2. BASIC DUNE PHYSICAL CHARACTERISTICS

New Jersey's Beach and Dune Characteristics

Dunes in New Jersey are mainly confined to a narrow strip of land between the beach berm and upland development, and are limited in height and width by the sediment available from the beach berm area. As a result, in most locations, only primary dunes exist. These primary dunes are particularly susceptible to scarping, overwash, and breaching during extreme storms. In a few other locations however, there are exceptions in which the sediment supply and beach width are adequate for dunes to reach their full form. Throughout much of New Jersey and the mid-Atlantic, present-day dune heights reach 8 to 15 feet above the beach berm (Hammer et al., 1992; Psuty and Ofiara, 2002) due to limitations of energy from wind to move the sand higher or deposition of sand on the lee-side of the dune (Hamer et al., 1992). Dunes have potential with ideal conditions to grow in height up to 4 feet per year, though less than 2 feet is typical. Maintenance requires a vigorous program of planting, fertilization, and fencing (Hamer et al., 1992).

Dune Evolution

Dunes are constantly changing in response to both the short and long-term environmental processes at a given location. Dune size fluctuates in response to the amount of available sand on the beach berm, the strength and duration of the wind, and the storm surge and wave action during storms. Dunes can either "erode", or get smaller, due to the lack of sediment supply or processes that remove sediment, or they can grow or be "depositional" or "cumulative" when sediment is added by the physical processes. Sand loss from wind and wave generated erosion can decrease the amount of sand supply in the berms, and therefore, decrease the amount of sand that is blown up into the dune. Occasionally, high water levels during storms may allow waves to erode the base of the dune and create a scarp (see Figures 5a, b below). The eroded sand gets swept into the surfzone and becomes a part of the littoral transport, and will usually be deposited on another beach that is down-drift. In general, off shore winds blow sand from the dune onto the beach, while onshore winds blow the sand back up onto the dune and rebuild its seaward side. These alterations in the environment are what can cause sand dune development to shift between erosive and cumulative phases, which move the dune's physical position on the beach landward and seaward, respectively (Figure 1).

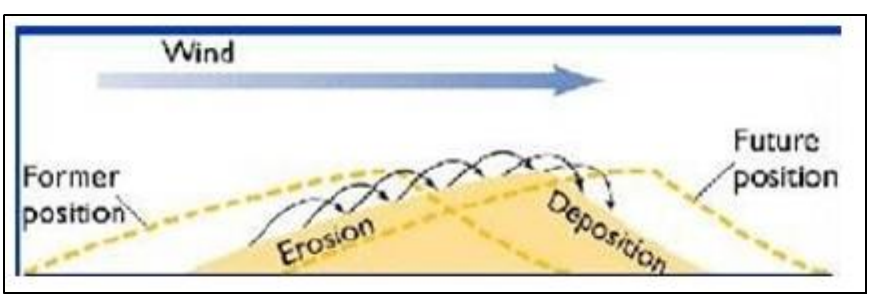

Figure 1. Dune migration due to sand movement from wind (Dune migration).

Dune Growth

Wind is the main force responsible for the establishment, growth, and maintenance of coastal dunes. When a strong wind blows across a sandy beach, it picks up the grains of sand which move by sliding, rolling, or even hopping past one another. Lighter grains of sand are capable of being moved easier and can travel further, while the heavier grains are left behind. Natural and man-made obstructions on the beach cause the wind to slow down, which results in depositional areas in select locations. On a natural beach, vegetation is the most common obstruction, while on developed beaches, snow or sand fencing is frequently installed to mimic the effect of vegetation and accelerate dune growth (see **Error! Reference source not found.** above). The rate at which the wind can supply sand to a dune depends on the availability of a sand source. A beach with a wide berm typically provides an adequate source and will allow the dune to grow; however if the beach is narrow, there may not be a sufficient sand supply and dune growth will be limited. On naturally narrow beaches, beach nourishment projects represent an opportunity to encourage dune growth that might not occur otherwise.

As a dune grows, it becomes asymmetrical in shape with a steep seaward face and a mild sloping landward tail. As the dune becomes taller and vegetation becomes denser, the back dune is sheltered from the wind and growth landward of the crest is reduced, while the growth seaward remains steady during consistent conditions. On coasts which experience growth, a number of dune features can develop, each separated by a low area. It must be noted that for more than one line of dunes to exist, the landward line of dunes must be established before the line closer to the shoreline forms; otherwise the line closest to the shoreline will trap sand and keep it from reaching the original dune. The foredune will continue to grow seaward until the toe of the dune reaches the landward limit of seasonal beach fluctuations.

Vegetation

Vegetation is an important part of the evolution of dunes, as it serves multiple purposes and significantly contributes to the growth of dunes. Vegetation slows the wind causing some of the trapped wind-blown sand to settle to the ground. Heavy grains will fall out first as more energy is required to keep them suspended. As the wind deposits the sand, it accumulates around the vegetation and builds up the existing dune, or begins the growth of a new dune. The accumulating sand does not kill the existing plants, instead it actually promotes their growth, and thus both the vegetation and the physical dune grow in elevation simultaneously. As the vegetation and dune grow together, the roots strengthen and help hold the base of the dune. While other barriers, such as sand fences, cause the same decrease in wind speed and help accumulate sand deposits, they cannot grow with the dunes like vegetation, and therefore require maintenance over time.

Figure 2a, b, c. American Beach Grass on dunes in Long Beach Island, New Jersey.

"Cape" American Beach Grass (*Ammophila breviligulata*) is the primary plant species found on foredunes (or pioneer zone) in New Jersey (for more info, see the dune planting section of the guide) (Figure 5a-c). Once established, American Beach Grass will continue to accumulate sand while its extensive root system helps to bind the sand in place. American Beach Grass thrives on wind-blown sand deposits, and collects sparse nutrients from the incoming sand, stimulating growth and reproduction. The harsh environmental conditions in the pioneer zone allow the dune vegetation to grow without competition from less tolerant plant species. It establishes quickly and spreads rapidly by cloning itself, effectively trapping sand during its first season of growth. Trapping rates of 2 to 4 feet per season have been observed along densely cultivated dunes.

Figures 3a, b. Multiple species of dune plants that colonize along the landward side of an established dune.

While American Beach Grass often is naturally established or planted by communities on dune systems, as dune growth progresses, multiple species of plants will begin to colonize areas landward of the foredune. In New Jersey, typical species are Rugosa Rose (*Rugosa rosa*), Bayberry (*Morella pensylvanica*), and Goldenrod (*Solidago sp.*) (Figures 3). Multiple species are important for dune stabilization as each plant type has a different capacity to retain sand through their roots and above ground vegetation. The most effective dune systems in both promoting habitat and providing storm protection are those in which the appropriate vegetation is encouraged in each zone.

Snow/Dune Fencing

Snow fencing is often used as a means to accelerate or control the growth of dunes on a beach. The snow fence functions similarly to the stems of the vegetation on a natural beach. By slowing the wind velocity to a point below that which is required to keep the sand particles entrained, deposition is encouraged. Sand accumulates around the base of the fence, similar to the way snow accumulates around a fence in colder climates. Snow fencing is available in various materials and densities. Experiments have found that the typical wire-bound, wood-slat fencing that has a width roughly equal to the spacing between slats (50% porosity) will trap about as much sand as other materials (Manohar and Bruun, 1970) (Figures 4a, b). Due to the relative cost-effectiveness of this type of fencing, it is the type most frequently used in New Jersey.

Figures 4a, b. Example of dune fences with sand accumulation.

Sand will accumulate and eventually reach a level about three-fourths of the exposed height of the fence (Hamer, et al., 1992). Although there are some subtle differences in sand-trapping ability, the most important factor is the total length of the fence. Geometric analysis of sand deposits formed in the lee of dune fencing in Dover Township, NJ indicate that 40-foot wide, 3.5 foot-high concave sand deposits form landward of 4 foot-high fencing placed parallel to the ocean (Herrington, 2004). Studies have shown where wind-blown sand is abundant, installing twice as much fence (one about 40 feet behind the first fence) traps about twice as much sand, regardless of the alignment (Hamer, et. al., 1992).

In New Jersey, snow fencing is frequently utilized to control dune growth and manage wind-blown sand. An added benefit is that it creates a barrier to people who might walk or drive on the dunes. Dune manipulation in New Jersey is regulated by the NJ Department of Environmental Protection (NJDEP). Individuals and communities are encouraged to contact the NJDEP prior to commencing projects intended to create/modify an existing dune. An activity that is fairly common for coastal communities is the deployment of seasonal snow fencing to limit the amount of wind-blown sand that ends up in the street and/or on private property during the winter months. Most communities simply redistribute the sand on the berm during the spring. Snow fencing is also used throughout the year by some communities to alter the geometry of the dune. By strategically placing sand fencing, dune characteristics such as height, width, and uniformity can be modified. This practice must be undertaken selectively to ensure that the resulting dune is stable and can provide adequate protection for the community.

Another activity that is commonplace is the creation of a “winter berm” or dune through mechanical beach scraping prior to storm. This process, while not detrimental to the beach has not been shown to have significant protective benefits either. A “dune” created in this manner is generally highly unstable and erodible due to the “loose” configuration of the sand.

Sand Grain Size
The range of sand grain sizes present on a beach influences the sand transport rate and the rate of dune growth. On a natural beach, a given sample of sand will contain particles of varying sizes, each of which will respond differently to a given set of wind conditions. Fine grain sands will move more easily, remain in motion longer, and therefore travel farther than coarse grain sands once picked up by the wind. The result is a tendency for the wind to sort the beach sediment. Fine grain sand is more easily removed from the beach face and is commonly found in dunes. Once the initial layer of fine sand is removed from the beach, the remaining larger grains armor the ground surface, making it more difficult to transport additional sand. Higher wind speeds are the required to continue the transport process after the fine surface materials have been removed. It is for this reason that sand grain size typically varies with location along the beach profile. The finest sands are typically found in the dunes and offshore in deep water, while the sand found on the beach berm and along the foreshore tends to be coarser, with the coarsest material found at the bottom of the foreshore slope, near the location of most intense breaking.

Dune Erosion
Dune erosion occurs over several different time scales. Seasonally dunes will experience minor winter erosion which on a stable coast balances out any summer advancement. More significant erosion can occur during individual storms, or as a result of long term processes.

Seasonal Variability
On stable or eroding coastlines, the seasonal fluctuation in the beach profile limits the seaward extent of the coastal dune system. Dune grasses typically grow into the berm during the summer, advancing the dune seaward. This growth is limited by winter storms which erode the berm and undermine immature dune vegetation. Where fully-established dune systems exist, the berm will typically be eroded back to the seaward line of dune vegetation. This process gives rise to the relatively clear, straight vegetation line found on many natural beaches (Rogers and Nash, 2003), which typically reflects the landward limit of wave-induced erosion during the last one or two storm seasons.

In New Jersey, seasonal weather patterns cause dynamic changes in the beach profile. Large storms occur frequently in the winter, while wave energy decreases in the summer. Throughout the winter, the large storm waves generated by frequent coastal storms erode a portion of the berm and deposit the sand along the offshore sandbar. If these storms are severe enough, the erosion may impact the base of the dune causing a portion of the dune to collapse. The near vertical dune face that is created is known as a scarp. During the summer, the coast is exposed to less frequent, smaller storms and long-period ocean swell that transports the sand from the offshore sandbar back onto the dry beach. While there can be a seasonal winter retreat of 75 to 100 feet and a decrease in elevation of 2 to 5 feet, this pattern is a natural fluctuation and is generally not considered erosion.

Long Term Erosion

On eroding shorelines, dunes respond by shifting landward as the beach retreats. The dunes and the beach both erode and migrate inland when there is a lack of sediment supply along the coast. It is important to realize that dunes do not stop erosion, but rather share the loss of mass and sand volume as the beach erodes (Psuty and Ofiara, 2002). The presence of dunes on eroding shorelines indicates that sand is being transported into the dunes intermittently, thus adding mass to the crest of the dune and to its landward side, even as it loses sand on the seaward side (Psuty and Ofiara, 2002). Along developed coastlines, there is typically limited space for the dunes to shift inland; this exposes the dune to increased wave attack, scarping (vertical erosion) and overwash that eventually destroys the dune system (Figures 5a, b).

Storms and Recovery

Small storms typically only affect the beach/berm system and do not impact the dune system. Beach width, elevation, vegetation, and the cumulative effect of multiple storms can affect the severity and longevity of the erosion experienced. If the beach has been left vulnerable to erosion due to the effects of recent storms, increased erosion is likely. In fact, the cumulative effects of two closely spaced minor storms can often exceed the impact of one severe storm. Dune recession typically only occurs during the larger, but more infrequent storm events. During these strong storm events the berm erodes first, exposing the dune to the wave impact, which will typically result in erosion and collapsing of the foredune. Fortunately, most of the sand eroded from the berm and dune is moved only a short distance offshore during routine storms. As the waves and storm surge subside, sand moved offshore during the storm is transported slowly back onshore by smaller ocean swells. The beach berm can recover to its pre-storm width and elevation in a matter of months. Post-storm dune recovery, however, is delayed due to the temporary insufficient width of the berm, which limits wind generated sand transport. Once the berm is re-established, dune recovery will begin to occur. Note that the surviving vegetation spreads to initiate reconstruction of the dune. In most instances, the initial recovery of the dune will therefore take a minimum of one seasonal (summer) fluctuation. The slow dune recovery by the wind may take as much as a decade following the worst storms (Rogers and Nash, 2003). In the wake of severe storms, emergency beach nourishments are often utilized as a way to rebuild the beach and accelerate dune recovery. Sustained planting, fencing and maintenance programs are often critical to ensuring the success of dune recovery in the wake of major storms.

Breaches

Storms that generate extreme surge and wave action can generate breaches in the dunes. Breaches can occur either from the land side or the bayside depending on relative elevation of the water. Breaches are one of the most destructive short-term erosion hazards as swift currents can create deep channels across the barrier island, undermining everything in its way. This type of event was experienced in Mantoloking, New Jersey as a result of Superstorm Sandy in October of 2012. Multiple beaches formed in Mantoloking's section of the barrier peninsula, and caused extensive damage to the community. As storms rework the coastal landscape, a portion of the beach is deposited offshore in water depths deep enough that sand is permanently lost from the system. Over decades, the net loss of sand due to storms results in a recession of the shoreline.

Figures 5a, b. Eroded dune base resulting from strong wave action during a severe storm (a. Dunes eroded by Ida in New Jersey).