Shifting gravel

A case study of Slapton Sands

This case study considers the causes, consequences and management of coastal erosion of a gravel beach-barrier system on the south Devon coast. It will be useful to those studying coastal zone management at AS and A2.

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About 70% of the world's coastline experiences erosion and this presents serious problems for coastal planners and managers. Coastal erosion is usually the result of a number of processes operating at different timescales and a thorough understanding of these processes is necessary when designing coastal management strategies.

Slapton Sands

Slapton Sands is a gravel beach in Start Bay on the south coast of Devon (Figure 1). It is a classic example of a bay barrier and stretches between two small headlands, so that it encloses a freshwater lagoon. The 3.5 km long barrier runs in a more or less south–north direction from Torcross to Strete. At its southern end, the barrier is 80 m wide at high tide and the maximum elevation is 6 m above mean sea level. At its northern end, the barrier is 120 m wide at high tide and the maximum elevation is 8 m above mean sea level (Figure 2).

The freshwater lagoon behind the barrier is called Slapton Ley and is the largest freshwater lake in the southwest of England. It is only 1–2 m deep and is fed by three small rivers. The lagoon drains into the sea via an artificial outlet south of Torcross, but there is also significant seepage through the highly permeable gravel barrier because the water level in the lagoon is almost always higher than the sea level.

The mean tidal range (difference between high and low tide level) in the bay is 4 m and wave conditions are generally modest, with wave heights less than 0.5 m. However, wave height during storms can be greater than 2 m.

In January 2001, a severe storm struck Slapton Sands. The road running along the central section of the barrier was undermined, leading to its collapse. The closure of the road caused severe disruption to local traffic. A 200-m long section of road was later rebuilt 20 m landward of its previous position. There is now real concern about the long-term stability of the gravel barrier. If the barrier were breached during an extreme storm event, not only would the road be lost, but the sea would connect with

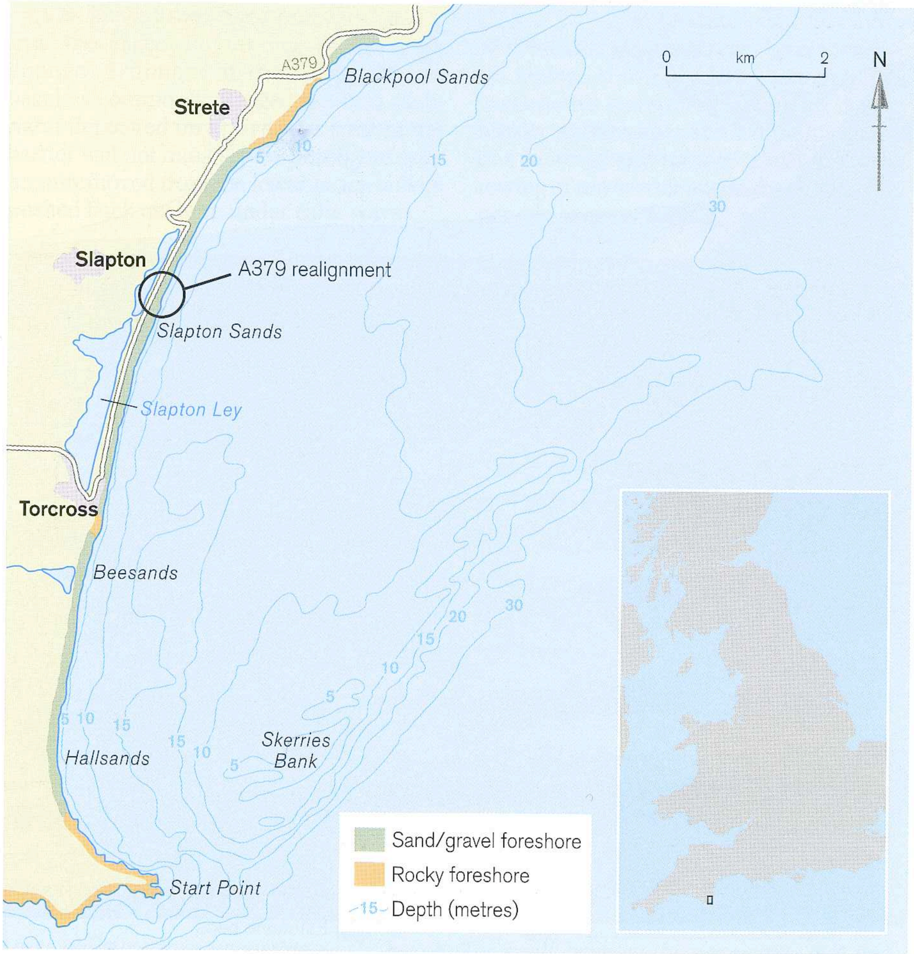
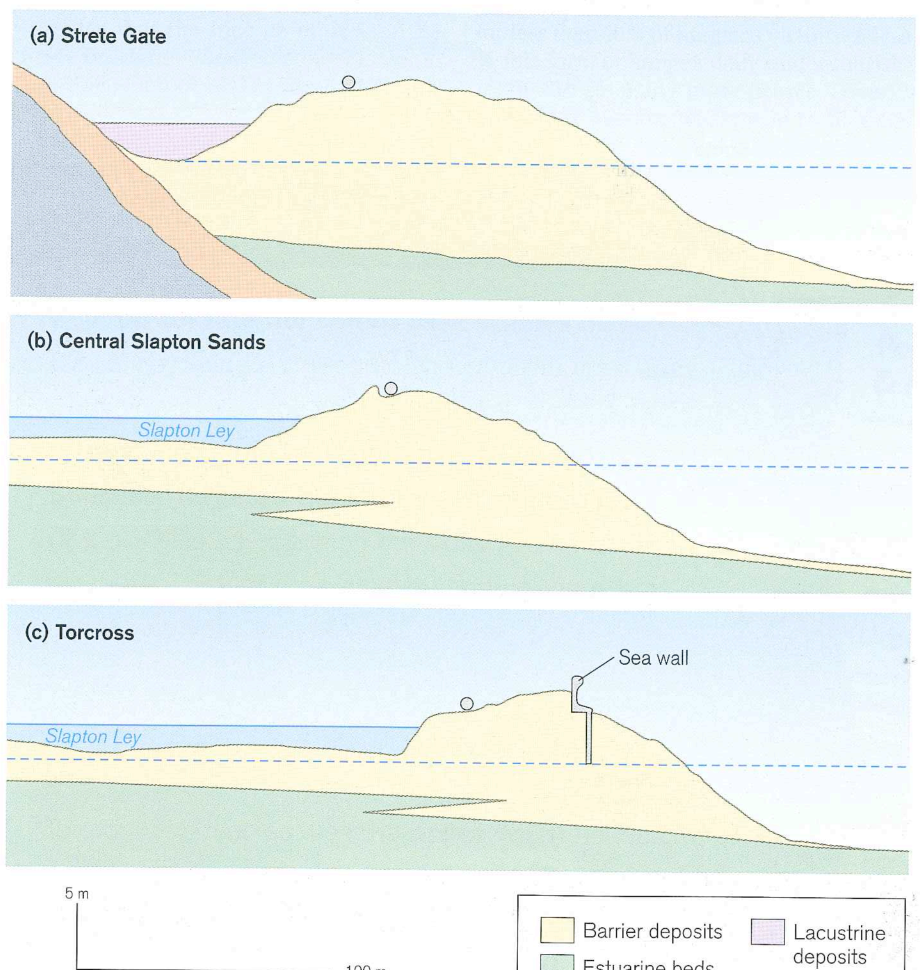


Figure 1 *Map of Start Bay showing all the gravel barrier systems. The barriers are protected from waves from the southwest by Start Point and Skerries Bank, but exposed to waves from the east*

Slapton Sands and Slapton Ley



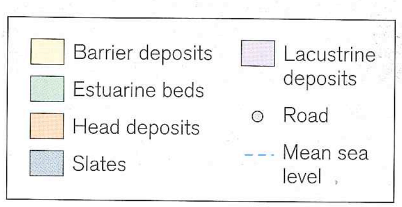


Figure 2 *Cross sections through the barrier at three locations. It is clear that the gravel barrier is sitting on top of saltmarsh deposits*

the lagoon and Slapton Ley would lose its freshwater status (Inset 1).

Timescale

In managing coastal erosion humans tend to think in terms of the timescale they are most comfortable with — the human lifespan. However, coastal erosion is driven by processes operating over timescales ranging from day-to-day to centuries and millennia. These different processes interact and it is often difficult to attribute a particular coastal erosion event to a single cause. The three main processes that drive coastal erosion are:

- sea-level rise
- longshore transport
- storms

Sea-level rise (decades–millennia)

Slapton Sands is one of five barrier systems in Start Bay (see Figure 1). They are mainly composed of flint pebbles, which are now only found about 30–40 km offshore. This suggests that the barriers must have originated offshore. It seems that proto-barriers developed during the Holocene transgression — a 10,000-year period of rising sea level following the last ice age (Figure 3). As sea level rose, the barrier systems were pushed landward.

The sea drives a barrier landward by a process called **roll-over** (Figure 4). Material is removed from the front of the barrier (the actual beach), washed over the crest of the barrier and dumped into the lagoon. As sea level rises, the barrier is gradually pushed landward.

There is strong evidence to suggest that 5,000–8,000 years ago, with sea level 5–15 m below present, a chain of barrier islands extended across Start Bay. Tidal inlets between the islands allowed salt and freshwater to mix in the lagoon behind the barriers. As sea level continued to rise the barrier chain became dissected by smaller headlands and formed separate beaches. About 3,000 years ago the Start Bay beaches, including Slapton Sands, reached their present position and the brackish water lagoon behind the chain of barrier islands developed into a freshwater lagoon (Inset 2).

Is Slapton Sands still moving landward or has this process stopped? Sea-level rise over the last 100 years for the Slapton barrier is 1–2 mm per year. It is likely to increase to 3–4 mm per year over this century due to climate change. This, combined with the fact that the road is often covered by beach gravels after major storms, suggests that the barrier is still migrating landward at an estimated 0.5 m per year.

> **inset 1**
>
> ### Importance of Slapton barrier system
>
> Slapton Sands is a designated Geological Review Site (GRS) and Slapton Ley is a Site of Special Scientific Interest (SSSI), as well as a National Nature Reserve (NNR). Both are located in the Devon Area of Outstanding Natural Beauty (AONB) and are part of the Heritage Coast.
>
> The gravel barrier is significant from a military-historical viewpoint, because in April 1944 the beach was used by the US 4th Infantry Division to practise for the D-Day landing on Utah beach in Normandy.
>
> The A379 runs along the top of the gravel barrier and is an important transport link between local communities, as well as providing access to the beach for visitors. Note that road realignment involves the loss of land within the nature reserve.

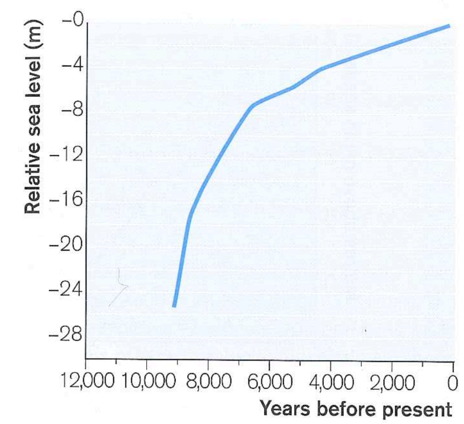


Figure 3 ***Relative sea-level curve for the south coast of Devon. Sea level has been rising at a steady 1 mm per year over the last 5,000 years***

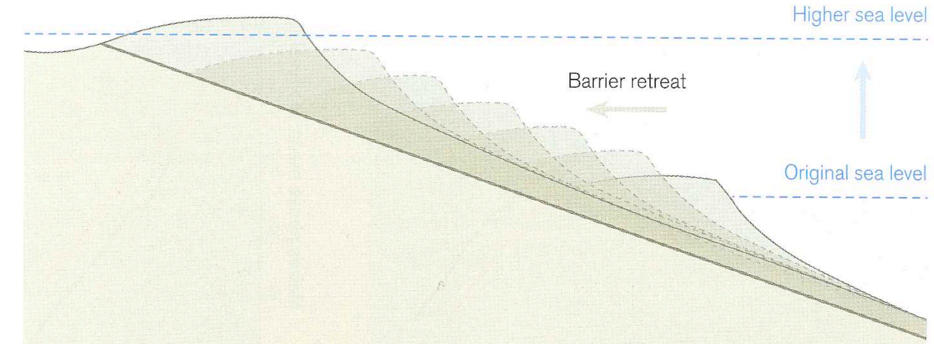


Figure 4 ***The roll-over model. Sediment is eroded from the front of the barrier, transported across the barrier crest and deposited on the back of the barrier***

Longshore sediment transport (months–centuries)

The movement of beach sediment along the coast occurs when waves break on the beach with their crests at an angle to the shoreline. The greater the breaker angle and the higher the waves, the stronger the longshore current and the larger the amount of sediment transported alongshore. The rate of longshore transport varies with changes in wave direction: gravel may move to the north one day, and back to the south the next day.

One way of estimating the amount and direction of longshore transport over time is to conduct frequent beach surveys to see if there are any consistent changes in the beach width and volume at different points. This was done on Slapton Sands from October 2006 to October 2007 (Figure 5). During this period the southern and central section of the beach lost a large amount of sediment and retreated by 5–10 m, whereas the northern end of the beach gained sediment and increased its width by about 10 m. This, along with the prevailing wave direction which was from the southwest, suggests that beach material was drifting north.

However, longshore sediment transport can vary hugely over time. On Slapton Sands, northward and southward longshore transport can alternate from year to year, and century to century.

Storms (hours–days)

The most dramatic changes to beach morphology occur during storms. Extreme wave conditions usually flatten the profile of a gravel beach. Sediment at the top of the beach is generally pushed landward and may be pushed over the crest of the barrier into the lagoon if the waves are high enough. Sediment at the bottom of the beach is commonly dragged seaward. Sediment deposited on or over the crest of the barrier will not return to the beach, but sediment removed from the lower beach will be pushed back onshore under calm waves.

The recovery of the beach under calm conditions is important, because it makes the barrier less vulnerable to the next storm. A sequence of storms in quick succession is therefore more damaging to a barrier system than a series of storms spread out over a year. Weakening of the beach by a series of autumn storms in 2000 probably contributed to the dramatic damage to the barrier during the 2001 storm.

A combined effect

It is clear, then, that landward movement of Slapton Sands is not only caused by storm events. A steadily rising sea level increases the chance of storm waves overtopping the barrier crest and spilling sediments into the lagoon. At the same time sediment removal due to longshore transport results in narrowing of the barrier and makes it more vulnerable to overwashing.

Large oblique waves impacting on the beach. The angle between the wave crests and the shoreline is almost 90° and the waves are about 1.5 m high. Note how some of the waves almost reach the vegetated part of the barrier. The image is a still from a video so is a little fuzzy

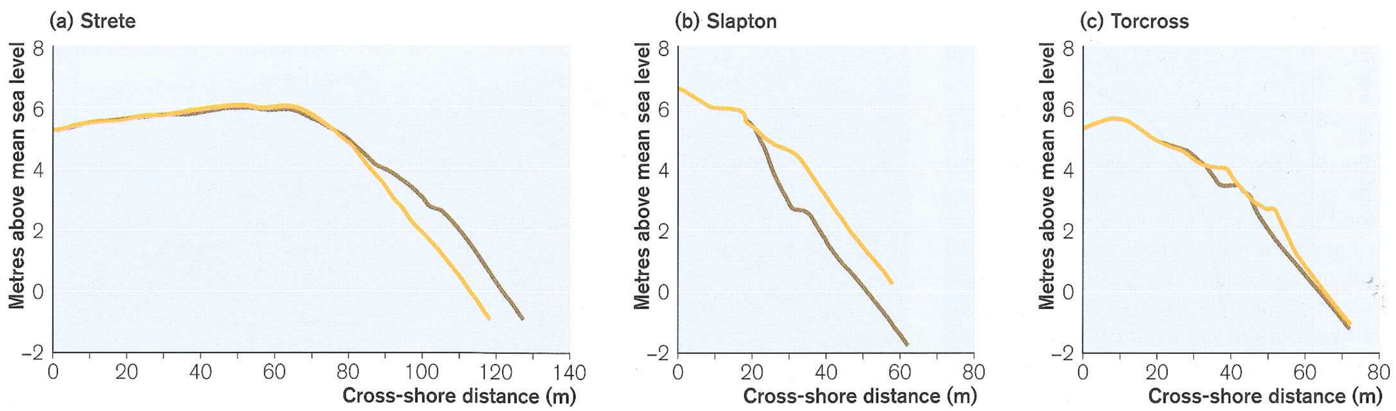


Figure 5 *Beach profile change from October 2006 to October 2007 at three locations along the barrier. The beach at Torcross and Slapton eroded by 5–10 m, whereas at Strete the beach became about 10 m wider. This suggests a northward drift*

Effective management of the barrier depends on understanding how each of these processes affects its stability.

Management of Slapton Sands

In shoreline management, three options are generally considered:

- do nothing
- hold the line
- managed retreat

To do nothing at Slapton would allow erosion to continue until the road was lost and the barrier breached. Holding the line would mean protecting the barrier, with either 'soft' engineering (beach nourishment) and/or 'hard' engineering (rock revetments, seawall, retaining walls). Managed realignment would either involve building a new road inland, upgrading the existing inland route or moving the road landward on the gravel barrier.

Consideration of the coastal processes and consultation with the local community led to a proposed management solution based on a combination of the three options:

- Immediate realignment of a 500-m section of road along the most sensitive part of the barrier. (This involved some small loss of land from Slapton Ley National Nature Reserve.)
- Realignment of the road at other locations, but only when damage to the road is imminent or has occurred.
- Localised movement of shingle to protect short lengths of road or reinstate them following damage.

The cost has been estimated at £300,000 for the first measure and £50,000 per year for the others. At some point in the future, sea-level rise will make the localised realignment of the road unsustainable and it may have to be permanently closed. This is unlikely to happen in the next 30–50 years, but a severe storm or series of storms could occur in any year, and cause unprecedented damage.

Questions for discussion

(1) If money was not an issue, what would be the best solution to the erosion problem at Slapton Sands?

(2) What are the pros and cons of realigning a main road through a nature reserve?

(3) If there are barrier beach systems near where you live, do these experience coastal erosion problems? If so, what sort of measures have been put in place to tackle these erosion problems and why were these particular measures chosen?

inset 2

Barrier evolution

How can we be sure that several thousand years ago the Start Bay barriers migrated onshore under the influence of a rising sea level? The evidence is contained in the sediments underneath the barrier system, referred to as the **stratigraphy.** Sediment cores taken from the current Slapton Sands barrier show that a 10 m deposit of beach gravels sits on top of muddy saltmarsh sediments. The muds were deposited about 5,000 years ago and, because saltmarsh development requires a sheltered tidal environment, a discontinuous barrier system must have been present then. Since the barrier is now resting on top of the former saltmarsh, it must have been pushed there by the rising sea level.

Photos taken after the 2004 storm showing beach gravels behind the seawall at Torcross on the barrier crest. Also note the fresh cliffing of the vegetated crest of the barrier

Further reading

Burt, T. (1999) 'Snapshot: Holding the line', Geography Review Vol. 12, No. 5, p. 42.

Chell, K. (2002) 'Coastline in decay', Geography Review Vol. 15, No. 3, pp. 32–36.

Job, D. (1993) 'Coastal management', Geography Review Vol. 7, No. 2, pp. 13–17.

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Key points

- Coastal change is often the result of a number of processes operating at different timescales.
- Sea-level rise, longshore sediment transport and storms are the key processes causing coastal erosion.
- A thorough understanding of these processes is necessary for creating good coastal management strategies.
- The three main shoreline management options to deal with coastal erosion are do nothing, hold the line and managed retreat.

erratum

Figure 1 on page 24 of Geography Review Vol. 21, No. 3, February 2008, showed drumlin topography. The upper profiles of the drumlins were undulating and should have been smooth. A correct version of the diagram is printed here. Drumlins normally have smooth profiles because they are formed under heavy ice sheets.