Oregon's ever-changing coastline

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Where does beach sand come from?
Where does sand go?
Why do beaches erode?
Why does sand build up behind a jetty?
What is a seawall?

Visitors and coastal residents frequently ask questions like these. They want to understand better the natural forces that have helped to make the Oregon coast so attractive. This bulletin is a nontechnical introduction to these forces—what they do, how engineers sometimes can modify their effects, and why these modifications can have unpredictable consequences. (See figure 1.)
"Suggested reading," page 8, shows where greater detail is available, if you want it.

Figure 1.—*European dune grass sown on Siletz Spit stabilizes the sand dunes. Nonetheless, the coastline changes. Homes on the spit are vulnerable to high tides and storm waves. Attempting to defeat natural processes that continually alter the coastline, homeowners have placed riprap—large rocks—along their seaward boundaries. The resultant slowing of erosion shows in the contrast between the prominence of the protected homesites and the receding dunes on the adjacent vacant land.*

Sand sources for Oregon beaches

The Oregon coast is primarily a series of bold, rocky headlands (capes), with "pocket beaches" between them that are often backed by steep cliffs (see figure 2). There are expanses of sandy beach and some long spits, too, but these generally lie within the pocket beach areas.

"Sand" is a general term; some beaches affected by vigorous wave action are composed not of grains of sand but of cobbles (small rocks) and coarser materials.

Erosion from the cliffs and headlands surrounding the beaches is the primary source of sand. Landslides play an important local role in delivering the material to the beach (see the Byrne and North title under "Suggested reading"). Rivers and sand dunes provide minor contributions of beach sand. However, these can vary greatly: Heavy rainfalls add larger quantities of sediment to the rivers; strong winds can severely erode the dunes. Beaches may lose sand offshore (to deeper water) and to estuaries.

Every beach has what is called a "sand budget," putting into human terms a process that one can almost see happen over, say, a year's time on a given beach. The beach will receive sand; the beach will lose sand. If these contributions and losses balance, we say the beach is in equilibrium. If either factor is greater than the other, a change in the beach will occur, as the beach "attempts" to reach this equilibrium.

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Figure 2.—*Coastlines develop characteristic landforms that give evidence of the geologic structure of the coast. Headlands, pocket beaches, and spits are typical examples. Under the onslaught of ocean weather and wave action, even the most resistant coastal features change continuously.*

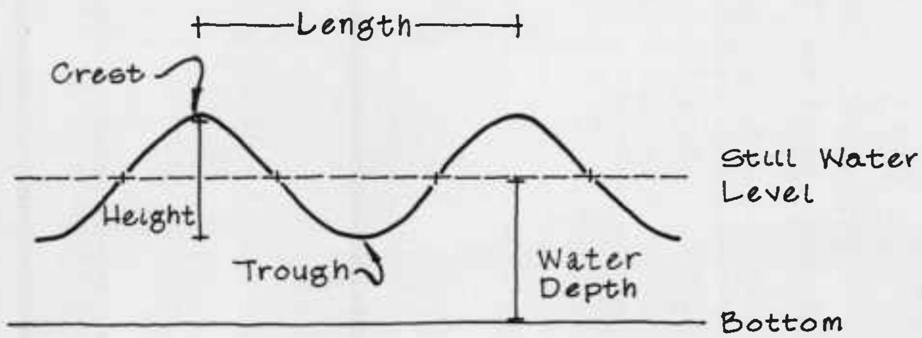

Figure 3.—*Waves can be described by referring to the height from crest to trough and the length from the peak of one wave crest to the peak of the next. An important aspect of wave motion is wave period: the length of time it takes one complete wave (one wavelength) to pass a stationary reference point. Waves of differing heights, lengths, and periods have differing effects on coastlines.*

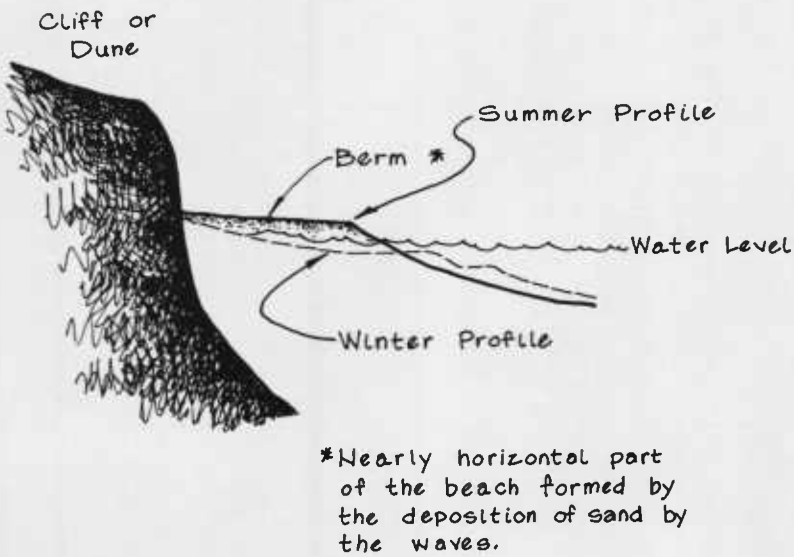

Figure 4.—*Beaches change hour to hour, day to day, and season to season. The typically long waves that strike beaches in summer move submerged offshore materials back onto the beach. The steeper, shorter-length waves of winter scour materials off the beach, depositing them offshore. Thus, the profile of a beach changes appreciably between summer and winter.*

Wave action

Apart from the Oregon shoreline's geological structure, ocean waves are the major force that determines its form and appearance. Wind is the chief agent that forms waves. Wind blowing on the sea surface creates waves through the frictional drag of air moving against water.

The time required for two successive wave crests to pass a fixed reference point (wave period) depends on the wind speed, how long the wind continues to blow, the distance that the wind blows over the open water (fetch), and the distance the wave travels after leaving the generating area (decay distance).

The same factors also determine the heights of wind-generated waves. Generally, a strong wind blowing for a long time, over a long distance, generates large waves. Because wind variations can simultaneously generate waves of many sizes and speeds, the decay distance is the key factor in determining the wave's size when it reaches the shore (see figure 3).

As waves move into shallow water, they become unstable because their height quickly increases relative to their length. The wave finally becomes completely unstable and breaks when the water depth decreases to about 1.3 times the wave height.

Breaking waves move water in random directions. This agitation (turbulence) stirs up bottom sand, which is then moved (transported) by the continuing arrival of new waves.

If you know a certain beach very well, and have visited it in all seasons, you know that the way it looks in winter can be very different from the way it looks in summer. During winter, local storms create short, steep waves, which tend to erode the beach and deposit much of its sand offshore, sometimes uncovering a rock base you never see in summer.

When summer comes, distant storms bring long swells, and these move sand back onshore. If you could see a beach in cross-section, you would see what is called a "beach profile" (figure 4). On the Oregon coast, seasonal changes make the big difference in these profiles. (These same seasonal storms can push driftwood up on beaches and pull it away again; see the Van Vliet and Panshin title under "Suggested reading.")

Longshore currents and littoral drift

Longshore currents distribute sand along the coast; this movement is called "littoral drift." The longshore currents flow parallel to the shoreline in the surf zone and are caused by the waves that strike the beach at an angle rather than head-on. Waves approaching shore at an angle other than 90° bend and begin to change direction as they move into shoaling water. Usually, the process is not complete because of variations in the ocean floor. As a result, the waves break at an angle to the beach (see figure 5).

In Oregon, littoral drift—the sand movement that longshore currents cause—changes seasonally (see figure 6). During the winter, the predominant wind and swell come from the southwest, creating a littoral drift to the north. Summer wind and swell are mostly from the northwest, resulting in a drift to the south. Unlike other West Coast beaches, the Oregon coast has no net littoral drift (the southward drift in summer cancels the northward drift in winter).

Large headlands that interrupt the littoral transport of sand create the pocket beaches so characteristic of the Oregon coast.

Erosion and accretion

A beach's sand budget is in equilibrium when the amount of sand washed onto the beach is equal to the amount of sand removed. Sometimes, this natural flow of sand is interrupted. For example, a jetty dams sand, trapping it on the "upcurrent" side. When a jetty is built, sand previously carried along by the longshore current is prevented from reaching the "downcurrent" side. Erosion may follow on this downcurrent side as its sand supply is now greatly reduced. (See "Jetties," below.)

Rip currents, an important erosion agent along the Oregon coast, flow as temporary, concentrated offshore currents. They scour sand from the beach and deposit it in deeper water. These currents may also hollow out small bays (embayments) along the shore—allowing storm waves to do greater erosion damage.

The causes of rip currents are not completely understood. They are sometimes called "rip tides" or "undertows," but they are not tides, nor are they vertical currents that drag swimmers underwater: They are strong, *horizontal* currents that run off the beach and back to sea (figure 7).

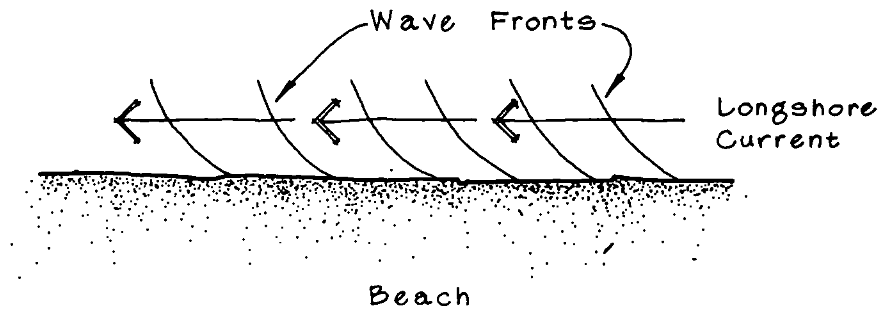

Figure 5.—*Ocean waves that strike the shore at any angle other than 90° release part of their energy perpendicular to the shoreline and part of it along the shoreline. The portion of wave energy directed along the shoreline causes water and sediments to move along the coastline in a* longshore current.

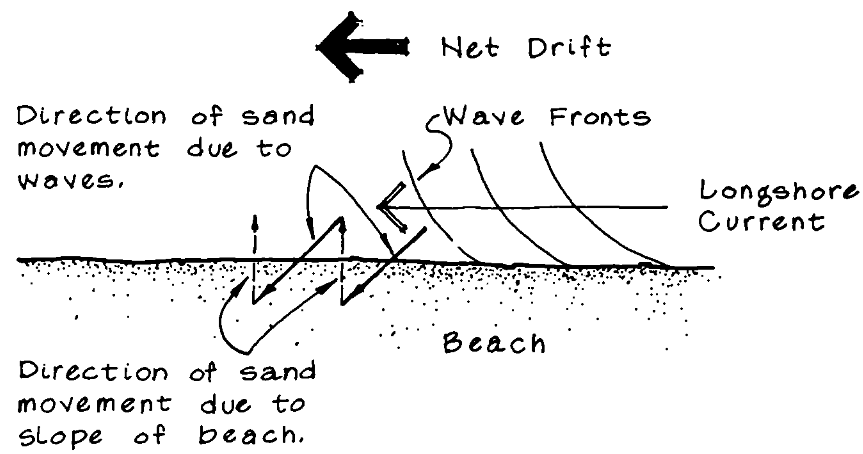

Figure 6.—*Longshore currents pick up and move beach materials along the coast. These materials are moved up onto the beach by breaking waves, drain downslope back to the ocean, are washed up onto the beach by the next wave, and so on. The result is an irregular, somewhat stairstep movement that results in sand and other beach materials being transported along the coast in what oceanographers call* littoral drift.

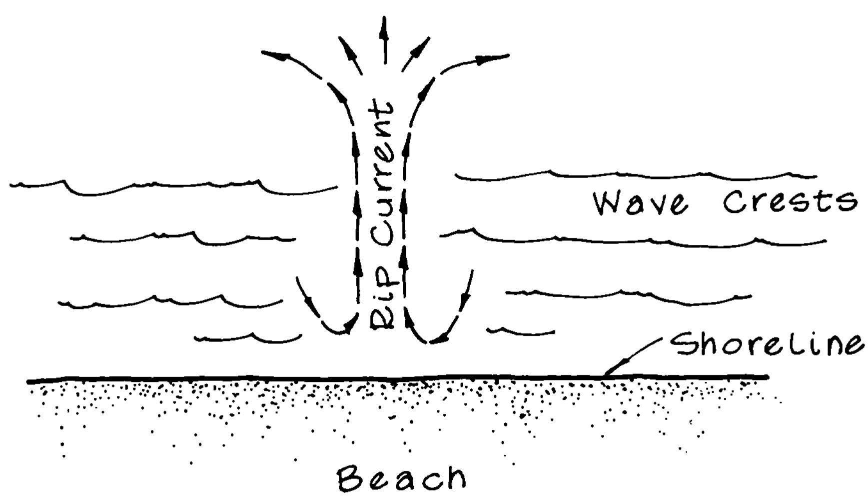

Figure 7.—*Breaking waves pile up appreciable volumes of water on relatively short stretches of shoreline. Such buildups occasionally run back to sea in strong currents of surface water that move directly offshore. They are called* rip currents; *they are unpredictable and account for many drownings. Although their causes are not well understood, oceanographers emphasize that rip currents are horizontal, usually short-lived currents. They do not flow vertically, as the misnomer* undertow *would suggest.*

The short, steep waves of local winter storms also erode the beaches. Sometimes several winter storms occur in rapid succession, and there is no chance for the beach to be rebuilt between them—thus allowing severe erosion by the next storm. Large waves acting with high tides also cause heavy erosion. Most of the eroded sand is deposited offshore; usually, long swells move it back onshore before subsequent storms strike. Much erosion is seasonal, and this is reflected in the changing profiles of the Oregon coast.

Shoreline modifications

Property owners along the beach depend on various methods of shoreline protection—to modify natural forces and to stabilize the beaches. These methods often impose exacting design requirements to keep them from causing other erosion problems. The following description focuses on methods used along the Oregon coast.

Riprap. A protective mound of rocks and stones, riprap is a common sight on the seaward faces of beach slopes in populated areas. The rocks are placed as high on the slope as topography and wave characteristics will allow. They help reduce the force of waves and currents by absorbing and weakening the energy of wave action. Riprap adjusts easily to settlement along the slope, and repairs are fairly simple—just add more rocks. The rocks must vary in size, with large ones lower down to absorb energy and smaller ones higher up.

Many homeowners along Siletz Spit have used riprap since 1970 to protect the beach slopes where their homes are built. A spit is a narrow finger of land extending from the shore, commonly (not always) in the direction of the littoral drift (figure 2). The littoral drift moves sand along the coast and helps to build the spit.

Spits are unstable because of seasonal changes in littoral drift and vulnerability to storm waves. Historically, Siletz Spit has been subject to varying cycles of erosion and buildup.

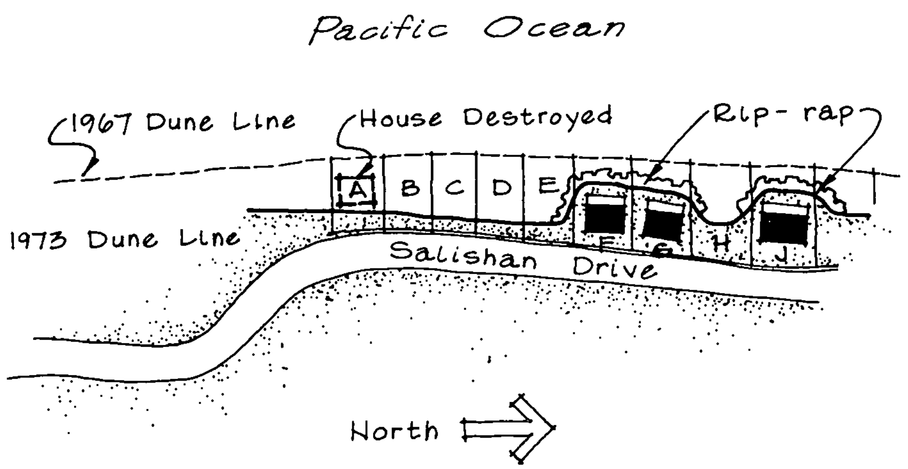

Figure 8.—*From 1971 to 1973 Siletz Spit eroded considerably. The change became noticeable because the spit was being developed. In 1972 homes were built or being built on lots A, F, G, and J. The dashed line shows the approximate location of the foredune in 1967. Storms during the winter of 1972-1973 moved the foredune line eastward, tumbled the home on lot A into the ocean, and scoured away sand where lots B, C, D, and E had been laid out. The homes on lots F, G, and J were saved, at least temporarily, by riprapping the retreating foredune. (Figure 1 shows a later view of these same lots.)*

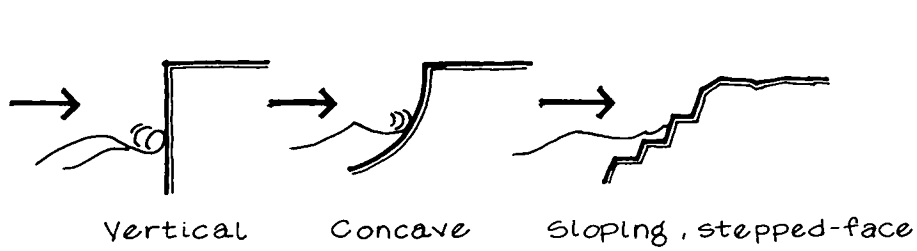

Figure 9.—*Property owners often resort to building seawalls to thwart the natural forces along the coast. Vertical walls reflect much of the energy of incoming waves. Sloped seawalls redirect and spread wave energy. All seawalls have to be built of enduring materials to withstand the erosive force of ocean waves.*

During the winter of 1972-1973, homeowners feared a breach in the middle of Siletz Spit. One partially constructed house was lost, and riprap was placed in front of three others. Wave action cut deeply around the sides of the riprap and into the adjacent foredune (closest to shoreline) and vacant lots. The riprap had to be extended around three sides of the homes. The dune retreated 30 meters in three weeks, leaving the houses on a promontory that juts into the surf (figure 8).

Wave action in front of riprap frequently erodes (scours) the beach material at the riprap base, weakening its support. More large rocks buried at the base is the only answer! Some riprap in front of the Siletz Spit homes that were most severely threatened in 1972-1973 has since fallen away because of this powerful water action, faulty riprap construction, and the use of rocks too small to be effective. Some homeowners have spent as much as $15,000 on riprap and face additional expense to continue preserving their homes.

Why did such a marked erosion occur so suddenly? During the three weeks of severest erosion, large storm waves (6 meters and higher) combined with high tides to produce wave action that reached farther landward than usual. Rip currents also played a role in the erosion; one persistent rip current developed and remained most of the winter just in front of lots A to E (figure 8). The rip hollowed out a section of beach there and allowed the storm waves to attack still farther up the slope.

A final factor, mining of sand just south of the spit, had removed between 112,000 and 196,000 cubic meters of sand between 1965 and 1971, depriving the spit of a small source of sand normally brought to it by northward longshore currents. This probably worsened the erosion.

Erosion also occurred on Siletz Spit during the winters of 1974 and 1978, threatening other homes and requiring more riprap.

Seawall. The name suggests its purpose—to retain the upper beach and present a steep, clifflike face to reflect the onrushing waves. Seawalls are usually made of concrete and are tall and thick (about 3 meters thick). Their height and thickness depend on wave conditions, the topography—and the homeowner's willingness to spend money.

Only the land immediately behind a seawall is protected. Frequently, homeowners next to unprotected lots are forced to extend wing walls along the sides of their property. Seawalls last much longer than riprap, but they are more expensive and need careful planning (studying the seawalls others have built is a good way to start).

There is no easy answer to the best type of seawall for a given lot. The vertical type is possibly the easiest and cheapest to construct, but wave energy is deflected downward and concentrated at the foot of the wall, scouring the beach material in front. A seawall with a concave face prevents waves from overtopping the seawall, but this shape increases scour by deflecting water back down to the foot of the wall. A sloping, stepped-face seawall reduces scour by allowing water to run up the face, but it increases the chances of overtopping (and is the most difficult type to construct). See figure 9.

The effectiveness of a seawall was evident during the storms of December 2-3, 1967, when Cannon Beach sustained $125,000 in damages to three motels and ten stores. Although waves broke over the seawalls, their progress was slowed. Moreover, their principal entry point into town was at the beach end of Third Street, where there was no seawall. A seawall stands there today!

Dike. Oregon's example of this special kind of seawall was built in 1956 to close a breach that had opened in the Bayocean Spit near Tillamook four years before (figures 10 and 11). Costing $1.7 million, the dike is a rock and sand fill 2.2 kilometers long, connecting Pitcher Point with the township of Bayocean. It stands 6 meters above mean lower low water (see the Swanson title under "Suggested reading"). The dike was placed back from the previous shoreline, in the hope that the setback would fill in with sand and form a protective beach in front of the dike. Beach and dike have succeeded in preventing overwashing and breaching of the spit.

Figure 10.—*In 1952 ocean waves cut through Bayocean Spit near Tillamook. This aerial view, taken in 1955, shows the breach. The remaining land at the bottom is Pitcher Point.*

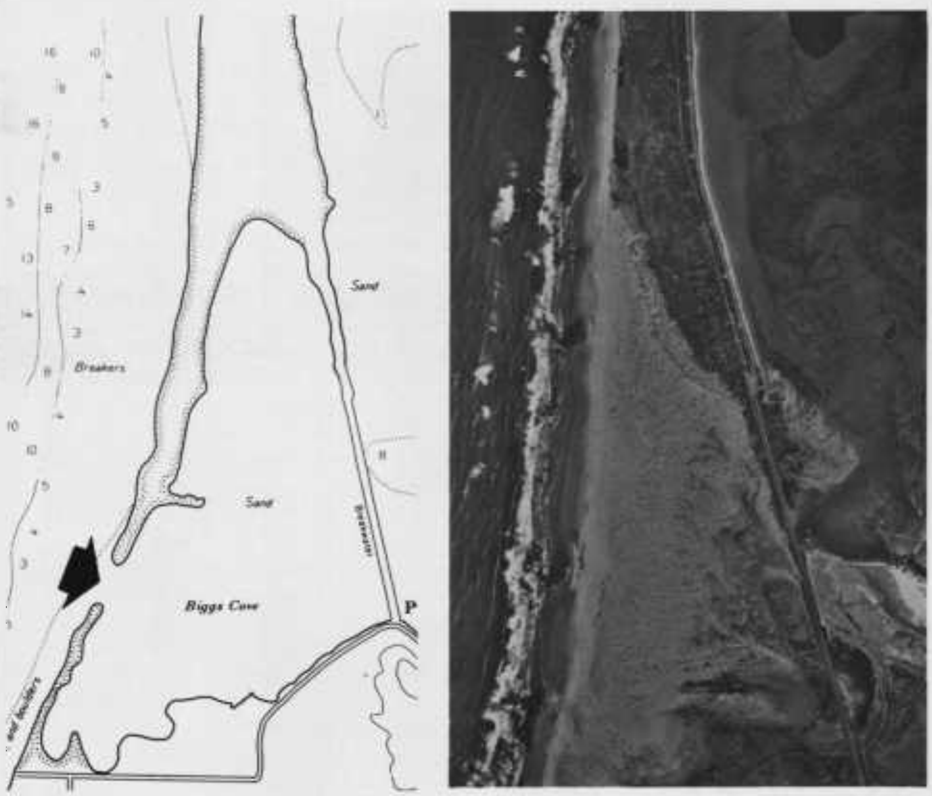

Figure 11.—*In 1956 a dike was completed between Pitcher Point and Bayocean township. The map and aerial photo show where the breach occurred and illustrate how the dike has altered the natural erosion patterns. The arrow on the map shows the breach; see figure 10. Note how sand has built up seaward of the dike in the region where the breach happened. (The map is reproduced from chart C&GS 6112/NOS 18162.)*

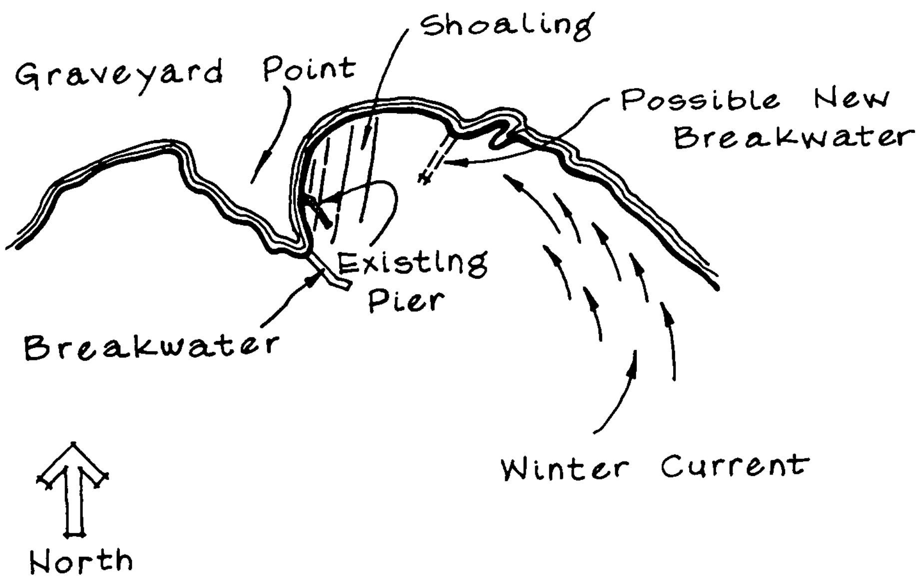

Figure 12.—*Port Orford, Oregon, is a harbor with a problem. A breakwater, constructed to give more protection to the harbor, has interfered with littoral drift. Sand builds up quickly in the quiet waters of the harbor, and the port needs frequent dredging now to maintain usable water depths.*

Breakwater. More massive than either seawall or riprap is the breakwater, an artificial wave barrier protecting a shoreline, harbor, or anchorage from wave action. Breakwaters can extend from land (most do), stand completely away from land, or even float freely.

Fixed breakwaters are generally made of rubble (stones in mixed sizes) with a concrete cap—though Oregon's only example, at Port Orford, has no cap. These breakwaters absorb the impact of incoming waves and stand between these waves and the quiet waters behind them.

Floating breakwaters are very much in the experimental stage. They can be anchored structures of rubber tires, log booms, structural steel—even kelp beds. Unlike breakwaters that extend from land, they permit normal sand movement to continue, but they offer harbors protection from wave and swell action.

A community needs careful planning and expert advice before undertaking any type of breakwater. They are constantly battered by waves; positioning, construction, and followup repairs are difficult.

But even careful planning and expert advice are sometimes not enough to offset the power of the sea, as is the case at Port Orford. Though the natural cove there provides protection against summer waves from the northwest, winter waves from the south continually pound the town's pier inside the cove. These waves washed away the first breakwater.

The town added some 167 meters to the length when they rebuilt the breakwater in 1968; the extension stands more than 6 meters above mean lower low water and is almost 8 meters wide at the top. Then Port Orford faced another problem. When a breakwater extends out from land, it sometimes interrupts longshore and scouring currents, and sand accumulates in the quiet waters behind. This happened here. Since 1970, this buildup of sand has required constant dredging of the cove—at costs of more than $20,000 a year.

The Army Corps of Engineers believes that winter currents still move sand into the cove but that the breakwater cuts off summer's scouring currents from the northwest. The Corps is studying the practicality of constructing another breakwater, on the opposite side of the cove, which would literally surround the port with breakwaters. The harbor now becomes almost useless in winter, waiting for the dredging to resume each spring (see figure 12).

Jetties. These are the most visible human interaction with coastal processes. Jetties are found at a number of river mouths. They are designed to keep the channel free-flowing, by confining the tidal flow to a narrow zone and by keeping the littoral sand transport out of the channel. They also protect the channel from wave action and cross currents (as breakwaters also do).

Jetties in Oregon are generally built of rubble, in massive proportions. The south jetty at Tillamook involved 1.58 million metric tons of stone and cost $11.35 million. Exposure to rough seas makes repairs quite difficult.

It is crucial that each pair of jetties be properly spaced to maintain the needed tidal flow through the channel. Winds, wave direction, tides, sedimentation, and the desired channel size are the important factors in jetty design and construction.

After completion of the Tillamook north jetty in 1917, sand built up significantly on the north side (762 meters seaward in three years). This happened because the littoral drift had been interrupted (see figure 13). The sand trapped by the jetty would normally have been supplied to the Bayocean Spit with each summer's southward drift. Without this sand, the spit was badly eroded—slowly in the early years, more swiftly after the lengthening of the north jetty in 1932-1933. This extension virtually doomed the spit's resort town of Bayocean Park.

Finally, on November 13, 1952, storm waves and high tides tore a breach more than a kilometer long on the spit's narrow southern section.

Sand was also trapped *south* of the north jetty. When winter brought its northward shift in longshore currents, sand began accumulating in the channel itself.

In 1974, Tillamook's south jetty was completed, about 2 kilometers long. It formed a pocket with the inwardly curving spit, and sand built up here as the shoreline attained a new equilibrium. As sand has been trapped south of the south jetty, shoaling in the channel and erosion to the spit have both decreased.

Figure 13.—*For many years the entrance to Tillamook Bay was protected by a single jetty, on the north side of the channel. This jetty, in the upper left of this 1939 aerial photo, interrupted the littoral drift, accumulating sand to the north. Note also the rough water on the bar and to the south of the channel, with the single jetty installed.*

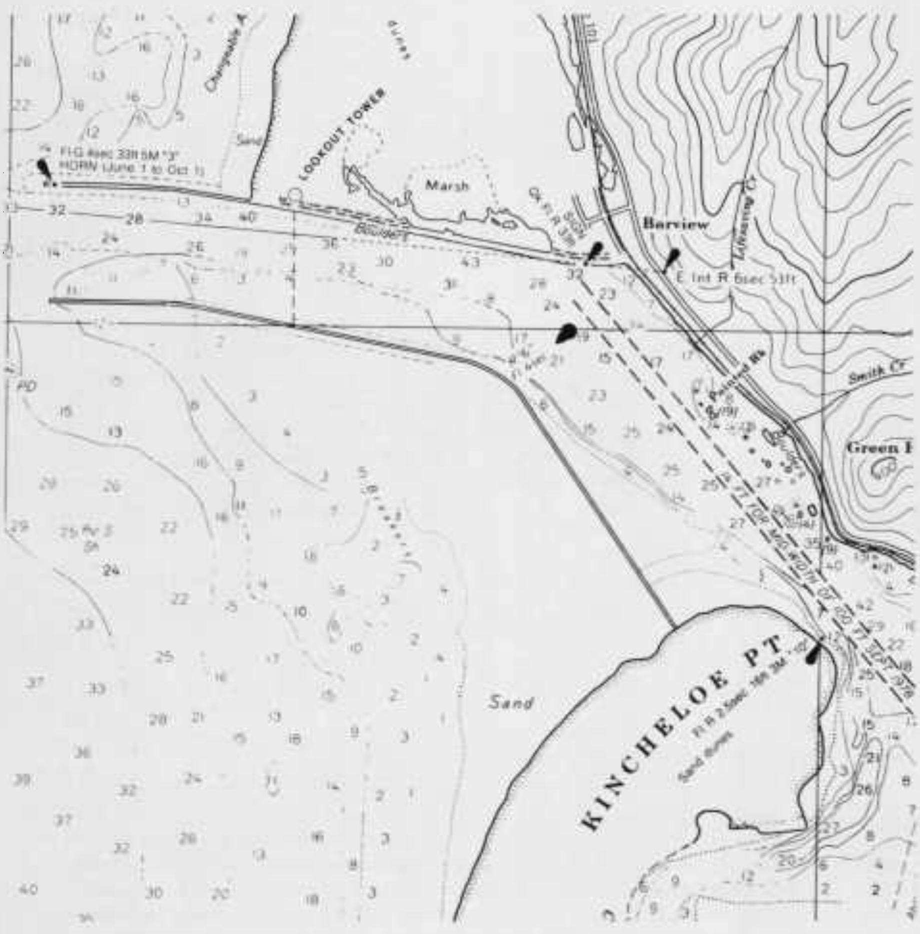

Figure 14.—*In 1979 a second jetty was completed on the south side of the entrance to Tillamook Bay. In addition to affording better protection from waves at the entrance to the bay, it has captured sand on its south side, slowed the rate of shoaling in the channel, and helped reduce erosion to the sand spit to the south. This map has been adapted from the most recent NOAA chart.*

So what have we learned?

An extension to bring the south jetty to the same length as the north jetty was completed in 1979 (see figure 14).

Does some of this begin to sound like "You can't fool with Mother Nature!"? Perhaps it should. Probably since as far back as ancient Egypt, town councils have stayed up nights worrying over sand buildup behind jetties or breakwaters, paid out money for expert advice, paid out much more money for repairs—and then still more for more advice.

Perhaps by now we have learned *why* certain things happen when people try to obstruct a natural process—most of the time, anyway. Can we do better?

People will always want to live, work, and play along our attractive Oregon coast. If they really try to understand, and develop a respect for, the physical and geological processes that constantly shape and reshape this coast, maybe they can make better decisions about altering these processes.

The experiences at Siletz and Bayocean Spits illustrate the impact of those ocean processes on coastal development—as well as the limited options available for coping with problems this impact causes.

The "eternal sea"? Well, in a limited sense, perhaps that idea has some use. But eternal coastline? Never. Only when we appreciate that it *does* change, that it always *has* changed and always *will* change, that erosion *will* come, that jetties or breakwaters or seawalls *do* have effects, sometimes unpredictable ones . . . perhaps then we will be ready to play a truly responsible role in "shaping" that coastline—for ourselves and those who come after us.

Suggested reading

Bascom, Willard, *Waves and Beaches: The Dynamics of the Ocean Surface* (Garden City, N. Y.: Doubleday, 1964 [Anchor paperback, Science Study Series S34]).

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Lizarraga-Arciniega, J. R., and Paul D. Komar, *Shoreline Changes Due to Jetty Construction on the Oregon Coast*, Oregon State University, Sea Grant College Program Publication, ORESU-T-75-004 (Corvallis, 1975). *Out of print.*

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Terich, Thomas, and Paul D. Komar, *Bayocean Spit, Oregon: History of Development and Erosional Destruction*, Oregon State University, Sea Grant College Program Publication ORESU-R-74-027 (Corvallis, 1974).

Van Vliet, Antone C., and Alexis J. Panshin, *Identifying Oregon Driftwood*, Oregon State University Extension Service, Sea Grant Marine Advisory Program, Extension Manual 2 (Corvallis, 1976).

Appendix—Metric/English conversion factors (approximate) for the units cited in this bulletin

To convert	to	multiply by
meters	feet	3.28
feet	meters	0.30
kilometers	miles	0.62
miles	kilometers	1.61
metric tons	tons (2000-lb.)	1.10
tons (2000-lb.)	metric tons	0.91

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