Stable Bay Technology

Naturally Stable Beaches

Naturally stable beaches have one common feature, in that each is in the form of a bay between rocky outcrops, or **headlands**. Founded on rock, the headlands themselves are effectively fixed coastal features. However, the beach between them is made up of sand and subject to storm-attack. How then might it be regarded as stable? The key lies in the bay shape. Storms will attack the beach, removing some of its sand in the backwash from the storm waves. This is then deposited as an offshore sand-bar at the mouth of the bay. After the storm abates, milder waves wash over the newly formed bar, picking up the sand and redepositing it onto the beach. If the bar is no further offshore than the headlands at the ends of the bay, all the sand will be returned to the beach somewhere inside the bay, so there will be no net loss of sand from it. The width of beach may fluctuate but the total amount of sand within the bay remains constant.

Naturally stable beach at Rhossili Bay, South Wales, UK

Artificial Stable Bays

Artificial stable bays can be created by artificial headlands, in the same way that natural headlands produce naturally stable bays. If there is not enough drift sediment to create the bays within a reasonable time, then artificial replenishment can be used to good effect. This was applied in 1971 for a 30-km stretch of the Singapore coast. The average length of each headland was 30 metres and mean spacing between them nearly 300 m. This 10:1 ratio of spacing to length was vital for the bays to form, as well as minimising the cost of protecting the whole coastline.

With reference to artificial stable bays, concern has been expressed that downcoast regions could be starved of sediment if the erosion of upcoast regions is stalled altogether. Apart from river-borne sediment discharged into the sea, the only source of natural beach sand is littoral drift from offshore bars, formed from erosion of other beaches. It is essentially a game of robbing Peter to pay Paul. This is why the pioneers of stable-bay technology recommend building the downcoast headlands first. If there is a river mouth or harbour entrance at this downcoast extremity, silting up is likely to be a problem. Capturing sand in a stable bay then serves a dual purpose, as was the case for the beach near an oil refinery in Kwinana, Western Australia. The cooling-water intake flume was repeatedly silted up, until a stable bay scheme was installed to capture the sand. The beach was stabilised and the cooling-water flume for the oil refinery kept free of sand.

Use of headlands to stop erosion on the south coast of Singapore since 1971

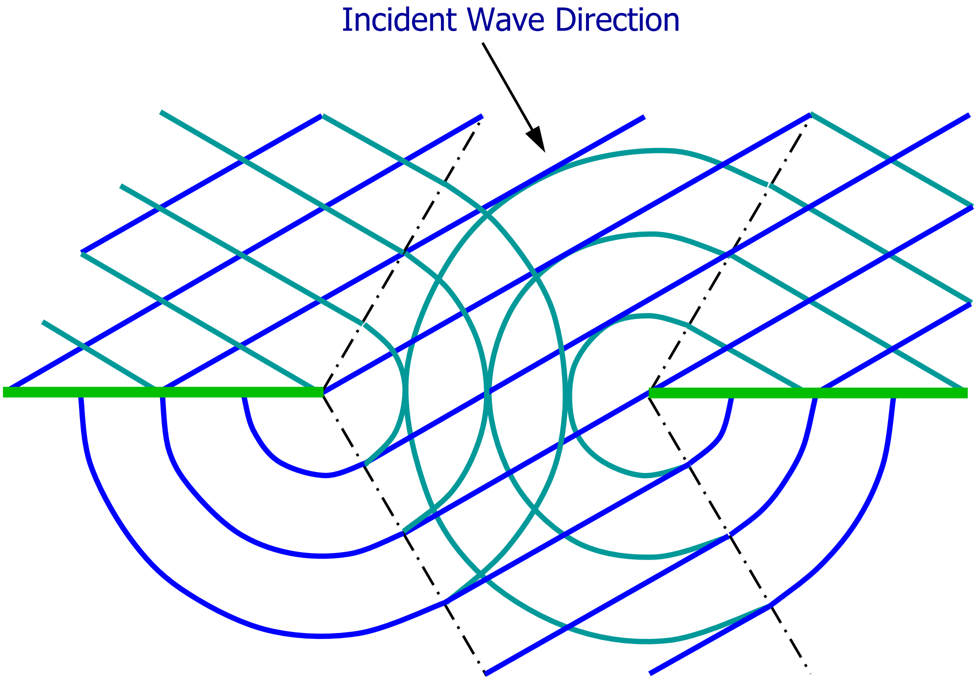
Use of headlands to stop sand incursion into a cooling-water intake since 1981

At Sea Palling in the UK there is a line of breakwaters built in two stages to protect the shore from storm waves while allowing littoral drift to pass. The first phase of four are each about 250 metres long with a similar gap between them. In fact sediment naturally collected behind them and stable bays were formed. This could have been continued further along the coast in a way similar to the Singapore scheme, stabilising a substantial stretch of the Norfolk shoreline. Instead, later breakwaters were installed much closer together, as shown by the five to the right. There is clearly no tombolo or bay formation there. The structures have nevertheless been credited with shielding the coastline from storm waves, whilst allowing littoral drift to pass along their seaward faces. As offshore seawalls, they perform this function well, as long as there is drift from further upcoast. Without this supply, drift sediment for downcoast beaches would be provided at the expense of breakwater foundations, leading to their subsidence and eventual collapse.

Breakwater scheme at Sea Palling, Norfolk, UK

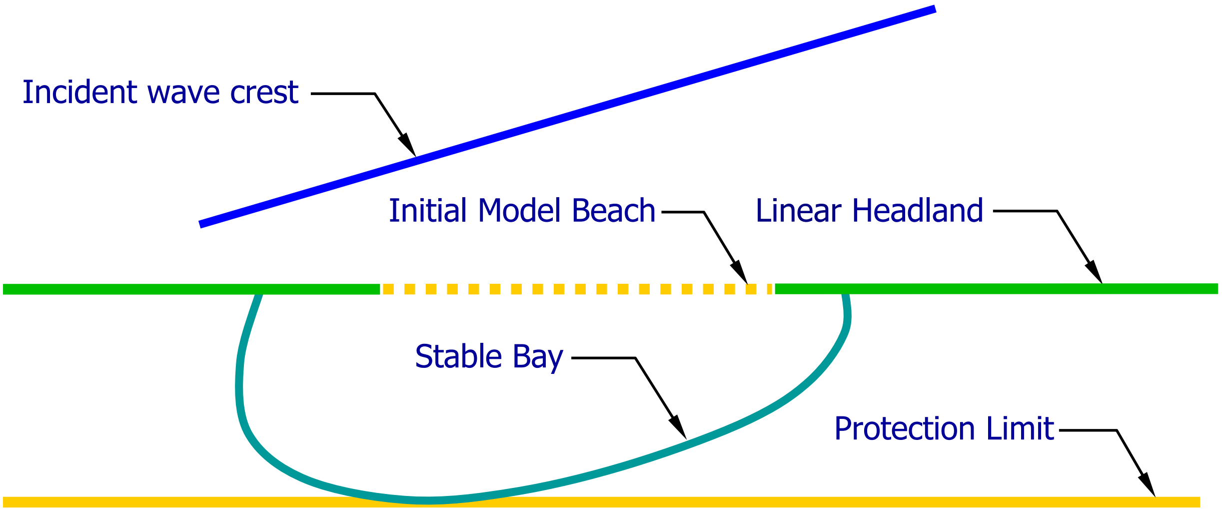
Headland Dynamics

Headland dynamics refers to the way that artificial headlands disturb the wave field and thereby influence sediment transport in their vicinity. The diagram below shows two breakwaters, in line with each other and separated by a smaller gap than we would recommend for a stable bay scheme. The diamond-crested wave pattern on the seaward side is produced by the interaction of incident and reflected waves. It acts like a sediment scouring machine, transporting it along the face of the wall more than twice as efficiently as would be possible with incident waves alone.



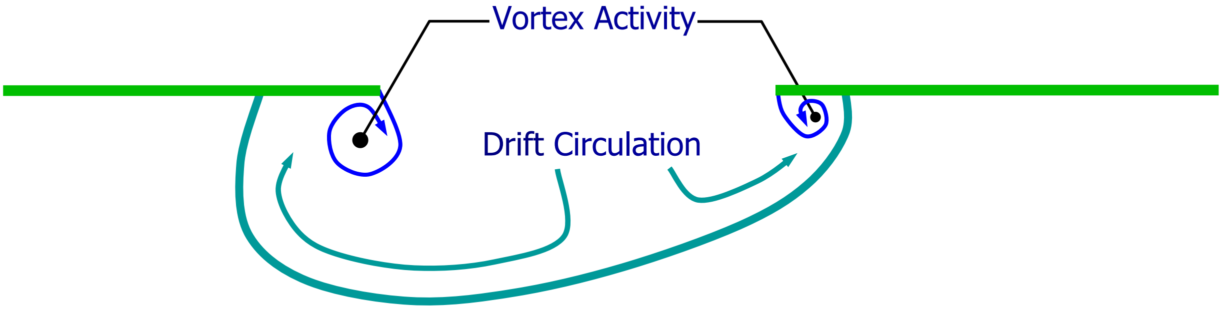
Wave disturbance pattern for linear breakwaters separated by a gap

The circular arcs in the diagram are diffracted waves, a consequence of incident or reflected waves spilling into water that was otherwise sheltered from them. The diffracted waves act like ripples emerging from the ends of the breakwaters. According to the diagram above, they should bring into the gap any sediment transported along the upcoast wall and beyond the end. This sand deposition should begin immediately behind the end, if wave reflection and diffraction were the only processes governing sand transport. As it turns out, they are not, with a more indented shape emerging for stable bays between linear headlands on both laboratory and field scales.



Typical stable bay shape for both model tests and field observations

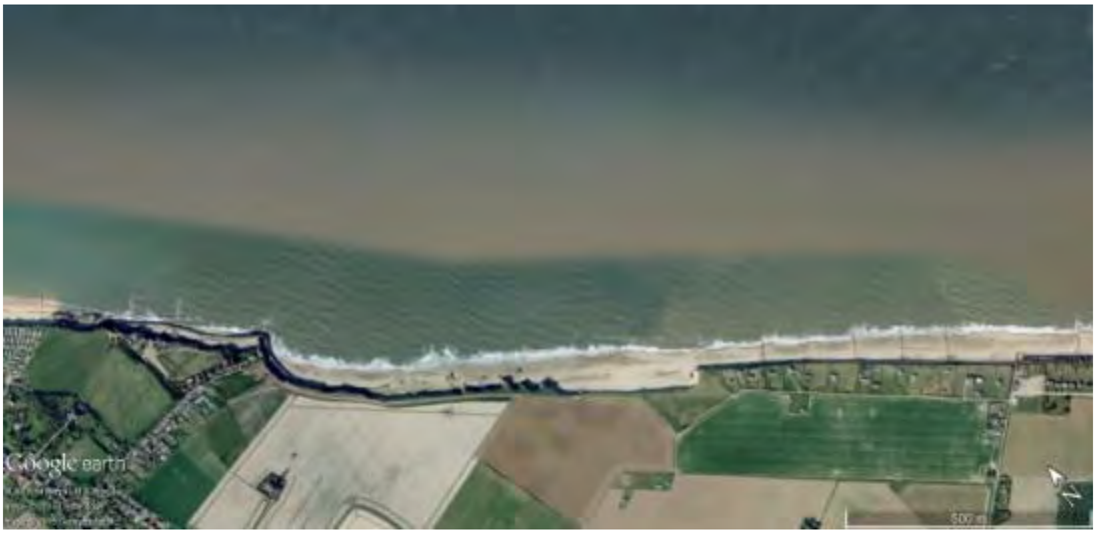
It should be mentioned that the bay shape developed in laboratory tests was produced by *erosion*, rather than accretion. The initial model beach, shown by the dotted line, was eroded into the bay shape indicated. Although erosion could not proceed beyond this curve, it is clear that the model headlands suffered scour on the leeward sides near the ends, leading to a more indented bay than might otherwise have been expected. To explain this, waves reaching the end of the breakwater might not be diffracted at all. Most of the wave energy tends to be fed into vortices, as shown below. In this way, sediment can be maintained in suspension near both ends of the gap. Drift circulation, also illustrated, would tend to sweep sand out of the bay, up to the stable limit.



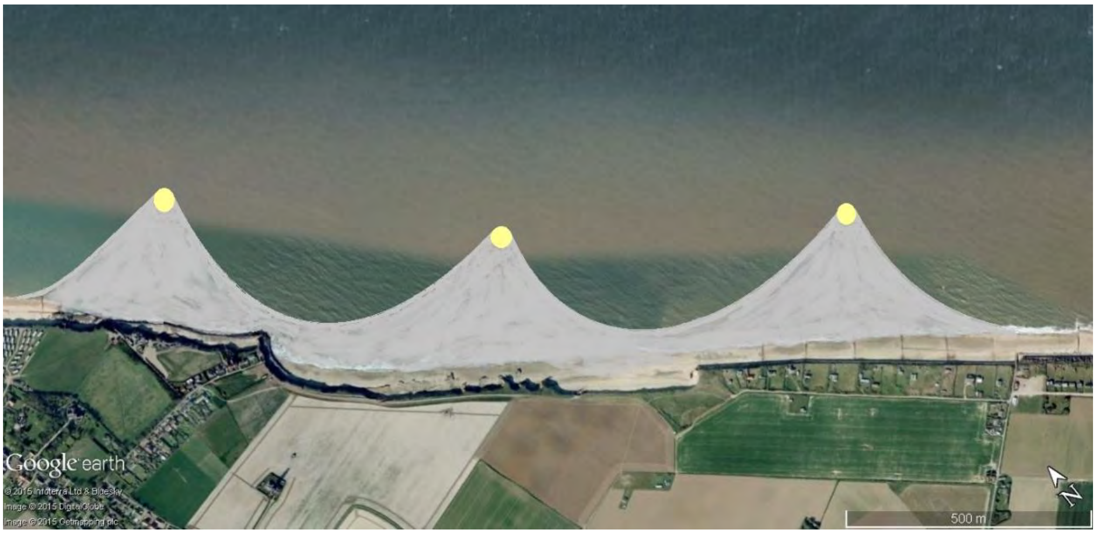
Vortex activity and drift circulation responsible for deep bay indentation

From this brief examination of headland dynamics, alternatives to linear headlands should be considered for artificial stable-bay schemes. The bays may be stable in their own right but could still be let down by the headlands. The seabed is subject to scour over a substantial area on the seaward side of each headland and near to the ends on both sides. If these problems could be solved, there would be an opportunity for reduced bay indentation, which allows for smaller and more widely spaced headlands. This reduces vastly the cost of protecting any length of coast. There is an alternative to linear island walls, which is the Shoreform Stable Bay design concept.

An example of how this concept may be applied to a practical coastal site may be found from a proposal developed for Happisburgh, just north of Sea Palling on the Norfolk (UK) coast. Each bay would take only the amount of sediment that it needs for a buffer against storm activity.



Existing eroding coastline at Happisburgh, Norfolk, UK



Proposed development of stable bays at Happisburgh, Norfolk, UK