# El Niño and coastal erosion in the Pacific Northwest

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## INTRODUCTION

El Niño Southern Oscillation (ENSO) has a profound effect on the Earth's weather and climate and on ocean processes including water temperatures, currents, mean sea level and wave generation. The paper by Taylor on the preceding pages of this issue focused on changes in weather and climate in the Pacific Northwest, while the present paper deals with the oceanic processes that are important in causing beach and property erosion.

We became particularly aware of the importance of El Niño to coastal erosion in the Northwest during the extreme 1982–83 event (Komar 1986, 1997; Komar and others, 1988; Komar and Good, 1989), and this awareness has been reinforced by the 1997–98 El Niño event. We have seen much news coverage of the erosion El Niño produced along the coast of California (with accounts of floods and landslides). Beach and property erosion also has been severe in the Pacific Northwest, having occurred at numerous sites along the coast.

The main objective of this paper is to examine the atmospheric and oceanic processes produced by El Niño that are important in causing erosion. Most of the discussion of the processes will center on the 1982–83 event, since data collected from that period have been thoroughly analyzed. While measurements of the processes during the ongoing 1997–98 event are still being collected, it is evident that the processes important to coastal erosion are very similar to those experienced in 1982–83. The paper will end with a brief account of erosional "hot spots" experienced during the 1997–98 El Niño event along the Oregon coast, which serve to illustrate how these processes combine to produce beach erosion and property losses.

## PROCESSES OF COASTAL EROSION

Most occurrences of coastal erosion involve one or more of the following processes or factors:

- *storm-generated waves;
- high predicted tides;
- *elevated water levels above the predicted tidal elevation;
- an increase in relative sea level due to glacial melting plus land-level change;
- *erosion of embayments by rip currents;
- *alongshore movement of beach sediment;
- *jetty or breakwater disruption of beach sand movement;
- *migrations of tidal inlets and river mouths.

The processes and factors that are enhanced during an El Niño event are designated by an asterisk (*). The greatly increased erosional impacts along the west coast of the United States during an El Niño event are accounted for by the increased intensities of these processes and by the fact that they generally reinforce one another to maximize their impacts. These important processes and factors are briefly recounted here.

### Enhanced sea levels

Particularly unusual during an El Niño occurrence are the processes that locally alter mean water levels in the ocean. They become readily apparent when we compare predicted tides, those found in tide tables, with the measured tides that are actually experienced. During both the 1982–83 and 1997–98 El Niño years, tides were typically on the order of 1.5 ft higher than predicted. The elevated water levels tended to drown out the beaches and were extremely important at times of high tides, since the water was able to reach sea cliffs and foredunes, allowing waves to attack and erode coastal properties.

Part of this elevated water level on the Northwest coast owes its inception to changes in processes acting along the Earth's equator during an El Niño event. Historically, the first recognized impacts of El Niño were dramatic changes in water temperatures and effects on fisheries off the coast of Peru. Upwelling normally brings deep ocean water to the surface, much as it does off Oregon and Washington. The cold water, high in nutrients, has made the Peruvian fisheries one of the richest in the world. However, during an El Niño occurrence this system breaks down: the water becomes warm and fish and sea birds die en masse. Such an event usually develops during the Christmas season—hence its name, El Niño, Spanish for "The Child."

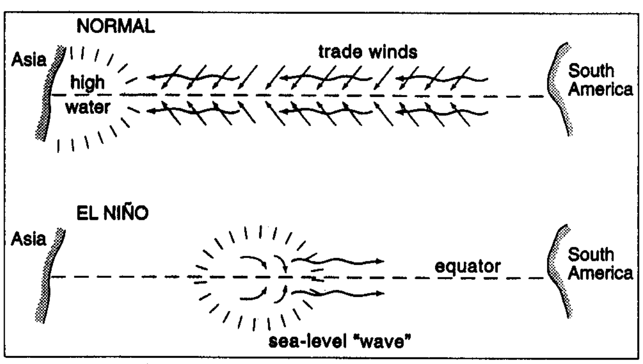


**Figure 1. Schematic diagram of the shift in trade winds and ocean currents along the equator in the Pacific Ocean during a normal year (upper part) versus an El Niño year (lower part). The cessation of the trade winds during El Niño produces a sea-level "wave" that travels eastward along the equator.**

It once was thought that the onset of El Niño off Peru was caused by the cessation of local coastal winds that produce upwelling. This view changed when the physical oceanographer Klaus Wyrtki demonstrated that these local winds do not necessarily diminish during an El Niño event (Wyrtki, 1975). Instead, he found that the breakdown of the equatorial trade winds in the central and western Pacific trigger El Niño, far away from the Peruvian coastal waters where its chief impact is felt. The process is illustrated schematically in Figure 1, contrasting a normal period with an El Niño year. During normal years, the trade winds blow toward the equator, but with a component directed toward the west, and generate ocean currents that flow toward the west parallel to the equator. The stress of the wind on the water and the westward flow of currents combine to produce an elevated water level in the western Pacific, centered in the area where the equator intersects the coast of Asia. The same effect is obtained when you blow steadily across a cup of coffee: the surface of the coffee becomes highest on the side of the cup away from you. If you stop blowing, the coffee surges back and runs up your side of the cup. The process is similar in the ocean, when the trade winds stop blowing during an El Niño year. This condition is depicted in the lower half of Figure 1. The potential energy of the sloping water surface is released, and it is this release that produces the eastward flow of warm water along the equator toward the coast of Peru, where it kills fish not adapted to warm temperatures.

Associated with this warm-water movement eastward along the equator is a wavelike bulge in sea level, also depicted in the lower diagram of Figure 1. The eastward progress of the sea-level wave has been monitored at tide gauges located on islands near the equator. Data from a tide gauge can be averaged to remove the tidal fluctuations, yielding a measure of the mean level of the sea during that time interval. Such analyses were undertaken by Wyrtki to demonstrate the eastward movement of sea-level waves during El Niño events (Wyrtki, 1977, 1984). Figure 2 shows the results for the 1982–83 El Niño. From this series one can easily see the passage of the released sea-level wave as it traveled eastward across the Pacific, affecting in turn tide gauges on a series of equatorial islands. Sea level at Rabaul in the western Pacific reached a peak in March or April 1982 and then began to drop. The crest passed Fanning Island south of Hawaii in late August, Santa Cruz in the Galapagos at the end of the year, and reached Callao on the coast of Peru in January 1983.

Upon its arrival on the coast of South America, the sea-level wave splits, and the separated parts respectively move north and south along the coast. Analyses of tide-gauge records along the full length of the west coasts of North and South America have demonstrated that the sea-level waves can travel as far north as Alaska (Enfield and Allen, 1980). The wave travels at a rate of about 50 mi per day, so it quickly reaches California and Oregon. The passage of the sea-level wave along the Oregon coast is depicted in Figure 3, which also shows the locations of tide gauges used to monitor its movement. Figure 4 gives the monthly mean sea levels measured by the tide gauge in Yaquina Bay, Oregon, during the 1982–83 El Niño year, contrasting the levels with more normal years (Huyer and others, 1983). As in the analyses of Wyrtki, the tide-gauge record was averaged

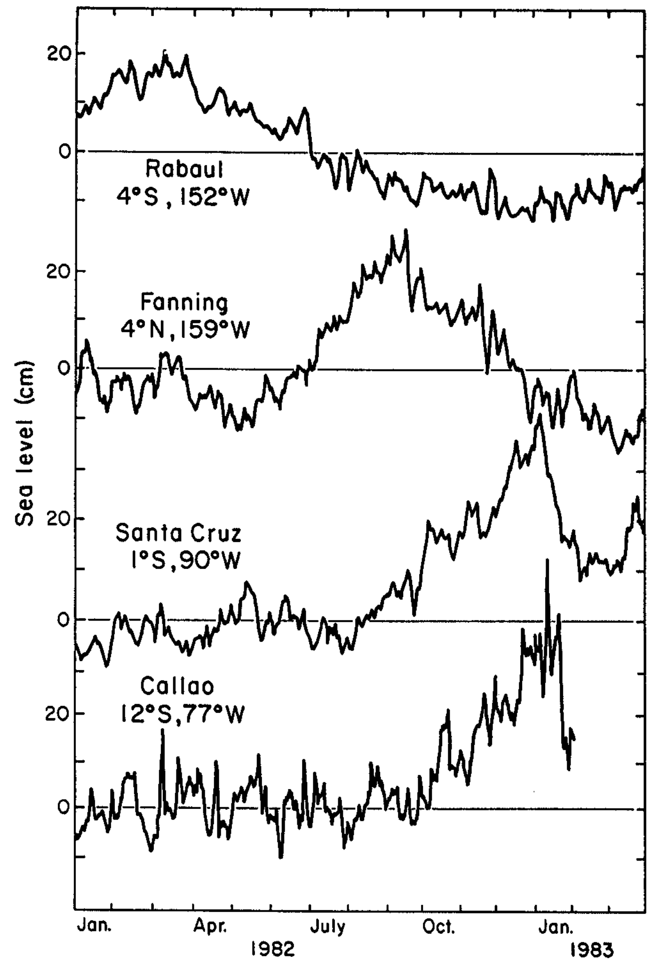


**Figure 2. Sea-level waves measured on tide gauges of islands located along the length of the equator during the 1982–83 El Niño event (after Wyrtki, 1984).**

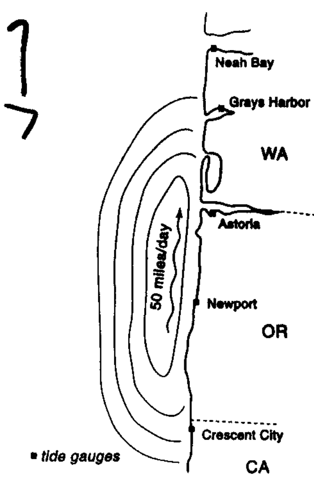


**Figure 3. Schematic depiction of the sea-level wave moving northward along the Oregon coast as measured by the series of tide gauges also indicated.**

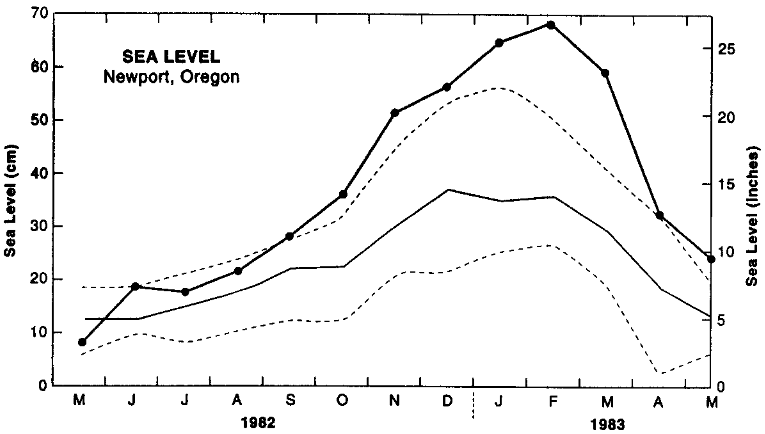


**Figure 4. Monthly averaged sea levels measured on the tide gauge in Yaquina Bay, with the 1982–83 El Niño extreme levels (heavy solid line) compared with previous years. The thin solid line in the figure follows the ten-year averages for the seasonal variations, and the dashed lines give the previous maxima and minima measured at Newport (after Huyer and others, 1983).**

to remove the tides, leaving the net difference between the predicted and measured tides for the month. During the 1982–83 El Niño year, sea level reached a maximum during February 1983, nearly 24 in. higher than the mean water surface in May 1982, nine months earlier.

The increased elevations in mean sea level along the Northwest coast during El Niño are only in part due to a sea-level wave originating at the equator. Other factors include changes in water temperatures along the coast and the development of a northward-flowing current. The curves in Figure 4 in part reflect the normal seasonal cycle of sea level that is produced by parallel variations in water temperatures—colder during the summer than during the winter, due to the occurrence of upwelling in the summer. The thermal expansion of the warm water of the winter raises the water level along the coast, while the cold, dense water of the summer depresses the level. There is also a reversal in current directions from winter to summer. During the winter, the current flows toward the north, and the rotation of the Earth (the Coriolis effect) deflects the current toward the right, that is, toward the coast, elevating the level of the sea along the shoreline. These processes tend to occur every year, causing sea levels along the Northwest coast to be higher during the winter than the summer. But in an El Niño year, these processes are more intense: the water during the winter is warmer than usual and the northward current stronger. So these factors add to the sea-level wave moving northward from the equator to produce the observed extreme water levels during an El Niño winter.

It is seen in Figure 4 that the 1982–83 sea levels were truly exceptional, reaching some 8–16 in. higher than previous winter maxima, about 14 in. above the average winter level. Similar analyses are underway for the 1997–98 El Niño. During January and February 1998, the measured sea levels were again 14–16 in. above the average winter level, indicating that water levels during this El Niño event reached higher elevations than during the 1982–83 event.

The water-level increase during an El Niño year along the Northwest coast is seen to be substantial, making the measured tides significantly higher than predicted (both high and low tides are elevated). For example, in the 1982–83 El Niño year, during a January 1983 storm, the highest spring tides of the month reached +12.4 ft MLLW (Mean Lower Low Water, the standard reference), 34 in. higher than the predicted tide (elevated by both the El Niño processes and the strong onshore winds of the storm). During a February storm, high tides of +10.3 ft were measured, 17 in. above the predicted level. All of these tides were exceptional for the Oregon coast, where a spring tide level of +9.0 ft MLLW is fairly representative (Komar, 1997). This elevated water level is extremely important in producing coastal erosion during an El Niño event. Beaches along the Oregon coast typically have a slope of about 1-in-50, so an increase in water level of 17–34 in., as experienced during the 1982–83 El Niño winter, shifts the shoreline landward by about 70–140 ft, drowning out most beaches at high tide. This moves the shoreline to the base of the sea cliffs or foredunes, and permits the direct attack of waves against coastal properties, in large part accounting for the extreme erosion during El Niño winters.

### El Niño storm waves

Coastal property erosion usually occurs when storm waves combine with elevated water levels, and this is especially true during an El Niño event, when these processes are intensified and act to reinforce one another. During El Niño, the high-altitude jet stream in the atmosphere becomes narrow and strong and spins off cyclonic storms over the Pacific that are more intense than usual. The jet stream is also shifted further south than normal, so the storms cross the North American coast in southern California rather than in the Northwest. These storm system are important to the generation of high-energy waves, and in an El Niño year, with the shift of storms to the south, communities such as Malibu Beach in southern California have a taste of wave energies to which they are not accustomed.

Wave conditions along the Northwest coast are also intensified during an El Niño year (Komar, 1986). Daily measurements obtained during the 1982–83 event demonstrated the occurrence of several storms that generated high-energy waves, three having produced deep-water significant wave heights on the order of 20–25 ft ("significant wave height" is the average of the highest one-third of the waves). The strongest storms occurred during January and February 1983, simultaneous with the occurrence of the highest water levels (Figure 4). Given this combination, it is understandable that extensive erosion took place during the El Niño winter of 1982–83.

An intensification of wave conditions along the Northwest coast also occurred during the 1997–98 El Niño. The first major storm of the winter arrived on November 14, 1997, when deep-water significant wave heights reached 16 ft. The first substantial property erosion of the El Niño winter occurred during a storm on December 13–14. Although the wave conditions were comparable to those on November 14, the tides were higher, and the beaches had been cut back during the preceding month, allowing the waves to attack sea cliffs and dunes. Storm wave activity increased significantly in January and continued through February. During those two months, 12 storms generated waves having deep-water significant wave heights in excess of 20 ft. Far and away the largest storm occurred on January 17, when the deep-water significant wave height reached 30 ft—the waves often growing to some 35 to 40 ft in height as they traveled to the nearshore and broke on Northwest beaches.

While we observed an overall intensification of wave energies along the Northwest coast during both the 1982–83 and 1997–98 El Niño years, compared with normal years, this intensification is significant more in the frequency of storm-wave occurrences than in the absolute extreme sizes of the generated waves. The 30-ft waves of January 17, 1998, have an expected return interval of about 10–20 years and so are exceptional, while the 20- to 25-ft storm waves have return periods of roughly one year, which means that we experience waves with those heights essentially every winter. The decisive difference is that we saw more storm wave occurrences having 20- to 25-ft heights during the El Niño winters than during normal years. Higher waves can occur along the Northwest coast even during normal years, in part because the paths of storms cut directly across our shores. While extreme waves are generated by El Niño storms (Seymour and others, 1985), their impacts are felt more directly in southern California than on the Northwest coast.

**Longshore movement of beach sand**

An important aspect of coastal erosion in the Northwest caused by El Niño storms and the waves they generate is the southerly shift of the storm systems. The result of this shift is that the storm waves approach the Northwest coast more frequently from the far southwest quadrant, compared with normal years. This results in the northward movement of sand along Northwest beaches, which exerts a strong control on the alongshore centers of "hot spot" erosion.

Important to this control is the fact that the Oregon coast is divided naturally into a series of littoral cells, stretches of beach isolated by large rocky headlands (Komar, 1997). The stretches of beach may range from only a couple of miles to as long as 50 mi (in the case of the Coos Bay littoral cell that extends from Cape Arago in the south to Cape Perpetua in the north). There is little or no exchange of beach sand around the bounding headlands (shown by differences in beach sand grain sizes and mineralogies), so the stretch of beach within a littoral cell is largely isolated and self contained.

A schematic diagram of a littoral cell is depicted in Figure 5, contrasting the wave directions and alongshore sand movements during normal years (left) with El Niño years (right). In a normal year the summer waves dominantly approach the coast from the northwest, causing sand to move southward along the beaches, while the winter waves arrive from the south-

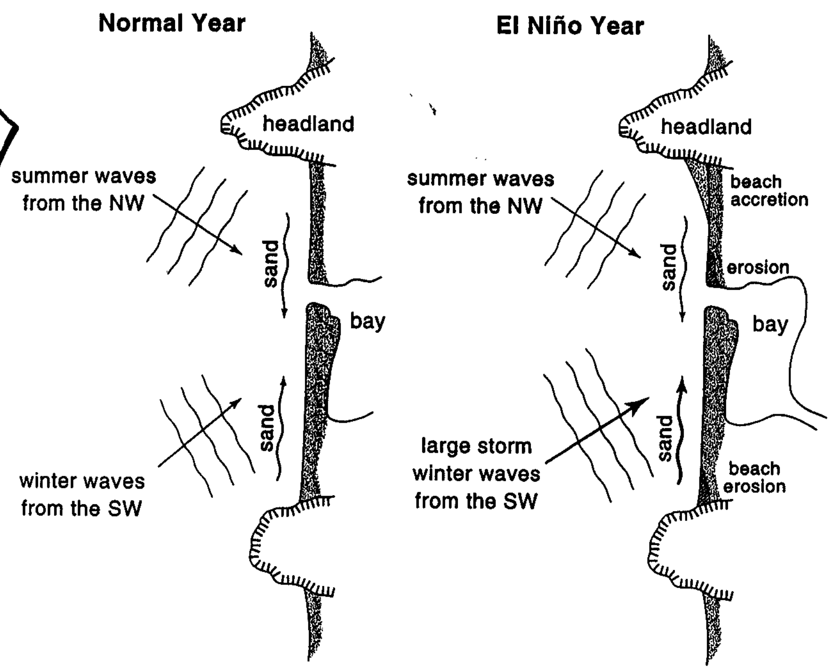


**Figure 5. Schematic depiction of alongshore movement of beach sand within a littoral cell on the Oregon coast due to the seasonal shift in directions of waves approaching the coast. During normal years, there is an approximate balance of north and south sand movements, but in an El Niño year the strong storm waves from the southwest move large amounts of sand to the north, causing "hot spot" erosion as shown.**

west and move sand back toward the north. Over the span of several normal years we observe an equilibrium, with approximately equal amounts of sand moving north and south. This equilibrium was seen in the shoreline changes that occurred when jetties were constructed along the coast early in the century (Komar, 1997), with a symmetrical pattern of shoreline change north and south of the jetties. In contrast to the equal north and south movements of sand in a normal year, during an El Niño event (Figure 5, right) more sand moves toward the north under the more frequent storm waves arriving from the southwest. One effect is that sand is systematically moved away from the south ends of the littoral cells, producing erosion there, while sand accumulates at the north ends, where the beaches widen.

Jetties on inlets can have much the same effect as a headland. During an El Niño year with the enhanced sand movement toward the north, the jetties block this drift, causing beach accretion to the south of the jetties, while erosion occurs to the immediate north. This pattern may be obscured in part by the seasonal cross-shore movement of sand along the beach profile: During the winter, the high waves erode sand from the dry part of the beach and transport it to offshore bars, while low waves of the summer reverse this process (Komar, 1998). Thus the actual response of the beach (net erosion or accretion) at a specific site depends on the combined effects of the alongshore movement of sand related to El Niño and the cross-shore movement associated with the seasonal cycle of beach profile change.

Natural inlets to bays and estuaries on the Northwest coast, that is, inlets not controlled by jetties, tend to migrate toward the north during an El Niño event, due to the stronger northward movement of beach sand. This can result in beach and property erosion to the immediate north of inlets, as depicted in Figure 5. The shift is temporary—during subsequent normal years, the inlets tend to migrate back toward the south.

## OCCURRENCES OF EROSION DURING THE 1997–98 EL NIÑO EVENT

In the preceding section it was seen that a number of processes are involved in producing enhanced coastal erosion during an El Niño. In this section we will examine several erosional "hot spots" that occurred along the Oregon coast during the 1997–98 El Niño and attempt to understand their development in light of the processes described above.

### Port Orford

The erosion at Port Orford during the 1997–98 winter illustrates several factors that are important in an El Niño year. Port Orford is a small community on the southern Oregon coast, with the center of the city situated immediately south of a headland known as The Heads. However, the community extends to the north of The Heads, and it is this area that has been experiencing severe erosion. This stretch of beach comprises a littoral cell that extends north to Cape Blanco, a distance of about 8 mi. The erosion occurred at the south end of the littoral cell and fits the normal pattern of El Niño impacts with storm waves arriving from the southwest, moving the beach sand alongshore toward the north.

The shore erosion is centered on the narrow beach/dune barrier that separates the ocean from Garrison Lake. The beach is composed of coarse sand with some gravel, is steep, and has a narrow surf zone. This type of beach erodes very rapidly when attacked by storm waves that break directly on the beach face close to shore (Komar, 1997). Prior to the El Niño erosion, extensive dunes had accumulated in this area, and the City of Port Orford had installed the drainage field for its sewage treatment system within the dunes. Erosion this winter has all but eliminated the dune field and destroyed most of the drain field (Figure 6). The threat now is that continued erosion may break through the beach/dune barrier into Garrison Lake. This lake is the principal source of fresh water for the community, and a several homes have been built along its shore and may be adversely affected by a breach. The combined elevated mean water levels and runup of storm waves from El Niño have frequently washed over the barrier into the lake. This overwash process has eroded sand from the beach and carried it over the top of the barrier and into the lake. This has had a positive effect of building up the elevation of the barrier, making it less likely that the erosion will break through and create an

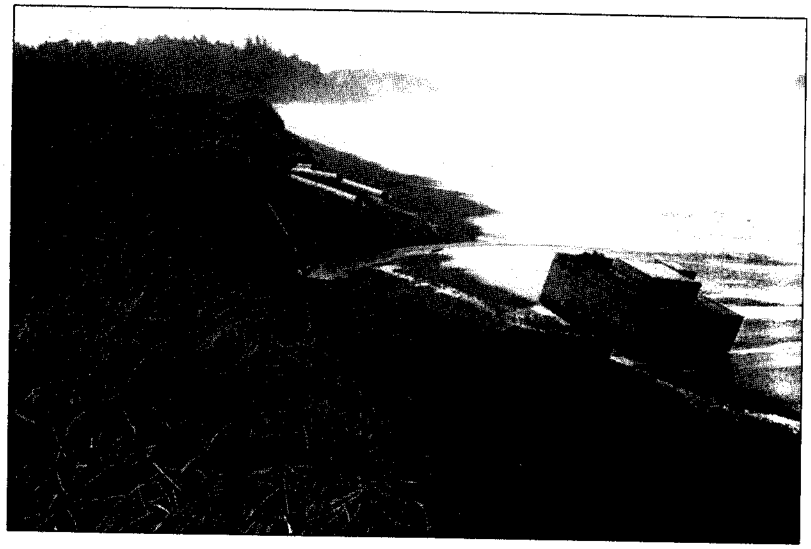

**Figure 6: Erosion at Port Orford, north of The Heads, during the 1997–98 El Niño event. The erosion of sand dunes has destroyed the drain field of the sewage treatment plant.**

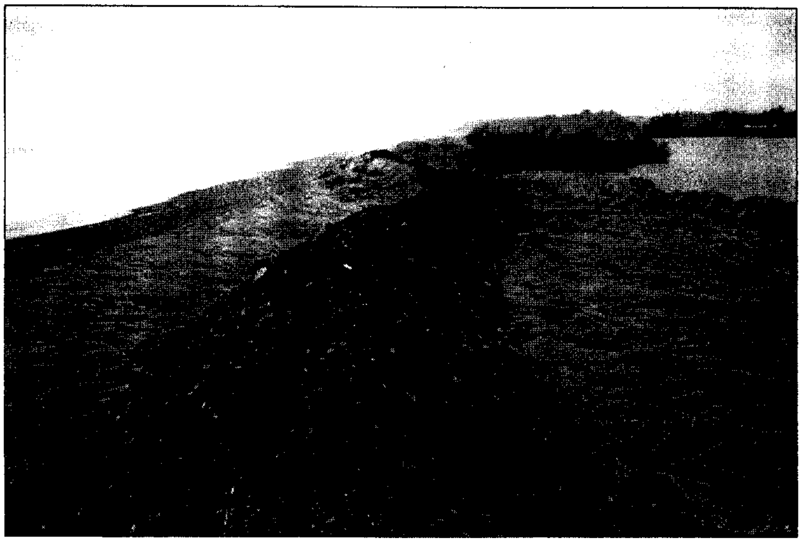

**Figure 7. Erosion at Port Orford, north of The Heads, during the 1997–98 El Niño event. View is to the south from the location of Figure 6. The erosion is now threatening to break through the beach/dune barrier and wash into Garrison Lake, which is being prevented by the placement of a gravel ridge.**

inlet connecting the ocean with Garrison Lake. There is still a critical area at the south end of the barrier, where the erosion is cutting back the dunes and forming a nearly vertical scarp. Although washovers of ocean water have occurred frequently in this area, they did not carry sand to build up the elevation of the barrier, as has occurred further to the north. The barrier at the south end is now very narrow, so there is the possibility that the ocean could break through into the lake. The City of Port Orford has placed a ridge of gravel and cobbles along the top of the barrier (Figure 7) to prevent further washover that, at this stage, could develop into a breach of the barrier and form an inlet. If dune erosion continues, the mass of gravel and cobbles will slough off onto the eroding dune scarp and upper beach, where its presence should provide some temporary protection from continued wave attack. It is hoped that this is a sufficient defense until the impacts of the 1997–98 El Niño end.

## Alsea Spit

One of the main areas of erosion during the 1982–83 El Niño event took place along Alsea Spit on the central Oregon coast (Komar, 1986, 1997; Komar and Good, 1989). The primary factor important to erosion was the northward migration of the inlet to Alsea Bay. This inlet migration combined with elevated water levels and storm waves and completely eroded away the beach along nearly the full length of the spit. The waves and currents then began to cut back the foredunes, where a number of homes had been constructed. One house was lost, while the others were saved by the placement of riprap at the base of the eroding dunes.

In the years subsequent to the 1982–83 El Niño event, the return of lower water levels and less severe wave conditions has allowed the beach to recover along Alsea Spit. The beach has become very wide, and onshore winds have blown sand into the dunes so they had fully recovered from the El Niño erosion. Eventually the riprap revetment was covered by the accumulating dune sand, and apparently forgotten. Development began once again, and a number of new homes were build on the spit. Unfortunately, some were constructed atop and across the now buried revetment, seaward of this line of defense, in the area where erosion had occurred only a decade earlier.

The return of El Niño during the winter of 1997–98 has brought about a recurrence of erosion processes and problems on Alsea Spit. Older homes landward from the line of riprap placed in 1982–83 are likely safe from the renewed attack, but the newly constructed homes that extend seaward from the riprap line are now in danger. It is possible that another line of riprap will have to be installed to protect those homes.

## Cape Lookout State Park

Another area of significant erosion during the 1982–83 El Niño event occurred at Cape Lookout State Park on Netarts Spit (Komar, 1997; Komar and others, 1988; Komar and Good, 1989). This park is located at the south end of the Oceanside littoral cell, so again much of its erosion can be attributed to the northward transport of sand by the approach of high storm waves from the southwest during El Niño, moving sand toward the north. Much of this sand has disappeared from the beach, apparently carried into Netarts Bay. The reduction of sand volumes on the beach along this littoral cell now makes the beach more susceptible to attack by waves, during normal years as well as in an El Niño event. Another factor in the erosion during the 1982–83 El Niño event was the presence of a large rip current flowing seaward from the area of the park, carrying sand offshore, and contributing to the local erosion. Erosion in the park partially destroyed an old log seawall and then eroded away the high ridge of dune sand that had sheltered the park development.

Erosion of Cape Lookout State Park during the 1997–98 El Niño year has essentially picked up where the 1982–83 event left off (Figure 8). The last remnants of the log seawall are rapidly disappearing, leaving the tall iron beams that had supported the logs sticking up from the beach—the beams remaining after the 1982–83 erosion were cut off by the Parks and Recreation Department. Additional dune erosion has occurred, and

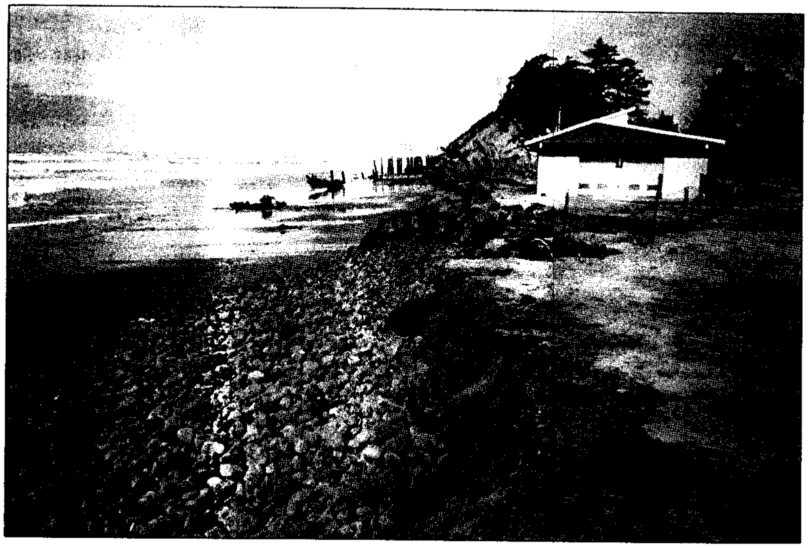

**Figure 8. Recent erosion at Cape Lookout State Park on Netarts Spit has cut back the large coastal dunes and is now eroding the campground.**

the public bathrooms were in danger of being undermined by waves until a line of riprap was placed for protection. High water elevations have combined with storm wave runup to wash over into the park lands, depositing a large amount of beach sand in the campground. Such extensive washovers did not occur during the 1982–83 El Niño event.

### The Capes

Most dramatic and newsworthy during the 1997–98 El Niño year has been the erosion at The Capes, a development consisting of expensive condominiums recently built on the high bluff to the immediate north of the inlet to Netarts Bay (Figure 9). The site is centered within the Oceanside littoral cell, about 6 mi north of Cape Lookout State Park. Erosion at The Capes is dramatic not only in its potential economic impact for the home owners, but also with regard to the number of coastal hazards involved.

Since the condominiums are situated immediately north of the inlet to Netarts Bay, the northward migration of the inlet during the 1997–98 El Niño winter has acted to erode the fronting beach and has created deepened water directly offshore. Normally, the low-sloping beaches in this littoral cell cause the waves to break well offshore, so that most of their energy is dissipated before they run up on the beach face at the shore (Komar, 1997). With the creation of deeper water due to the migration of the inlet, the waves can now travel closer to shore before breaking and lose less energy in the process. The runup of the stronger waves now combines with the elevated mean water levels associated with El Niño, allowing the runup to reach the toe of the high bluff below The Capes. The resulting toe erosion has made the bluff unstable, and slippage of the land now poses the immediate threat to the front line of condominiums (Figure 10). Unfortunately, the condominiums had been constructed with only a 10-ft setback distance—insufficient, considering the potential for erosion and instability of the site. So now many of the homes have immediately been placed in danger.

The development site is located atop an old massive landslide. The lower portion, now exposed by the toe erosion, consists of a layer of mud that is extremely mobile. Rather than participating in the rotational slippage typical of many landslides, this mud appears to be squeezed out like toothpaste by the weight of the overlying material. This overlying material is sand of old dunes deposited atop the bluff—sand that has minimal internal strength, so that it tends to cascade downslope, much like the loose sand of an active modern dune. Thus, only part of the problems at The Capes can be attributed to the occurrence of El Niño and its erosion processes. The preexisting hazardous conditions are that the development was constructed on a landslide, the upper part of which consists of dune sand. The present instability and movement of the landslide can, however, be attributed to the 1997–98 El Niño occurrence and its erosional impact, which has cut away the toe of the landslide.

**Figure 9. The Capes, north of Netarts Bay, is a recent development of condominiums, located on the edge of an old massive landslide.**

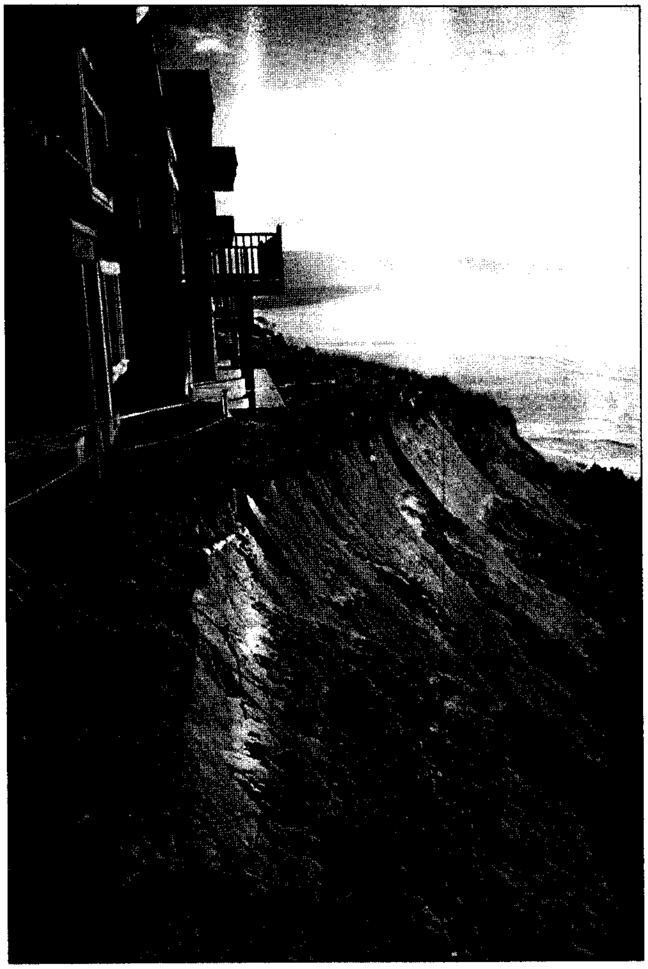

**Figure 10. Homes at The Capes. Erosion of the toe of the landslide during the 1997–98 El Niño winter has caused the slide to become unstable, and slippage is threatening the first line of homes.**

## CONCLUSION

The Northwest coast now has experienced two major El Niño events, in 1982–83 and again in 1997–98. Both have resulted in substantial beach erosion and damage to or loss of coastal properties. Although data from the recent event are still being collected and analyzed, the evidence thus far is that the processes are very similar to those which occurred during the 1982–83 El Niño event. Important to coastal erosion are the elevated water levels that cause tides to be 1–1.5 ft higher than predicted, the generation of high energy waves by more frequent storms, and the fact that the waves approach the coast more from the southwest, causing a northward movement of sand that redistributes beach sand volumes along the coast and causes inlets to migrate toward the north. It is the combination of these processes and the fact that they reinforce one another that accounts for "hot spot" erosion areas along the Oregon coast such as at The Capes.

At the time of this writing (April 1998), El Niño is continuing but it looks as if it is decreasing and will likely soon come to an end. Water temperatures and sea levels in the equatorial Pacific are returning to more normal levels. The same can be expected off the Northwest coast. As discussed above, wave energies along the coast abruptly declined at the end of February, following the usual pattern of decreasing wave conditions in the summer (Komar, 1997). The eroded beaches have noticeably begun to rebuild. So additional property erosion is unlikely, at least through the summer. But we may not have seen the last of the impacts that can be attributed to El Niño of 1997–98. Following the 1982–83 event, significant erosion took place during subsequent winters, returning to the areas that had eroded during the El Niño winter. The processes directly associated with El Niño had ceased (unusually high water levels, etc.), but the beaches were unable to fully recover during the following summer. Sand that had been shifted far offshore to deep water did not completely return to the dry beach, and sand moved alongshore to the north within the littoral cells did not all shift back to the south. So when the next winter returned with its high storm waves, the beaches still depleted of sand were not able to adequately buffer coastal properties, so that erosion began once more. It took two to three years before the beaches finally recovered and the lingering impacts of the 1982–83 El Niño event finally ended. It remains to be seen whether history repeats itself and whether or not we have seen the last of El Niño 1997–98.


## ACKNOWLEDGMENTS

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