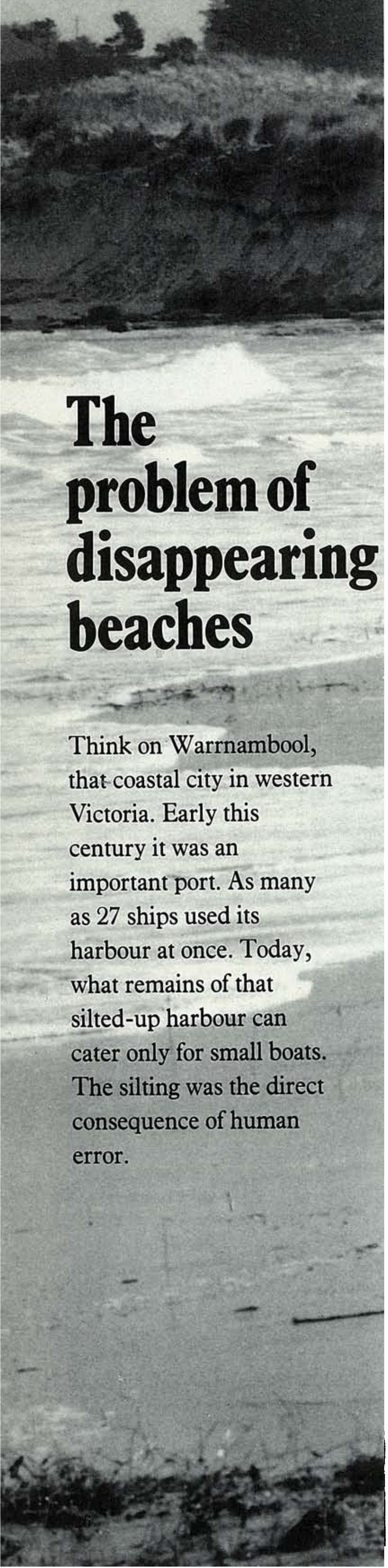


The problem of disappearing beaches

Think on Warrnambool, that coastal city in western Victoria. Early this century it was an important port. As many as 27 ships used its harbour at once. Today, what remains of that silted-up harbour can cater only for small boats. The silting was the direct consequence of human error.

Further along the coast at Portland they're having another problem. There the harbour isn't silting, but unfortunately the harbour works have caused the nearby holiday beaches to erode away. And it's not only the holiday beaches that are eroding. Blocks of land along the shoreline have vanished, leaving poles that once lined the bores used for pumping up fresh water sticking up out of what is now the beach. Some even jut out of the surf.

These two situations and others such as the well-known beach erosion problems at Surfers Paradise are not acts of God. They are monuments to our own ignorance about the forces of nature that act along our coasts. It would be far too glib to suggest that these mistakes were avoidable. They probably weren't. Much more knowledge would have been needed at the time to have avoided them.

By the 1960s one may think we had enough knowledge. But when Portland harbour was built early in the 1960s CSIRO carried out a thorough investigation into sand drift along the local coast to make sure the new harbour would not fill in. It didn't, but nobody stopped to wonder what erosion the harbour structure itself might cause. The people of Portland gained a port and lost their beaches. Today many tourists who used to holiday at Portland go to nearby Port Fairy instead.

Erosion going on along western Victoria's coast has been of particular interest to Mr Edmund Gill, now of the CSIRO Division of Applied Geomechanics and formerly Assistant Director of the National Museum of Victoria. For some years he has been investigating where the sand on western Victoria's beaches comes from, at what rate it is produced, and where it goes. In addition he has been gaining a perspective on how we should expect the shoreline to behave. He has been doing this by looking into how the existing beaches formed once the sea rose to its present level 6000 years ago.

Professor Bruce Thom, now of the Royal Military College, Duntroon, Dr John Chappell of the Department of Geography at the Australian National University, and Dr Don Wright of the Geography Department at the University of Sydney are also carrying out somewhat similar research on the coast of New South Wales.

Australia's coasts different

Coastal marine science grew up in Europe and North America, where most of the coastal erosion by the sea is caused by the pounding of the waves during storms. The situation around the coast of Australia (and New Zealand) is different. Australia abuts onto the Southern Ocean, which, unlike the seas in the equivalent northern latitudes, contains no large land masses that subdivide it. Thus the westerly winds blowing over this ocean have an unlimited reach as they circle around the globe. As a result the Southern Ocean absorbs much more energy than any other, and the big swells beloved by our surfies are a manifestation of that energy.

Rocky shore near Warrnambool. Sand forms as the rocks erode away.

Henty Bay Estate, east of Portland, Vic. These pipes once lined bores for pumping up fresh water onto blocks of land located along the shoreline.

While the coasts of Europe and America may be pounded from time to time by big seas whipped up by storms, Australia's coasts receive a much more continuous scouring from the Southern Ocean's swells.

In addition, western Europe in particular experiences large tides — the intertidal zone at Morecombe Bay in the United Kingdom, for example, is a beach 5 km wide, and people have lost their lives because they couldn't keep up with the incoming tide. The 0·91-metre range of the spring tides at Warrnambool is small indeed in comparison. Those large European tides do much to lessen the effects of the pounding waves even during the fiercest storms, since the waves will only be eroding the coastal rocks with their full force for a relatively short period around high tide.

As may be expected, coastal erosion under the influence of the near-continuous Southern Ocean swells is generally much faster around the southern Australian coast than around those of Europe or America. European and North American solutions to coastal engineering problems do not necessarily apply here. If in future we're going to avoid mistakes like those made at Warrnambool, Portland, or Surfers Paradise, we must build up a sizeable amount of local knowledge.

People building too close to the water's edge do so at their peril.

Some years ago a statement appeared in the 'Warrnambool Standard' saying that the local fishermen could not understand why the Public Works Department was convinced that the drift in the local bay was from west to east. They knew it was in the opposite direction. Obviously, it's essential to know something as elementary as the direction of drift before any works to mitigate erosion can be undertaken.

As it happened both protagonists in this particular argument were right. Drifts from two directions occur along the coast of southern Victoria — an easterly one that rolls in mainly during summer, and a westerly one that comes in during the rest of the year. The local fishing boats spend most of their time at sea during summer, thus avoiding the rough waters of winter.

Where the sand comes from. . .

Having established which way the drift goes, the coastal manager needs to know where the sand is coming from, where it's going, and in what volume.

Being a continent that is old, dry, and flat, Australia has few rivers, and most of those it does have are usually slow-moving and so do not bring down much silt. Thus, in some areas, river sediment, a common source of coastal sand in many other parts of the world, contributes little to our beaches. Instead, these beach sands come mainly from two sources — the shells of marine shellfish, and erosion of coastal rocks. According to Mr Gill's estimates, about 10% of the sand on western Victoria's beaches comes from shells. The rest comes from the erosion of coastal rocks and old sand dunes.

By using a combination of measuring the actual erosion taking place on exposed rock faces along the coast and subjecting the same rocks to various tests in the laboratory, Mr Gill has been able to estimate just how much sand is being produced by erosion. He has also been able to estimate confidently how rapidly different parts of the coast are retreating.

Most surprising, perhaps, are the remarkable variations in the rates at which different rocks along the coast erode. Consequently, various parts of the coast erode at very different rates — a fact that has considerable importance when deciding, for instance, where to site a coastal road. These erosion rates can be predicted. Mr Gill found that the softest local sandstone erodes at about 4 cm a year, while the hardest basalt doesn't perceptibly erode at all.

An erosion rate of 4 cm a year may not seem great, but the fact that the cliff face made of a particular sandstone will retreat one metre every 25 years would make a considerable difference to (say) the design of a sewer outfall. Indeed, the sewage outlet for Warrnambool, which was constructed during the 1930s, has had to be replaced because of the land's retreat.

Each centimetre of erosion along a kilometre or more of cliff face represents a great deal of new sand. Thus, Mr Gill has calculated, the coast near Warrnambool has produced about 3000 cubic metres of sand from each metre of coastline since the melting of the northern ice cap at the end of the last ice age raised the sea to its present level.

European and North American solutions to coastal engineering problems do not necessarily apply here.

. . . and where it goes

Where does all this sand go? A quick look at headlands such as Cape Reamur just west of Port Fairy reveals large sand accumulations, particularly on the western side. Sand carried along by the eastward drift (powered by the south-westerly winds) has piled up high. The lesser westerly drift of summer has produced a smaller accumulation of sand on the eastern side. It seems that all the sand reaching Cape Reamur from the west becomes trapped on the Cape, so none progresses further eastwards.

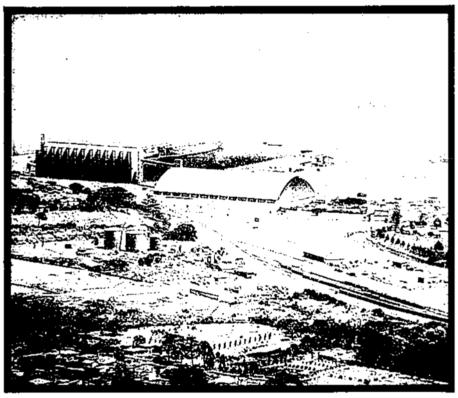
This is proved by the fact that the piled-up sand on the western side is light brown and derived from cliffs to the west, while the sand on the eastern side is white, derived from modern sea shells.

Not even basalt sea walls prevent erosion of the beaches round Portland Bay. Here the sea has eaten out the dune behind the wall.

Rapid erosion of the beach-front at Henty Bay.

Mr Gill calculates that about 30·3 million cubic metres of sand have accumulated on the western side of Cape Reamur since the sea reached its present level. This has come from 9·75 km of coast to the west, so about 3100 cubic metres of sand have been produced from each metre of that coast during the last 6000 years — a result that agrees remarkably closely with the calculations of sand production from the coast nearer to Warrnambool.

Can we be certain, though, that much of the sand accumulating on the headlands isn't rather older? In the past other researchers suggested that as its level rose,



Portland harbour's breakwater. Building this caused the local beaches to vanish.

Warrnambool harbour: once a thriving port, only boating enthusiasts can now use its shallow waters.

Remorseless pounding of the Southern Ocean's swells erodes these cliffs near Warrnambool to create the sand that lines western Victoria's beaches.

the sea swept up the existing dunes with it. If this is true, then the bulk of the sand piled up will give a false impression of the rate at which the sand accumulated.

By drilling down to the base of the sand at suitable places along the coast, Mr Gill was able to take core samples. Finding the age of each sample was then a simple matter of extracting sea-shell fragments from each and radiocarbon-dating them. The sea-shell component dated back to not more than 6000 years.

Discovery that such huge volumes of sand move along western Victoria's coast could have immense implications. For example, does a vast amount of sand move along the coast, round Cape Otway, and proceed towards Port Phillip Bay and Westernport — thus contributing to sanding problems in these important harbours? Happily, Mr Gill has been able to check this possibility and has found that it does not. Instead, the sand is filling in coastal estuaries to the west before finally becoming trapped on Cape Otway.

Nevertheless, it's worth bearing in mind that large sand deposits have accumulated on West Head at the entrance to Westernport Bay. This must have built up during the last six millennia as a result of erosion of the coast to the west. In time this sand may fill the entrance, but just how long this will take nobody knows. Finding out, Mr Gill points out, would not be difficult.

Eastern beaches studied

While Mr Gill has concentrated on studying rock weathering and sand transport along the Victorian coast, Dr Chappell, Professor Thom, and Dr Wright have been cooperating in a joint study that is investigating in detail the actual day-to-day processes going on at the beach-front along the New South Wales coast. The disastrous eating away of the sea-front at Surfers Paradise just over the border, some Sydney urban beaches, and elsewhere in recent years has happened without man-made structures like wharves located up-current obstructing sand movement. The studies these scientists have made of the movements of beach systems undisturbed by human activity illustrate very clearly why.

Beaches are in a constant state of movement, yet they remain roughly fixed in their locations — in other words they are in a state of dynamic equilibrium. The actual shape of the water-line at any particular moment is the result of a combination of natural forces acting on the sand. As in Victoria, the ocean beaches of New South Wales are almost continuously subjected to swells generated by the strong winds of the Southern Ocean (although these beaches are protected from the south-westerly

Portland's beaches — what can be done?

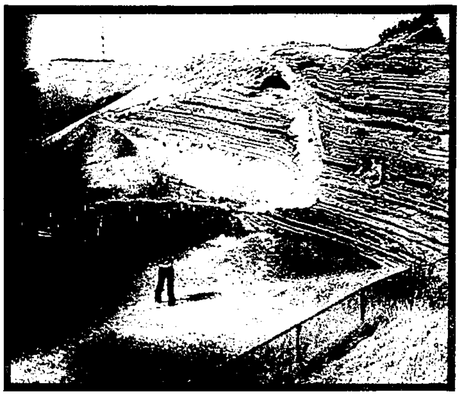
What were once popular beaches to the east of Portland are now a sad sight. In places pipes sticking up in the sand mark the sites of what 10 years ago were 80 blocks of land along the shoreline. Elsewhere, basalt rocks piled along the sea front form sea walls that are slowing down the sea's advance but are not entirely effective. Is there anything that the local authorities can do?

To begin with, Mr Gill points out, even if the people of Portland decided to forgo their thriving port and remove the wharfs that caused the trouble, the beaches would not re-form. The fact is that Portland is in a rather unusual location for that particular coast, and no sand is flowing across the town's local beaches from further along the coast. Sand coming on the westerly drift is cut off by nearby Cape Nelson, while that coming from the east in summer is also cut off — by a lava flow that juts out into Portland Bay a few kilometres to the east to form Julia Reef.

People have suggested that putting in groynes should halt the erosion, but, says Mr Gill, it won't. Groynes (walls built down the beach at right angles to the waterfront) let sand accumulate on one side as it is swept onto them by currents passing along the shore, but unfortunately they cause sand to erode away on their downstream side. (The new Portland harbour has itself acted as a groyne and caused the erosion of the beaches on its downstream side to the east.) The groynes can't accumulate sand where there's no sand to accumulate.

The local authority, Mr Gill thinks, has two options, or rather, Hobson's choice. It can accept that the shoreline equilibrium has been upset and let the sea find its new rightful position, or it can try to construct effective sea walls.

The first option would be difficult politically, since it means allowing more coastal land to wash away. Presumably, therefore, the local authority would have to buy back from its present owners the land that would disappear. Mr Gill thinks that it is possible to predict where the new shoreline would be, so presumably it would be advisable to



Tower Hill crater near Warrnambool erupted about 7300 years ago and lava flowing from it inundated the nearby coastline. This feature has provided an excellent fixed historical point for studies of recent processes along the coastline.

Rocks forming a sea wall at Surfers Paradise have proved no substitute for the original foredunes.

Many years ago fishermen carved this inscription on the cliff wall at St Bees on Britain's Cumbrian coast while waiting for the tide to come in. Britain's big tides reduce the amount of time that the sea's waves pound the cliffs.

swells). On top of the swells are superimposed high-energy wind waves that local storms generate from time to time. During some summers, tropical cyclones move down the coast and create havoc on the beaches by generating very high seas. Beach and dune erosion results.

No more sand

Background studies by Professor Thom of how and when the eastern coast beaches were formed once the sea rose to its present level show that no new sand is being added to these beaches, so the situation differs from the western Victorian one. Radiocarbon-dated shells show that most of the beaches were constructed between 6000 and 3500 years ago. After that, production and accumulation of sand tailed off almost to nothing. Today, in fact, beaches and foredunes seem to be slowly retreating, and studies of old maps of Queensland and New South Wales have indicated a retreat of as much as one metre per year. If nothing else, such a retreat indicates that there's no new sand being deposited on the beaches, and any sand loss caused by human error isn't likely to be made up.

Natural movement of the beach alignment back and forth within the limits of its dynamic equilibrium is usually seasonal. Normally, beaches are constructed mainly in autumn as sand moves onshore under the influence of low-energy swells. This period, when the beaches grow 'up and out', may go on into winter, since the prevailing westerlies blow as offshore winds.

What happens in winter depends very much on the year. During some years, the beaches may continue to grow because of the prevailing offshore winds. During others, like 1974, low-pressure cells developing in the Tasman Sea produced strong onshore winds and large waves. Then the beaches retreat. If sustained long enough, these storms may raise the sea level as a 'surge'. This is when disastrous erosion of urban beaches usually occurs.

The people of Portland gained a port and lost their beaches.

Each season thus brings its own particular wave regimes. The long-term studies of the cooperating research workers at Moruya and elsewhere have shown that the beach's response pattern can be classified according to the six different types described in the box. Thus the form of the beach after particular weather conditions can be predicted.

The form that interests planners most is,

buy up enough land to allow for the sea's encroachment plus a little more to provide a margin for error.

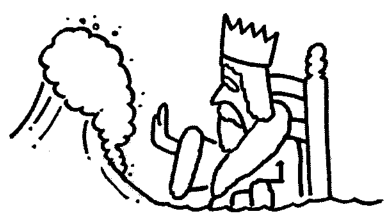
Building sea walls is an expensive and frustrating business — the sea always succeeds in breaking them down sooner or later. However, Mr Gill points out, the shoreline is not the place to build them. The point of a sea wall is to keep the sea's energy off the shoreline where it does the damage. Mr Gill thinks that at Portland, and probably elsewhere, sea walls should be built some distance offshore, and that they should remain totally submerged.

Waves, of course, are not only restricted to the sea's surface. A large swell moves water down to a considerable depth. Thus an underwater sea wall can modify the amount of marine energy reaching the shore. And it would not be unsightly.

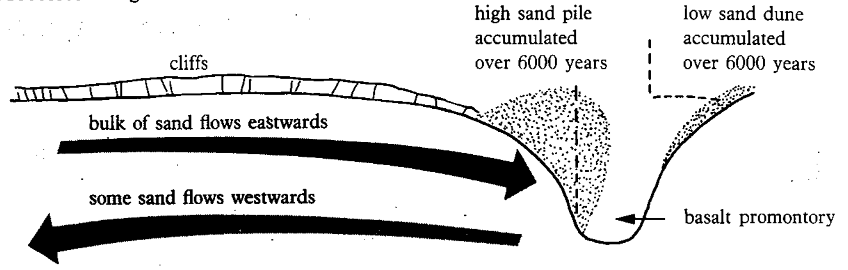
The advantage of underwater sea walls is that they will be less vulnerable than walls along the shoreline. It's the force of the breaking waves smashing against them that really does the damage. The disadvantage is the cost.

At Portland consultants have already looked into building submarine sea walls offshore, and have come to the conclusion that it would be too expensive. However, Mr Gill claims to have worked out a way of reducing their costs possibly by as much as four-fifths. His solution is simple; building continuous walls beneath the surface is unnecessary. Instead, he calculates, it's possible to obtain almost the same effect by building a series of short ones with gaps between them. Such sea walls have the additional advantage that they do not impede the natural exchange of sand between the sea bed, beach, and dunes.

Portland, Mr Gill thinks, would be an ideal place to test such discontinuous sea walls.



Processes along western Victoria's coastline



Sand moves both ways along western Victoria's coastline. South-westerly swells that usually predominate in winter push large amounts eastwards, while south-easterly summer swells move lesser amounts westwards.

Rates at which various cliffs erode

	mean retreat of cliffs (cm per year)
basalt	0
greywacke	0·9
siltstone	1·8
aeolinite	4

Cliffs along Victoria's coast composed of various types of rock erode at very different rates. Engineers need to take such factors into account.

Discovery that huge volumes of sand move along western Victoria's coast could have immense implications.

of course, the one that occurs during storms. At such times sand from the beach is swept out to sea and deposited on one or more bars several hundred metres out from the shore. Man-made structures thus become exposed to the full force of the waves.

Beach-front yo-yoes

The point to remember is that the actual position of the beach-front can move back and forth across a wide zone, depending on the prevailing weather conditions. As long as sand movement is restricted within this buffer zone, the beach will re-form after stormy weather since the sand will merely have moved a few hundred metres out to sea to form a bar. People restricting the amount of sand available during storms by building on the foredune too close to the water's edge do so at their peril. The whole moving system will be thrown off-balance and the man-made structures take the brunt of the force of the waves.

Once this has happened engineers have three options: to build sea walls along the shore that may have to be repaired again and again, to remove the man-made obstructions and let the sea find its new position of equilibrium, or to construct submerged sea walls offshore that lower the energy in the waves before they reach the shore (see the box 'Portland's Beaches — What can be Done?') Obviously, when siting new buildings or works along the shore, local authorities should take care to ensure that the buffer zone between sea and property is wide enough to allow landward movement of the sea under the most extreme storm conditions that are ever likely to strike.

Ensuring this may sound easy, but at present most authorities lack even the most rudimentary information about the forces to be encountered in waves striking their beaches and the direction from which they will come.

Routine monitoring of wave heights can easily be done using wave-rider buoys permanently moored in position. At present there are only two such buoys along the entire south-eastern coast of Australia. One is located off Cronulla at the southern end of Sydney's suburbs, and the other is off Newcastle. Both are operated by the Maritime Services Board of New South Wales. Mr Gill could obtain no long-term wave-height information for western Victoria.

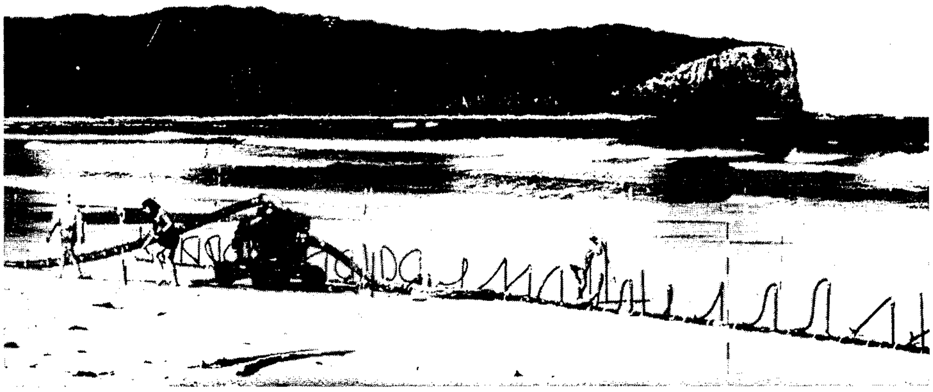
In addition, it should be possible for any coastal engineer to obtain information on the direction of waves over long periods by using 'hind-casting' techniques (the opposite of forecasting ones). With these it's possible to estimate the wave pattern at any time from coastal weather maps. However, computer programs suitable for doing this are not operating in Australia at present.

More about the topic

Quantification of coastal processes as a basis for coastal management and engineering. E. D. Gill. *Proceedings of the Institution of Engineers Fourth Conference on Coastal and Ocean Engineering, 1978*, (in press).

Open beaches: an unstable resource. B. G. Thom. *Australian Parks and Recreation*, 1979 (in press).

All that remains of the sea wall that was built in 1949 at Clarke's Slip a few kilometres east of Lorne, Vic., to protect the Great Ocean Road. Rock fill was stacked as high as the top of the piles.



Staff and students from the Geography Department of the Australian National University study how pumping water out of the beach increases sand deposition at Durras Beach, N.S.W.

The well-known beach erosion problems at Surfers Paradise are not acts of God.

How the weather moulds a beach

Big waves whipped up by storms usually cause beaches to retreat landwards, while gentle swells build them up. Professor Thom, Dr Chappell, and Dr Wright have found that they can classify the ways beaches react to different weather patterns into six types.

Type 1. Storm waves erode sand from a beach and cause it to be deposited on one or more well-developed bars that form between 100 and 400 metres out to sea. The high, short-period waves whipped up by the storm winds create rapid return-flows of water that remove sand from the beach and dune face and deposit it on the bars. The beach becomes flat and narrow. The waves may pile up water inshore giving what's called 'wave set-up', which may allow waves to continue to attack frontal dunes. These are the circumstances when sea fronts wash away.

Type 2. As the storm winds abate, but a heavy swell continues, the bar remains parallel to the beach, but it moves landward and the trough between it and the beach deepens. Waves can thus re-form in the 2–3 metres of water in the trough after first breaking on the bar. If such conditions persist for several months the beach-front grows to produce a low platform, or 'berm', whose face often forms into regular bays.

Type 3. Under slightly lower-energy conditions the waves produce a curved offshore bar, and this bar may even join the beach at certain places. Waves do not re-form after breaking. Instead they continue to the beach as 'swash bores', giving ideal body-surfing conditions. Some landward movement of sand occurs over the bar's surface.

Type 4. Lower-energy conditions still allow well-developed rip channels to develop. Bays form along the beach's seaward edge and rip channels become located opposite the bays. Transverse bars jut out from the 'headlands' between the bays. Swimming in the water off the bays is, of course, very dangerous.

Type 5. Extended periods of westerly offshore or gentle onshore winds produce low wave-energy conditions that can no longer maintain the rip channels. These channels may therefore become completely sealed off to leave holes in the gently shelving inshore beach zone. The beach usually becomes quite high with a well-developed berm (platform).

Type 6. There is one other beach type, but it rarely forms on ocean beaches. It occurs in localities such as inside estuaries or in very sheltered bays where the wave energy persistently remains very low. This beach consists of a wide high berm with a steep face that reflects much of the energy of the waves seaward after they have broken directly onto its face. The face of this type of beach is advancing seaward as sand is swept towards it from inshore flats.

A beach may exhibit several of these six forms along its length at any one time. Over an extended period all six may occur on any given stretch at different times.

The six beach types found along the beaches of New South Wales