COASTAL EROSION, FLOODING AND DEFENCE

Coastlines are one of the most varied landforms. Erosion, deposition and transport are finely balanced and all affect the geology. If any of these factors are disturbed then the coastal system will restore the equilibrium.

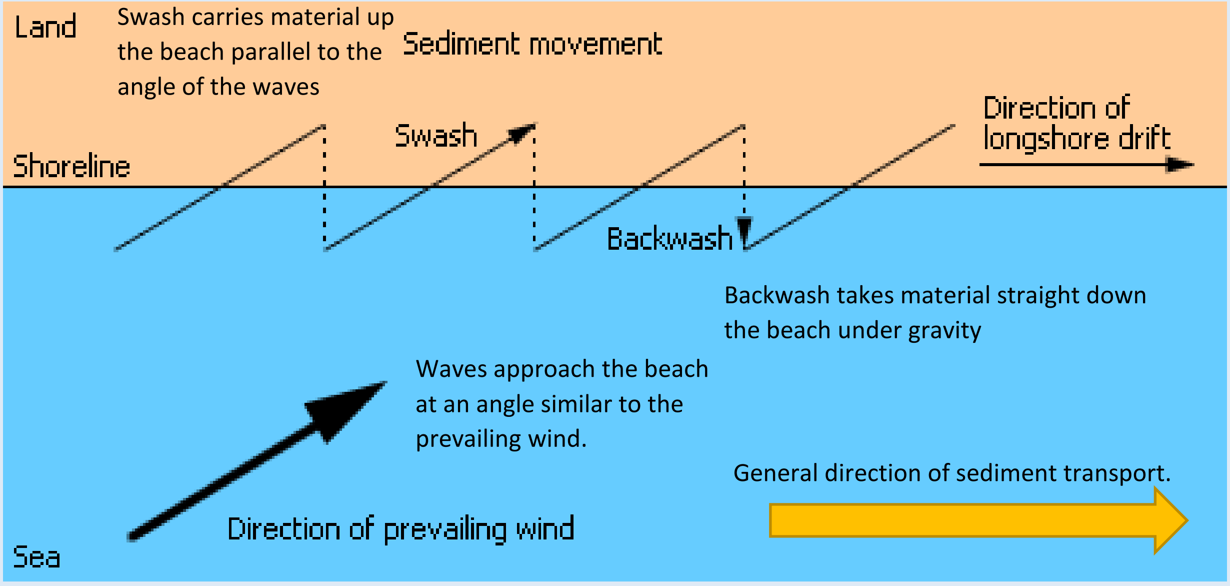
<u>What natural factors affect coastal erosion?</u>

1. **Rock type**
2. **Attitude of strata**
3. **Geological Structures**

There are similar considerations for all engineering projects, tunnels, dams, roads and coastal defences, they all must evaluate the local geology and determine which factors may be of consideration.

Key terms
<u>#Swash</u> is the water that washes onshore as a wave breaks.
<u>#Backwash</u> is the water that moves back down the beach (at right angles) due to gravity.
<u>#Longshore drift</u> is the process that moves sediment along the coast. Waves breaking at an angle move sediment up the beach which then rolls straight back down due to gravity.

Wave action is the dominant process causing erosion and deposition at the coast. Sediment transport is brought about by the transfer of sediment by the **swash** and **backwash**. If waves break at an oblique angle then sediment is transported along the shoreline (**longshore drift**).



1. ROCK TYPE

The **strength and hardness** of rock influences the **rate of erosion** and the **maximum stable slope angle (the angle of repose)**. *– see 'LANDSLIP AND SLUMPING HAZARDS' – slope angles for a recap .*
Along rocky coastlines, the rock type determines cliff profile.

- **Unconsolidated material** offers **little resistance** to wave attack due to the lack of strong bonds between grains. These form **gently sloping cliffs**, with marine erosion at the **cliff foot** and **weathering** taking place on the **cliff face.**
- **Strong competent,** especially crystalline or well cemented, rocks will erode at slower rates (take granite for example). These form **steeper, vertical cliffs**, which are dominated by **marine erosion at the cliff foot**.

In Britain, areas composed of **boulder clay**, deposited form the glaciers of last ice age, are eroding the most rapidly.

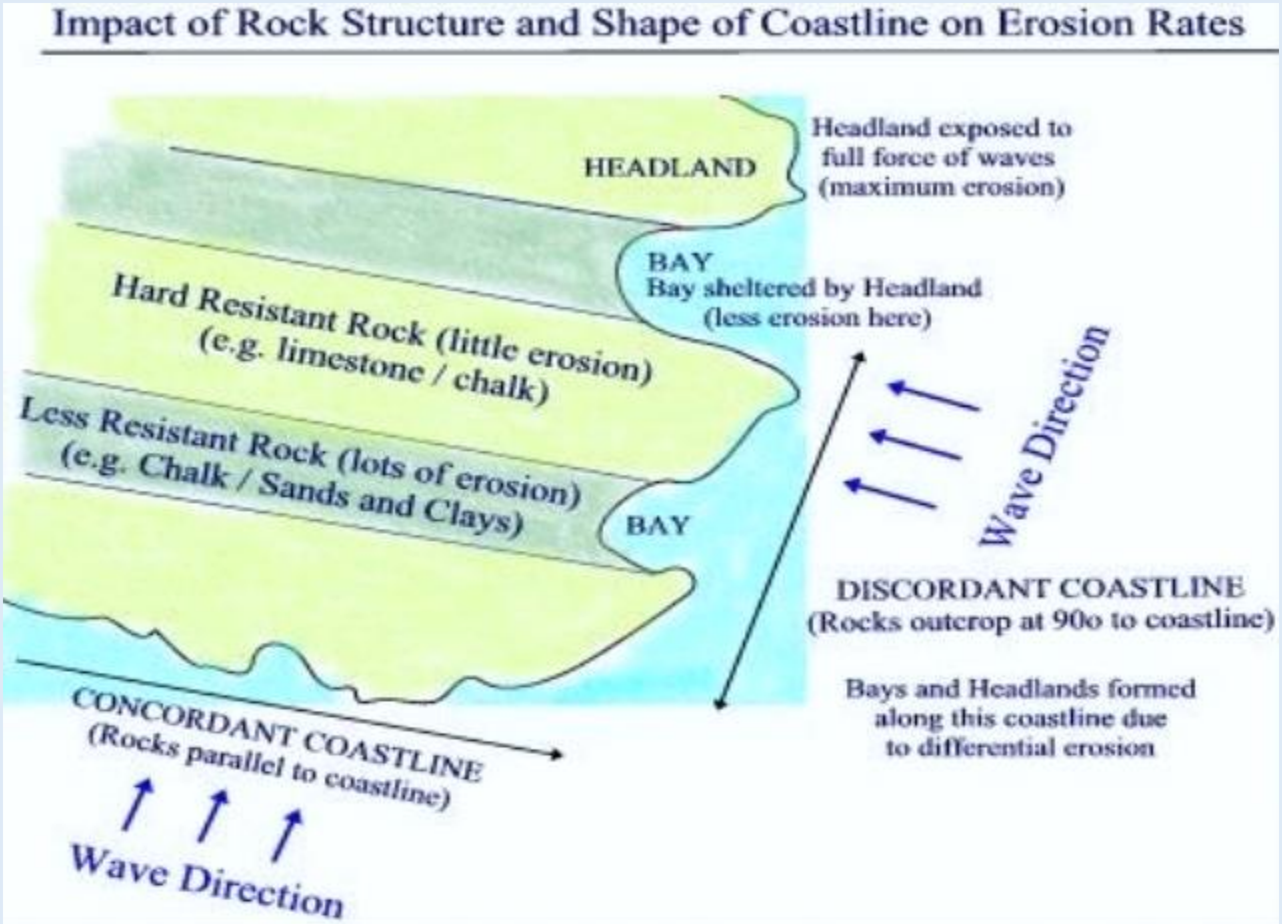
2. ATTITUDE OF STRATA

- Steepest cliffs arise where **strata dip either horizontally or away from the sea.**
- The gentlest cliffs form where **rocks dip in towards the sea**, these tend to undergo **landslips and slumping**. Scree will build up at the cliff foot.

Cliff profile (bays and headlands) is shaped by both **differential erosion rates** (rock types) as well as the effect of the **attitude of strata.**

1. The beds of **alternating resistance** must strike the **coastline at an angle.**
2. Stronger rocks with a higher resistance to mechanical erosion will form **headlands and the we**aker or unconsolidated rocks form sheltered **bays in between**
   Thus determine cliff profile

- **Concordant coastlines**: Where alternating rocks of **different resistances** strike **perpendicular to the coastline**, a **bay and headland** will form.
- **Discordant coastlines**: Rocks may also **strike parallel** to the coastline, if differing strengths exist then erosion breaks through the resistant outer rock layer before scouring the inner less resistant rock to form a **cove.**



Typically **longshore drift** will transport material along the bay and deposit it on the headland to form a **spit, such as Hurst Castle Spit, near Milford on Sea.**

A cove is a bay with a **narrow entrance**, such as that found at Lulworth Cove in Dorset.

3. GEOLOGICAL STRUCTURES

Faults, joints and lineations (**bedding planes, foliation** and **cleavage**) are lines of weakness in the rock that will be exploited by wave action. Selective erosion along these planes of weakness in headlands leads to the formation of ca**ves, blowholes, arches and stacks.**

A blowhole is formed as sea caves grow landward and upward into vertical shafts and expose themselves at the cliff top. When waves enter the sea cave with sufficient force, water travels upwards with great pressure and is expelling from the top of the blowhole. This is named so due to the blowhole of a whale coming to the surface and blowing out water to clear its airway.

CASE STUDY: THE THAMES BARRIER

The **1953 North Sea storm surge** was the worst natural disaster to hit Northern Europe in the last 200 years.

The surge was caused by an **intense, rapidly moving, low pressure weather** system that travelled southwards into the **North Sea.**

The low pressure and the high rainfall caused the sea `bulge' along the English Channel. Due to the funnel shape of the North Sea, the water could not escape through he narrow straights of Dover. This caused flooding of low lying coastal areas (Eastern England and the Netherlands).

Over 600km^2 of land was flooded, resulting in the **drowning of 307 people in England and over 1800 in Holland**.

In the aftermath, **the Thames Barrier** was constructed to protect London. Completed in 1984, the **barrier is 540m wide**, consists of 10 movable gates with 4 main openings between, each span 61m.

Date	Number of closures for high tides
Prior to 1990	2 a year
Since 1990	4 a year
2003	14 a year
2014	28 a year

The barrier's operation manager Andy Batchelor said: "The long term plan for the barrier recognises that we will use it on average more frequently year-by-year and we are still forecasting not to need a replacement until 2070."

Total construction cost was around £534 million **(£1.6 billion** at 2016 prices)

CASE STUDY: THE HOLDERNESS COAST, NORTH YORKSHIRE

- This is **one of the most rapidly eroding coasts in Britain**. The coast is retreating **~ 2m a year**. (with the exception of events like the 1953 storm surge where it was double that in 24 hours) 50 villages mentioned in the Domesday book of 1086 have disappeared.
- Since the Roman times, the coast has moved 3km inland.
- The Holderness cliffs are composed **of boulder clay**. Pounding waves attack the base of the cliff and rainwater adds weight from above leading to the **failure by slumping.**
- The **fine grained clay** is carried out to sea **in suspension**.

STRATEGIES TO REDUCE COASTAL EROSION AND FLOODING

1. **Sea walls and banks**
2. **Rock buttresses, revetments and rip rap**
3. **Groynes**
4. **Beach nourishment**
5. **Slope stabalisation**

1. **Seawalls and banks** protect against both **flooding and coastal erosion**. They are built **close to the high water mark** to **reflect wave energy**. They are usually made of concrete and may be sloped, vertical or curved.

They are particularly effective in the short term but their seaward side is susceptible to undercutting and scouring .
They are expensive costing **up to £1000 per metre.** Cheaper banks and mounds may be built, mainly to reduce flooding.

(e.g. earth banks Bangladesh or levee dykes in Holland).

2. **Rock buttresses, revetments and rip rap**. Waves enter spaces between rocks and multiple reflections absorb wave energy preventing erosion to the coastline. The method is relatively cheap, although heavy rock material may be shipped long distances (from super quarries).

Large blocks of hard granite can be piled up along the shore or at a cliff foot. Imported rocks often look unsightly and foreign to the environment.
A revetment is like a sea wall only it is sloped at a lower gradient.

3. Groynes

They are employed to **prevent longshore drift** and thereby reduce erosion. However, they can **cause erosion further downstream** where the sediment would have been transported. The shoreline downstream becomes '**starved**'.

They are **relatively cheap** and **do not restrict beach access** and have become **quite a familiar sight**.
They extend out to see at right angles so sediment will **build up on the up-drift side** of the Groynes so the beach is retained. These days, some Groynes are made using rip rap instead of **wood, which rots**.

Constructing Groynes that are too close together or too long also starves the beach on the down-drift side.

4. **Beach nourishment**
This is a **soft engineering** strategy, aiming to restore the beach by **importing and depositing sand**. The **strategy is expensive and** once begun needs **regular maintenance** to remain effective. It does not reduce erosion directly but does replenish its effects.

For success, the sand imported must **match the texture of the local sands.** When sand is deposited onto the offshore part of the beach, it can have an adverse effect on the ecosystem; b**urying wildlife, plants and blocking out light.**

Shingle nourishment may offer more protection against destructive backwash and wave action.

5. Slope Stabalisation methods *- see Landslides and mass movement for a recap –* are used to stabilise cliff faces and reduce the impact of weathering and erosion on coastal areas. However, **high costs** mean they are only used to protect vulnerable built-up areas, where insurance claim costs exceed engineering costs.

- Slope modification
- Retaining wall
- Gabions
- Rock bolts
- Rock drains
- Wire Netting
- Shotcrete
- Vegetation

An insight into the cost to benefit analysis of coastal defence

Engineering Strategy		Protection type	Description	Cost	Advantages	Disadvantages
H	Sea wall	Cliff foot	Massive, made of rocks or concrete, to absorb and reflect wave energy.	£1000 per m	Traditional solution that is very effective. Protects against flooding too.	High cost. Scoured, undercut and eroded over time.
H	Revetment	Cliff foot	Massive, made of concrete, used to reflect rather than resist waves	£200 per m	Same as sea walls but generally cheaper	Restricts beach access. Looks unsightly Does not cope well against strong waves
H	Gabions	Cliff foot	Wire cages holding rocks	£100 per m	Same as above but much cheaper	Relatively lightweight and small scale solution
H	Groynes	Cliff foot	Rock or wooden walls built at 90^0 to coastline to reduce longshore drift.	£10,000 each (sited 200m apart)	Effective are reducing longshore drift. Quite familiar Quite cheap	Cause starvation and scour down-drift. Need regular maintenance Rotting of wood
H	Rip-rap	Cliff foot	Very large boulders of rock absorb wave energy	£3500 per m	Effective at absorbing energy and prevent undermining	May move in severe weather Becoming more expensive Imported so look unsightly
H	Cliff drainage	Cliff face	Removal of water (drains of broken rock inserted or a steel barrier to collect groundwater with a series of pipes connecting to clay/sand junctions)	£2500 per m	Cost effective	Drained cliffs may dry out and lead to rock falls.
H	Slope modification	Cliff face	Reducing the angle of slope of the cliff to stabilise it.	£800 per m	Works on clay or unconsolidated material when little else will	Retreat of cliff lien uses up some valuable land
S	Beach nourishment	Cliff foot	Sand pumped or redistributed to replace losses by longshore drift	£150 per m	Appears natural looking Effective at protecting cliff foot or tourist resorts	Needs continuous maintenance Possible ecological effects Expensive in the long term
S	Planting vegetation	Cliff face	Vegetation reduces infiltration of water and roots stabilise cliff	£50 per m	Relatively effective at stabalisation	May create or destroy an ecosystem