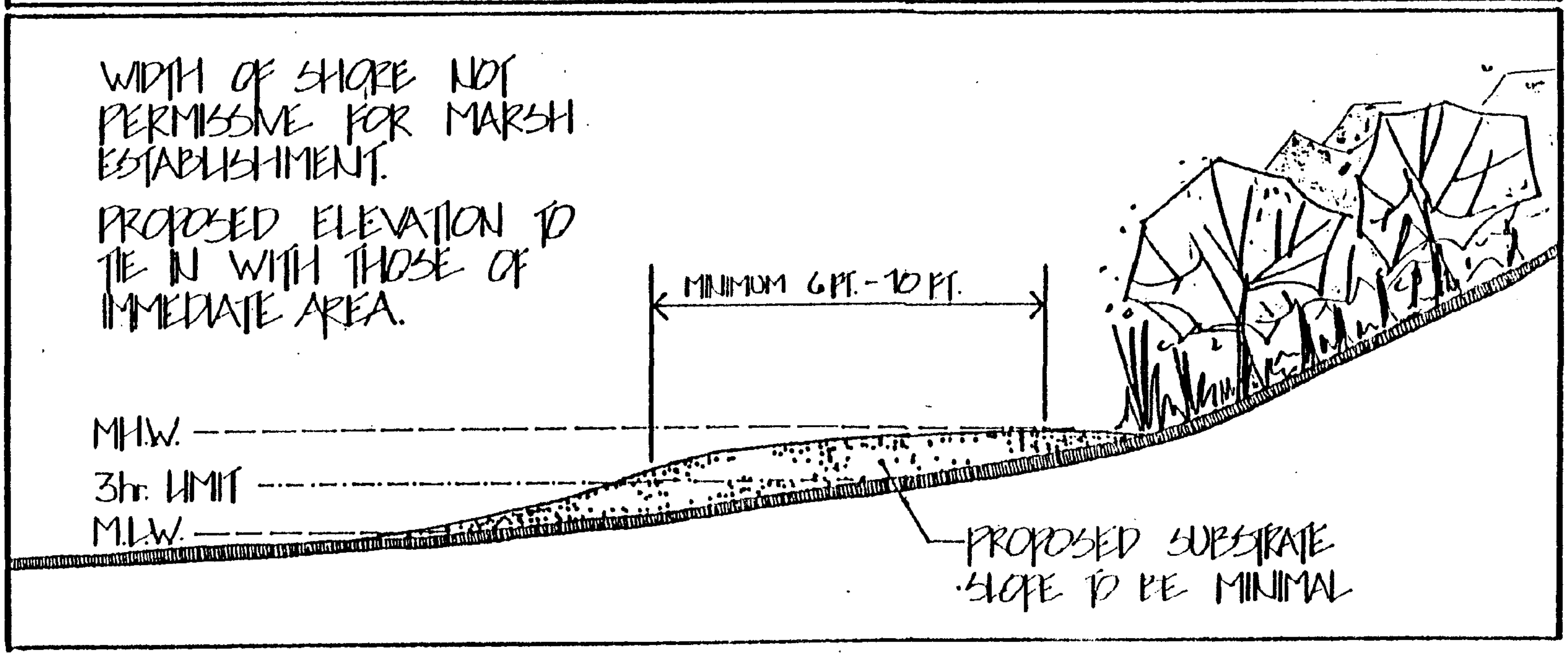
If natural marshes exist in the area of the site, preferably the immediate area, new marshes can be established artificially either on fill materials or on existing sediments of suitable elevations. New marshes sometimes can be developed in areas where prevailing stresses are too severe to allow natural marsh establishment. Generally, in areas subject to open water fetches in excess of nine miles are not likely to be suited for establishment.

Sediment, or substrate surface elevation is a most critical parameter for site suitability. It is recommended by Garbisch, to set the low elevation vegetative boundary at the Mean Tide elevation. As previously stated, if shoreline erosion abatement is of concern, a minimum vegetative band width of 6-10 ft. is required. The erosion abatement will increase with increasing vegetation band width; however, if sandy sediment can be trapped, a 15-20 ft. band of marsh vegetation will control a broad range of shore erosion situations.

To estimate the width of shore that is available for marsh establishment, measure the width of non-flooded shore three hours after or before the predicted high tide for the area (illus.22). This measurement should be made at a time when no major weather systems are passing or have recently passed through the area. Also, it is advisable to make the band width measurement on a day when tide tables predict average low tides (19,20).

Shading markedly restricts the productivity of most marsh vegetation. All areas of the site should be exposed to direct sunlight for at least four hours each day during the growing season. Shoreline trees should be removed or pruned to permit the necessary exposure to direct sunlight. Heavily wooded and steep sloped shorelines facing north may never receive the required sunlight to allow marsh establishment. Other vegetative erosion controls should be used.


PROPOSED SALT MARSH ESTABLISHMENT
NON-FLOODED AREA TO BE MEASURED 3hrs. AFTER NORMAL HIGH OR LOW TIDE.
PROPOSED PLANTING
MINIMUM 6 FT.- 10 FT.
M.H.W.
3hr. LIMIT
M.L.W.
EXISTING SUBSTRATE


WIDTH OF SHORE NOT PERMISSIVE FOR MARSH ESTABLISHMENT.
PROPOSED ELEVATION TO TIE IN WITH THOSE OF IMMEDIATE AREA.
MINIMUM 6 FT. - 10 FT.
M.H.W.
3hr. LIMIT
M.L.W.
PROPOSED SUBSTRATE
SLOPE TO BE MINIMAL

SITE PREP

Substrate types. There is no apparent limitation of uncontaminated substrate types to marsh establishment. Clay, silt, sand, and peat and combinations thereof are acceptable for marsh establishment. Because of its poor fertility, poor nutrient absorption capacity, and unsuitability for grading and for most seeding and transplanting techniques, marsh peat is the least desireable substrate for marsh establishment.

Slopes. Surface slopes should be as low as practicable without impounding water and should not exceed those that are unstable under normal conditions in the absence of vegetative cover.

Elevations. Surface elevations are the key to successful marsh establishment. In areas subject to low tidal amplitudes of two feet or less, acceptable elevation tolerances are most stringent. Variances of just inches could mean unsuitability for establishment. The existing or proposed elevations of a particular site should be tied in with those in the immediate area that support the marsh types designed for establishment (22).

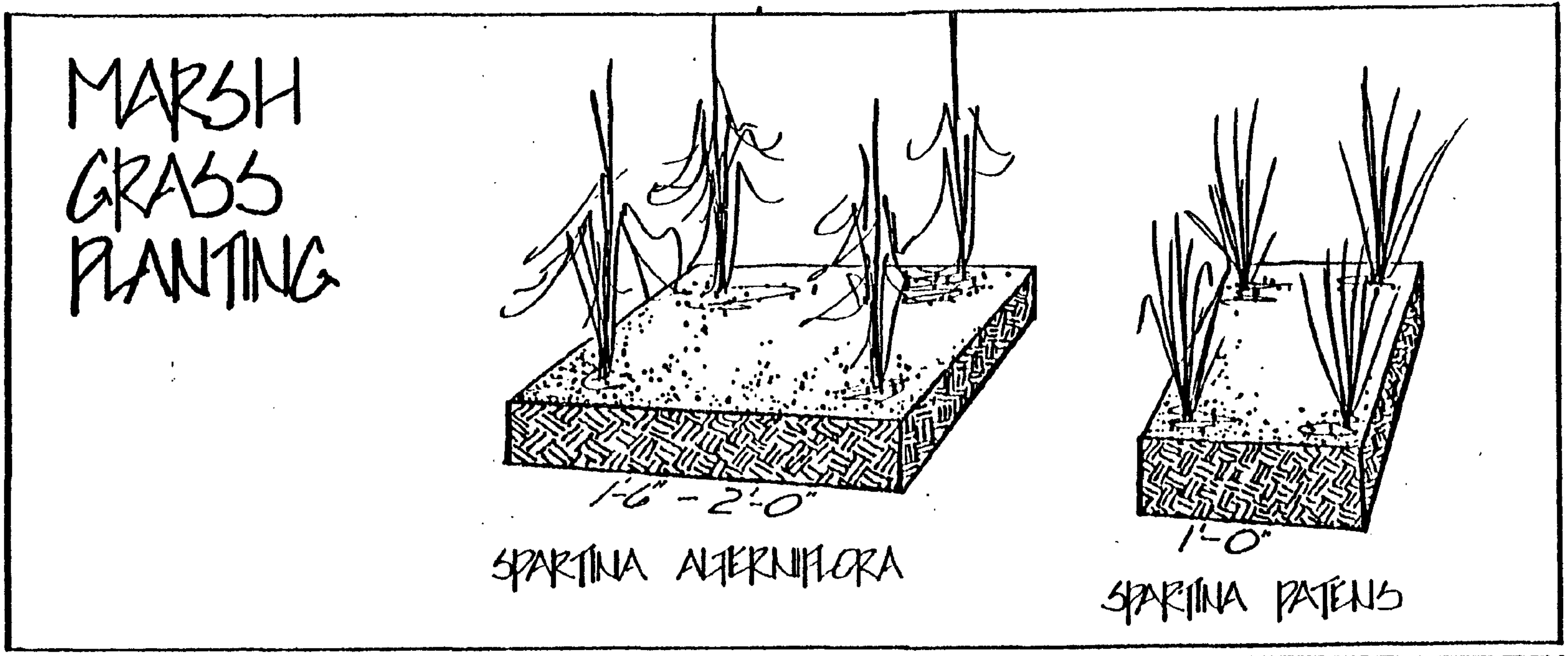
PLANTING

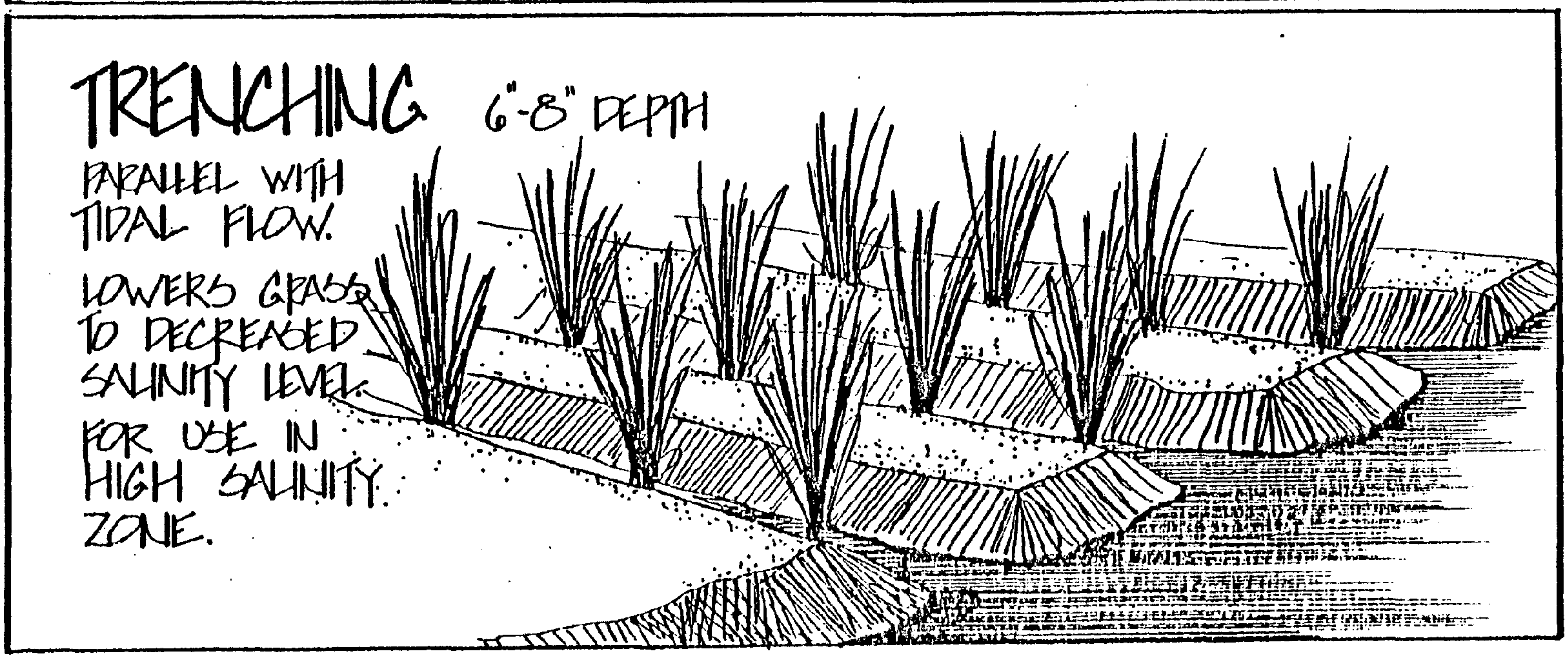
Sprig and Bare Root Plants.

Sprigs are single culm plants. A culm may contain several single stemed plants. If gathered in the field they should be collected in late winter or early spring before the plants resume vigorous spring growth. Early growth is derived from stored energy and it is important to plant before the spring growing season so plants can root and become established before the warm summer months. Otherwise a high mortality rate should be expected. Mortalities can also be reduced by cutting back the aerial part of the transplant to reduce transpiration.

Bare root plants are normally single plants that have been gathered or ordered. If ordered they have most likely been grown from seed. If bare root plants are purchased they could be held outside in tubs of estuarine water for approximately 2-3 weeks. Planting should be done no later than June in Rhode Island.

Sprigs and bare root plants of Spartina patens should be transplanted on a grid of 1ft. and Spartina alterniflora on a grid of 1.5-2ft. (illus.23). Uniform cover can be expected during the second growing season. It is recommended that three bare root plants be placed in each planting pit (21,22).


MARSH GRASS PLANTING
1'-6" - 2'-0"
SPARTINA ALTERNIFLORA
1'-0"
SPARTINA PATENS


TRENCHING 6"-8" DEPTH
PARALLEL WITH TIDAL FLOW.
LOWERS GRASS TO DECREASED SALINITY LEVEL.
FOR USE IN HIGH SALINITY ZONE.

Peat potted stock that has been ordered can also be used. This type has been the most successful in terms of survival, sustaining site stresses, and providing flexibility in establishment. Peat potted stock is the most expensive. It has the advantage being planted any time of the year and can be held over at the site for as long as six months.

The extraction of transplant material from a natural stand of marsh can be a very laborious process, and if not done properly can damage the site.It should be avoided since the existing stand of vegetation can be severely impacted upon. Any ordered plant material should come from a local source. For local listings contact the Division of Fish and Wildlife.

After planting has been completed a slow release fertilizer should be applied by side dressing. For late winter or early spring apply one ounce of 8-9month release Osmocote 18-6-12 fertilizer per transplant. For mid-spring to early summer, apply one ounce 3-4 month release Osmocote 19-6-12 fertilizer per plant. According to Garbisch, water salinities do not have an effect on nutrient release properties of fertilizer (19,22).

FACTORS LIMITING ESTABLISHMENT

Assuming that toxic substances are not present in the substrate or in tidal waters, wave and salt stresses are the most important factors limiting vegetative establishment.

Salt concentrations are most likely to arise in areas where tidal waters have a salinity content of 20-30ppt,having porous sandy substrates as opposed to muddy or peaty substrates, and within the M.H.W. and spring tide elevation range. In such areas and during times of summer drought and wind setup leading to extended periods of unusually low tides, evaporation of soil moisture leads to increases in soil and soil solution salinities. Capillary action tends to carry salt water to the sediment surface where it evaporates, leaving deposits of crystalline salt and creating a soil salinity that decreases sharply with depth (20,22).

Unfortunately, salt stress problems are difficult to forcast. They relate to meteorological conditions and regional wind and tide influences. Toxic salt concentrations may develop months after an area is planted. Vegetative establishment should not be attempted during periods of concentrated salinity levels. Planting should be delayed until rain or tidal water reduce the salinity level.

If there is a liklihood of salt stress developing at a site, it would be advisable to consider transplanting the planted vegetation into trenches (illus.23). This will put the plants in a lower salinity zone, and the salt would tend to be drawn to a higher salinity zone (22).

MAINTENANCE

Three principal maintenance requirements for wetland establishment or restoration are: debris and litter removal, protection against waterfowl depredation, and fertilization.

Organic litter which often deposits throughout the uppermost elevations of the tide should be periodically removed, especially during the first growing season. Such litter can produce extensive damage even to natural stands of wetlands. During the latter part of the growing season, submerged aquatic plants begin washing out and depositing throughout the upper elevations of the tidal zone. Such deposits can have a particularly adverse impact to newly planted salt marsh vegetation, and should be removed (22).

Populations of Canada geese can also be detrimental to salt marsh grass. Geese normally feed on marsh grass from the seaward edge in. Their feeding habits can be detrimental for the first two growing seasons of newly planted marsh grass. The stringing of nylon line onto stakes has proven effective in other southern locations. Normally 1/8" nylon line is tightly strung to 15-20' spaced wooden posts that extend from 6" above the sediment surface to roughly 6" above Mean High Water (19).

Fertilization required beyond those previously mentioned depend on water quality and wave stress at the site. When plant development is inferior to that found in other marshes then fertilization should be conducted. Where high physical stress occurs on site then fertilization should take place every other year. Fertilizer should be surface broadcasted at ebb tide. For further information contact the state Division of Fish and Wildlife.

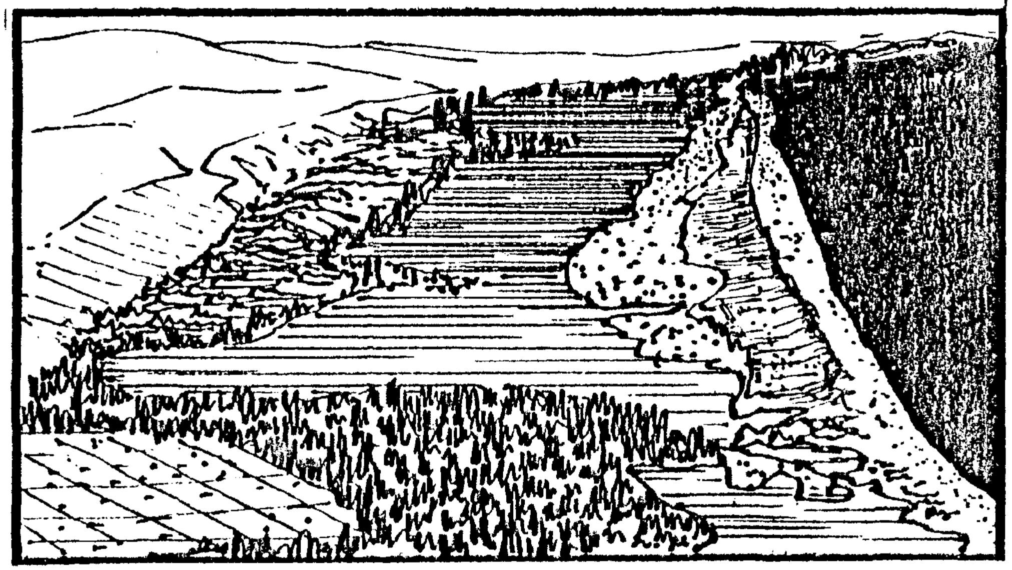
BARRIER
BEACHES

BARRIER BEACHES

In Rhode Island barrier beaches are located along the southwest shoreline; extending from Jerusalem Beach west to Napatree Point, in Westerly, and along the eastern shoreline from Sakonnet Pt. to Quicksand Pond, in Little Compton, and along the northeastern shoreline of Block Island.

Barrier beaches have been defined by the Rhode Island Coastal Resources Management Program as:

"narrow strips of land made of unconsolidated material extending roughly parallel to the general coastal trend and separated from the mainland by a relatively narrow body of fresh, brackish or a wetland."



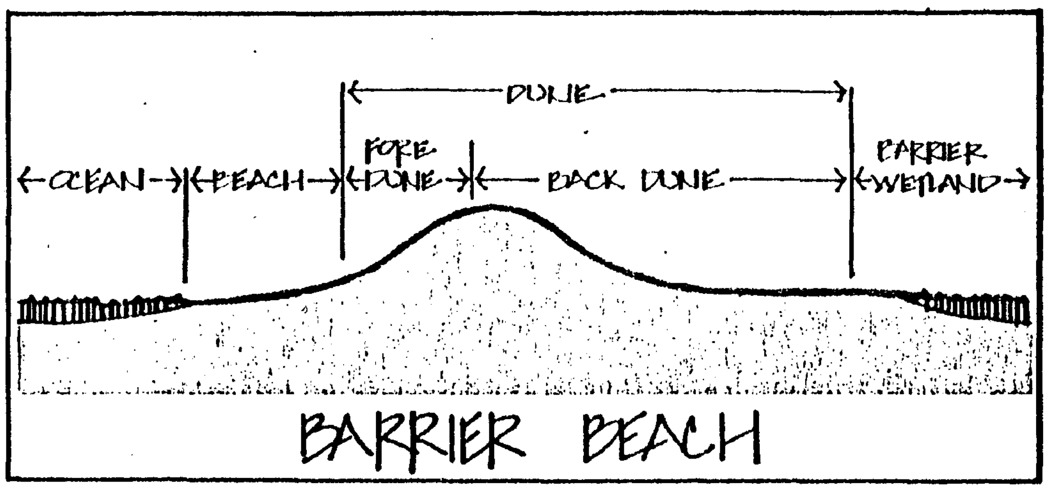
Along barrier beaches exist sand dunes. They are an important and integral part of the beach and commonly form a ridge running parallel with the trend of the beach. Dunes and barrier beaches are rugged, they receive the full bruht of ocean storms. They do not have delicate and easily damaged tidal areas like the salt marshes ot confined waters. Dunes and barrier beaches are tough and resilient. They require minimum management attention if not vulnerable to destruction by construction and users. Unlike, beaches dunes can be easily damaged and require extensive safeguards if improperly used and abused. Their great capacity to store sand makes them the chief stabilizer of the ocean beachfront. When the dunes are damaged so that they erode away, the essential buffer is gone and the whole shore and adjacent low-lying inland area is threatened with each storm or hurricane. A generally poor understanding of the development of both barrier beaches and sand dunes to withstand alteration has frequently led to disastrous and expensive consequences.

Rhode Island barrier beach systems are very delicate, and in an undisturbed state are a public asset of the greatest degree. Approximately 65% of R.I.'s 27.3 miles of barrier beaches are undeveloped. The recreational opportunities and uniquely beautiful open space they provide are of immediate and growing benefit in an increasingly developed region. It is a fact that these areas are being more heavily used each year by growing local populations and by increased tourist populations. Therefore, it is of utmost importance for people to understand how they can be better become a part of these exceptionally dynamic features.

NATURAL INVENTORY

PHYSIOGRAPHY .. GEOLOGY

The natural physical form of Rhode Island barrier beaches is a result of both geologic and natural forces. They have formed as a result of energy transferred by wind, waves, and currents. They have been delineated according to topographic form as seen below.



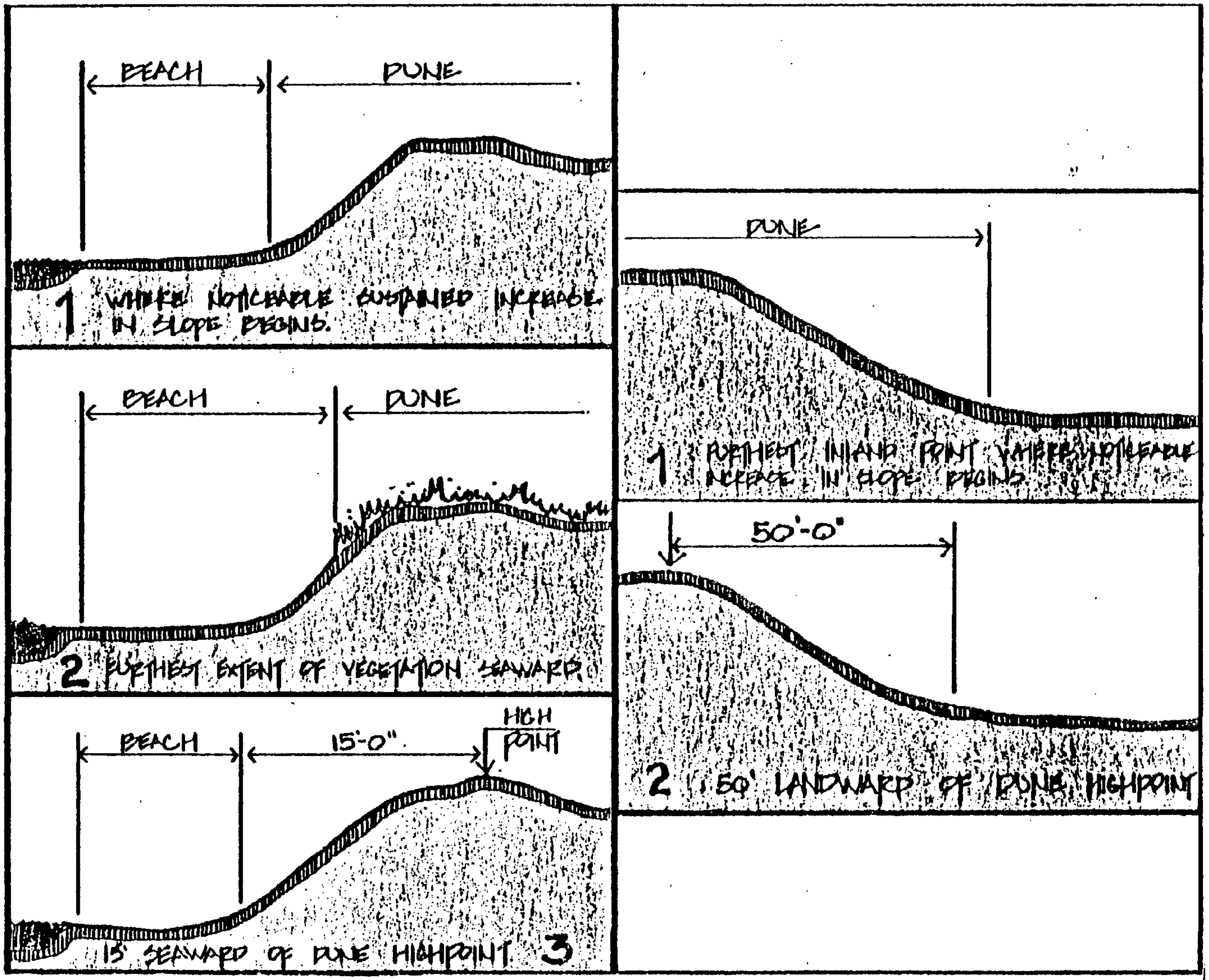
Barrier beaches typically formed as sand spits with their sediments being derived from accumulations at headlands. The transport of sediments, to form barrier beaches was done by longshore currents, running primarily in a direction from west to east (illus.24).As the spits continued to accumulate sediments they grew in size and became attached to the adjacent headland. Technically, these barrier spits are termed "Bay-mouth Bars".Hence, there remains a body of water on the landward side. Often during storms and hurricanes these spits become breached by wave energy and currents and the inland body of water becomes tidal once again. These breachways become static when sediments fill them in and close them off from the ocean (23).

Once the bay-mouth bar becomes wide and stable dunes form directly behind the beach because of the invasion of vegetation. When sand accumulates on the seaward slope of a dune it will extend, or build, the dune seaward toward the ocean. According to the Rhode Island Coastal Resources Management Program:

"A sand dune is an elevated accumulation of sand formed by wind action and normally follows the general coastal trend immediately inland of an unvegetated beach." Refer to the illustration on the following page.

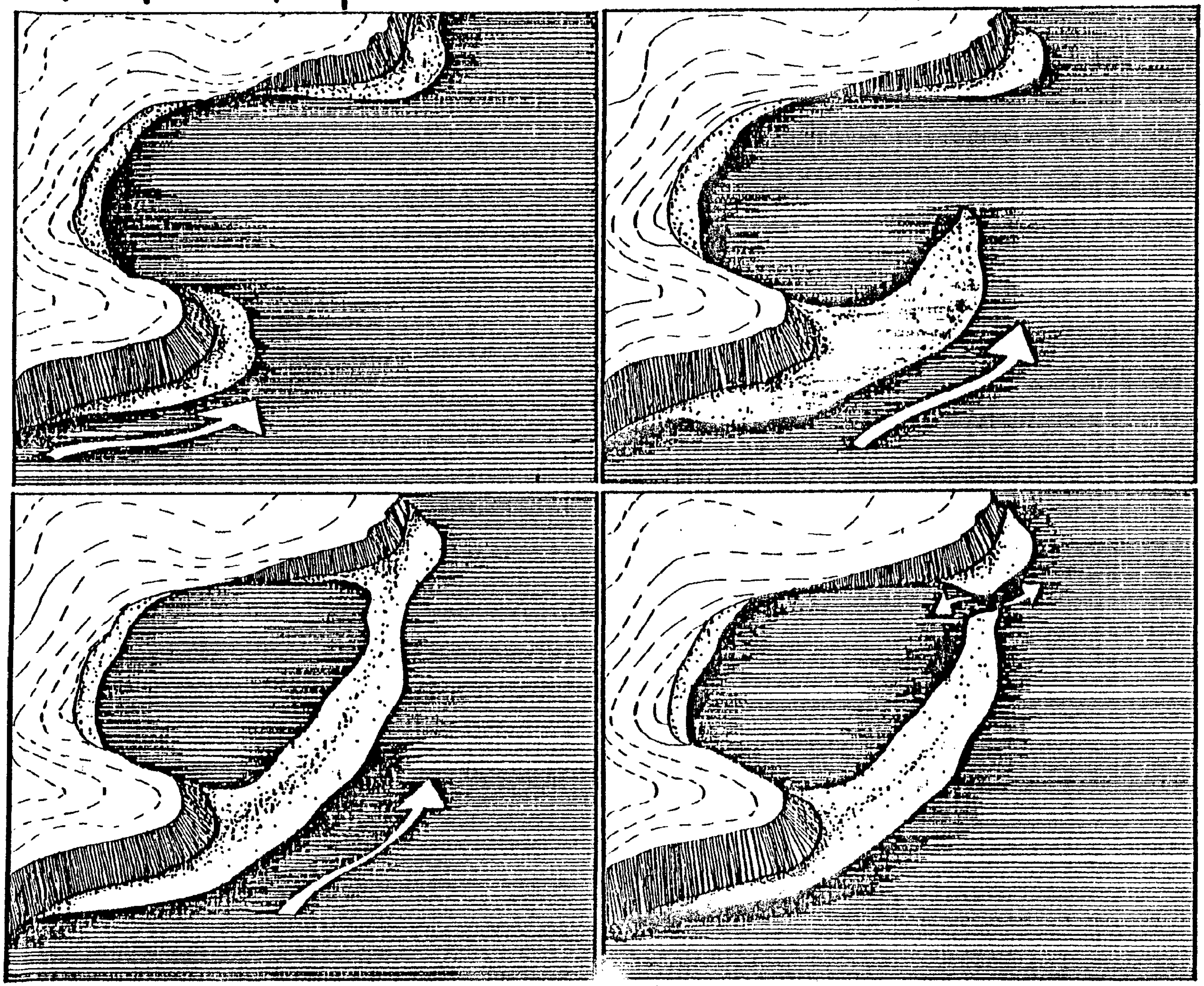
Barrier beaches are ever-changing landforms. They are constantly under pressure by the natural forces to migrate inland. The annual rate is approximately 4 feet (24). To the casual observer this inland advance is not obvious until photographs are examined or until exposed peat substrates are uncovered on barrier beaches during storm activity. This substrate that is normally found 30-40 inches under the ocean beach is proof that marsh once flourished farther out to sea (illus.26).

During periods of increased wave activity, primarily in winter months, the beach topography undergoes change. Waves attack the beach berm fronting the dune and when it is completely diminished they begin to attack the dune and transport the berm and dune sand offshore and deposit it onto a bar. During periods of calm the ocean swells will transport the sand back onto the beach and the wind will transport it further atop a newly forming dune (illus.25). This dune building, however, is generally at a very slow rate (24).

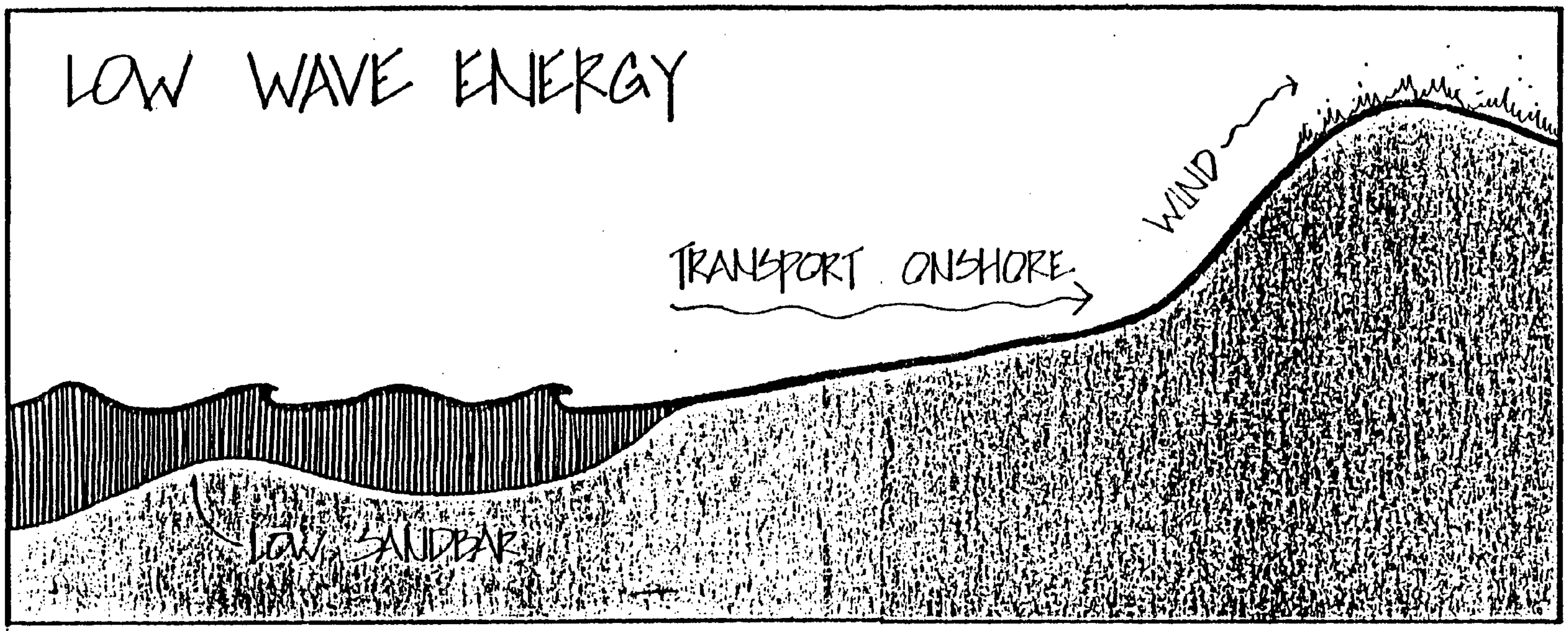


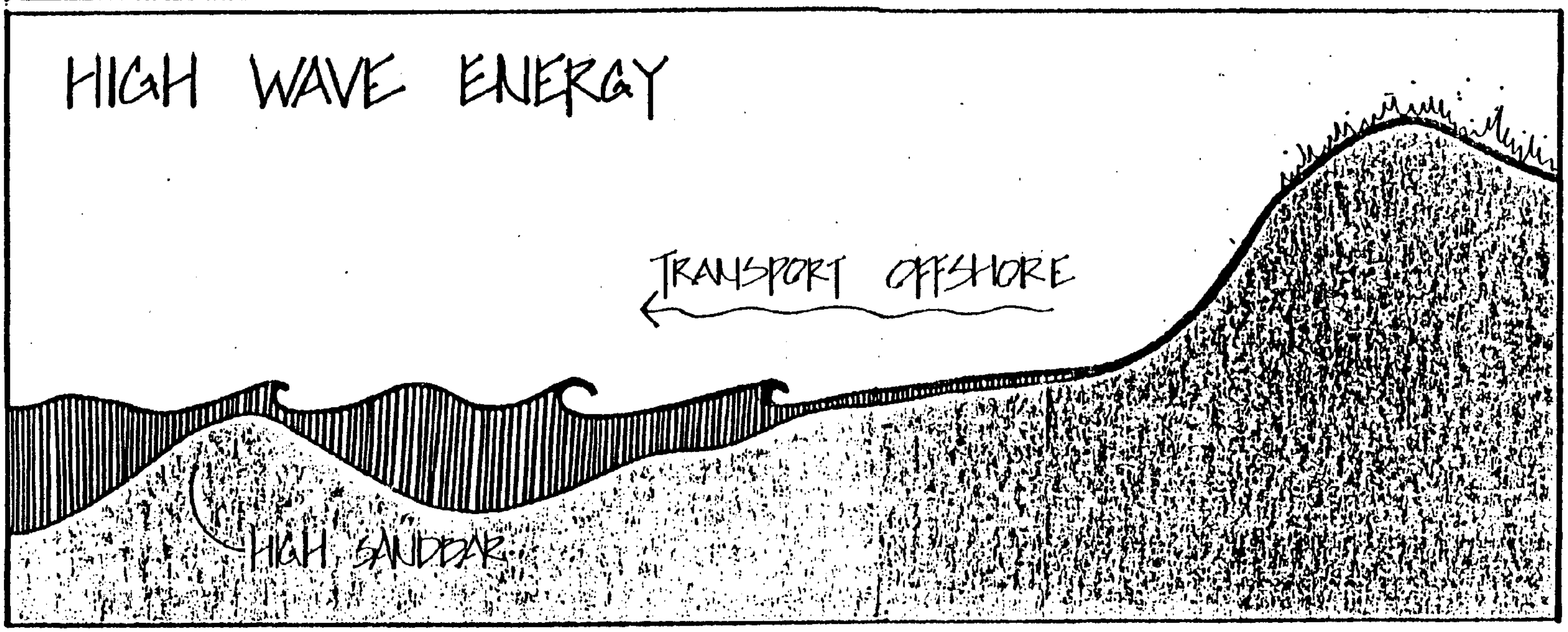
RHODE ISLAND SAND DUNE DELIMITATIONS

PHYSIOGRAPHIC FORMATION OF BARRIER BEACH



2/


LOW WAVE ENERGY
WIND
TRANSPORT ONSHORE
LOW SANDBAR


HIGH WAVE ENERGY
TRANSPORT OFFSHORE
HIGH SANDBAR

SOILS

Barrier beaches consist of sorted sands and gravel derived from headlands and inland areas. Generally, these soils are found along the southwestern barrier beaches, whereas the barrier beaches along the eastern shore have accumulations of pebbles and in certain areas cobbles have been left by eroded till. Generally, the soils on the southwestern barrier beaches are derived from outwash.

Due to the porous nature of these coarse materials water percolates through them very rapidly. Salt derived from ocean water leaches through at the same rate. On the backdune is where winds have deposited larger accumulations of salt. In soils containing organic matter, near vegetation, higher percentages of salt prevail. By nature, the water retaining clay and organic soils, retain moisture and trap salts.The pH level of these salty soils is generally high causing them to fall into the alkaline range (25).

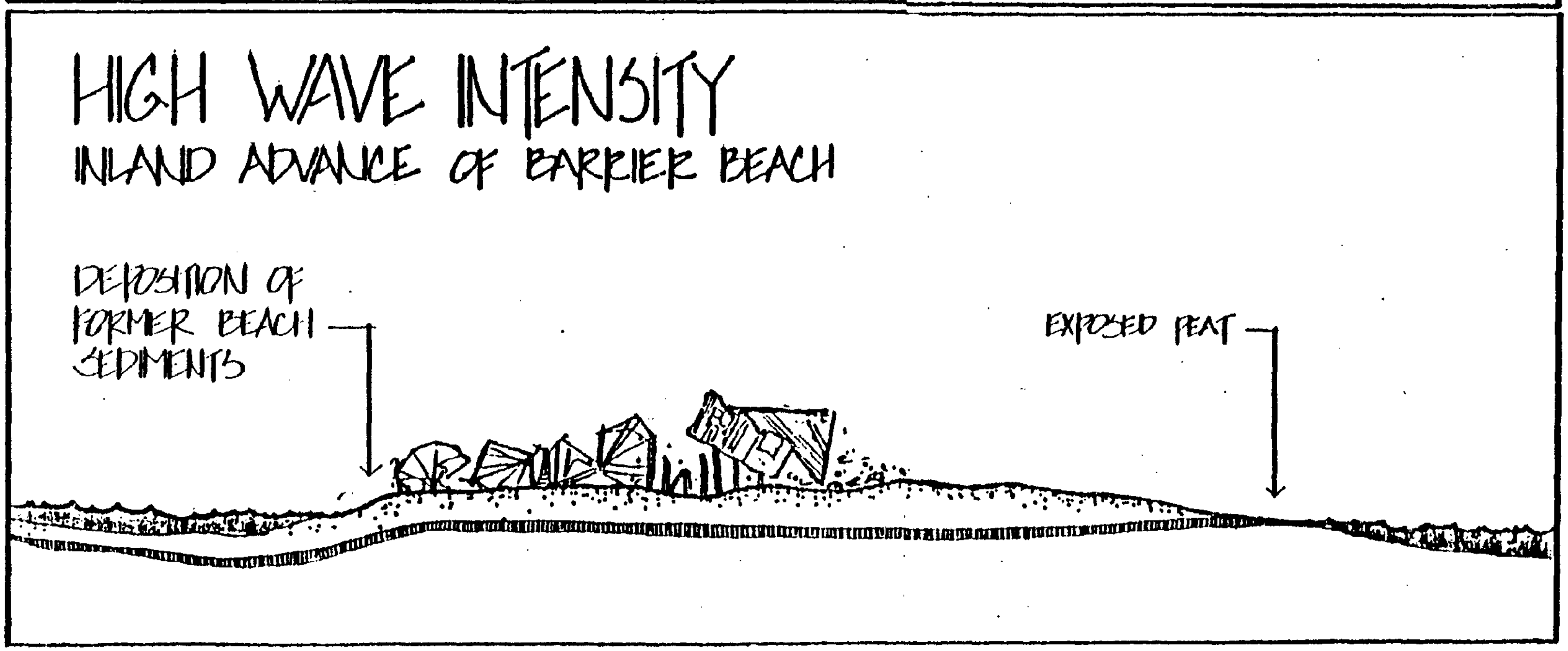
Sand dunes consist of fine light weight sands. These sands are rounded in shape and hold a very low natural angle of repose unless bonded by moisture or vegetation. When water surrounds sand particles it enables them to become bonded and they are able to support one another. Moist sands hold an increased degree of slope. Vegetation plays the same role, although the plant roots act more as anchors.

HYDROLOGY

Longshore currents transport sediments via water. This is a constant process and large quantities of sediments can be transported. The direction of current is dependent upon waves, wind and tides. Not only are currents running parallel to the shoreline responsible for sediment transfer, but waves play a large role in causing "Washovers". These occur when waves and water penetrate through the dune line and inundate low-lying inland areas. The great force behind the flow of water has literally leveled dunes in the past (illus.26).

The forces of water seem to dictate activity on barrier beaches over an extended period of time. The force is responsible for the wellbeing of barrier beaches as well as the destruction and there is assurance that nothing will defeat its force without causing impact down the line.


NORMAL CONDITIONS
SLOW ADVANCE INLAND OF BARRIER BEACH GOES UNNOTICED.


HIGH WAVE INTENSITY
INLAND ADVANCE OF BARRIER BEACH
DEPOSITION OF FORMER BEACH SEDIMENTS
EXPOSED PEAT

VEGETATION

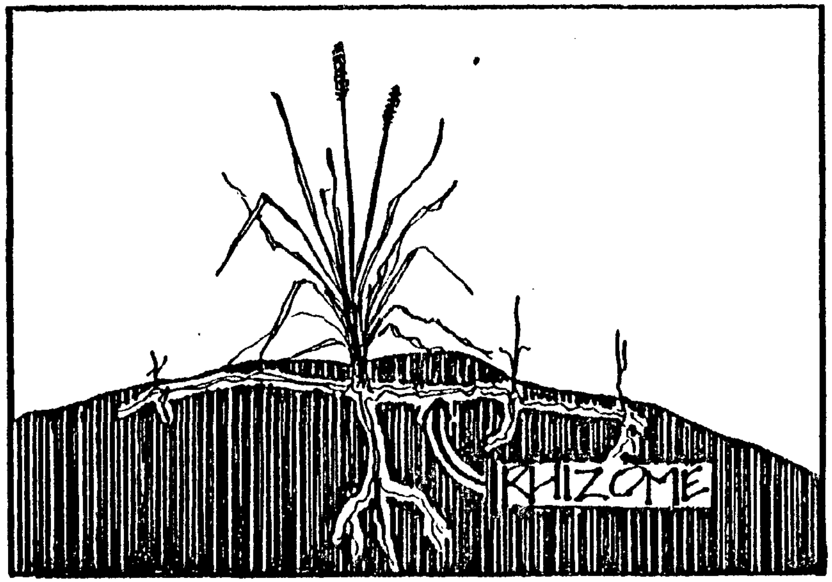
Plants of the high energy barrier beaches are part of a very dynamic natural system and are subjected to some unusual stresses. The stresses experienced by plants varies according to the physiographic form of the barrier beach. Within each zone there exists a plant community (illus.27). Each plant community exists because of its ability to adapt. Within the barrier beach plants are exposed to the critical effect of freshwater availability, wind erosion, and wind born salt spray.

Water held between sand particles is normally a reliable supply for the dune plants, however, other plants must have deeply penetrating roots or live on the dune's lower slope to absorb water from groundwater zones in order to survive (26).

Sand is blown from beaches to dunes and among dunes almost constantly, where there is little or no protective vegetation on the dunes, sand moves in the general direction of the prevailing winds until it encounters an obstacle sufficient in size to trap it. The shifting mass of dune sand provides only a precarious surface for plants. Wind can not only cover plants with sand but it can cause it to tear foliage, defoliate plants, reduce moisture content, and occasionally causes plants to become uprooted. As a result plants have become adapted by becoming smaller and more compact, having shorter stems, and foliage has become thinner and smaller. Plants have also been able to establish deep root systems and to form special facilities for storing moisture. Winds carrying salt spray in from the ocean also discourage plant growth. Protective coatings and rain water helps the plants to survive in areas experiencing salt spray. Beach grass for instance has a long narrow leaf structure that reduces surface area. Bayberry has glossy wax-like leaf coatings that prevents salt absorption; the salt forms a crust and rain washes it away.Still other plants like Dusty Miller and Rugosa Rose have a tomentum characteristic. Their leaves are covered by tiny hairs causing salt crystals to form on the hair tips. With time the salt dries and falls to the ground.

In general the barrier beach community is greatly influenced by the presence or absence of the associated plant community. Inland areas are more protected and, as a result, more fully stabilized by plants.

Ammophila breviligulata, American beachgrass, plays a dominate role in the development of coastal vegetation communities, and performs vital functions in the stabilization of the ephemeral barrier dunes. Beach grass is best known for its stalks of seed heads that appear during late July or early August. American beachgrass usually starts to green-up and grow along the beaches in late March and becomes dormant by late fall. It grows in bunches containing many culms, stems, that may reach a height of two to three feet. Many new culms appear beneath the sand in early spring. These come from the base nodes or from rhizomes that have spread beneath the sand for several feet as seen on the next page (26,27).

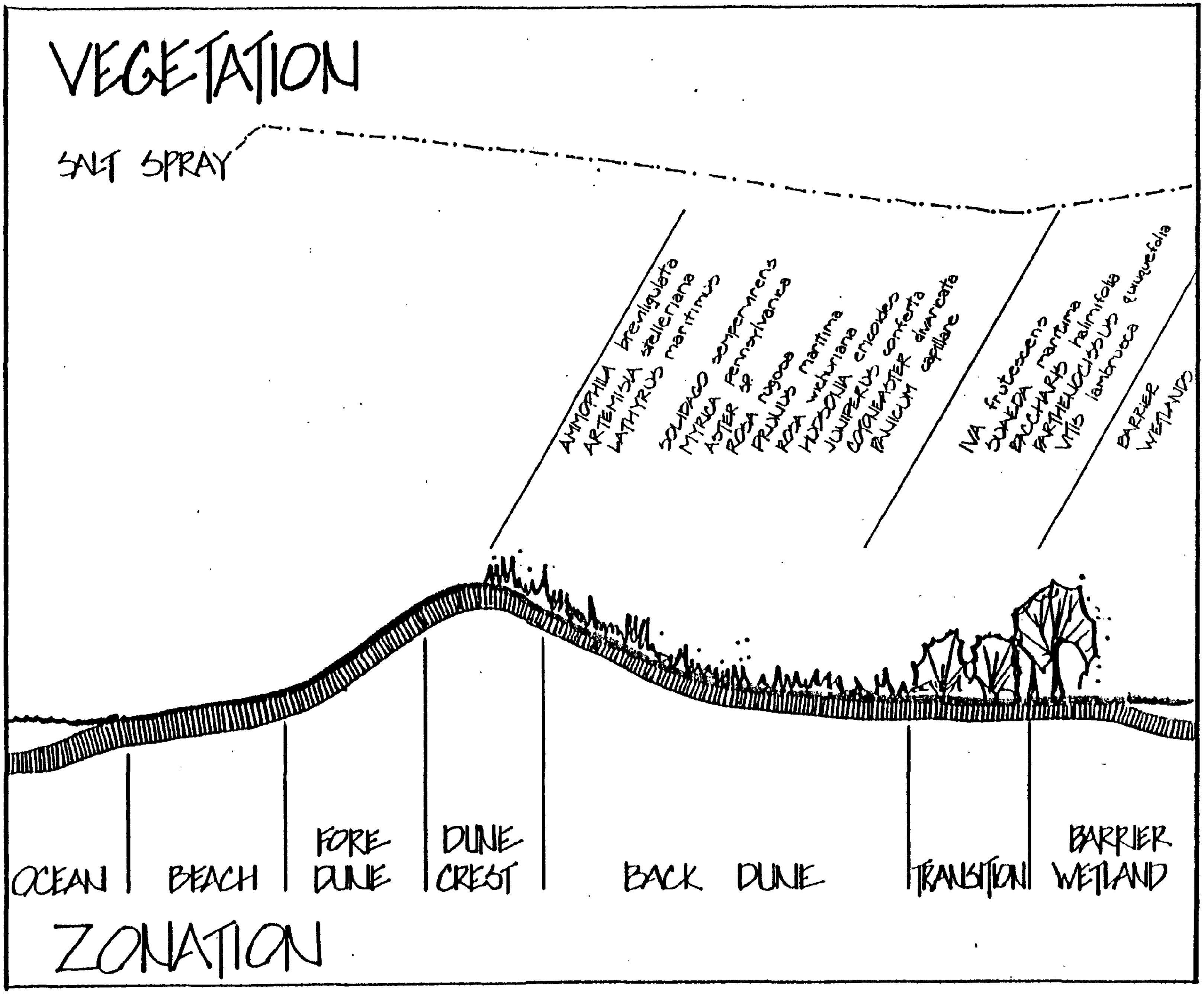


BEACHGRASS

Beachgrass is by far the most dominate specie associated with barrier beaches. Other dune and backdune plant species are scattered throughout in dense clumps. Farther toward the barrier wetland a transition zone of plants occur. Here barrier beach plant species are found interspersed with those of barrier wetlands. There is no clear delineation of species in the transition zone.(illus.27)

BIOTIC COMMUNITY

Along with vegetation a barrier beaches aquatic and terrestrial creatures alike are subjected to unusual stresses. Because of the stress factor barrier beaches are the least productive of ecosystems. Because there is so little opportunity for food-producing plants to exist on the beach, animal life is supported by imported detritus that originates, for example, in the highly productive salt marsh ecosystem. Few animal organisms are adapted to the strenuous sandy beach environment, though their population may be high where breachways exist. Most beach animals are filter or deposit feeders that must live below the


VEGETATION
SALT SPRAY
AMMOPHILA breviligulata
ARTEMISIA stelleriana
LATHYRUS maritimus
SOLIDAGO sempervirens
MYRICA pensylvanica
ASTER sp.
ROSA rugosa
PRUNUS maritima
ROSA wichuriana
HUDSONIA ericoides
JUNIPERUS conferta
COTONEASTER divaricata
PANICUM capillare
IVA frutescens
SUAEDA maritima
BACCHARIS halimifolia
PARTHENOCISSUS quinquefolia
VITIS lambrusca
BARRIER WETLANDS
OCEAN
BEACH
FORE DUNE
DUNE CREST
BACK DUNE
TRANSITION
BARRIER WETLAND
ZONATION

surface of the sand, extending their siphons and tentacle plumes into the flooding tidewaters for feeding. Crabs also emerge from their burrows on the incoming tide to search for food. Beach fleas, flies, crabs, and beetles feed along the high tide line where detritus is left by retreating water. Many shore-birds feed at the waters edge and the backdunes serve as nesting grounds.

Eventhough barrier beaches aren't highly productive ecological systems the biologic communities they serve are an integral part of the system. Therefore, it important to understand the potential impacts and effects of alteration to these zones. Beach and dune organisms are especially sensitive to disturbance by vehicular and pedestrian traffic. Nesting birds are put under stress by traffic. Nests are sometimes destroyed, particularly those of terns, which prefer the more open lower beach where traffic is the heaviest (14,16).

AESTHETIC ENVIRONMENT

The aesthetic quality of Rhode Islands barrier beaches is based on the unity of landform and water. Upland along the dune ridge and on backdune areas vegetation is another aesthetic attribute. The aesthetic environment offers unique variety and vividness. Variety is seen and vividness is perceived as a strong, clear impression on the senses. Variety and vividness are derived from terrain pattern, presence of water, weather characteristics, vegetational pattern, and cultural land use patterns. Uniqueness is derived from the composition of form, space, color, and texture.

The beach is a palette for ever-changing textures and formations. The dunes give a scale to the beach that is often times lost by the great expanse of ocean. Dunes paralleling the beach create visual barriers that hold back views inland. When on the beach side of the dunes one cannot help but feeling a part of the barrier beach environment. It is a feeling unique in itself. When cultural elements are seen behind dune ridges from the beach this perception becomes less fulfilling and distorted. In a way the presence of cultural objects begin to break down the unity of the natural landscape and adversely affect the sense of place.

The ocean water that flows onto the beach with every new wave brings the two elements of land, or beach in this case, and water together into a unified environment. Wind, percipitation, tides, and waves are the elements that offer variety and provide this environment with a unique vivid quality. This unique vivid quality provides for a fulfilling visual and mental experience. Vividness can also be produced ,for instance, by a sailboat being powered by the natural force of wind sailing offshore. This cultural element becomes a part of the environment and is subordinate within it ,as opposed to a dominant static house that is visually experienced as a dominate object in this barrier beach environment. This same house, however, could of become subordinate if careful attention was given to scale, form, texture, and color.

The dune and backdune landscape offer a different visual experience. Unlike the beach setting, one becomes more a part of the land environment instead of the water. Homogeniously spreading vegetation, gently sloping topography, water, and cultural influences are all a part of the composition. Within many backdune environments along the shore dominate cultural influences physically and visually degrade the landscape. This visual and physical degradation of this backdune landscape intensifies with every new cultural change.

It is a fact that buildings on barrier beaches are degrading to the landscape. In the last decade Rhode Islanders and others have moved at an increasing rate to coastal locations.Previously the risk of occupying these flood hazard zones was avoided since the ocean periodically reclaims its right of passage taking costly human life and property investments. The National Flood Insurance Program, however, has encouraged people to risk building in these hazardous areas. This does not happen without stipulation. The state and federal restrictions cause these buildings to degrade the environment that they are out to protect. These highly elevated buildings, often termed houses, become dominate and can be seen for long distances. Their height creates high visual contrast and often times conflicts with the natural topography and existing vegetation. When buildings become lowered and cleverly placed in the landscape they become subordinate and no longer visually degrade the landscape within the.barrier beach setting. Doing so enables the viewer to feel more apart of the natural environment and less apart of the impeding cultural world in these natural settings (illus.33).

EXISTING . . PROPOSED SOLUTIONS

Wind and water erosion occurs throughout the barrier beach environment because of natural and cultural forces working together and individually. The easily erodeable dunes are of primary concern since they absorb the shock of storm waves and help to shield land and human habitations from flooding tides and flooding. Paradoxically, they also are vulnerable to seemingly harmless activities. Even a footpath worn across a dune can have cummulative effects to that area; leading to a large leveled area. Plants are destroyed and the sand is left bare to the wind and erosion occurs. When erosion occurs over an extended period a "Blowout"results. A blowout is characterized by a negative space in the dune usually large in width. This process is liable to continue and whole stretches of dune may be lost and landward areas they once shielded are left open to the sea. Footpaths and motorized vehicles must be localized and not extend aimlessly through the dunes (illus.28).

The guiding principal is to preserve and protect dune grass especially on sites where they are most susceptable to destruction. Increased use should be designed for on both public and private property (illus.29 and 30).

Barrier beach management amounts to foresight and practical care wherever possible. This foresight should promote and hold these important beach and dune forms over a long period.

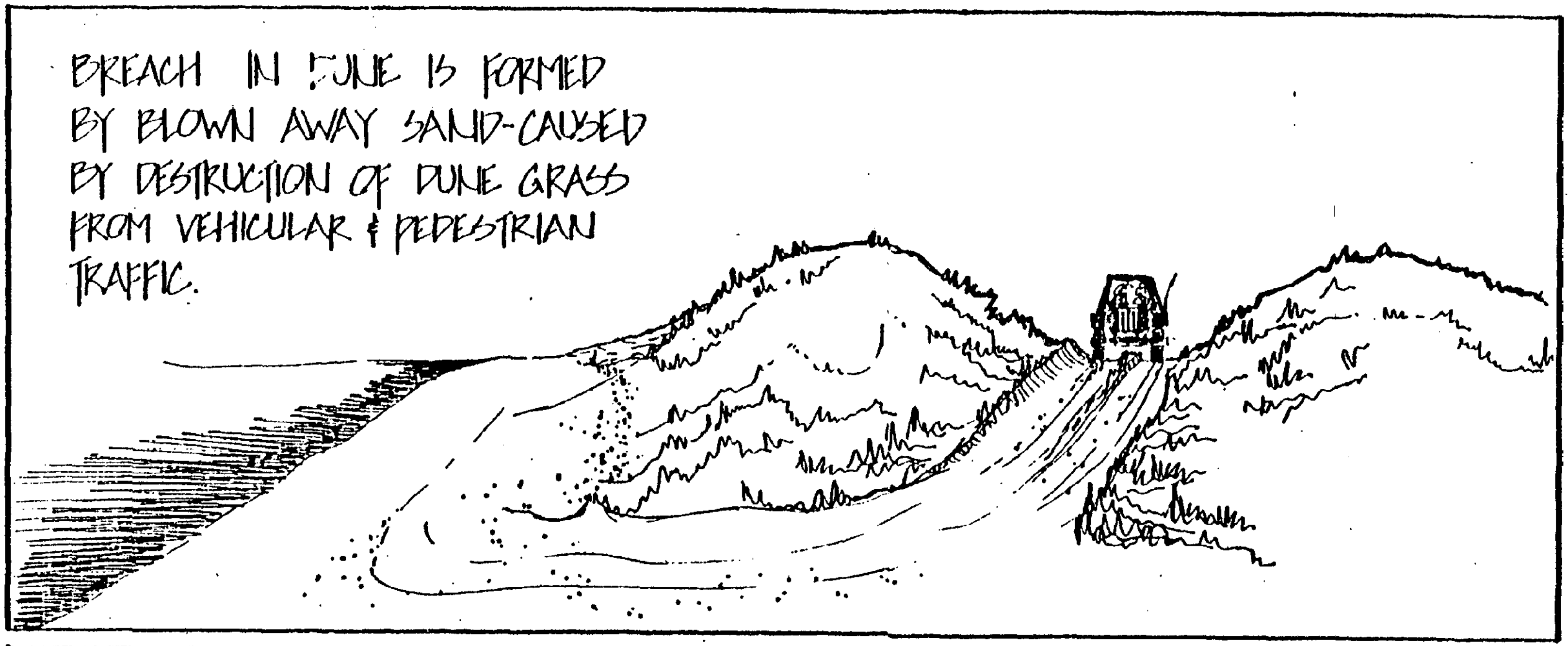
Beach fencing has become an accepted and integral part of erosion abatement along Rhode Island barrier beaches and others nationwide. There is no proof that they are physically degrading, and they have been used on beaches for so long they appear to be an integral part of the coastal landscape. Their function and best accepted implementation procedures are outlined in (illus.31).

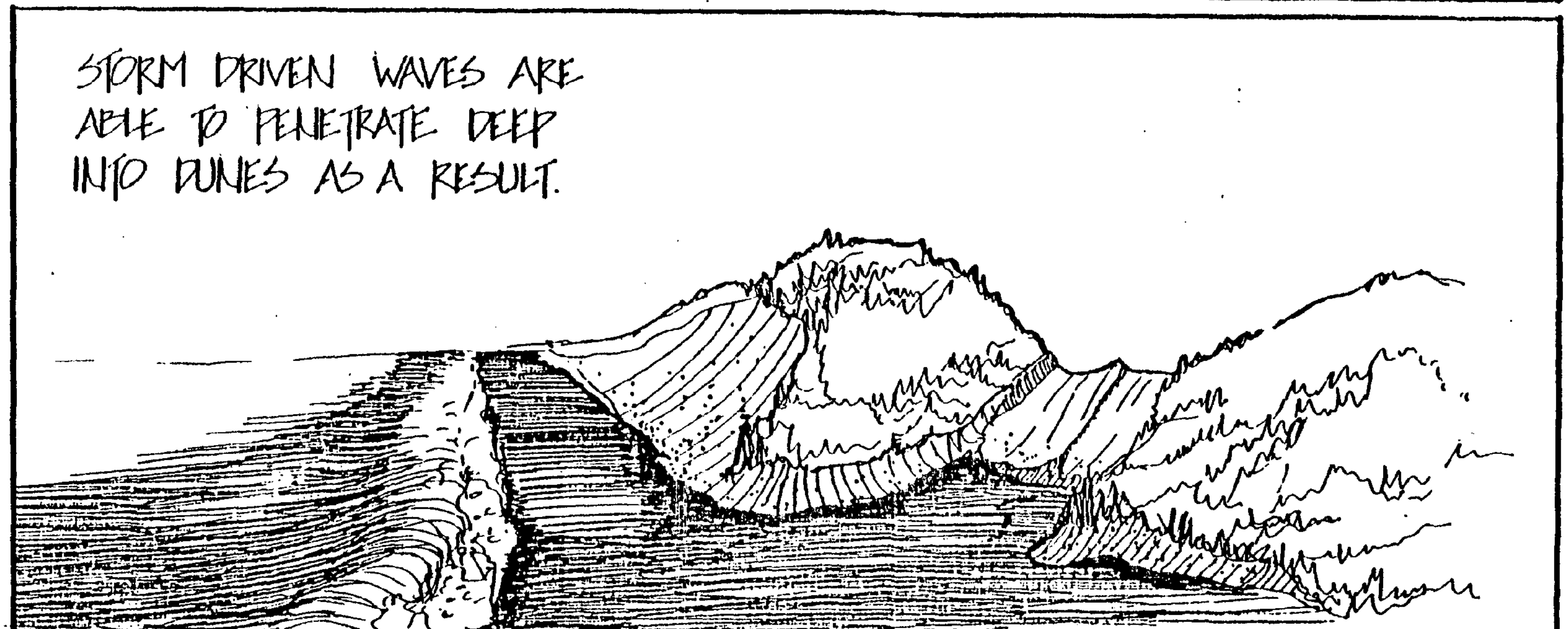
Where a dune "blowout" occurs hay bales can be staked along the blown out area (illus.32). This method has proven effective in Rhode Island, and the accumulation rate is faster than that of beach fencing. Also, with storms the bales breakdown and do not become a hazard. The use of Christmas trees for blowout construction and dune building has become widespread. Although, during storms these trees can cause adverse effects when they are hurdled about by waves and wind. They also cause increased erosion in their adjacent vicinity. The use of Christmas trees should be discouraged.

Another cause of sand erosion on barrier beaches is construction. During this time dune and backdune zones should be protected from alteration. The best way to do this would be to keep all construction activity within a pre-determined zone with respect to naturally occuring landform and vegetation. In the case of sewage disposal units only the specific disposal site and immediate access to that site should be permitted. After installation of the disposal system a cover of planted beachgrass is recommended to anchor the sand from blowing winds (illus.33). Any other non-vegetation material could be visually degrading.

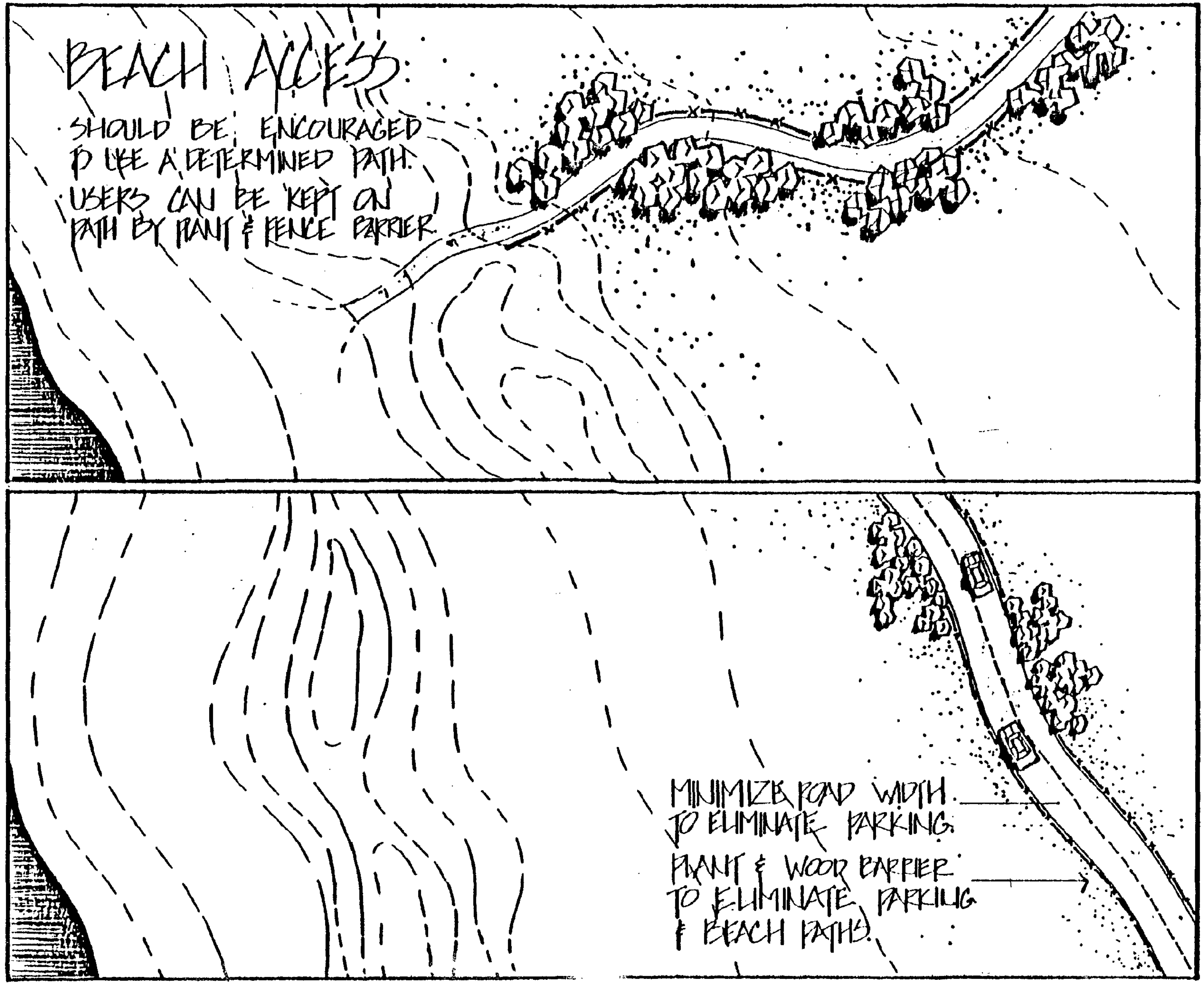
In addition to planting beachgrass within the barrier beach environment not only will they provide protection from erosion, but they also can provide a natural buffer between private and public properties. It is recommended to use low profile plants that allow salt-sprays, storm waters, and wind to pass over them. These low shrubs occur in the dune and backdune zones and are assumed to be the best adapted to these environments. Indigenous plant species should be used since they are the best adapted plants for these harsh conditions. The planting procedure for these areas is done much the same way as other locations. However, it is important to add an adequate amount of moisture retaining soil to provide organic nutrients and to allow plants to become established. Ground covers should be planted to protect the soil from baking plant roots and moisture loss. Since moisture holding soils also allow salt to accumulate an acidifying fertilizer should be used to lower the alkalinity. If possible, frequent watering will also help to remove salts from the soil (28).

For a listing of plants best adapted for barrier beach planting refer to page (109).


BREACH IN DUNE IS FORMED BY BLOWN AWAY SAND-CAUSED BY DESTRUCTION OF DUNE GRASS FROM VEHICULAR & PEDESTRIAN TRAFFIC.

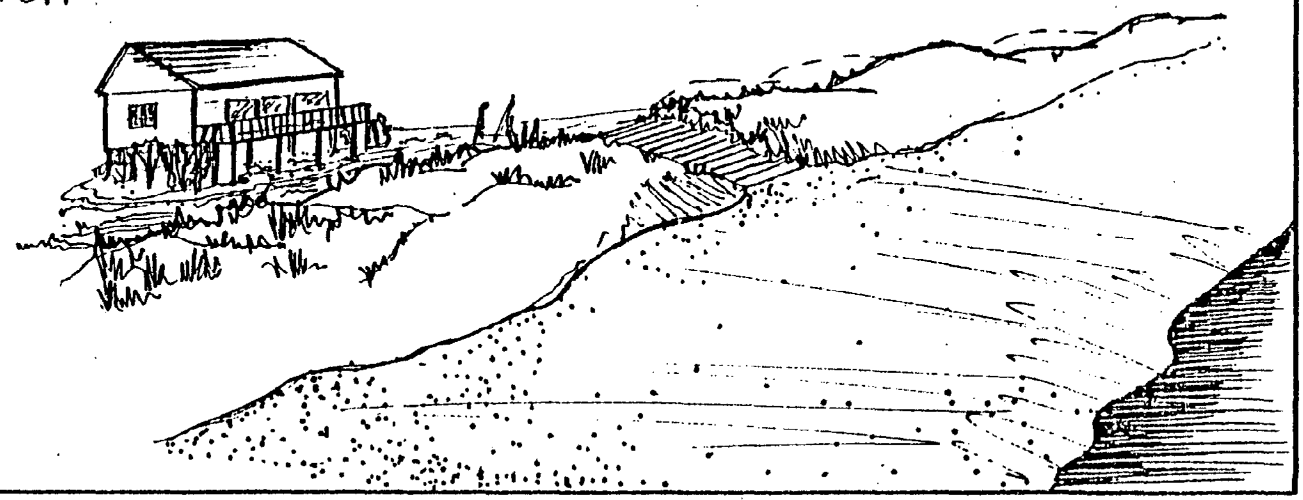

STORM DRIVEN WAVES ARE ABLE TO PENETRATE DEEP INTO DUNES AS A RESULT.

INCREASED USE

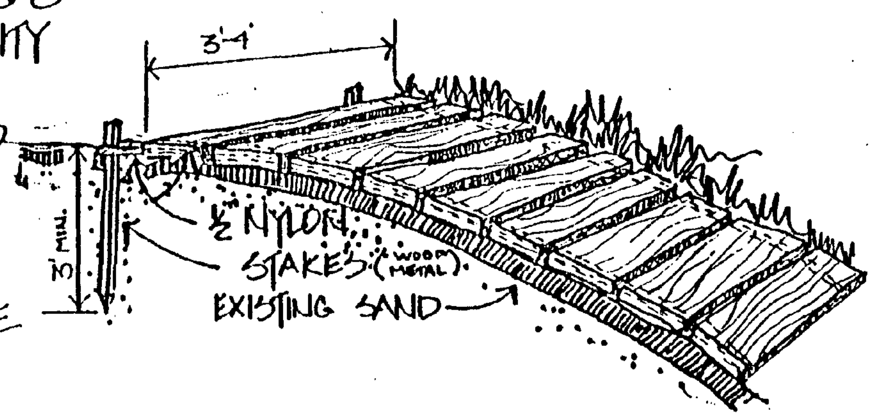


BEACH ACCESS

NON-ELEVATED BOARDWALK
TO BE USED IN RESIDENTIAL & PUBLIC BEACH AREAS

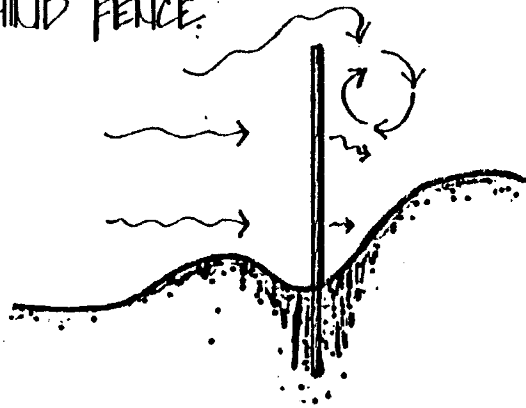


- BOARDWALK TO BE CONSTRUCTED OF 2"x8" NOMINAL PRESSURE-TREATED WOOD, ½" NYLON ROPE.
- TO BE CONSTRUCTED IN 6-8' SECTIONS FOR EASY MOBILITY
- NYLON ROPE TO EXTEND THROUGH SIDES OF WOOD WITH A KNOT BETWEEN FOR SPACING.
- IT IS IMPORTANT TO STABILIZE SIDES WITH BEACHGRASS.

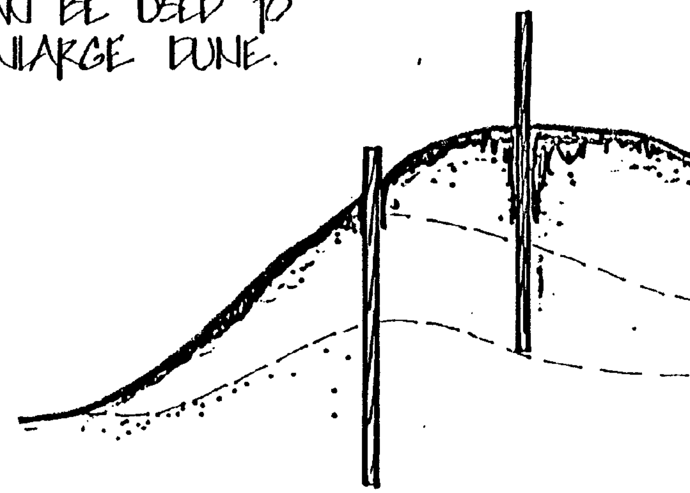


DUNE FENCE

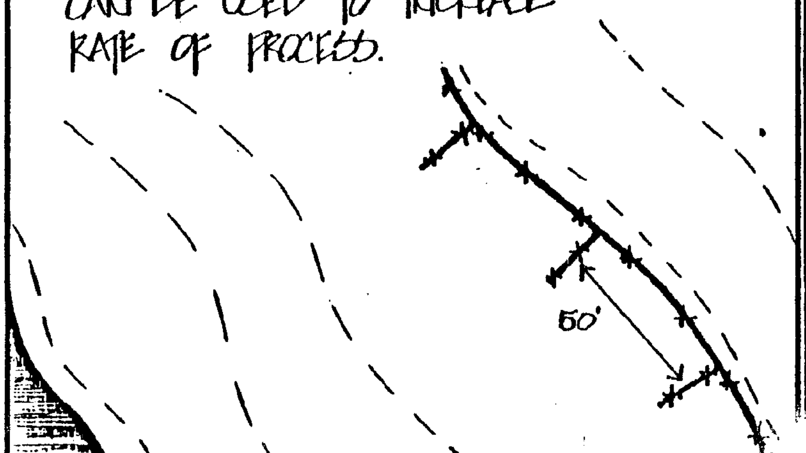
- BEACH FENCING AIDS IN DUNE BUILDING.
- SAND COLLECTS IN "STALL ZONE" BEHIND FENCE.



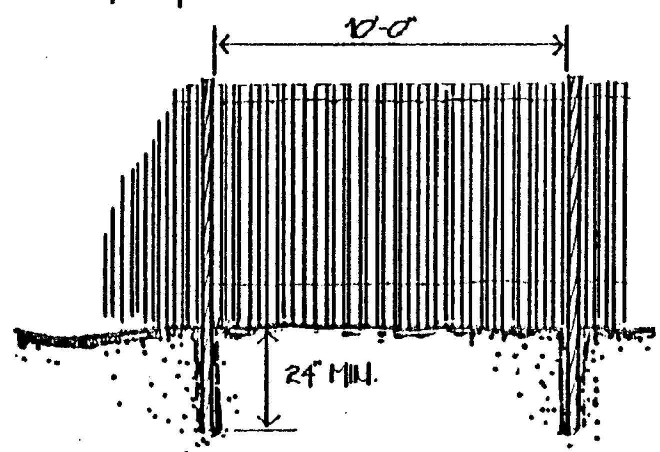
ADDITIONAL FENCING CAN BE USED TO ENLARGE DUNE.



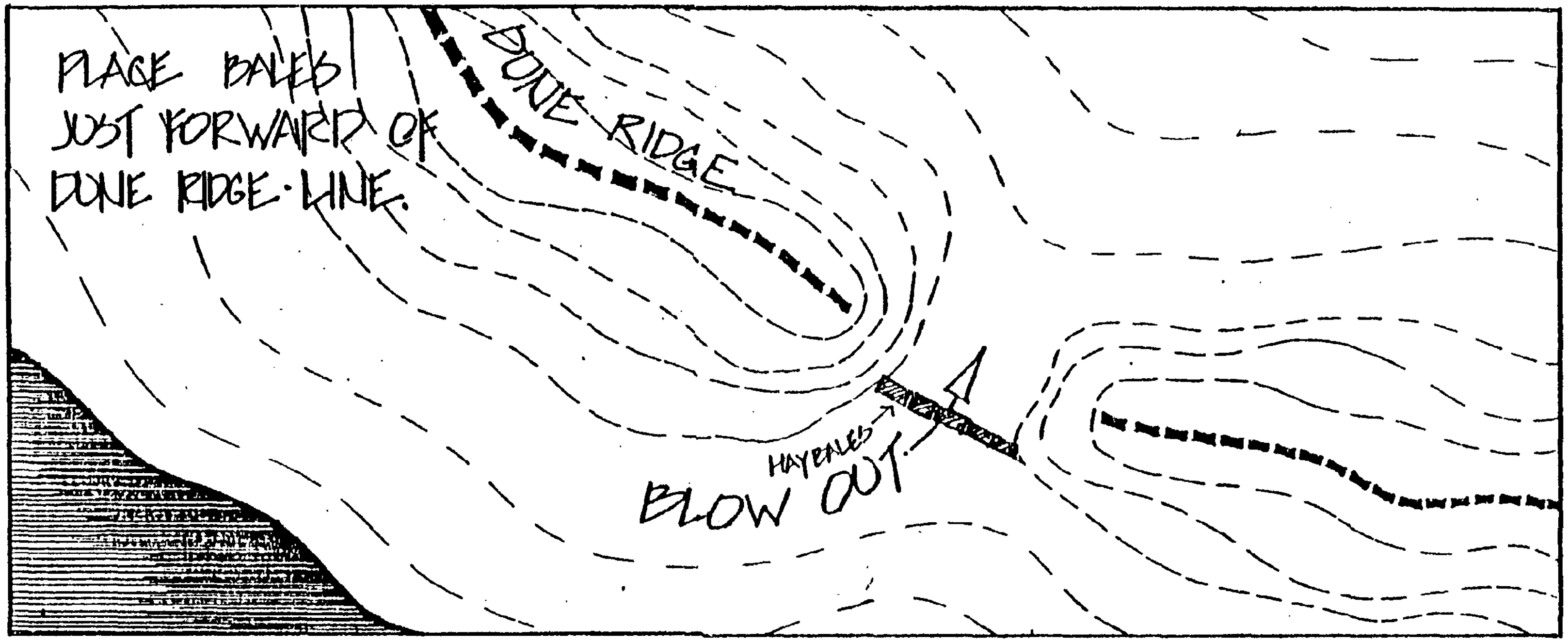
- FENCE TO FOLLOW NATURAL CONTOUR OF BEACH
- PERPENDICULAR FENCE CAN BE USED TO INCREASE RATE OF PROCESS.

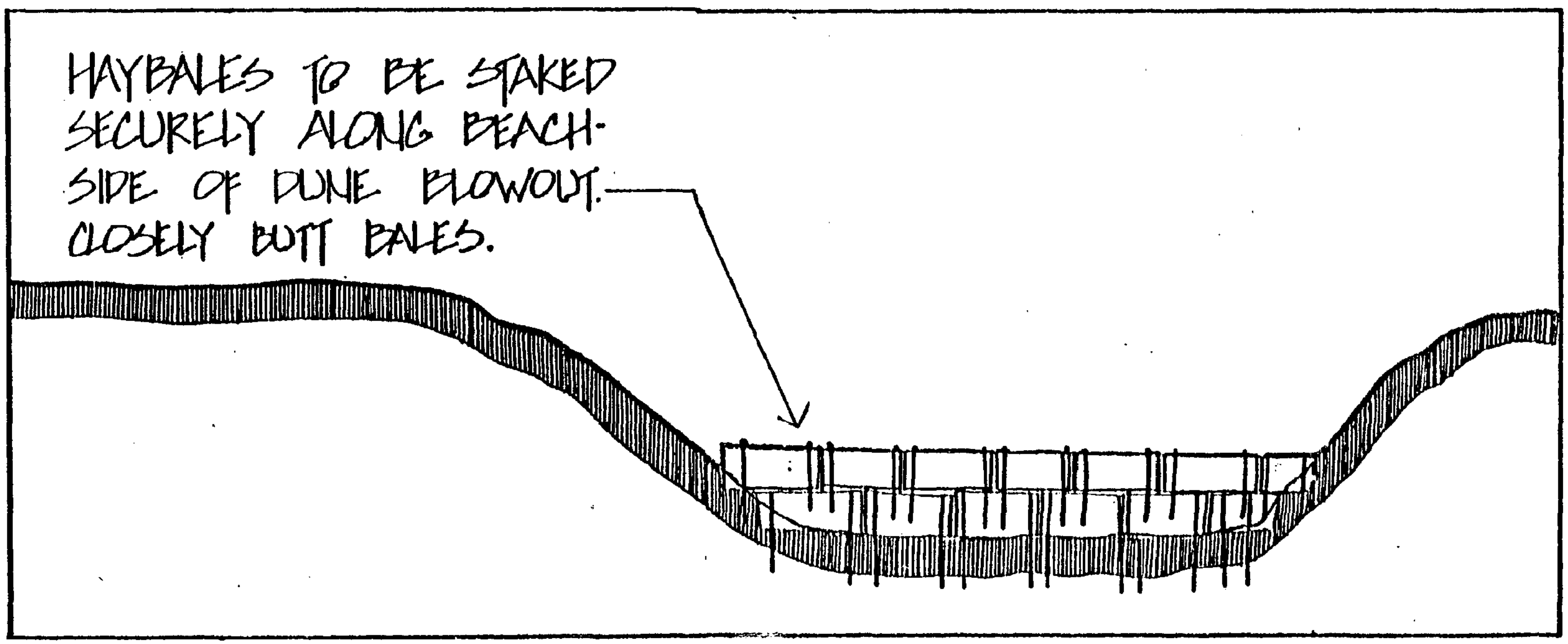


WOODEN POSTS KEEP FENCE ERECT.



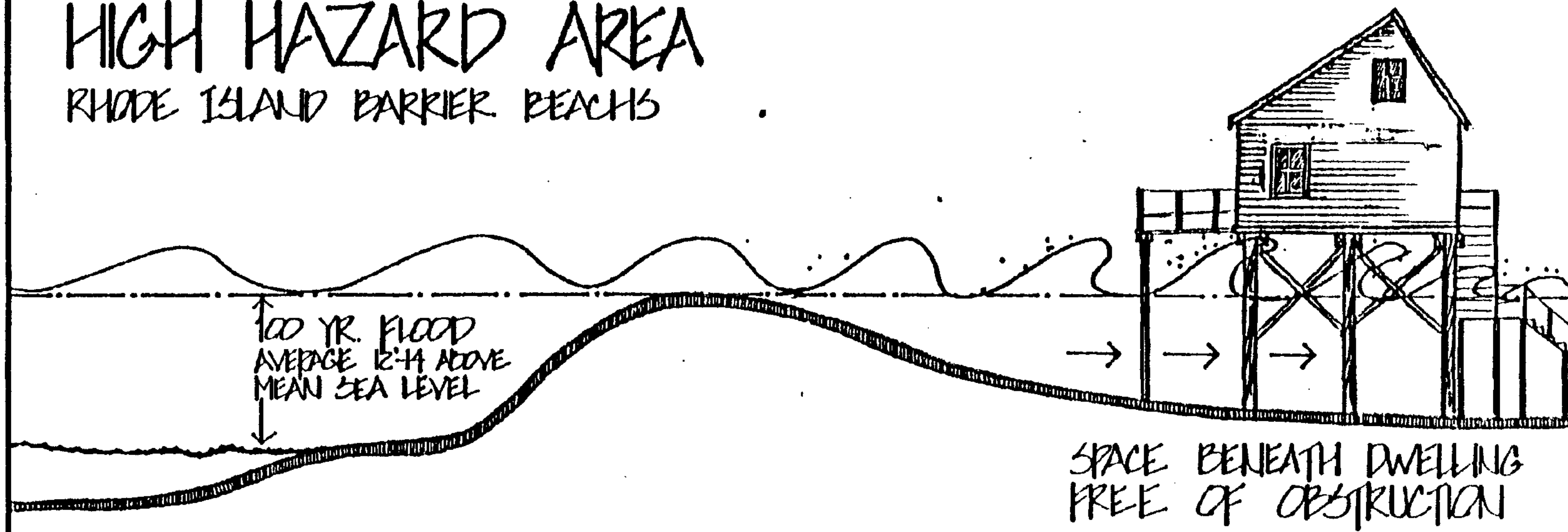
DUNE BUILDING





HIGH HAZARD AREA

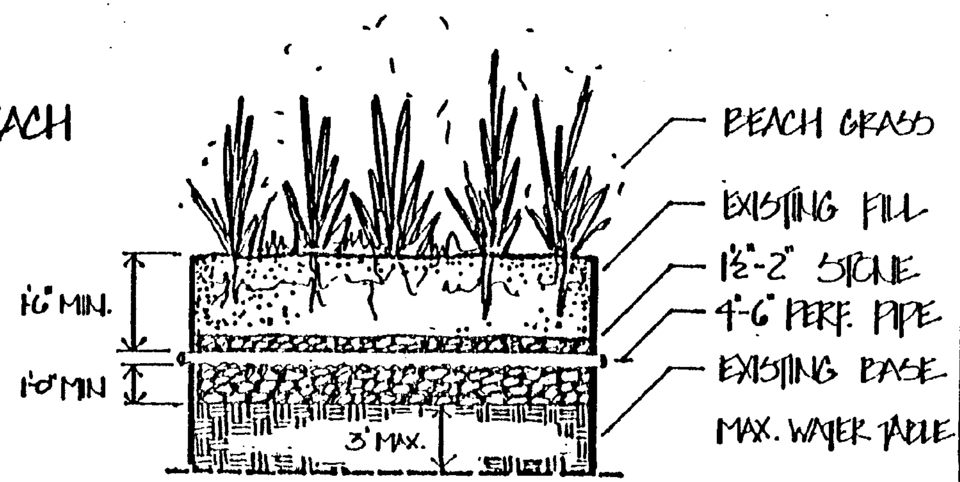
RHODE ISLAND BARRIER BEACHS



I.S.D.S.

INSTALLATION ON BARRIER BEACH

BEACH GRASS TO BE PLANTED OVER LEACH FIELD TO REDUCE SURFACE EROSION FROM CONSTANT WIND.



TO BE LOCATED A MINIMUM OF 150' FROM MOON TIDE LIMIT.

BEACH GRASS ESTABLISHMENT

The earliest recorded dune grass installation in the northeast was started about 1903, on Cape Cod. Its purpose was to reclaim areas of drifting sand where beachgrass had been depleted.The establishment of beachgrass to stabilize sand dunes has become a widely accepted practice. Extensive revegetation has taken place along the eastern seaboard as well as southern Gulf coast. In R. I.,and other parts of New England American beachgrass, Ammophila breviligulata,is the primary specie used. Although with the introduction of beachgrass from other places the introduction of disease is very likely. Therefore, a diversified plant species to stabilize dunes is becoming essential. To date no other species have been found to adapt as well as Ammophila breviligulata.

The effectiveness of establishing plantings for the various purposes of dune building and stabilization usually depends upon the methods of doing the following (29):

a.The selection and procurement without to much difficulty or expense.
b.The arrangement of the plantings which will aid and maintain the development of topographic forms.
c.The methods of planting and care of the plantings to promote the vegetation and forms of dunes required.

PROCUREMENT

Ultimately the best way to acquire beachgrass is to do selective and proper thinning of existing plants. The prerequisite for this procedure is having the proper knowledge. If the correct procedure is not followed the destruction of existing plants is almost guaranteed. Therefore, the safest way to obtain beachgrass, in quantity, would be to purchase it from commercial nurseries. Beachgrass is ordered in culms. Culms are bunches of grass with several stems. Generally 3,000 culms are enough to plant an area of about 2,000 square feet (28). A list of local commercial outlets can be obtained from the state Division of Fish and Wildlife. In areas requiring extensive stabilization seeding can be done for propagation directly onto the site. However, this method is not as effective as the use of transplants because of the slow rate of growth, and in most cases cover is desired immediately.

ARRANGEMENT

The arrangement of the plants foo dune formation and early stabilization should be related to the overall character of the beach area. Generally, the area should be planted nearly uniformly so as to prevent the final vegetation from becoming of unequal density at different places, because an irregular cover promotes erosion between areas of greater plant density. Planting in rows is not as good as random arrangement, because rows tend to funnel winds, but rows cannot be avoided at times if planting machinery is used. If sand fencing is used to start the dune formation, the design of fences determines the design of the plantings. Planting without fencing or hay-bales to aid deposition and stabilization is not recommended. Planting where some wind deposition is occuring is recommended, although if this is not the case then planting should be limited to the top of dune and backdune areas.

PLANTING

1-For dune establishment the zone of planting should be as wide as the dune ridge to be developed, so as to assure its development.

2-Planting times for best results are from October 15 through April. At this time the sand is moist,temperatures are cool, and most culms are dormant. Summer planting should be avoided, although at that time the rate of survival may be improved by watering.

3-After culms have been purchased dead leaves and underground stems that can interfere with planting should be removed. The culms may be clipped to a length of about 18 inches from the base to reduce bulk and to make planting easier.

4-All culms should be kept cool and moist and planted as soon as possible. The basal, or base, portion where new growth will develop, must be protected from drying out. This should be done by packing the culms tightly together or by covering the basal portions with moist burlap or sand. While planting, culms can be carried efficiently in a pail containing a few inches of water.

5-The first object to planting is to place culms close enough to assure a sufficient mass of underground parts. The mass of both underground and aerial parts will cause sufficient build-up and stabilization around the plantings. Clumps of three should be planted in one pit. Spacing should be 12" on active dune tops, 12"-18" on backdunes, and 24" for non-active areas (illus.34). Culms should be planted at a depth of 7"-9" from the base of the plant.

6-Within a few minutes after planting the pit should be backfilled with existing sand and firmed with the foot, not firmly packed.

FERTILIZATION

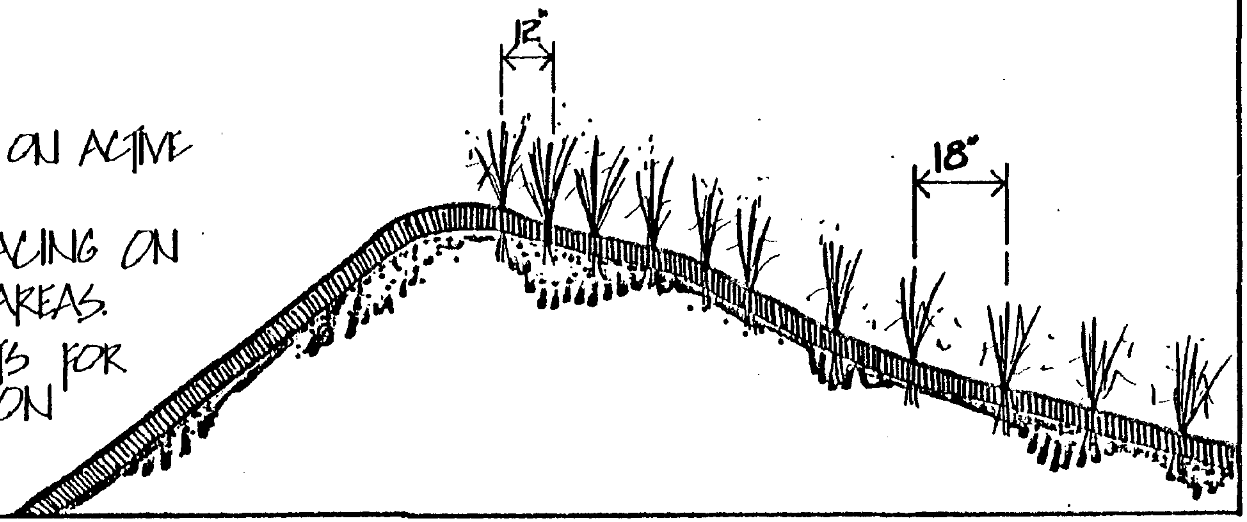
After planting fertilizer should be used to establish beach grass faster than natural conditions. Fertilizer can increase the plants height and encourage it to grow into unprotected areas.

Fertilizer should be applied either all at once in April or May, the beginning of the beachgrasses growing season, or it can be applied at once and again in July. If fertilizer is applied during two different months then the amount should be cut in half. As a general rule, planting done from July through Sept. should be fertilized immediately after planting. Those planted after Sept. should be fertilized in April. On small areas broadcasting can be done by hand, and machinery can efficiently spread it on larger areas.

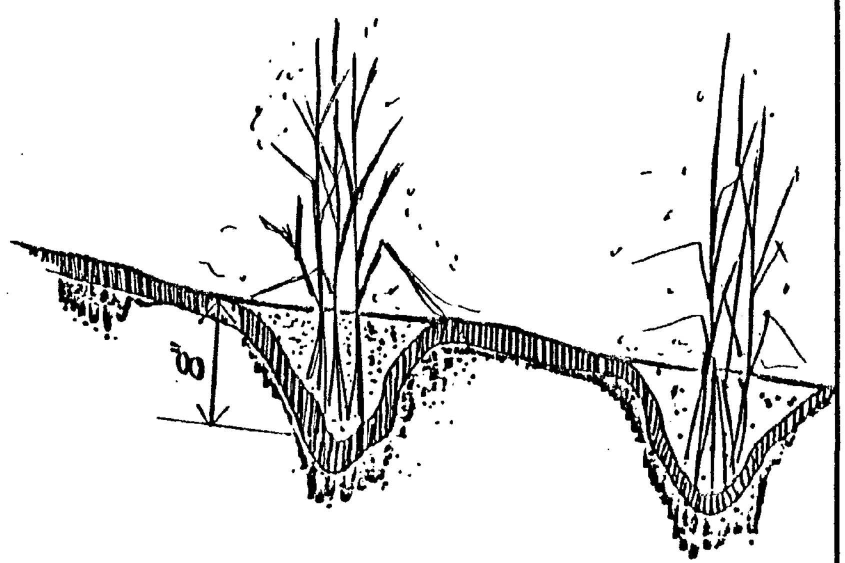
Inorganic fertilizers, high in nitrogen, are the most effective and least expensive to use.Granular ones such as 10-10-10, and ecetera are satisfactory. The first number indicates the percentage of nitrogen. The rate of application is 2-3lbs. per 1,000s.f. for two years. After this, fertilizer can be used to maintain a healthy stand (28,29).

DUNE GRASS PLANTING

- 12" PLANT SPACING ON ACTIVE DUNE AREAS.
- 18"-24" PLANT SPACING ON MORE STABLE AREAS.
- STAGGER PLANTS FOR MAXIMUM EROSION CONTROL.



- PLANTING TO TAKE PLACE FROM OCTOBER TO APRIL.
- 3-CULMS TO BE PLANTED PER HOLE.
- SAND TO BE FIRMLY PACKED AROUND CULMS TO ANCHOR AND ELIMINATE AIR SPACES.
- 3lbs. OF 10-10-10 FERTILIZER PER 1,000 S.F. TO BE SPREAD OVER NEWLY PLANTED GRASS. FOR BEST RESULTS SPREAD 50% IN APRIL & 50% IN JULY FOR ESTABLISHMENT.



BEACHES

BEACHES

In Rhode Island several beach types exist along the shorelines of Narragansett Bay, the Sakonnet River, and outside their proper limits. Beaches along unprotected southern coastline are the most physically stressed, and consequently the least productive of coastal ecosystems. Unlike the more sheltered beaches of the upper Bay, these areas are exposed to ocean swells and currents.

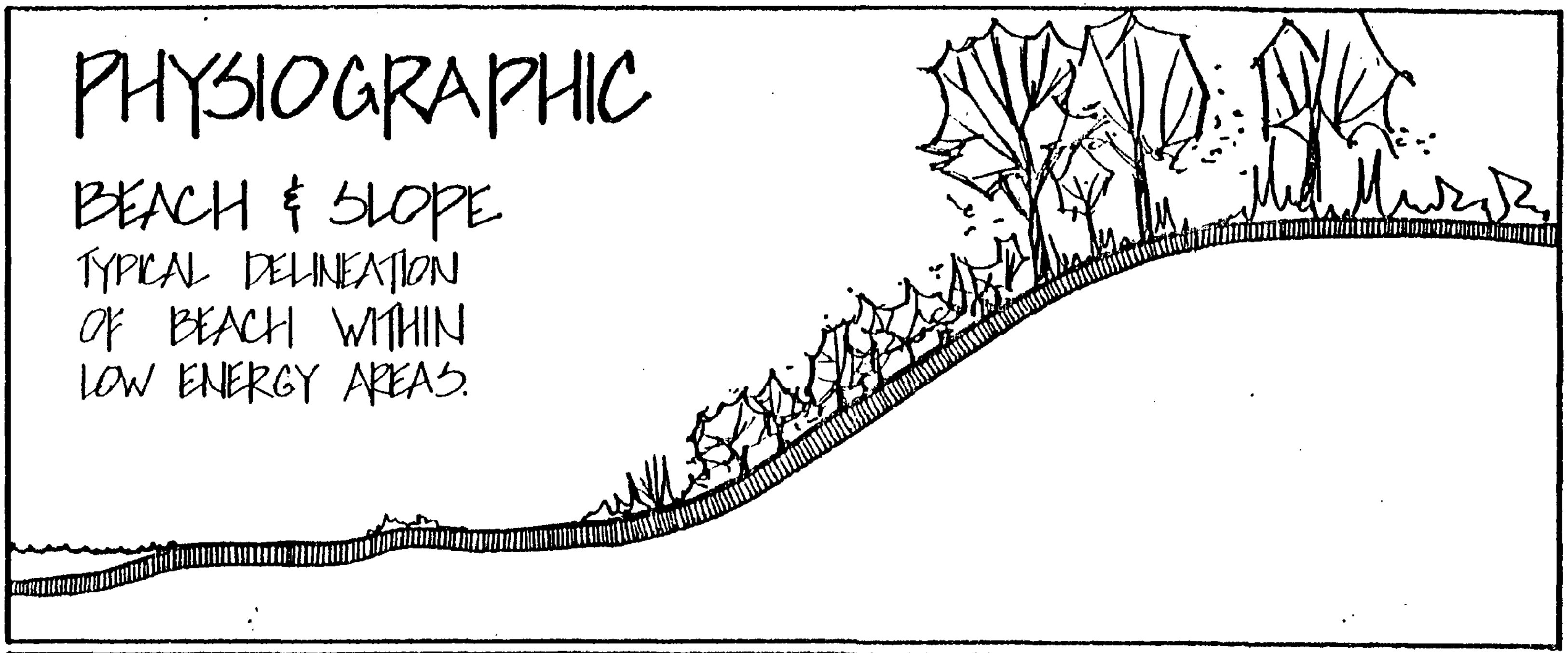
Beaches are highly variable landforms consisting of unconsolidated materials eroded from land based geologic formations. Waves and currents are continually at work changing the physiographic form and geologic composition. This constant alteration of beach forms within the littoral zone make these sites unsuitable for permanent structures.

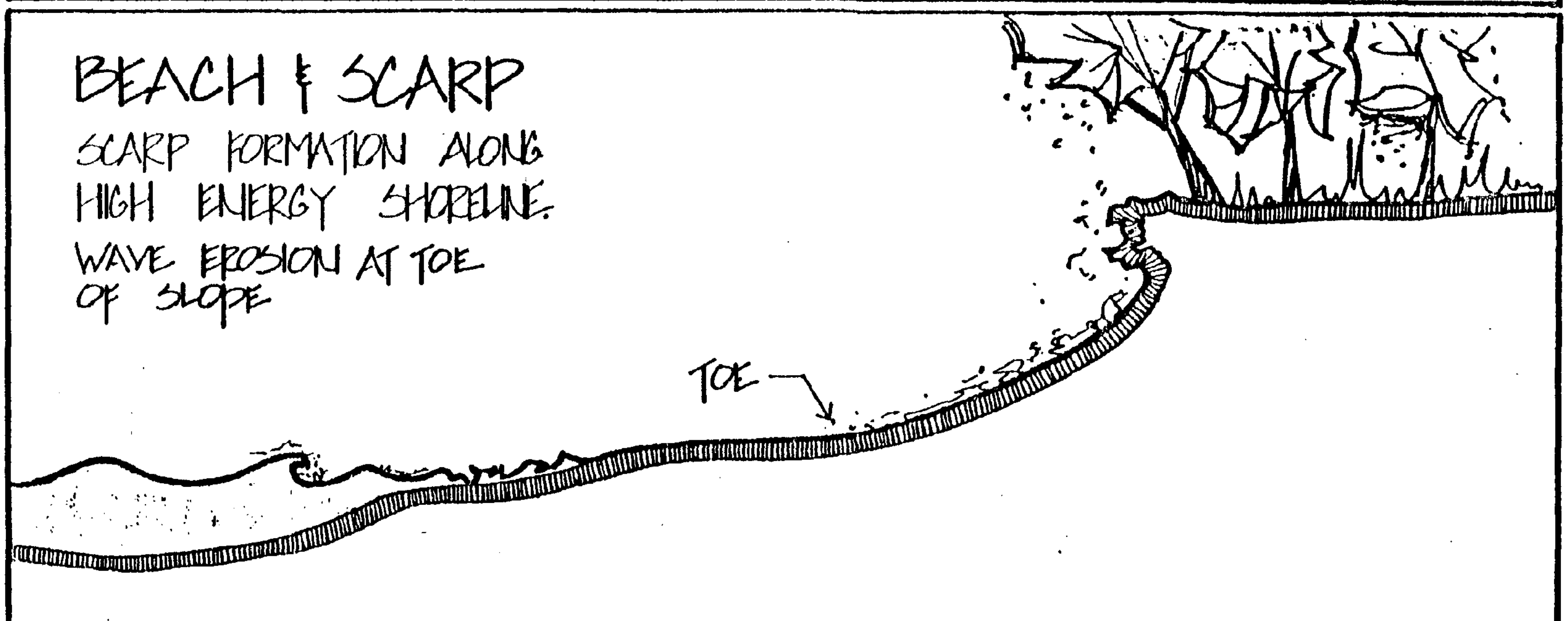
Beaches in Rhode Island are characterized by their particle size of sediments, wave and current action, and their associated landforms directly inland (6).

PHYSIOGRAPHY .. GEOLOGY

The physiographic and geologic form of beaches and their inland features are a result of past geologic action and more recent weathering processes. Typically, beaches are delineated by an inland rise in topography, or slope, when eroded is termed a scarp or escarpment (illus.35). These slopes and scarps range in height from 3ft. to 40ft.. Eventhough a beach may be temporarily eroded by storm waves, and later partly or wholly restored by swells, erosion and accretion patterns may occur seasonally (illus.36). The long-range condition of a beach, whether eroding, stable, or accreting depends on the rates of supply and losses of littoral sediments. The shore increases in size when the rate of supply exceeds the rate of loss. The beach is considered stable, eventhough subject to storm and seasonal change, when the rates of supply and loss are equal. Since the physiographic form of beaches is determined by its geology beaches can be characterized as steep or gently sloping. Generally the larger the sand particles which make up the beach, the steeper the beach will be. Beaches with gently sloping foreshores and backshore zones usually have an accumulation of the finer or smaller sizes of sand.

The height and angle of a backshore slope or scarp is also determined by its surficial and underlying geology. When the slope becomes eroded the sediments are transported by runoff to the beach where, with time, are transferred by waves and currents along the shoreline to nourish other eroded beaches.

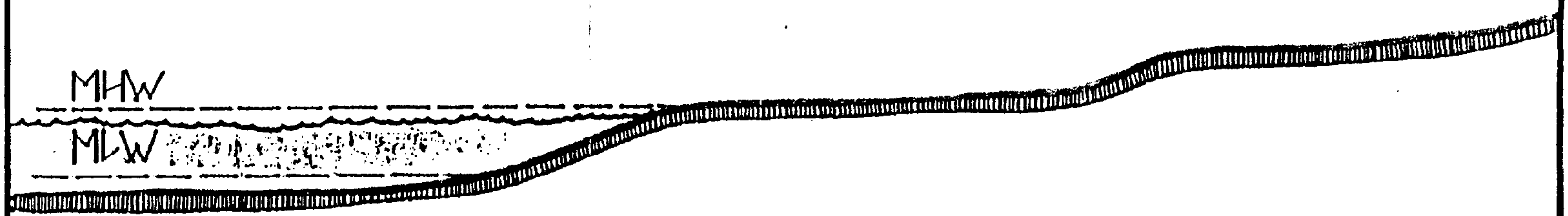

PHYSIOGRAPHIC
BEACH & SLOPE
TYPICAL DELINEATION
OF BEACH WITHIN
LOW ENERGY AREAS.


BEACH & SCARP
SCARP FORMATION ALONG
HIGH ENERGY SHORELINE.
WAVE EROSION AT TOE
OF SLOPE
TOE

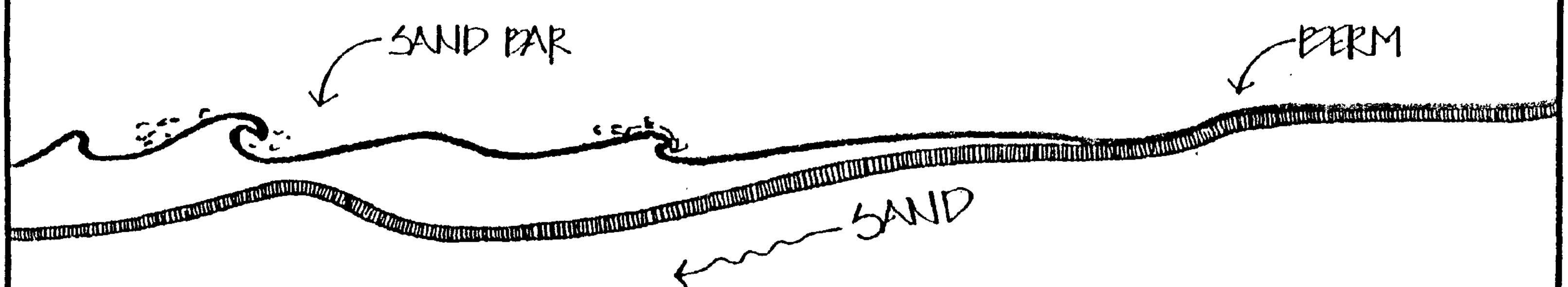
SEASONAL PHYSIOGRAPHY

HIGH ENERGY SHORELINE/SAND

BROAD AND FLAT BEACH
DURING LOW WAVE ENERGY.

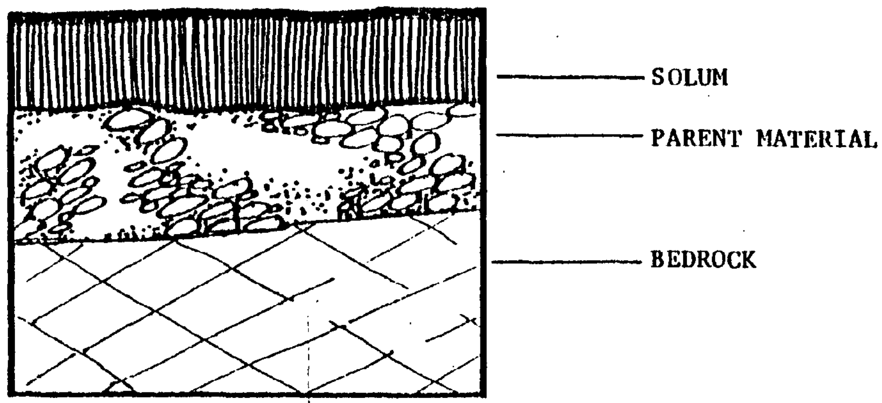


NARROW & STEEP BEACH
DURING HIGH WAVE ENERGY
NORMALLY OCCURING –
WINTER MONTHS.



SOILS

The lower slopes and scarps backing beaches generally consist of glacial outwash and till. The lower slopes consisting of outwash range from 3ft. to 20ft. in height, whereas the taller ones, consisting primarily of till, range from 10ft. to 40ft.. This outwash consists of sorted gravel, sand, and finnite interlayered zones of silt and clay. The till is characterized more by its' boulders and cobbles, and clay, although it does contain quantities of sand and gravel. Till is found directly over bedrock. For the most part, where vegetation exists and the weathering process has taken place ther exists a soil layer known as the solum. This solum is a cover found over till or outwash or both.



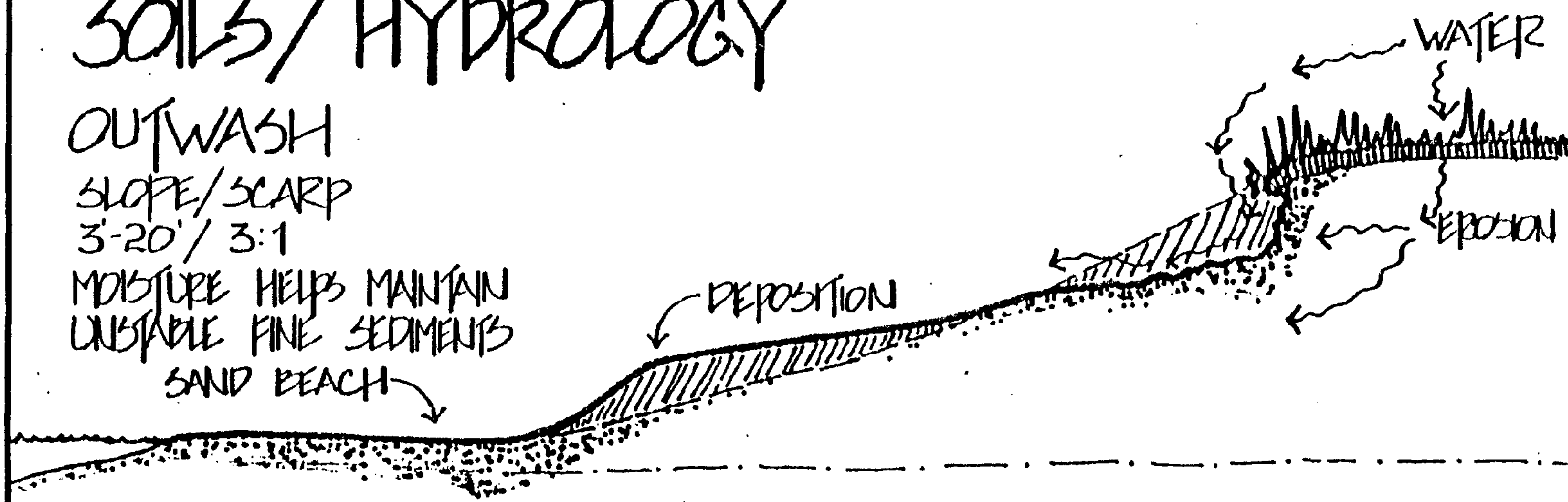
Where both outwash and till have been stripped bare of vegetation, these soils have taken on their natural angle of repose. Since outwash is fairly consistent in size and shape the angle is normally constant. Till is composed of sediments varied in size and shape and therefore, its degree of slope is often varied throughout the slope and often times steep in locations (illus.37).

Beaches contain eroded soils and consist primarily of sorted sand, pebbles, cobbles, and boulders. The most common beach types are sand, sand with pebble, and sand with cobble.The width varies with location. All of these beaches have great capillary action that allows water to pass through rapidly. The finer grained sediments become more or less saturated by a film of water in the tidal zone. This retention

SOILS / HYDROLOGY

OUTWASH

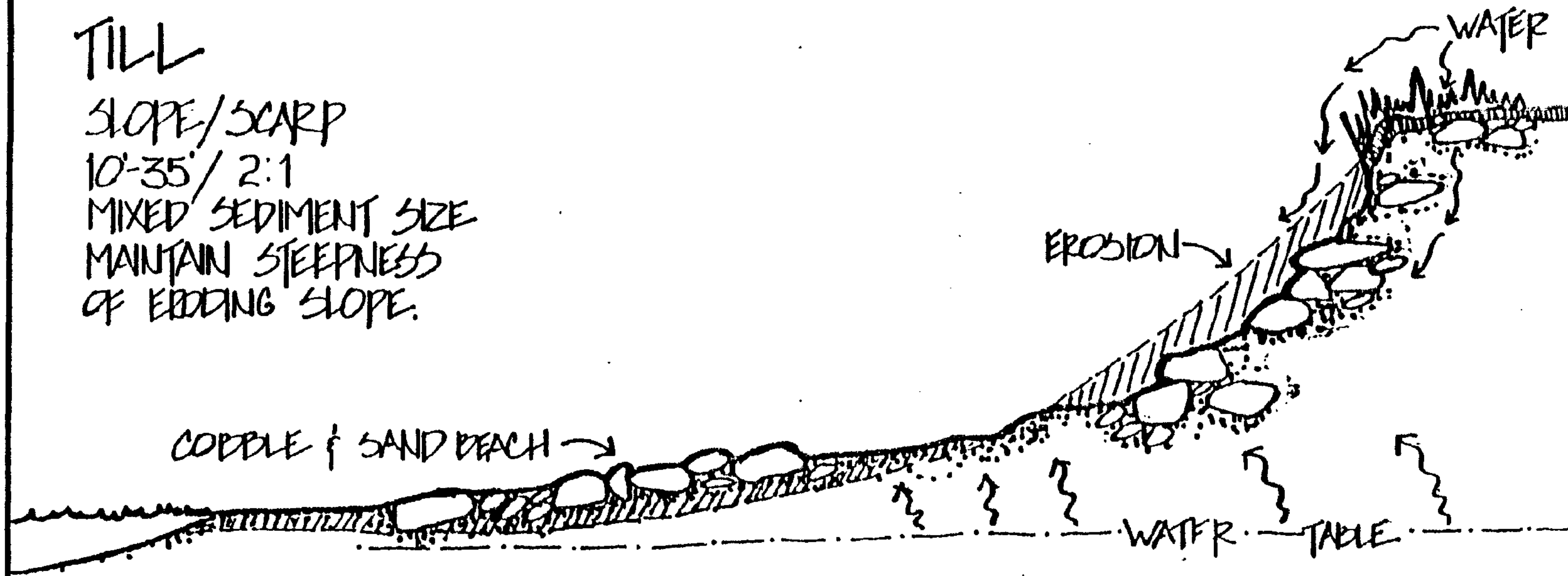
SLOPE/SCARP
3'-20' / 3:1
MOISTURE HELPS MAINTAIN
UNSTABLE FINE SEDIMENTS

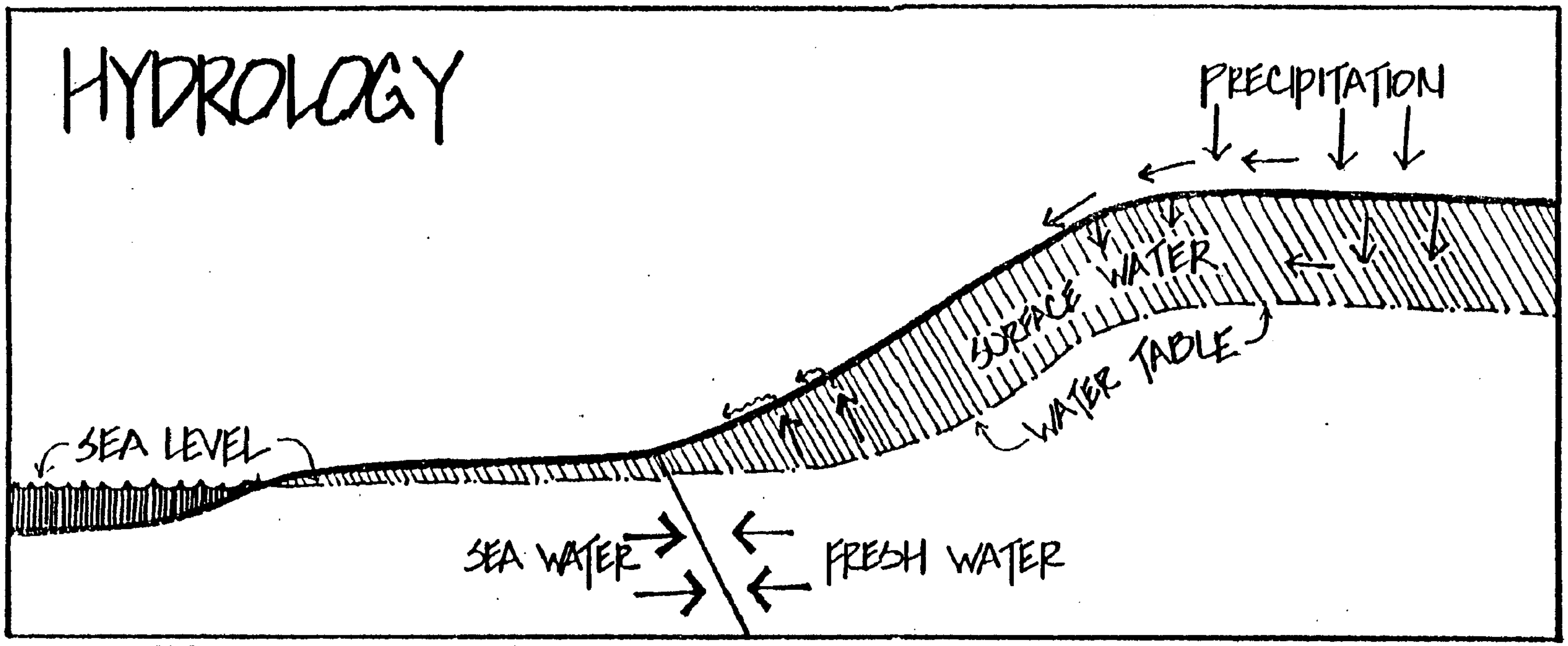


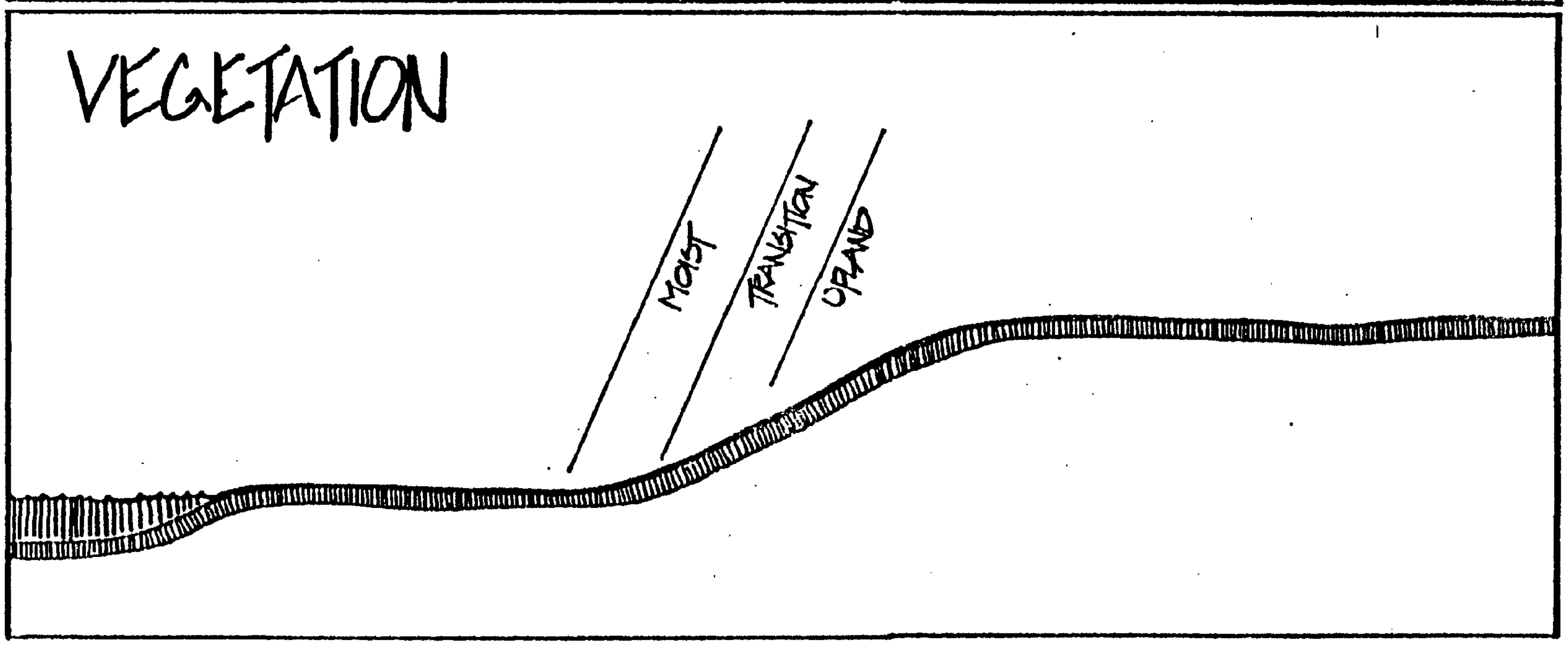
WAVE & RUNOFF EROSION (SLUMPING)

TILL

SLOPE/SCARP
10'-35' / 2:1
MIXED SEDIMENT SIZE
MAINTAIN STEEPNESS
OF ERODING SLOPE.




HYDROLOGY
PRECIPITATION
SURFACE WATER
WATER TABLE
SEA LEVEL
SEA WATER
FRESH WATER


VEGETATION
MOIST
TRANSITION
UPLAND

of water cushions the beach and reduces wearing action by waves and the beach becomes relatively flat. Where larger more coarse sands are prevelent the accretion and wearing action by waves and currents, if present, occurs more rapidly (6).

There are two types of stability failure on steep slopes. The first, slippage, involves a circular movement in section of the entire slope, or of a portion, that results in the falling of material to a lower angle of repose and causes the toe of the slope or immediate area to be pushed forward. This normally results when the soil has been weakened by pressure or if it becomes saturated with water and becomes too heavy. This can occur from on the slope or from waves eating away at the slope toe. The second type of failure involves the surface of the slope, where the surface is subject to surface erosion by precipitation (illus.37). Fresh-water runoff can be greatly accelerated by increased levels of subsurface saturation. This zone of saturation is most critical on an exposed slope when pressure forces the water to flow out near the base. This water can carry sediments with it and cause slope stability (23).

HYDROLOGY

The beach, slope, and scarp topography are constantly under physical stress from waves and currents, runoff from the land. The more sheltered beaches are mainly subjected to runoff and at times storm waves and currents, whereas the more exposed beaches are subject to constant forces of waves and currents from the ocean. Concurrently, the more exposed beaches are undergoing constant change. This is only noticed by the casual observer during storms or other periods of increased hydrological stress.

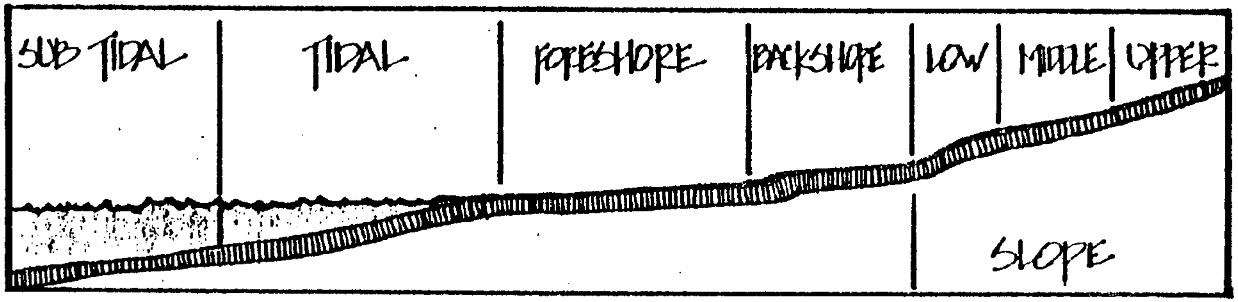
VEGETATION

Plant life is sparse on the physically stressed beaches. Here it is difficult for the plants to find anchorage. If stable long enough plants are able to secure themselves to the face of a scarp.

On less physically stressed beaches plant life has grown within the backshore zone and on the lower to upper portions of the slope. This vegetation receives its water and chemical nutrients from ground water that is supplied from stored quantities, and from that which has been stored in more surficial zones beneath the surface. Plants living on the backshore and lower slope receive an abundance of water since they are in the transition zone where salt water meets freshwater. Plants that exist on the drier sections of the slope are there because they have adapted themselves to these often strenous conditions. There are several plant communities that find their way to the coastal beach edge. A list of the more dominate species is on pp. 104-109. Naturally occuring vegetation plays a very important role in maintaining slope stability and providing a chemical nutrient balance for the optimum functioning of biological processes within the beach and associated environments (26).

BIOTIC COMMUNITY

Stress factors are also experienced by animals that live within the beach environment. It is the foreshore and tidal zones where life abounds.



BEACH COMMUNITY

The rocky shore represents one extreme of the intertidal habit and the sandy beach represents the other. Where beaches of unstable pebbles exist life is usually barren. Life on sandy beaches does not experience violent fluctuations in temperature as do those on rocky shores.

The animals living on cobble shores require protection from sunlight, dessication, and violent water movements, therefore they have made their homes in the mud that has been trapped beneath the cobbles. The faunal community depends upon the stability of the cobbles. If they are easily overturned by waves, the populations beneath will die from exposure. If rock movement is greatest in the winter, when waves are intensified, then the summer population will consist largely of summer annuals. The animals of the higher surface zone of the shore are able to endure the periods of exposure to the drying action of wind, sun and summer heat, low salinity during rainstorms, and the scouring of winter ice flows. Cradled within and growing on the face of water-worn boulders and cobbles, animal and plant organisms adapt to zones that meet their respective sensitivity to tidal exposure. Larger forms of algae play a dominant role in the productivity of the rocky shore ecosystem. They can be seen at a variety of elevations within and below the intertidal zone. These complex algae have no roots or rigid stems but fasten themselves to the rock-face with structures called holdfasts. Observation of the rocky shore community from the zone above the high spring tide level, the splash zone, reveals blue-green algae which leave a slippery scum on rocks and shells, and black lichens. One of the most striking aspects of rocky shore plants and animals is that they live on a solid substrate fully exposed to the forces of water. There is no opportunity to maneuver for living space above or below the surface as do organisms of sand and mud flat communities. Many of the plants and animals are long-lived and permanently anchored. Compared to other ecosystems, rocky shore animal populations exhibit less annual or seasonal change in numbers.

Also, unlike other coastal ecosystems, rocky shore communities use or retain very small quantities of nutrients they produce.Where there is much tidal and wave energy released against the rocky shore, much of the food material produced by plants and animals is carried away as detritus and becomes part of the food chain for fish, crustaceans, and molluscs found in the open water or on nearby tidal flats and sand beaches (14,30).

Unlike cobble and boulder beaches, life on sand beaches is subjected to continual movement from waves, tides, and wind. The sandy shore at low tide appears barren of life although beneath the sand, life exists waiting for the next high tide.

Eventhough the surface temperature of sand at midday may be 50 degrees F higher than the returning sea-water, the temperature a few inches below the surface remains almost constant throughout the year. Nor is there a violent fluctuation in salinity, even when fresh water runs over the surface of the sand. Below 10 inches, salinity is little effected. Organic matter accumulates within the sand, especially in sheltered areas. This detritus offers food for some inhabitants of the sandy beach, but where it accumulates in large quantities, it prevents the free circulation of water,and anaerobic bacteria form a black zone resulting from oxygen deficiency.

Most animals of the sandy beach either occupy permanent or semipermanent tubes within the sand, or they can burrow rapidly into the sand when they need to do so. Except for a few beach hoppers and a few plant-feeding insects, the true sand dwellers feed on detritus. For this reason sandy shores containing the greater amounts of organic matter support more life.

Whether hidden beneath the sand or exposed on the rocks, all forms of life along the waters edge of the shoreline has adapted remarkably well to the rise and fall of tides.Their survival is essential (14,30).

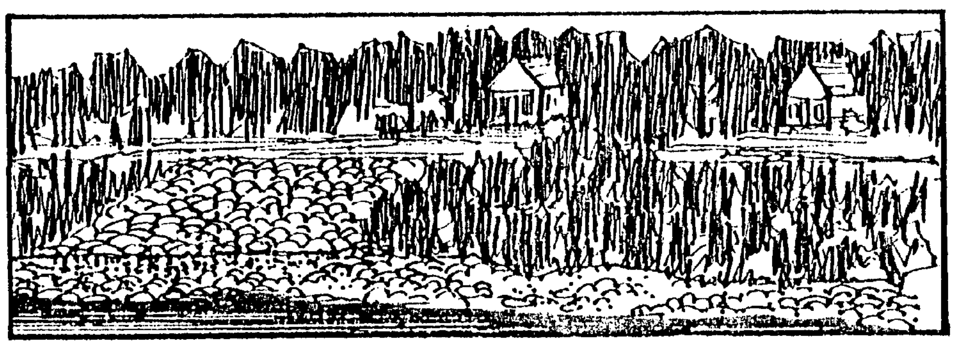
AESTHETIC ENVIRONMENT

The aesthetic quality of Rhode Island beaches is based on the unity of landform, water, and vegetation. Each coastal system offers unique variety and vividness. Variety is seen and vividness is perceived as a strong,clear impression on the senses. Variety and vividness are derived from terrain patterns, presence of water, weather characteristics, vegetational pattern, and cultural land use patterns. Uniqueness is derived from the composition of form, space, color, and texture.

When naturally occuring vegetation exists on a slope or scarp, there is no need for aesthetic judgement. These natural features exist because they serve a function within the landscape and natural world. This, however, forms the basis for aesthetic evaluation.

When cultural elements have been introduced into and onto these beach areas then aesthetic evaluation is warranted. The degree of degradation would depend on the cultural items composition in contrast with that of the beach and adjacent area and the quantity of the particular item. For example, where a plastic item is prevelent on a beach this zone is considered visually degraded. The degree of degredation depends on the composition of the plastic.

Along developed shorelines views onto beaches from adjacent areas are often focused on the edge where land meets beach because it is here a strong focal point exists due to alteration of the otherwise natural area. Normally, the focal point is on the edge where water meets beach in the natural ,culturally undisturbed landscape. This altered edge can be evaluated aesthetically by examining the natural features and comparing their composition with that of the altered edge. For example, if a beach consisted of cobbles and rip-rap had been installed it would be less visually degrading than if cobbles were used as opposed to concrete. Since natural vegetation exists on both sides of the property then this would be rated as a high degree of degradation as seen in the following illustration.



RIP RAP.. VISUAL DEGRADATION

EXISTING.. PROPOSED SOLUTIONS

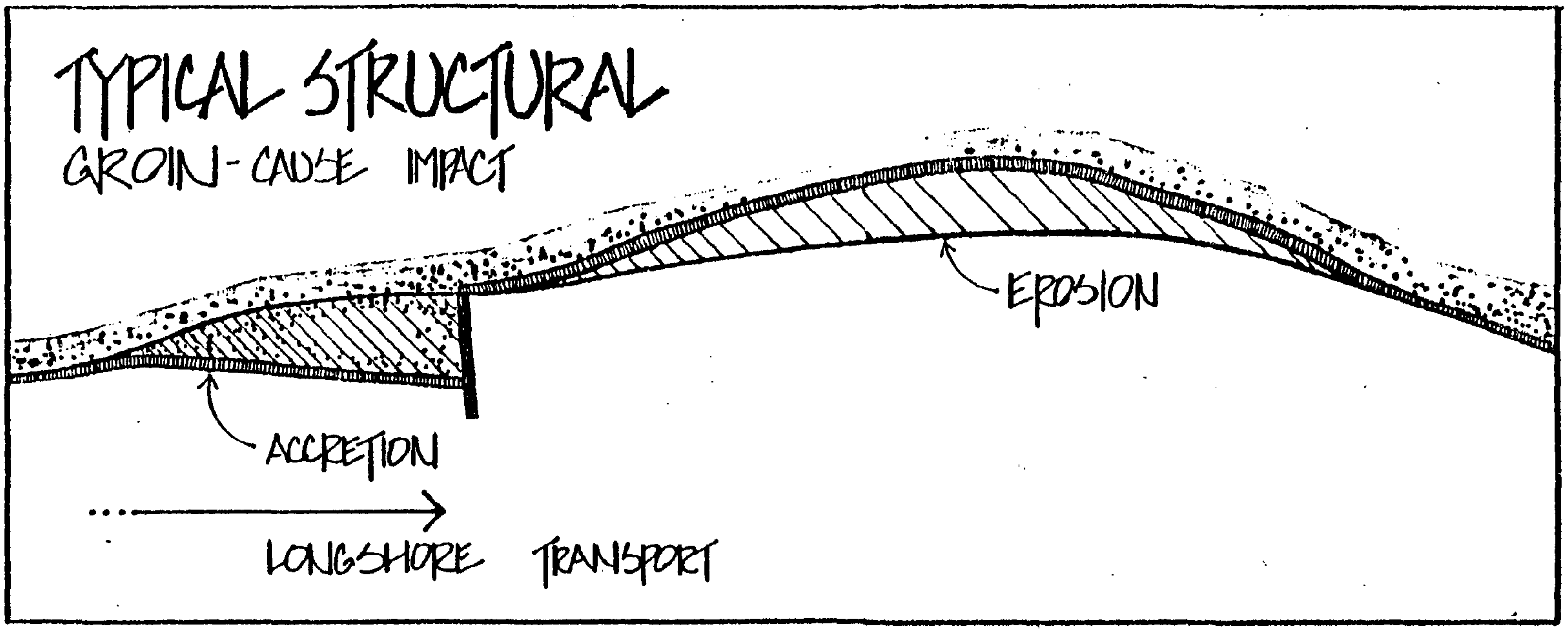
Increased erosion rates on beaches and their bordering slopes is primarily caused by human alteration.

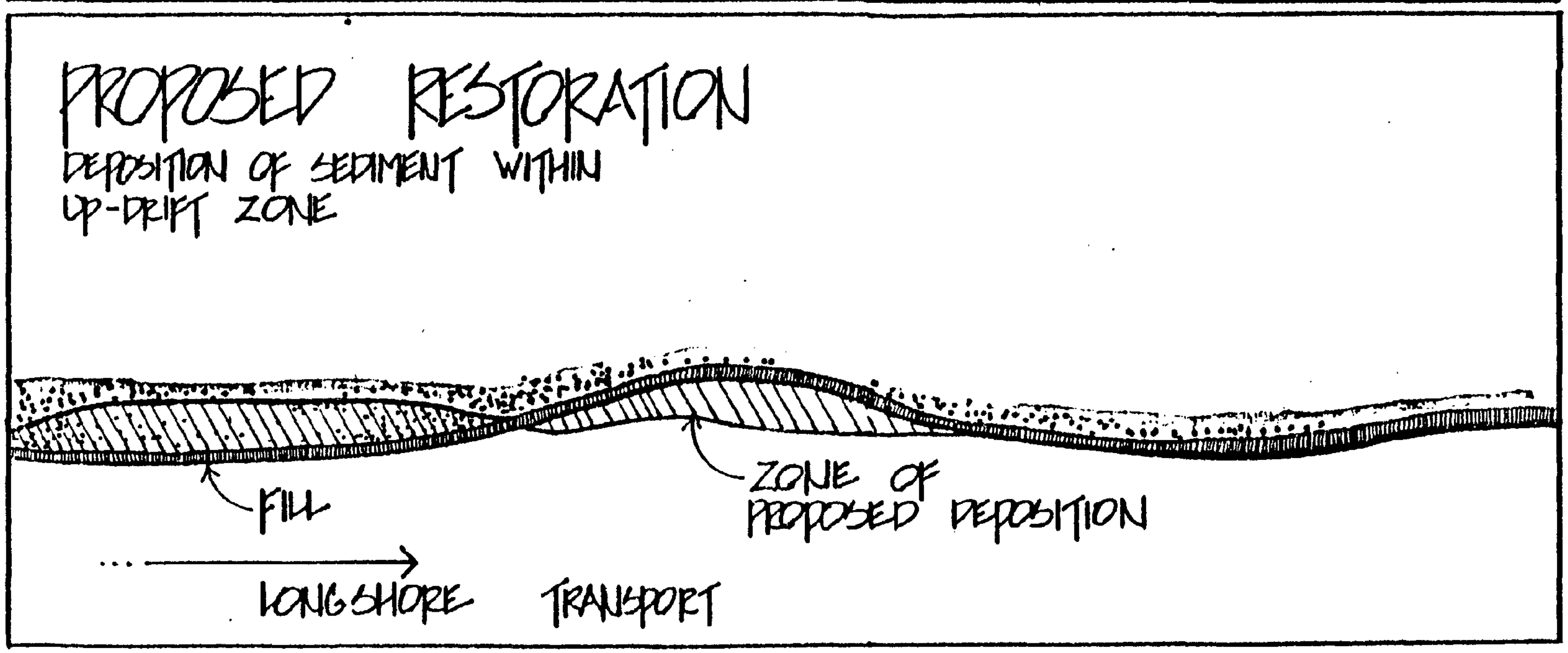
In the past groins have been placed perpendicular to a beach shoreline to trap littoral drift or to retard erosion of the shore. This is done to afford protection to the adjoining backshore, however, groins deprive downshore areas of deposition and the rate of erosion is greater than accretion in the downshore zone (illus.39). This type of erosion should become obsolete if it hasn't already. A less degrading method of building beaches is to deposit sediment on the updrift side of eroded area and let the longshore currents transport the sand to the area to be restored. This method has been done in Florida on several occasions and has proven effective for an extended period of time. The most important aspect of this beach restoration is to choose sediment that is closely characteristic to that of the existing without having to use another beach as a borrow site.

Inland from the beach, is where the concernable erosion takes place. For the most part people bring on their own erosion problems by altering the slope in some manner. The following slope protection measures should be followed:

- A setback line, pg.41, should be used during construction.
- Deposition of foreign matter onto slope should be prohibited.
- Foot traffic and other increased weight should be kept off of slope.
- Slopes should not be left bare of vegetation when the chance of erosion prevails.

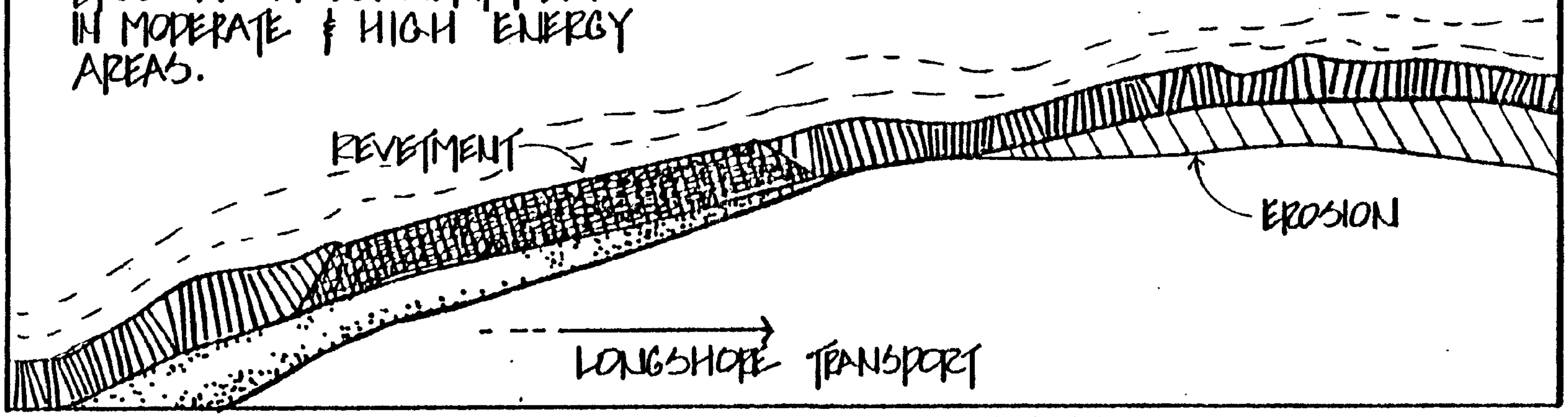
Revetments are another typical structural solution to erosion abatement on slopes. Fortunately installation costs are astronomical or their degradation would have become more widespread by this time. Revetments are negative features when used along the coastline, they accelerate erosion on adjacent beaches where moderate and high wave energy is present (illus.40). Their use should be restricted. In order to best simulate natural processes, that are more likely to be effective and less degrading, other measures have been formulated and should be chosen from a wide range of options.


TYPICAL STRUCTURAL
GROIN-CAUSE IMPACT
EROSION
ACCRETION
LONGSHORE TRANSPORT


PROPOSED RESTORATION
DEPOSITION OF SEDIMENT WITHIN
UP-DRIFT ZONE
FILL
ZONE OF
PROPOSED DEPOSITION
LONGSHORE TRANSPORT

TYPICAL STRUCTURAL

RIP-RAP & BULKHEADS CAUSE EROSION ON DOWNDRIFT ZONE IN MODERATE & HIGH ENERGY AREAS.



USE OF REVETMENTS IS ACCEPTED WITHIN HIGHLY DEVELOPED URBAN AREAS WHERE THEY BLEND WITH THE HIGHLY DEVELOPED FABRIC. RURAL NATURALLY VEGETATED AREAS ARE NO PLACE FOR THEM. THEY ARE PHYSICALLY & VISUALLY DEGRADING. & CAUSE IMPACTS TO LOCAL & ADJACENT AREAS. THEY RESTRICT SEDIMENTS FROM LAND TO ENTER THE DYNAMIC BEACH-BUILDING & TRANSPORT PROCESS.

NON-STRUCTURAL CONTROLS CLOSELY SIMULATE NATURAL PROCESSES, AND ARE LIKELY TO BE MORE EFFECTIVE. THEY AVOID IMPACT TO DOWN-SHORE AREAS & ARE VISUALLY PLEASING.

TREATMENT OF SLOPE TENDING TO SLIP

PROBLEM: Lack of subsurface stability.

SOLUTION:
1) Use of subgrade baffles to retain and support soil and to maintain visual quality. (illus.41)
2) Establish vegetation for utilization of roots to anchor soil.

PROBLEM: Weight at top of slope.

SOLUTION:
1) Reduce angle of slope. (illus.42)
2) Create dual slope gradients. (illus.42)

TREATMENT OF SLOPE SURFACE

PROBLEM: Runoff causing erosion.

SOLUTION:
1) Avoid damage to vegetation.
2) Consider and evaluate flow redirection.
3) Establish vegetation.
4) Terracing of slope.
5) Brushwood matt. (illus.43)
6) Hay/straw matt. (illus.43)
7) Jute matt. (illus.43)

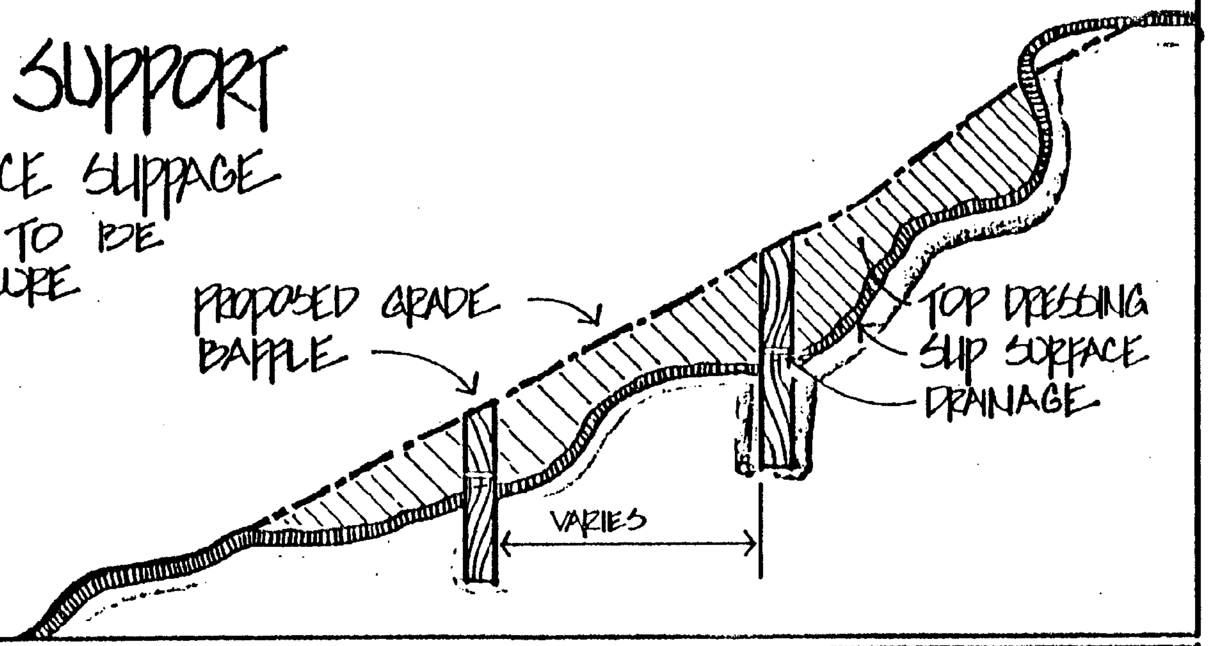
The aforementioned solutions, and those previously stated in earlier sections, can be adapted to specific uses individually and jointly for effective slope stabilization.

For a listing of plants best suited for slope planting refer to pages (104-108).

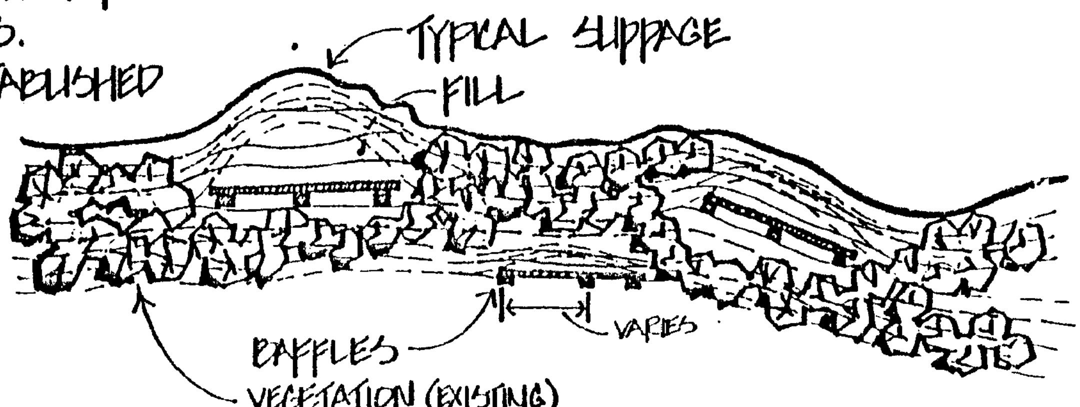
PROPOSED SUPPORT

BAFFLES - REDUCE SLIPPAGE

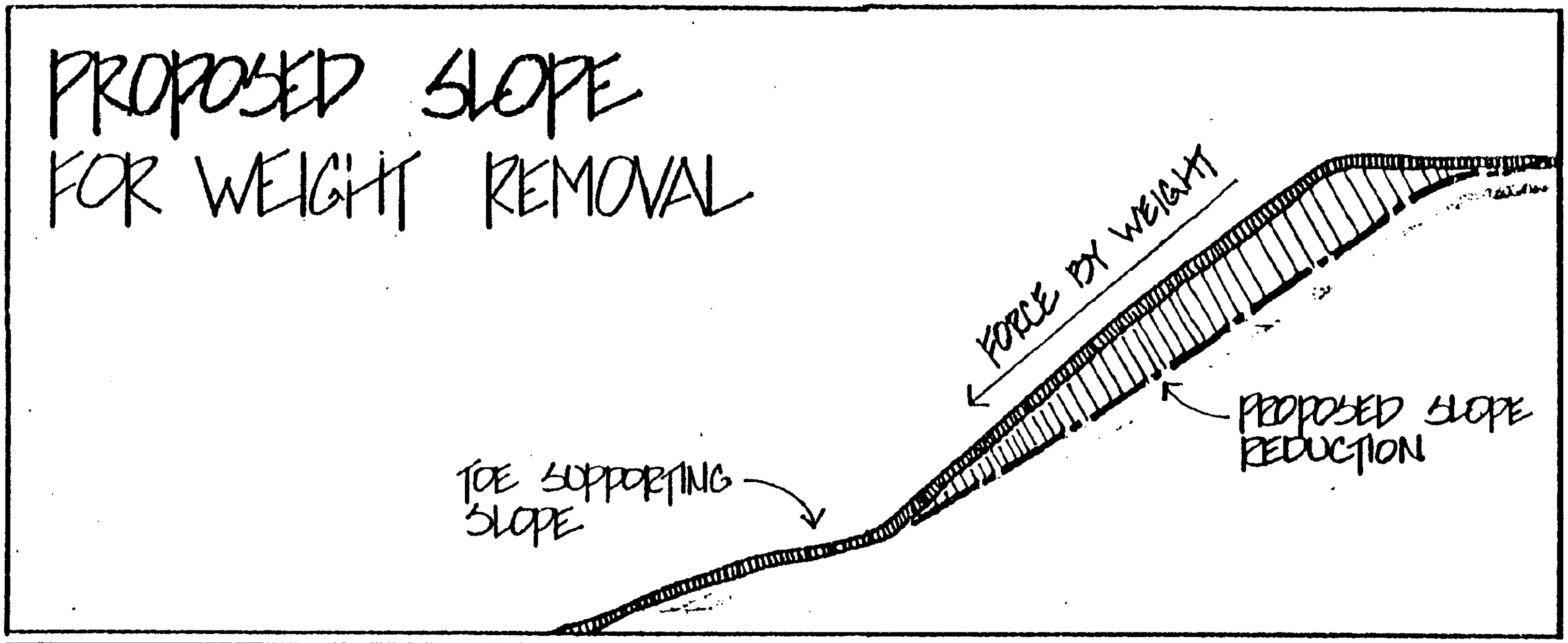
- BAFFLE STAKES TO BE PLACED AT A SECURE DEPTH BELOW SUB-GRADE.

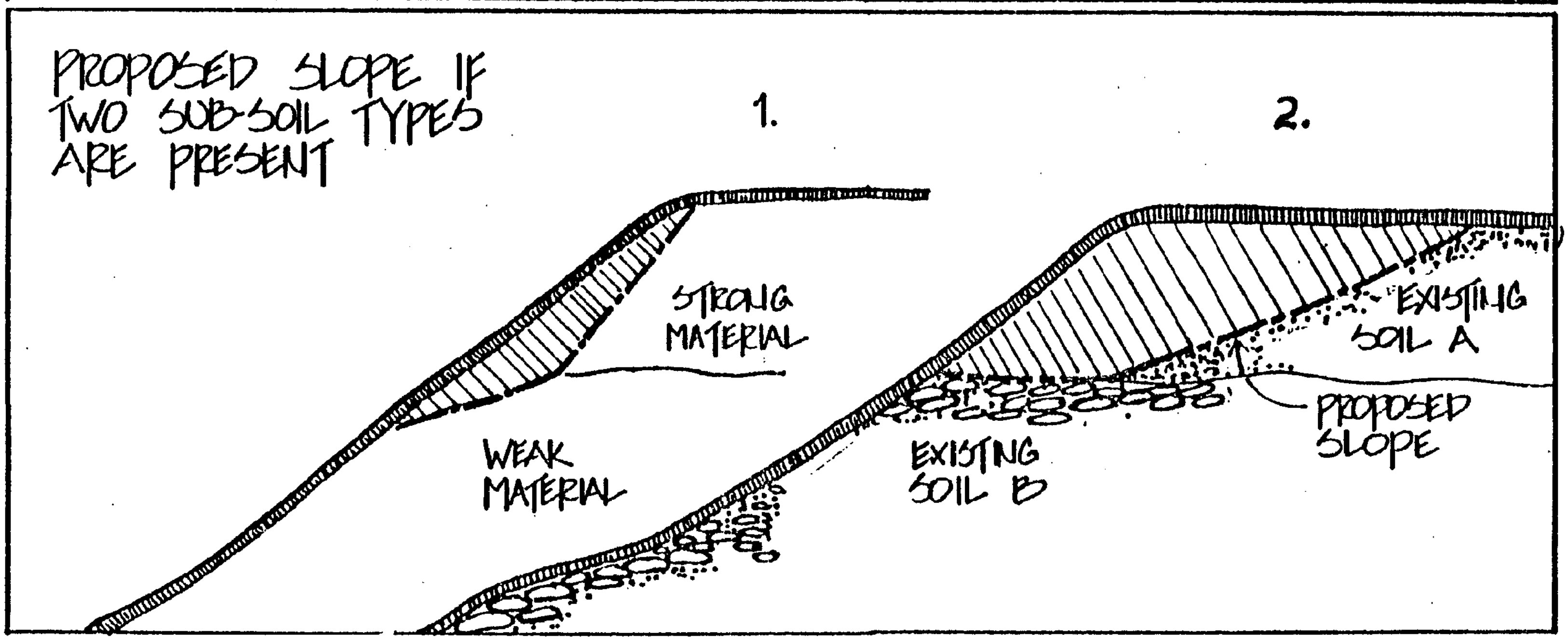


- BAFFLES TO BE CONSTRUCTED OF STANDARD LUMBER.
- DIMENSIONS ARE DEPENDENT UPON ON SITE FACTORS.
- VEGETATION TO BE ESTABLISHED ON PROPOSED FILL.
- BAFFLES CAN VARY IN SHAPE LONGITUDINALLY.



ALTERNATE SOLUTION WOULD BE TO STAKE DOWN DISCARDED BRUSH VEGETATION HORIZONTALLY, TO ACT AS BAFFLES. THESE WOULD BE SUB-GRADE.

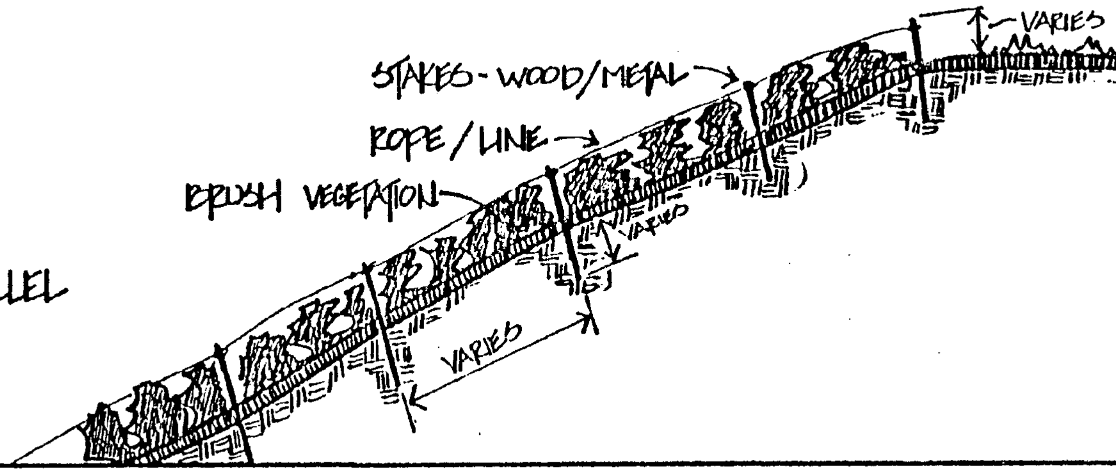

PROPOSED SLOPE
FOR WEIGHT REMOVAL
FORCE BY WEIGHT
PROPOSED SLOPE
REDUCTION
TOE SUPPORTING
SLOPE


PROPOSED SLOPE IF
TWO SUB-SOIL TYPES
ARE PRESENT
1.
2.
STRONG
MATERIAL
WEAK
MATERIAL
EXISTING
SOIL A
EXISTING
SOIL B
PROPOSED
SLOPE

REDUCED RUNOFF VELOCITY

- BRUSH MATTING TO BE TIGHTLY MATTED AGAINST SLOPE & HELD SECURELY BY THE ATTACHEMENT OF LINE ONTO STAKES IN A PARALLEL OR DIAGNOL MANNER.

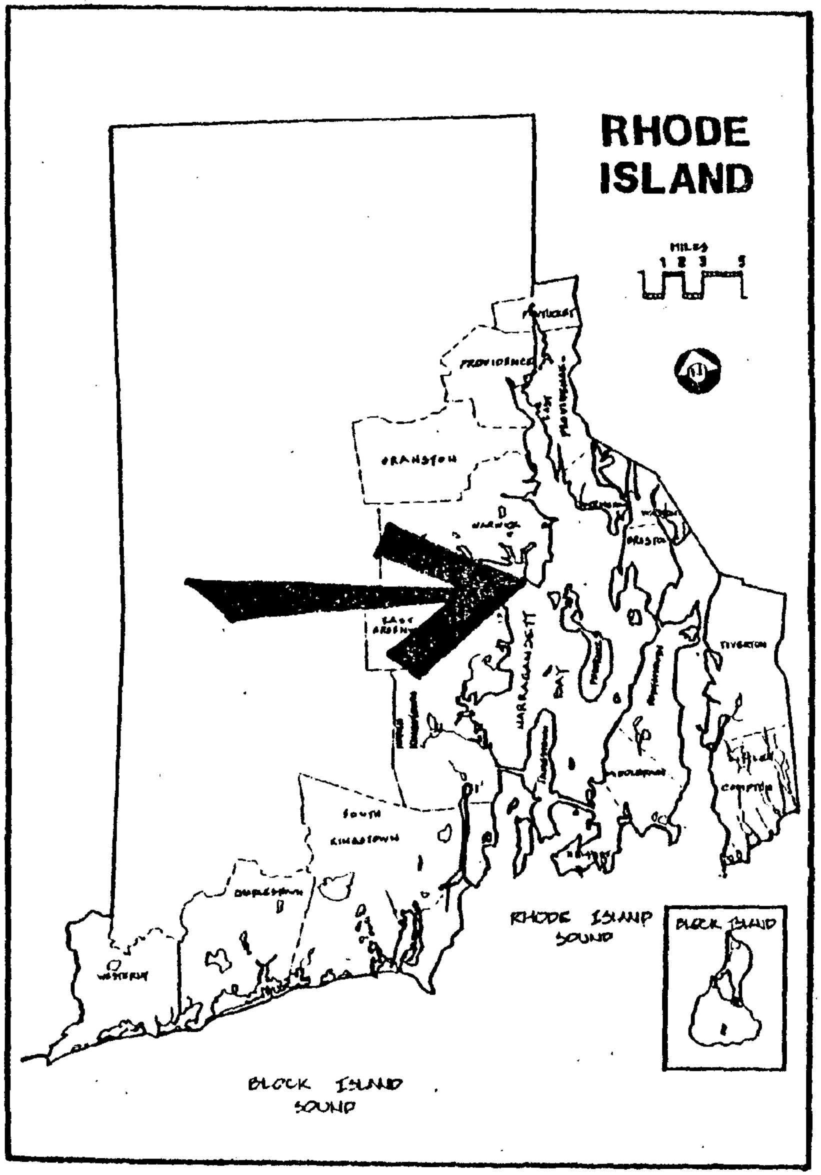
ALL DIMENSIONS VARY ACCORDING TO SLOPE.



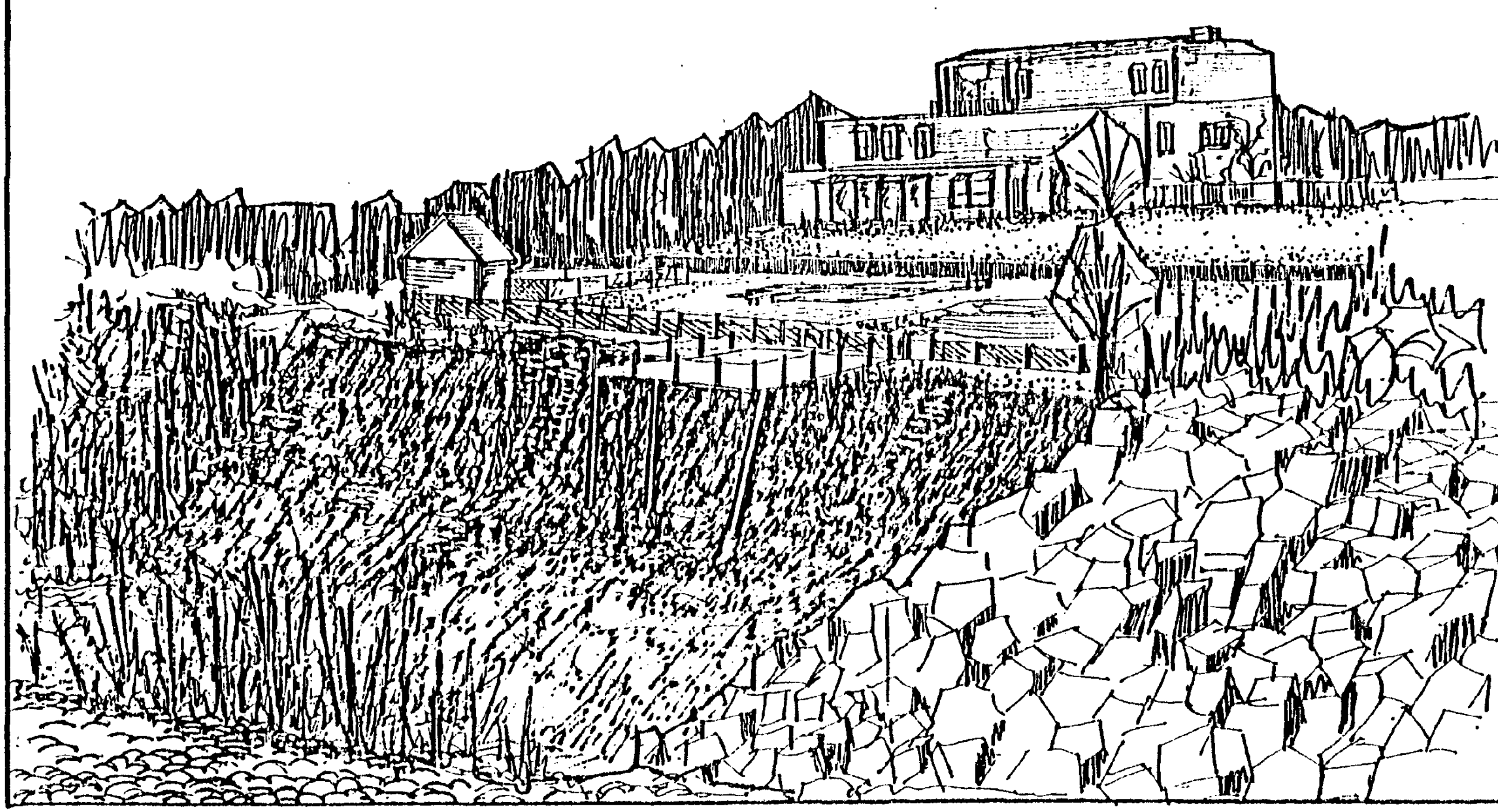
- BRUSH, HAY, OR JUTE MATTING CAN BE SECURED DIRECTLY ON SLOPES FOR PROTECTION OF LAND BASED RUNOFF.
- BRUSH SHOULD CONSIST OF TWIGS & BRANCHES NO LARGER THAN ½" O.D. WITH MINIMAL FOLIAGE SO WEEDS & OTHER FIRST STAGE SUCCESSION GROWTH WILL BE ABLE TO PENETRATE COVER & RECEIVE ADEQUATE LIGHT.
- HAY OR STRAW IS NORMALLY USED FOR SEED GERMINATION ALTHOUGH IT CAN BE USED FOR 1ST STAGE SUCCESSION. HAY OR STRAW SHOULD BE PROPERLY SECURED.
- JUTE MATTING, or NETTING, CAN BE USED FOR SLOPE STABILIZATION WHILE VEGETATION IS BECOMING ESTABLISHED OR FOR SEED GERMINATION ON SLOPES. GENERALLY IT SHOULD CONTAIN ¼" STRANDS WITH HOLES ¾" X 1". SECURE NETTING TIGHTLY TO SLOPE WITH 6"-8" no. 8 GAUGE WIRE STAPLES.

IF BRUSH MATTING IS USED SEEDS FROM INDIGENOUS PLANTS HAVE A CHANCE OF BECOMING ESTABLISHED. USE LOCAL PLANT SPECIES.

SITE
SPECIFIC DESIGN

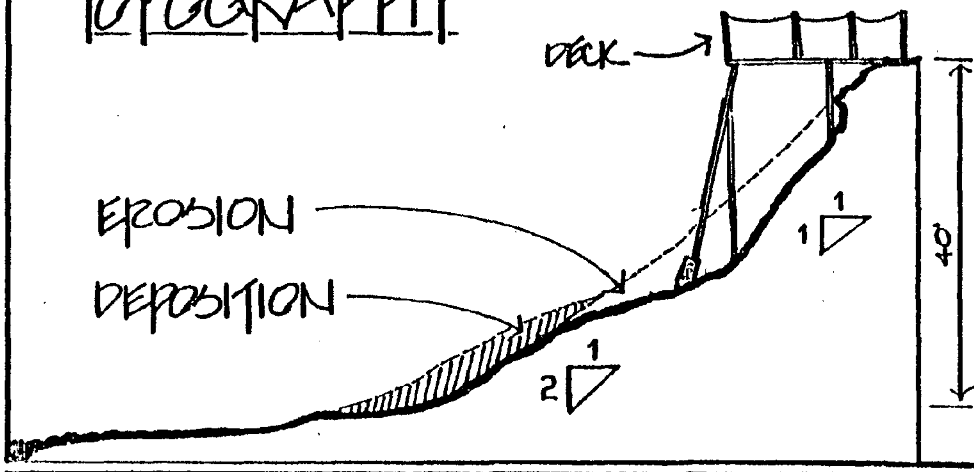

RHODE ISLAND
MILES
1 2 3 5
PAWTUCKET
PROVIDENCE
CRANSTON
WARWICK
TIVERTON
SOUTH KINGSTOWN
RHODE ISLAND SOUND
BLOCK ISLAND
BLOCK ISLAND SOUND

SITE / LOCATION
WARWICK NECK



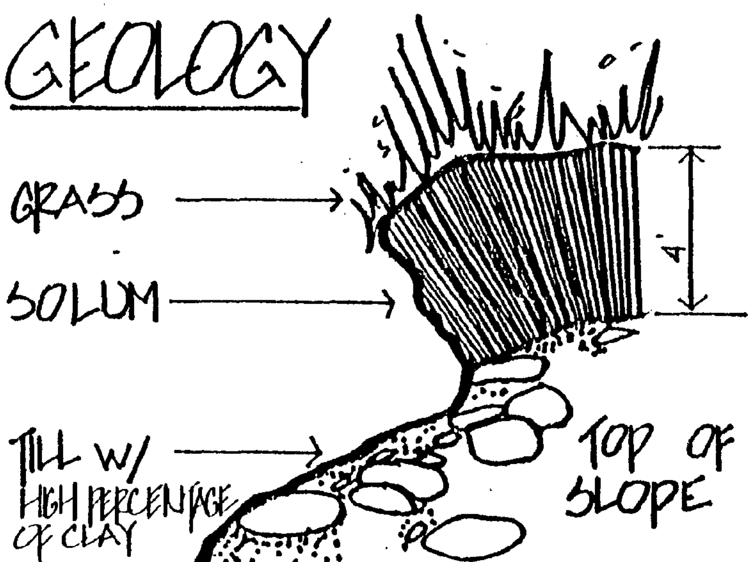
NATURAL INVENTORY

TOPOGRAPHY

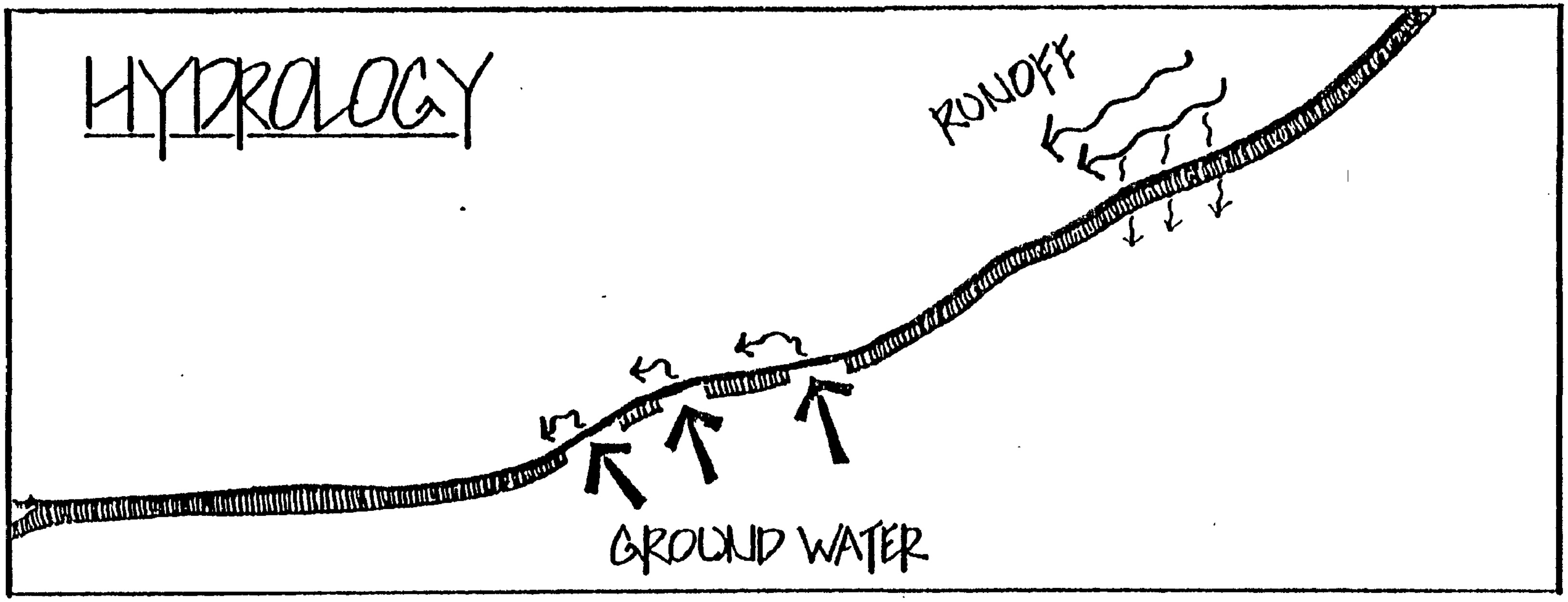


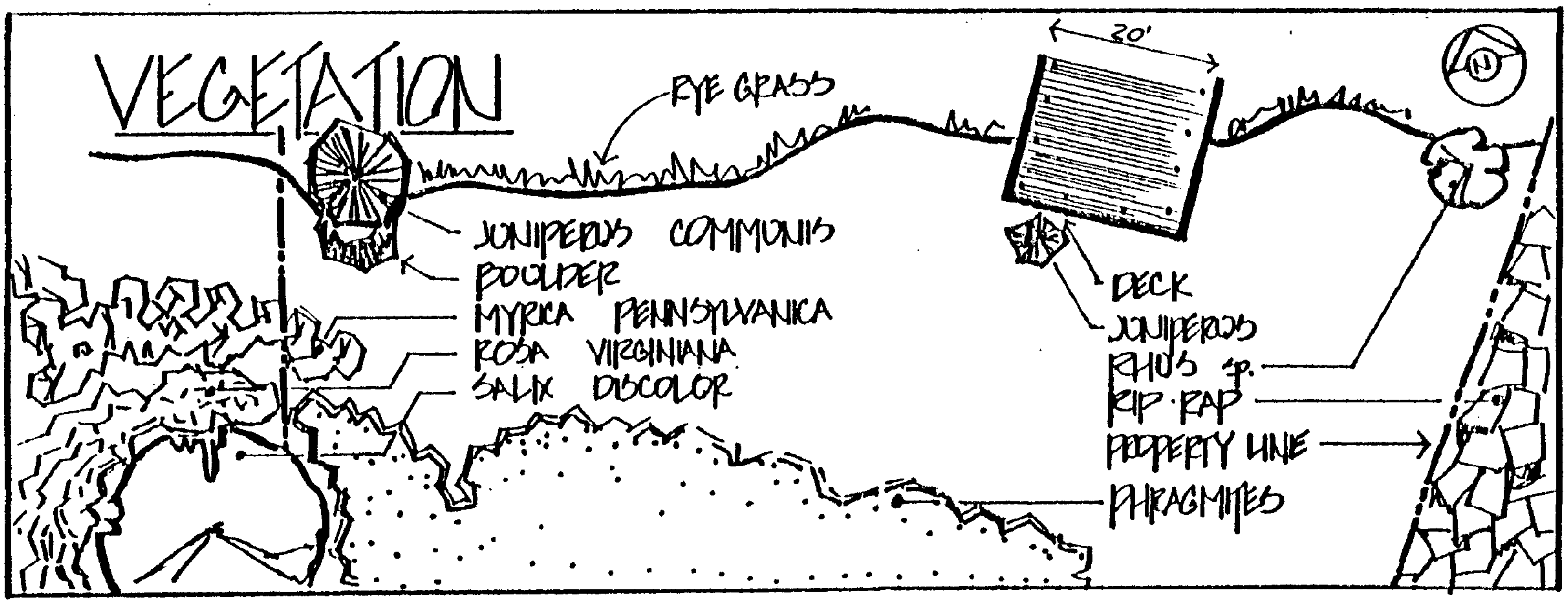
EXTREMELY UNSTABLE AT TOP.
TOE IS STABLE.
BEACH HAS 10% SLOPE & SEEMS TO BE STABLE.
IN ISOLATED AREAS WHAT APPEARS TO BE SLIPPAGE HAS OCCURED.

GEOLOGY



SOLUM CONTAINS SANDY-CLAY WITH NO CLEARLY DELINEATED HORIZONS.
TILL IS FAIRLY PLASTIC-SLOPE QUITE STEEP AT TOP AS A RESULT.
BEACH CONSISTS OF COBBLE W/ A FEW LARGE BOULDERS.
COARSE MATERIAL IS HOLDING SLOPE IN PLACES.


HYDROLOGY
RUNOFF
GROUND WATER


VEGETATION
20'
RYE GRASS
JUNIPERUS COMMUNIS
BOULDER
MYRICA PENNSYLVANICA
ROSA VIRGINIANA
SALIX DISCOLOR
DECK
JUNIPERUS
RHUS sp.
RIP RAP
PROPERTY LINE
PHRAGMITES

CULTURAL CONDITIONS

OWNER HAS BEEN DISCHARGING POOL WATER OVER SLOPE, DUMPING SOD OVER ERODED DISCHARGE AREA, AND CLAIMS THAT THERE ARE TRACES OF HERBICIDE WITHIN THE DUMPED FILL.

OWNER WANTS TO SAVE DECK.

ACCESS IS LIMITED FOR WORKING & BRINGING IN EQUIPMENT.

DECK WAS CONSTRUCTED WITHOUT APPROVAL BY CRMC 3 YEARS AGO.

RESIDENTIAL AREA WITH ONE NEIGHBOR TO THE EAST.

WEST SIDE OF HOUSE IS DENSE WOODS & SLOPE IS VEGETATED FOR SEVERAL HUNDRED YD.S.

SYNTHESIS
(NATURAL & CULTURAL CONDITIONS)

SLOPE HAS BEEN ABUSED BY OWNER.

JUDGING BY THE LOCATION & AND APPEARANCE OF THE ERODED AREAS THE CONCLUSION WAS MADE. LATER IT WAS ADMITTED THAT POOL WATER WAS BEING DISCHARGED. IT IS IMPORTANT TO FULLY ANALZE ALL CONDITIONS & SITE FACTORS DURING THE INVENTORY STAGE SO THE EROSION ABATEMENT CAN BE TAILORED TO SOLVING SITE SPECIFIC NEEDS.

AESTHETIC ENVIRONMENT

THE DEGRADING FEATURE IS NOT THE EROSION, BUT IT IS THE WOODEN DECK THAT STANDS DOMINATE ATOP THE SLOPE. OF ALL LOCATIONS THIS PROBABLY AMPLIFIES THE SCALE THE MOST.

TO THE EAST OF THE SITE IS EXTENSIVE RIP-RAP THAT CONTRASTS WITH THE NATURAL CHARACTER THAT PREVAILS.

STEEP SLOPES INCREASE VISUAL DEGRADATION, HENCE VIEWER PERCEIVES MORE OF A PARTICULAR IMAGE & IT HAS A LONGER LASTING IMAGE.

SOLUTIONS

BASED ON CLEAR RANGE OF OPTIONS.

A)
1. ANALZE SOIL FOR CHEMICAL; (HERBICIDE).
2. REMOVE DECK.
3. CONSTRUCT BAFFLES PER ENGINEERING SPECS.
4. INSTALL BAFFLES IN FRONT OF SLIPPAGE ZONES.
5. TOP DRESS W/LOAM. BLEND W/EX. CONTOURS.
6. SEED.
7. COVER SEEDED AREA W/ JUTE NETTING.

SEEDING OF SLOPE WILL ALLOW FOR PLANT SUCCESSION TO PROVIDE PROTECTION.

B) SAME AS (A) ALTHOUGH DECK IS SAVED.
FOOTINGS ON DECK NEED TO BE EXTENDED BELOW SLIPPAGE SURFACE.

SHRUBS, OF EXISTING SPECIES COULD BE PLANTED AT TOE FOR FURTHER STABILITY.

COASTAL VEGETATION

Provided are lists of dominate indigenous plant species best adapted to Rhode Island's coastal areas. These lists were composed after conversations with biologists who frequent in the "field", with other professionals, and after extensive observations by the author of this publication. The intention of these lists is not only to provide insight, but to provide plants that can best aid erosion abatement as well as support natural functions and biotic communities.

The majority of these plants are easily transplantable and can be purchased through statewide nurseries. Not listed, but equally important, are native perenials and grasses. For the most part, these species can be used as permanent ground covers or as temporary erosion controls while other plant species are becoming established.

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LINDA STEERE.......Biologist, Division of Fish and Wildlife
CAROLYN WEYMOUTH...Biologist, Wetlands Section

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COASTAL WETLANDS BARRIER WETLANDS BEACHES

GROUND COVER

BOTANICAL NAME COMMON NAME	TOLERATES SHADE	SOIL DRY/MOIST/WET	TYPICAL HEIGHT FEET / WIDTH	GROWTH RATE	FRUIT
Arctostaphylos uva ursi bearberry	Partial	D	6-12 2-4	Slow	Red 1/4 inch
Calluna vulgaris scotch heather	Partial	D M	1-2 2	Slow	
Celastrus scandens American bittersweet	Partial	D M W	10-20	Very Fast	Red 1/4 inch
Lonicera japonica Japanese honeysuckle	Partial	D M	15-20	Very Fast	Black 1/4 inch
Parthenocissus quinquefolia Virginia creeper	Yes	D M	15-20	Very Fast	Black 1/4 inch
Rhus radicans poison ivy	Yes	D M W	15-20	Very Fast	
Vitis lambrusca wild grape	Yes	D M	20-30	Very Fast	Black 1/2 inch
Comptonia peregrina	No	D	2-4 2-4	Slow Med.	

COASTAL WETLANDS BARRIER WETLANDS BEACHES

SHRUBS

BOTANICAL NAME COMMON NAME	TOLERATES SHADE	SOIL DRY/MOIST/WET	TYPICAL HEIGHT FEET / WIDTH	GROWTH RATE	FRUIT
Rhus sp. sumac	Partial	D	10-12	Fast	
Rhamnus cathartica common buckthorn	Partial	D M	10-15	Fast	Black 1/4 inch
Rosa rugosa rugosa rose	No	D M	3-5 3-5	Med.	Red 1/4-1/2 inch
Rosa virginiana Virginia rose	Yes	D M	3-5	Fast	
Spirea latifolia meadowsweet	Partial	D M	2-4 3-4	Fast	Dry Pod
Spirea tomentosa hardhack spirea	Partial	D	4-5 4-5	Fast	
Symphoricarpus albus snowberry	Yes	D M W	3-6 3-5	Fast	White ornamental
Vaccinium corymbosum highbush blueberry	Partial	D M	4-6 4-6	Slow	Blue-Black 3/8 inch
Viburnum dentatum arrowood viburnum	Partial	D M	4-6 4-6	Med.	Blue-Black 1/4 inch
Viburnum cassanoides withe-rod viburnum	Partial	D M	4-6 4-6	Med.	Blue-Black 1/4 inch

SHRUBS

BOTANICAL NAME COMMON NAME	TOLERATES SHADE	SOIL DRY/MOIST/WET	TYPICAL HEIGHT FEET / WIDTH	GROWTH RATE	FRUIT
Amelanchier canadensis shadbush	Yes	M W	6-20	Med.	
Aronia arbutifolia red chokeberry	Partial	D M	6-10 3-6	Med.	Red
Berberis thunbergii Japanese barberry	Yes	D	3-6 3-4	Med.	Red
Clethra alnifolia summersweet	Yes	M W	3-8 4-5	Slow	Black 1/8 inch
Cornus stolonifera red osier dogwood	Yes	M W	3-5 3-5		
Ilex glabra inkberry		M W	3-5 3-4	Slow	Black 1/4 inch
Iva frutescens marsh elder	Partial	M W	3-6		
Lonicera tatarica tatarica honeysuckle	No	D M	4-8 4-6	Very Fast	Red 1/4 inch
Myrica pennsylvanica bayberry	Partial	D M	3-5 3-5	Fast	Black Persistent
Prunus maritima beach plum	Partial	D M	6-8	Med.	Red 3/4-1 inch

COASTAL WETLANDS BARRIER WETLANDS BEACHES

TREES

BOTANICAL NAME COMMON NAME	TOLERATES SHADE	SOIL DRY/MOIST/WET	TYPICAL HEIGHT FEET / WIDTH	GROWTH RATE	FRUIT
Morus alba white mulberry	Partial	D M	20-30 20-25	Fast	Pod
Prunus americana American cherry	No- Partial	D M	15-25	Fast	Red 1 inch
Prunus serotina black cherry	Partial	D M	20-25	Med.	Red 1/2 inch
Pinus rigida pitch pine	Partial	D M	15-25	Med.	
Quercus sp. oak	No- Partial	D M	30-40	Slow- Med.	Nut
Salix discolor pussy willow	No	M W	10-20	Very Fast	Catican
Salix sp. willow	No	M W	30-50	Very Fast	Catican

COASTAL WETLANDS BARRIER WETLANDS BEACHES

TREES

BOTANICAL NAME COMMON NAME	TOLERATES SHADE	SOIL DRY/MOIST/WET	TYPICAL HEIGHT FEET / WIDTH	GROWTH RATE	FRUIT
Ailanthus altissima tree of heaven	Yes	D M W	45	Very Fast	Persistent Samara
Alnus glutinosa common alder	Partial	M W	12-15	Fast Young	
Acer rubrum red maple	Yes	M W	40-50 20-40	Med. Fast	
Crataegus mollis downy hawthorn	Partial	D	15-25	Very Fast	Red 1/2-1 inch
Eleagnus angustifolia Russian olive	No-Partial	D M W	10-15	Very Fast	Silvery 3/8 inch
Eleagnus umbellata autumn olive	No-Partial	D M	10-15	Very Fast	Red 1/4 inch
Betula populifolia gray birch	Yes	D M	20-40	Med. Fast	
Juniperus virginiana American red cedar	No	D M	20-25	Med.	
Juniperus communis common juniper	No	D	5-10	Slow	
Robinia pseudoacacia black locust	No-Partial	D M	30-40 20-25	Very Fast	Persistent Samara

BARRIER BEACHES

All plant species adapted to the barrier beach community have become indigenous to the slightly acid soils found along R.I barrier beaches. All are normally below five feet in height and are best adapted to full sun.

DUNE

Ammophila breviligulata
American beachgrass

Artemisia stelleriana
dusty miller

Lathyrus maritimus
beach pea

Solidago sempervirens
seaside goldenrod

TRANSITION (back dune/coastal wetland)

Baccharis halimifolia
groundselbush

Iva frutescens
marsh elder

Juniperus communis
common juniper

Parthenocissus quinquefolia
Virginia creeper

Suaeda maritima
sea blite

Vitis lambrusca
wild grape

BACKDUNE

Aster sp.
aster

Hudsonia ericoides
beach heather

Juniperus conferta
shore juniper

Myrica pennsylvanica
bayberry

Panicum capillare
witch grass

Prunus maritima
beach plum

Rosa rugosa
rugosa rose

Rosa virginiana
Virginia rose

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ILLUSTRATIONS

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