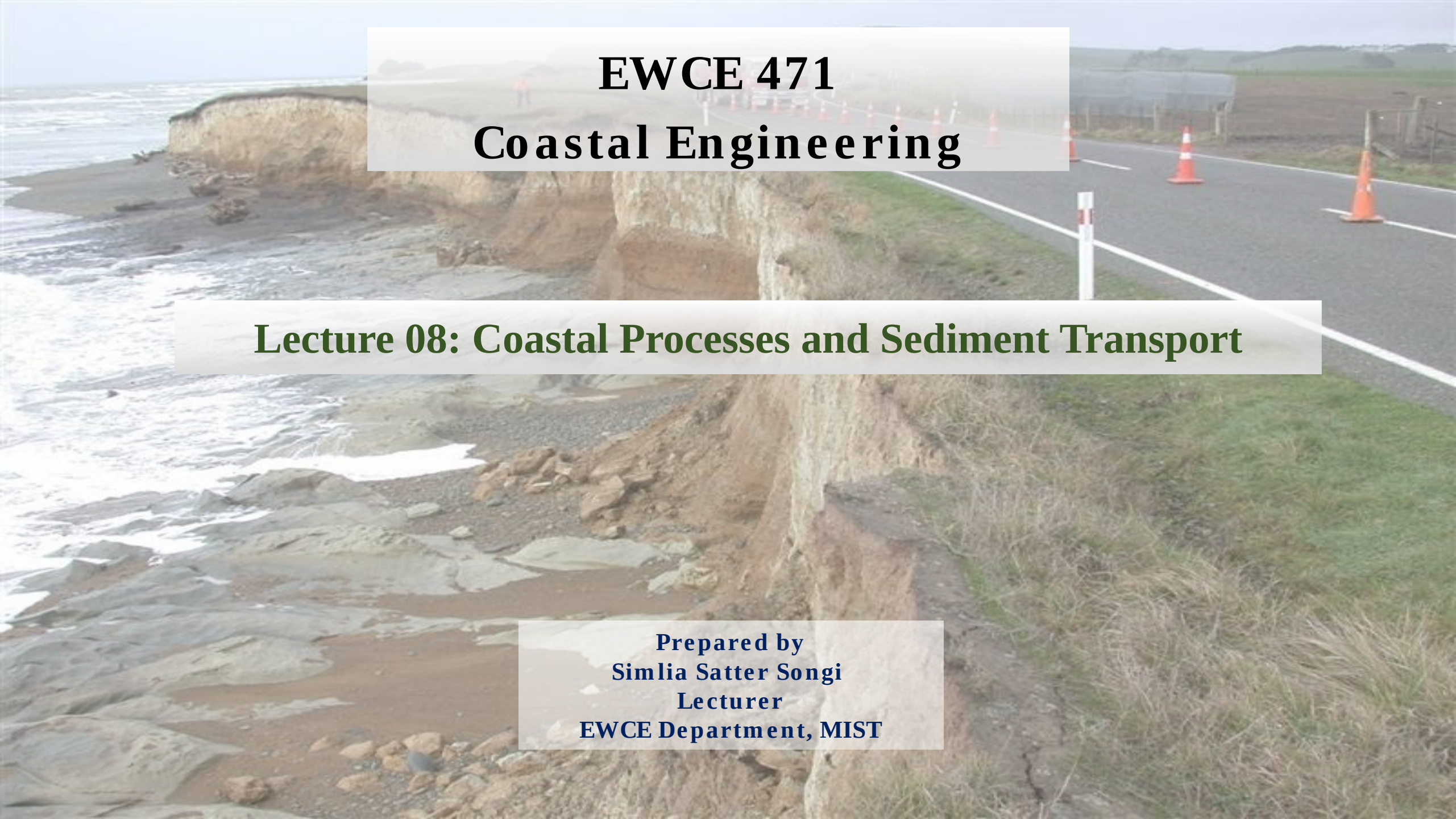


EWCE 471
Coastal Engineering

Lecture 08: Coastal Processes and Sediment Transport

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Coast

The coast is the **zone** between **land and sea**. The action of the waves and the sea constantly changes the shape and form of the coast, and people manage these changes in different ways.



The Importance of Waves

The power of waves is one of the most important forces that changes the shape of the coast. Waves are created by wind blowing over the surface of the sea.

The size of a wave depends on:

- Length of time the wind has been blowing
- Strength of the wind
- Fetch – how far the wind has travelled

Wave Types

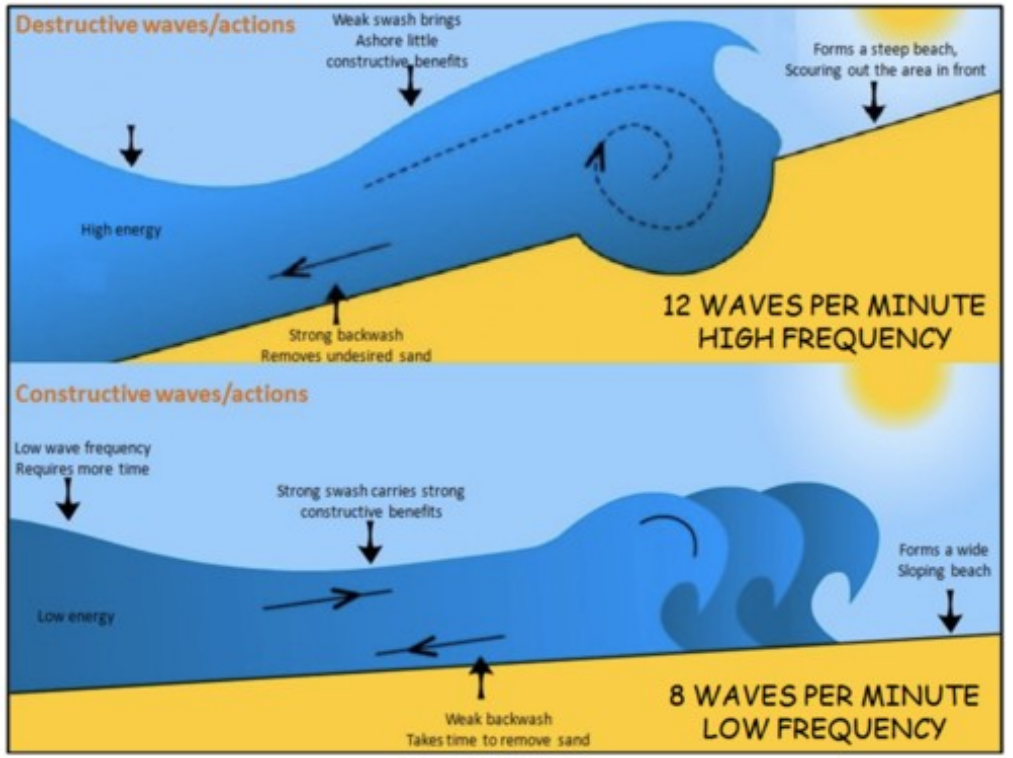
When a wave breaks, water is washed up on the beach. This is called **swash (powerful)**.

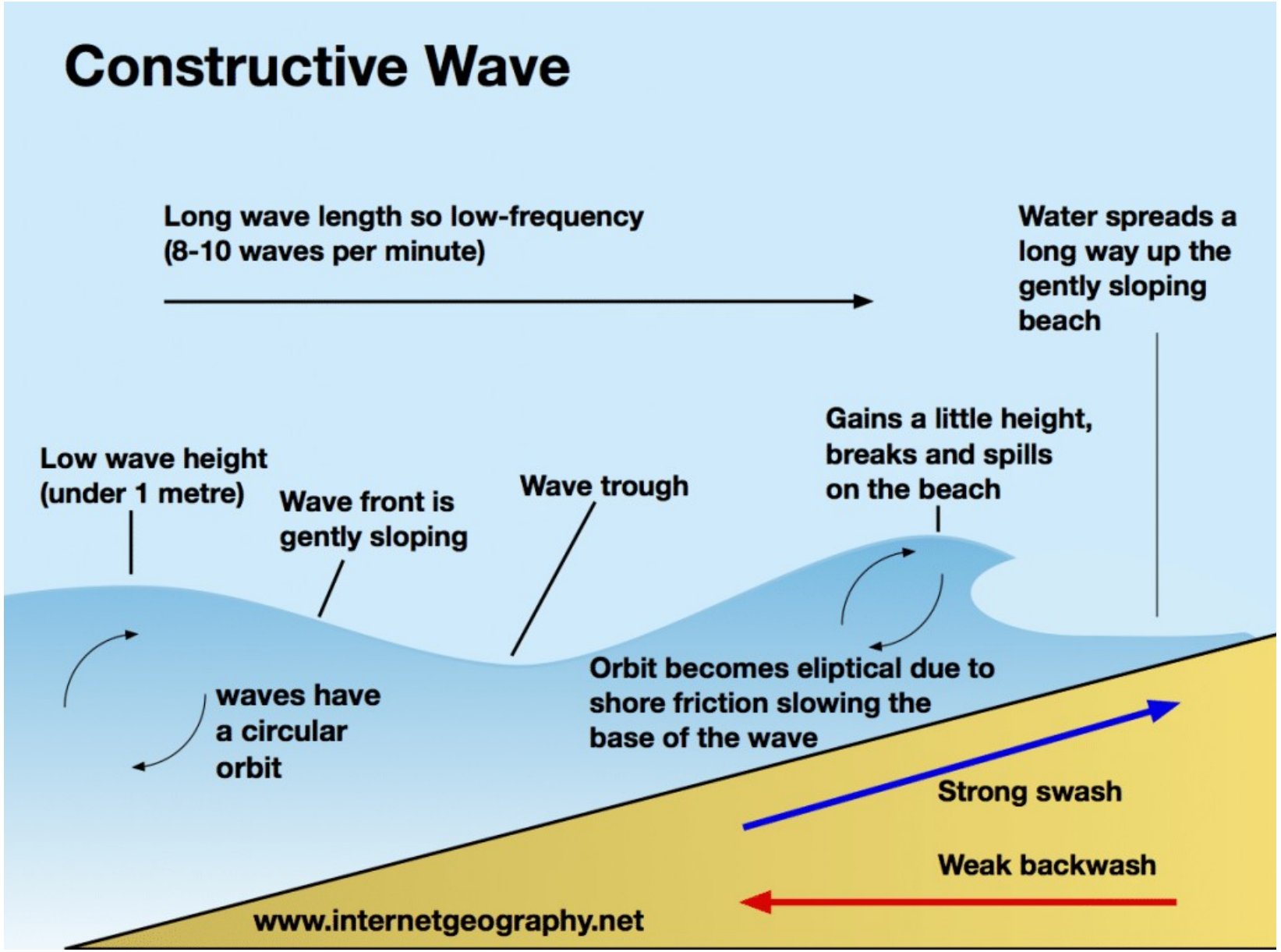
Then the water runs back down the beach, which is called the **backwash (less powerful).**

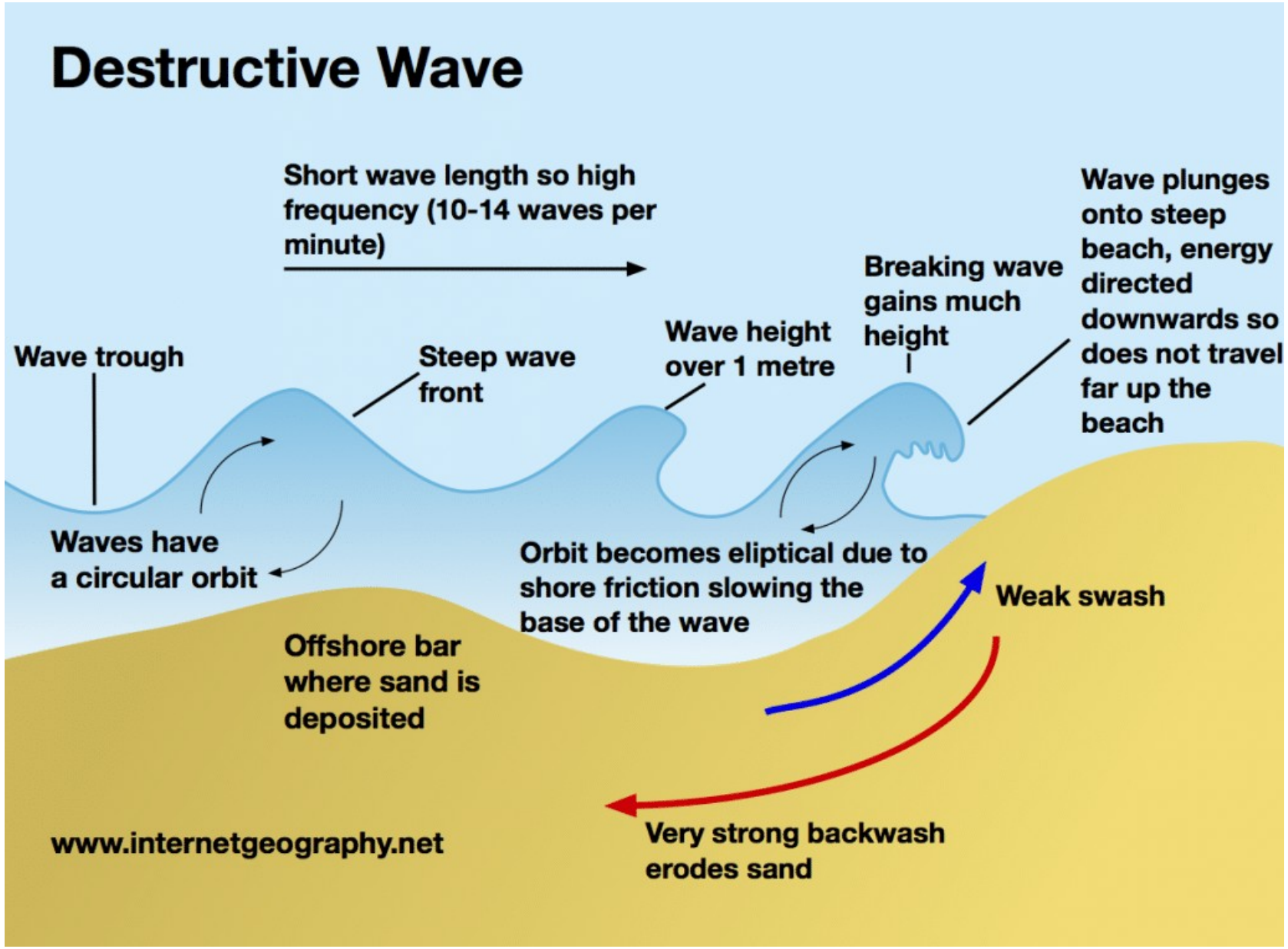
Waves can be constructive or destructive.

With a constructive wave, the swash is stronger than the backwash. It breaks gently, far from shore and swash pushes material into shore.

With a destructive wave, the backwash is stronger than the swash. It breaks very close to shore.




Constructive Wave
Long wave length so low-frequency
(8-10 waves per minute)
Water spreads a long way up the gently sloping beach
Gains a little height, breaks and spills on the beach
Low wave height (under 1 metre)
Wave front is gently sloping
Wave trough
waves have a circular orbit
Orbit becomes eliptical due to shore friction slowing the base of the wave
Strong swash
Weak backwash
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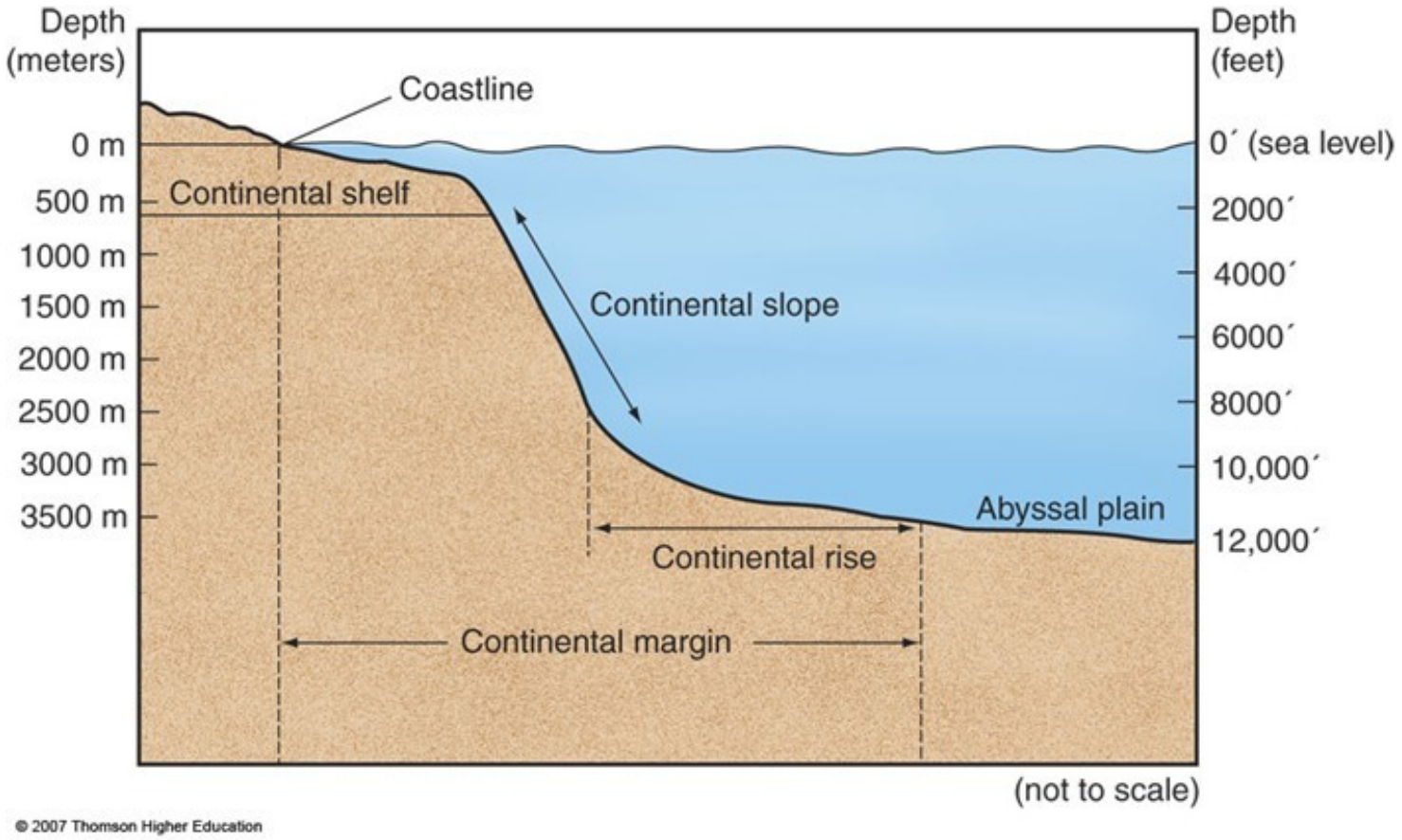

Destructive Wave
Short wave length so high frequency (10-14 waves per minute)
Wave plunges onto steep beach, energy directed downwards so does not travel far up the beach
Breaking wave gains much height
Wave height over 1 metre
Steep wave front
Wave trough
Waves have a circular orbit
Orbit becomes eliptical due to shore friction slowing the base of the wave
Weak swash
Offshore bar where sand is deposited
Very strong backwash erodes sand
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The table below outlines the key differences between the two types of waves:

Characteristics	Constructive	Destructive
Energy	Low	High
Swash	Strong	Weak
Backwash	Weak	Strong
Wave height	Low	High
Beach shape caused by this type of wave	Wide and flat	Steep and narrow
Frequency	Low (8-10 per minute)	High (10-14 per minute)

Continental Shelf

A continental shelf is the gently sloping submerged surface extending from the shoreline. Continental shelves contain important mineral deposits, large reservoirs of oil and natural gas, and huge sand and gravel deposits.



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Coastal Processes

Coastal processes are the set of mechanisms that operate along a coastline, bringing about various combinations of erosion and deposition.

Some of the coastal processes are-

- ❑ Erosion
- ❑ Deposition
- ❑ Currents
- ❑ Denundation
- ❑ Flooding
- ❑ Diffraction
- ❑ Refraction
- ❑ Sediment transport

Coastal Processes

Coastal developments can affect coastal zone processes by:

(1) changing the rate and/or characteristics of sediment supplied to the coast,

(2) adjusting the level of wave energy flux to the coast, and

(3) directly interfering with coastal sediment transport processes.

Two examples of the first effect are

i. the construction of a dam that traps sediment on a river that otherwise would deliver the sediment to the coast, and
ii. the periodic placement of sand on a beach, to nourish the beach.

Examples of the second and third effects respectively, are:

i. construction of a shore parallel offshore breakwater that intercepts waves approaching the shore to reduce the wave-induced alongshore sediment transport; and
ii. construction of a shore perpendicular groin across the surf zone to directly interrupt wave-induced alongshore sediment transport.

Coastal Processes

Erosion - the removal of sediment from a particular location by the action of wind or water.

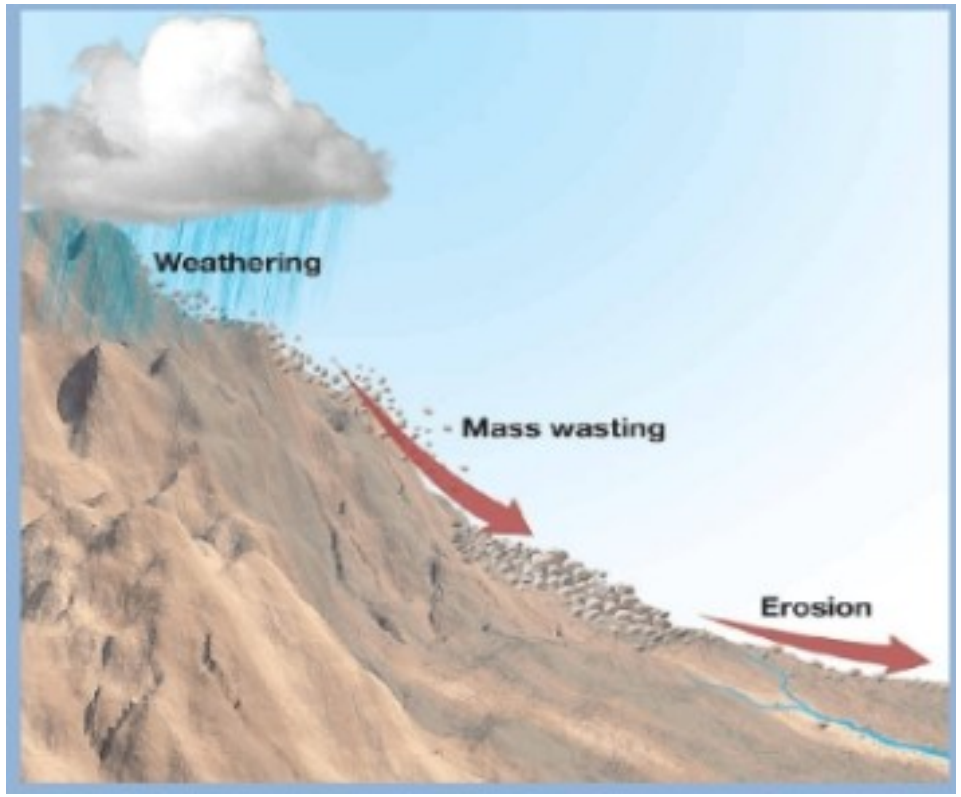
Transportation - Movement of eroded particles through stream channels to the point of deposition.

Accretion - natural or artificial deposition of sediment in a particular location.



Coastal Processes

Denudation - The term denudation refers to the wearing down, lowering, or stripping away of coastal landforms, but it is specifically applied to the shoreline and nearshore zones.



Coastal Processes

Coastal Flooding - Coastal flooding is the temporary or permanent inundation of normally dry, low-lying coastal land by seawater, caused by storm surges, tides, tsunamis, or long-term sea-level rise.



Coastal Processes

Coastal erosion is the process by which local sea level rise, strong wave action, and coastal flooding wear down or carry away rocks, soils, and/or sands along the coast.



Defining coastal erosion is rather straightforward.

Understanding coastal erosion is not as easy.



Processes of Erosion

- **Hydraulic action:** The force of the water causes cracks in the cliffs and material gradually breaks off
- **Abrasion:** Bits of rock and sand in waves grind down cliff surfaces like sandpaper.
- **Compressed air** - trapped in small crevices in the rock by waves, causes mini “explosions” which eventually shatter the rock
- **Attrition**: Waves smash rocks and pebbles on the shore into each other, and they break and become smoother.
- **Corrosion/Solution**: Acids contained in sea water will dissolve some types of rock such as chalk or limestone.
- **Wave refraction:** waves bending on contact with the coast, concentrating its effects in certain areas.

Landforms of Erosion

- Cliffs and wave cut platforms
- Bays and headlands
- Sea caves
- Sea arches
- Sea stacks
- Sea stumps

Erosion Structures

Hard

- Seawalls
- Groins
- Geotextiles
- Offshore breakwaters

Soft

- Beach nourishment
- Vegetation
- Sand fencing
- Jute mesh and bags

Coastal Deposition

- Whatever gets eroded from one area on the coast is eventually deposited in another area - nature always balances the books.
- Coastal deposition is the process by which sediments carried by waves, tides, or currents are dropped or laid down along the shoreline, forming landforms such as beaches, spits, bars, and dunes.
- The rate of erosion also affects the rate of deposition – an area with mostly hard rock (e.g. Granite) will erode slowly and thus have little material for deposition.
- Coastal deposition features (e.g. beaches) often have important economic benefits such as tourism.

Sediment Transport

Sediment transport is one of the important coastal processes. Sediment transport is the process by which sediment particles (sand, silt, gravel, etc.) are entrained, moved, and deposited by natural agents such as waves, tides, currents, wind, or gravity in coastal, riverine, or marine environments.

The analysis and prediction of sediment transport have great commercial, aesthetic, social, and scientific importance owing to the sustainable development and coastal zone management.

Sediment Transport

Processes responsible for initiating sediment transportation:

- Tides
- Changes in water level
- Waves
- Currents
- Stream outflow

Beach Sediment Properties

The physical properties of beach sediments **control their response to wind, wave, and current action and are important to the design of engineering works** in the coastal zone. We are primarily interested in noncohesive granular sediments. Physical properties of these sediments include:

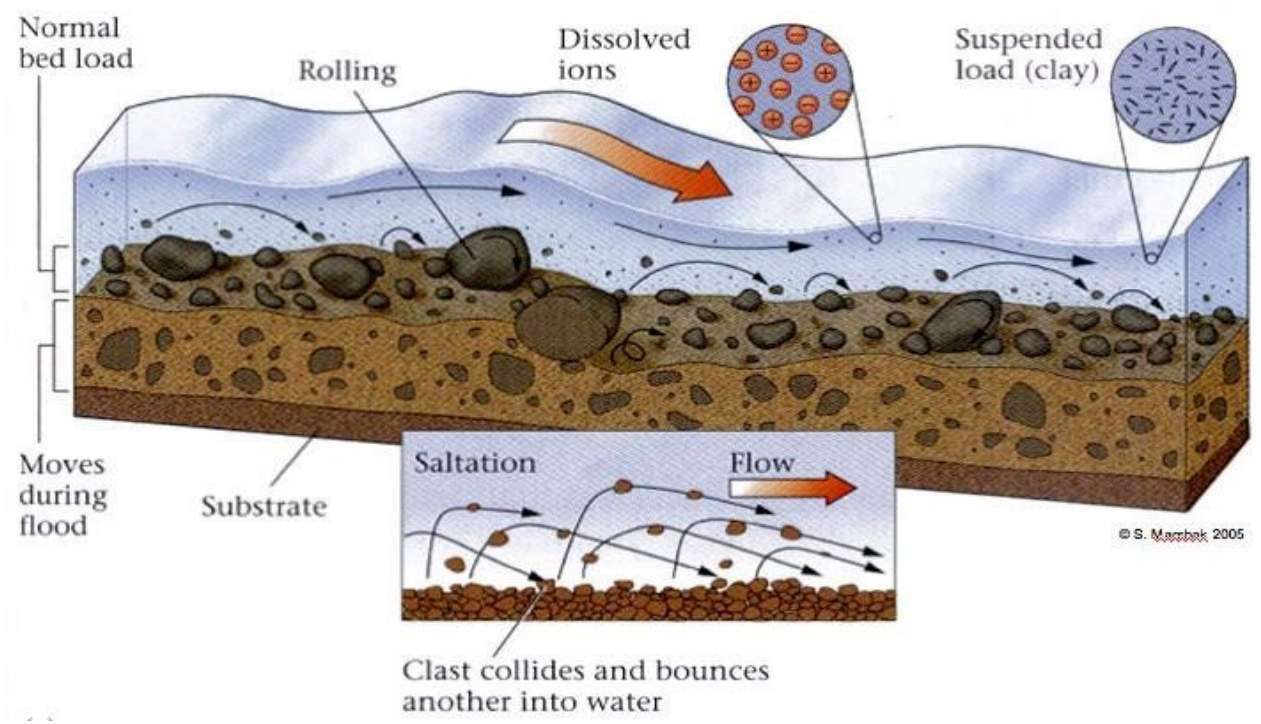
1. Petrology or chemical constituents of the sediment grains
2. Specific gravity of the grain materials and the bulk specific weight of the granular mass
3. Bulk porosity and permeability of the granular mass
4. Grain shape
5. Representative grain sizes and size distribution

Modes of Sediment Transport

Sediments are transported as,

Bed load transport

- The bed load is the part of the total load that is more or less in contact with the bed during the transport. It primarily includes grains that roll, slide or bounce along the bed.



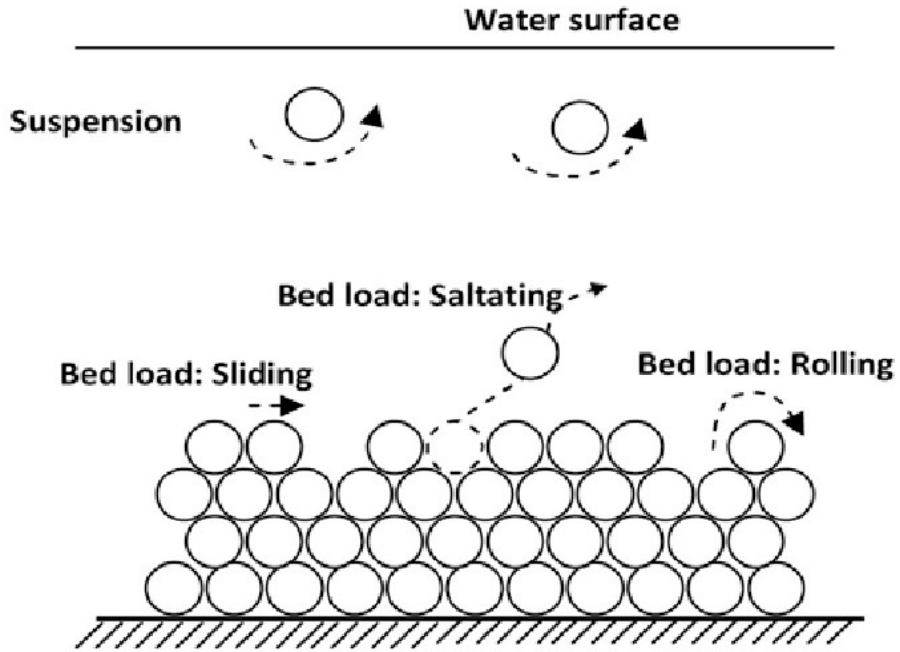
Modes of Sediment Transport

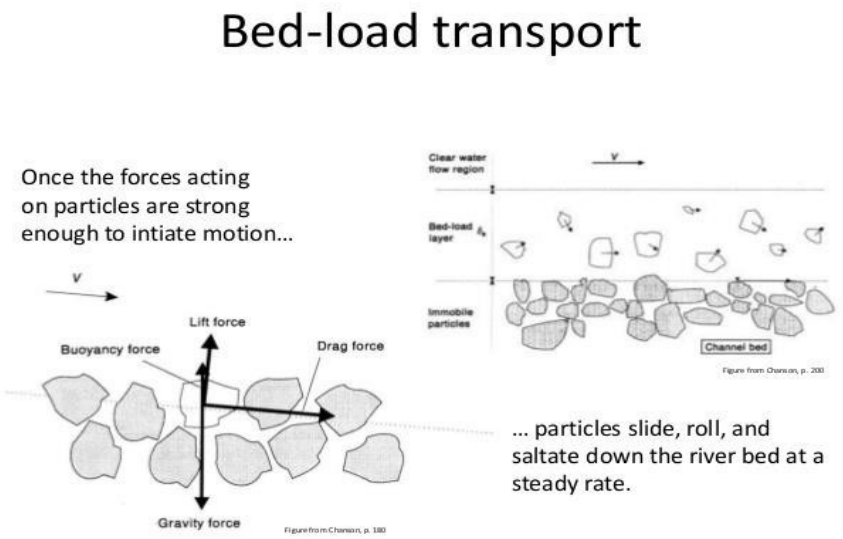
Sediments are transported as,

Bed load transport

- Experiment and theory suggest that the rate of bed load transport (qb) is proportional to the cube of the shear velocity,

$$qb \propto u^{*3}$$

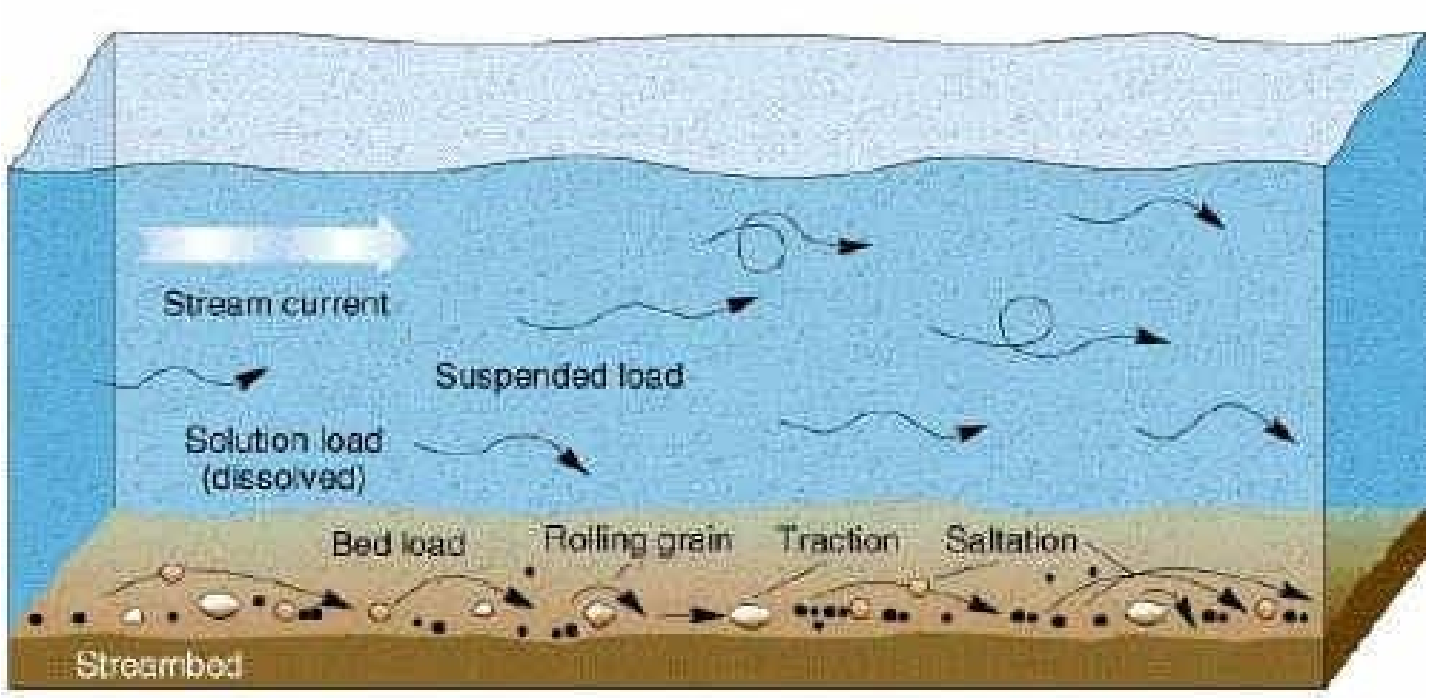




Modes of Sediment Transport

Suspended load transport

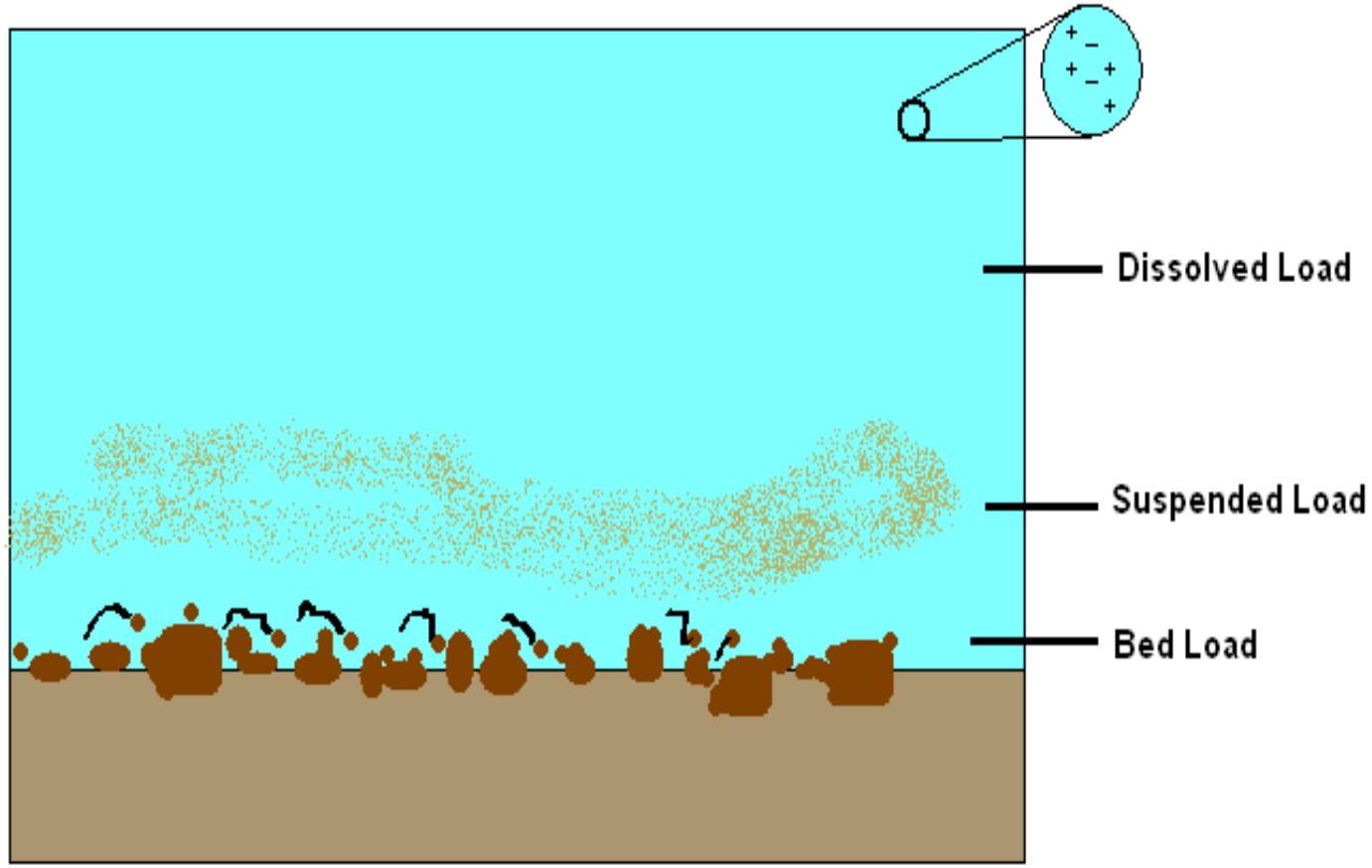
- It is the part of the total load that is moving in suspension without continuous contact with the bed.
- The determination of the rate of suspended load transport is straightforward by comparison with the measurement of the rate of bed load transport.



Modes of Sediment Transport

Wash load transport

- It consists of very fine particles transported in water.

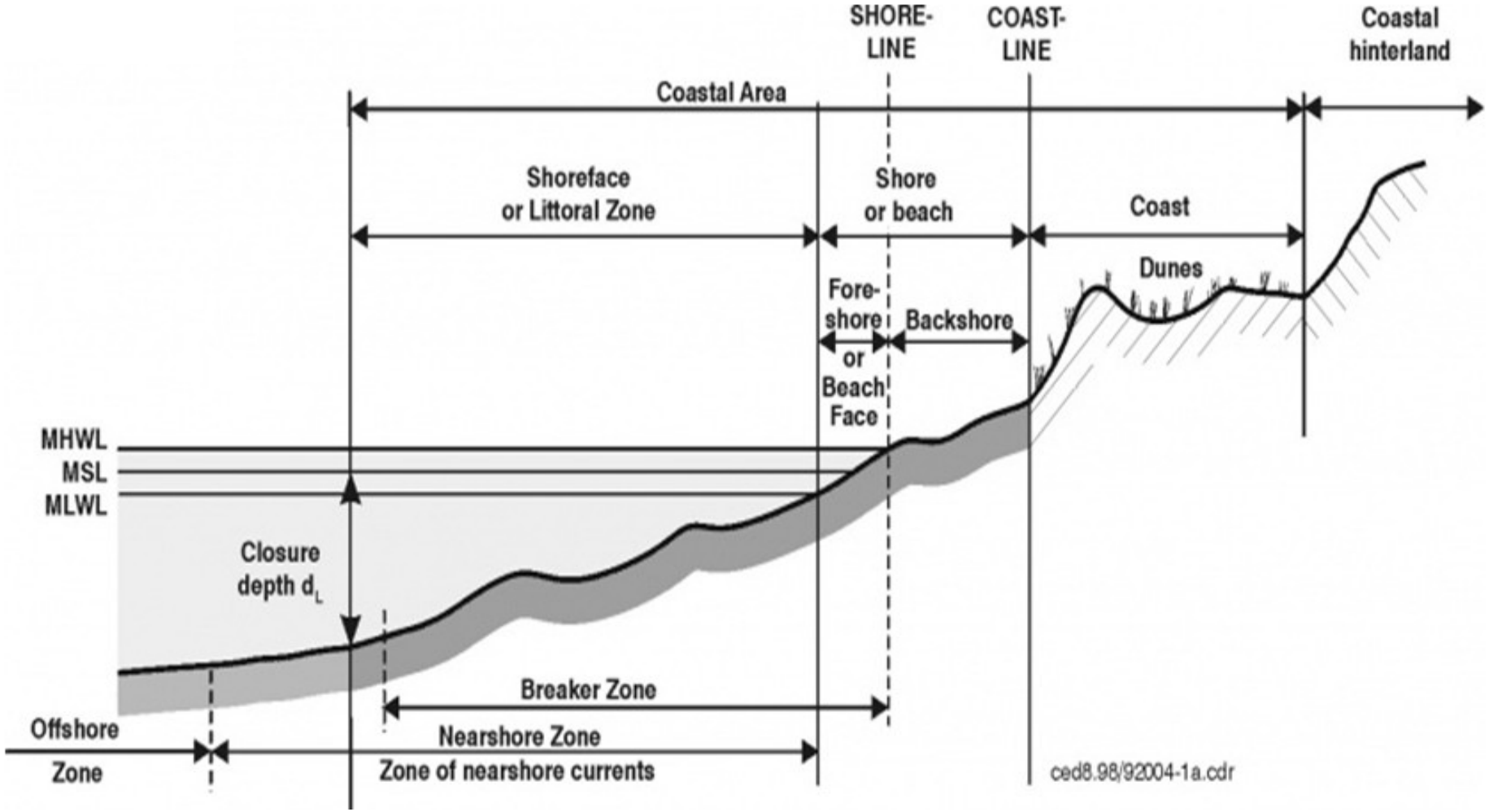


Coastal Profile

Backshore: Landward part of the beach, above high tide.
Usually dry, only reached by waves during storms or very high tides
Foreshore: That portion of the shore lying between the normal high and low water marks; the intertidal zone.
Nearshore: Between the low tide mark and where waves break at low tide
Offshore: Seaward of the breaker zone
Sediment movement is minimal under normal wave conditions

- Swash zone → narrow area on the foreshore where waves wash up and back.
- Surf zone → part of the nearshore where waves break.
- Breaker zone → outer boundary of surf zone where waves first break.
- Shoreface → seaward sloping part of the seabed between foreshore and Shoreface → seaward sloping part of the seabed between foreshore and offshore

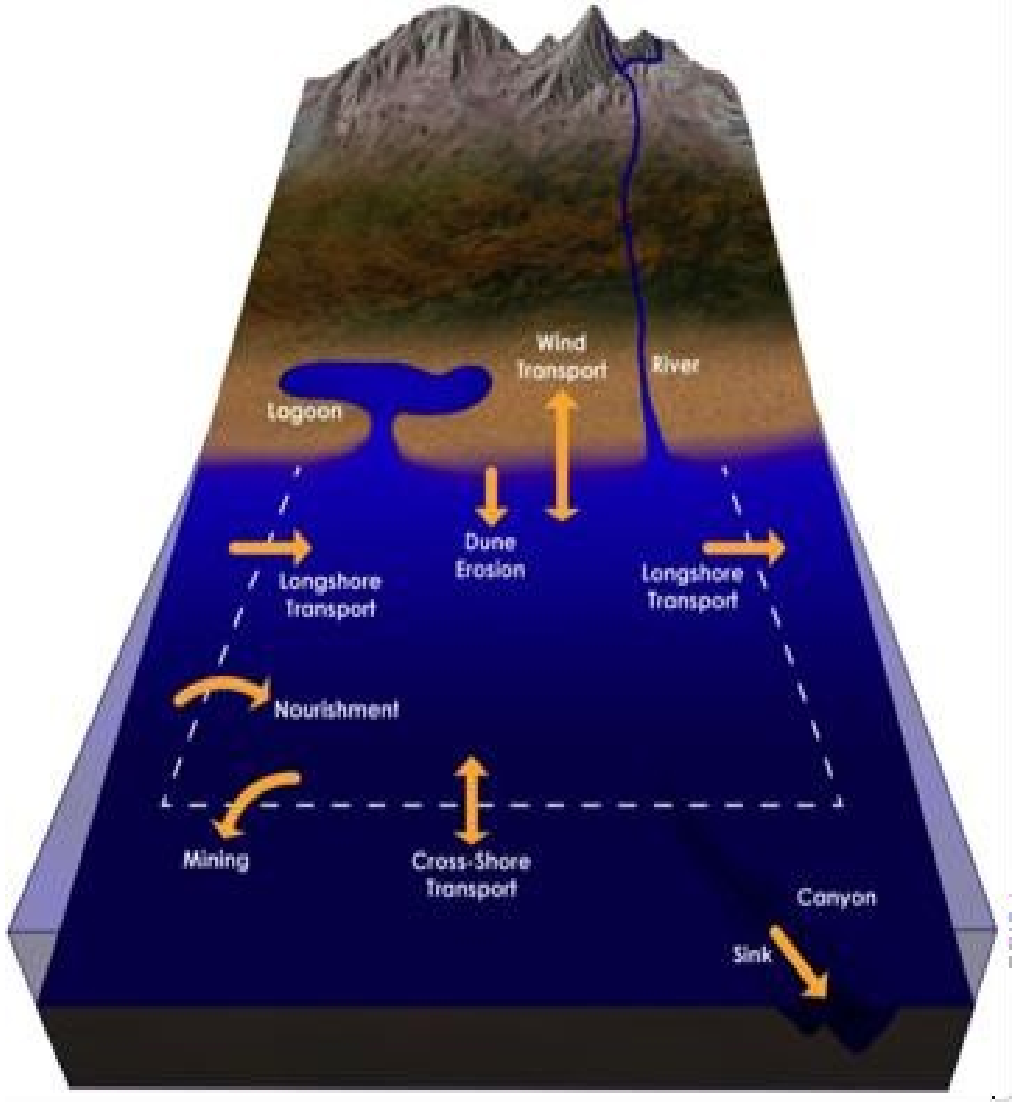
Coastal Profile



Sediment Transport

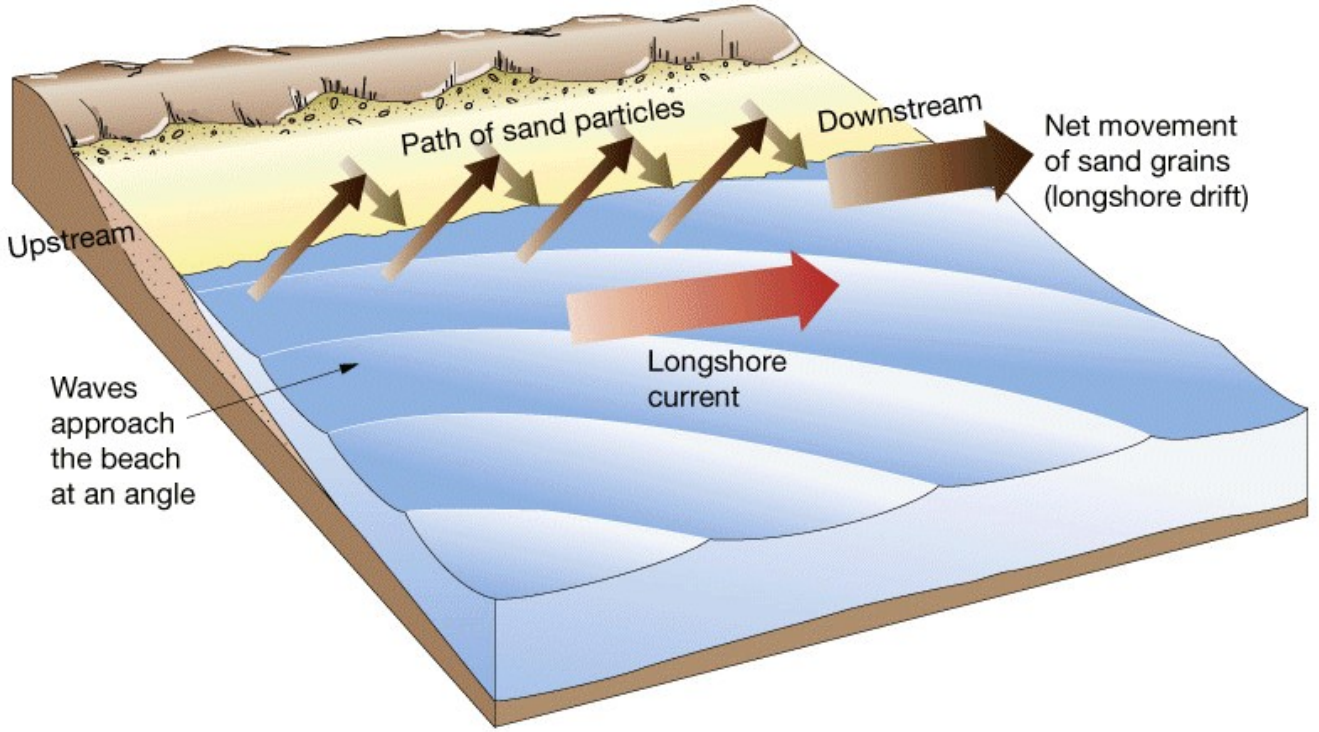
Offshore transport - Movement of sediment or water away from the shore

Onshore transport - Movement of sediment or water toward the shore



Sediment Transport

Longshore transport (littoral drift) - Longshore drift (also called littoral drift or longshore transport) is the process by which sediment (sand, gravel, pebbles) is moved along a coastline due to the action of waves approaching the shore at an angle.



Longshore Transport Processes

1. Waves approach the shore at an angle (caused by prevailing winds).
2. Swash (the forward movement of water up the beach) carries sediment up the shore at the same angle.
3. Backwash (the water running back down the beach due to gravity) moves sediment straight down the slope of the beach (at 90°).
4. This creates a zig-zag movement of sediment along the coast.
5. Over time, this continuous process transports beach material sideways along the coastline.

Model theories for the calculation of longshore drift

- Energy flux model
- Energetic model
- Suspended transport model

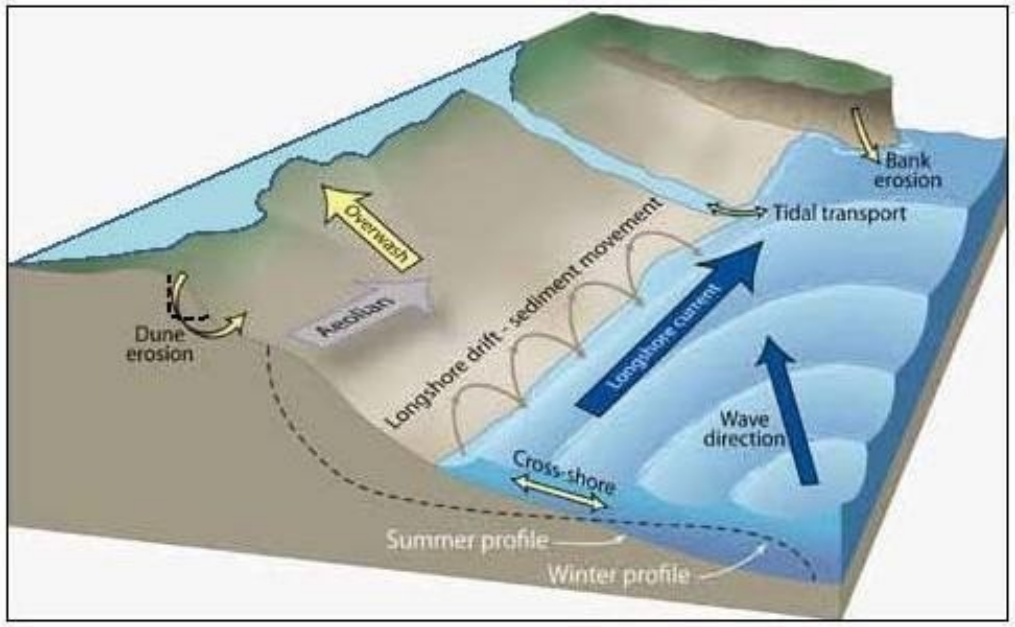
Energy Flux Model

- It is the simplest model used for the calculation of total amount of material moved along the shoreline.
- It is based on the amount of energy available in the waves arriving at the shoreline.

**Please go through the derivation of “Prediction of Potential Longshore Sediment Transport” and the related example problem discussed in the class.

Cross-shore Transport

- Cross-shore sediment transport is the movement of sediment (sand, gravel, or other coastal material) perpendicular to the shoreline, between the beach and the nearshore zone, mainly driven by waves, tides, and currents.



Cross-shore Transport

- It occurs in both directions:
  i. **Onshore transport** (landward), usually caused by **low-energy waves** that push sediment toward the beach, building it up.
  ii. **Offshore transport** (seaward), usually caused by **high-energy storm waves** that pull sediment away from the beach into deeper water.
- Important factors in determining the cross-shore transport of sand are:
  i. The **ratio of wave height to wavelength**
  ii. **Physical parameters** of the beach, i.e., grain-size distribution, cohesiveness, beach slope also play an important role.

Model theories for the Calculation of Onshore-offshore Transport Drift

- Simple cross shore transport model
- Fall time model
- Traction model for cross shore transport
- Energetics model
- Ripple model

Simple Cross-shore Transport Model

- This model was first proposed by Moore and later modified by Kriebel and Dean.
- The basic concept is that, for **a uniform sand size** across the profile and **an equilibrium beach**, there is a constant energy dissipation rate per unit volume.
- It is assumed that the amount of sediment moved will be dependent on the difference between the actual energy dissipation rate and that for an equilibrium profile D^*.

$$q_s = K(D - D^*.)$$

Where, q_s = volumetric cross-shore sediment transport rate per unit width in the offshore direction,

K = transport coefficient which depends on sediment characteristics, wave climate, etc.)

D = actual water depth at a location

D^* = equilibrium depth of closure (the depth beyond which no significant sediment movement occurs)

Simple Cross-shore Transport Model

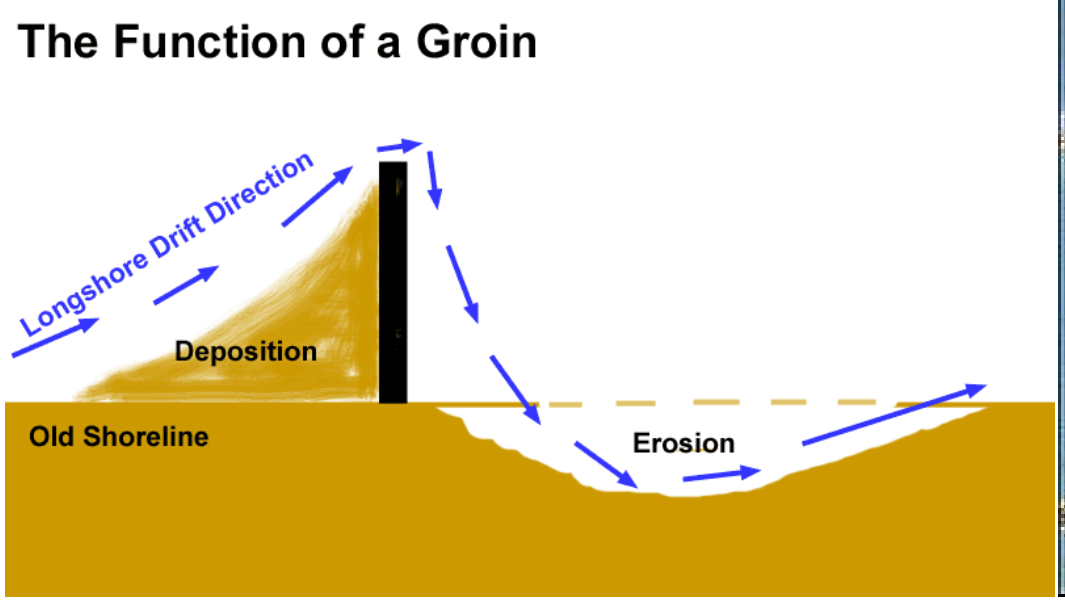
- If D is greater than the equilibrium value D* there is a greater turbulence level in the surf zone than that of the equilibrium profile. If q_s is positive then there will be a sediment transport in the offshore direction. On the other hand, for values of D less than the equilibrium value, onshore transport will occur. The value D can be obtained as,

$$\mathbf{D = (5\rho g k^2 (gh)^{0.5} dh/dy)/16}$$

which is dependent on the water depth and bottom slope, which has a stronger effect.

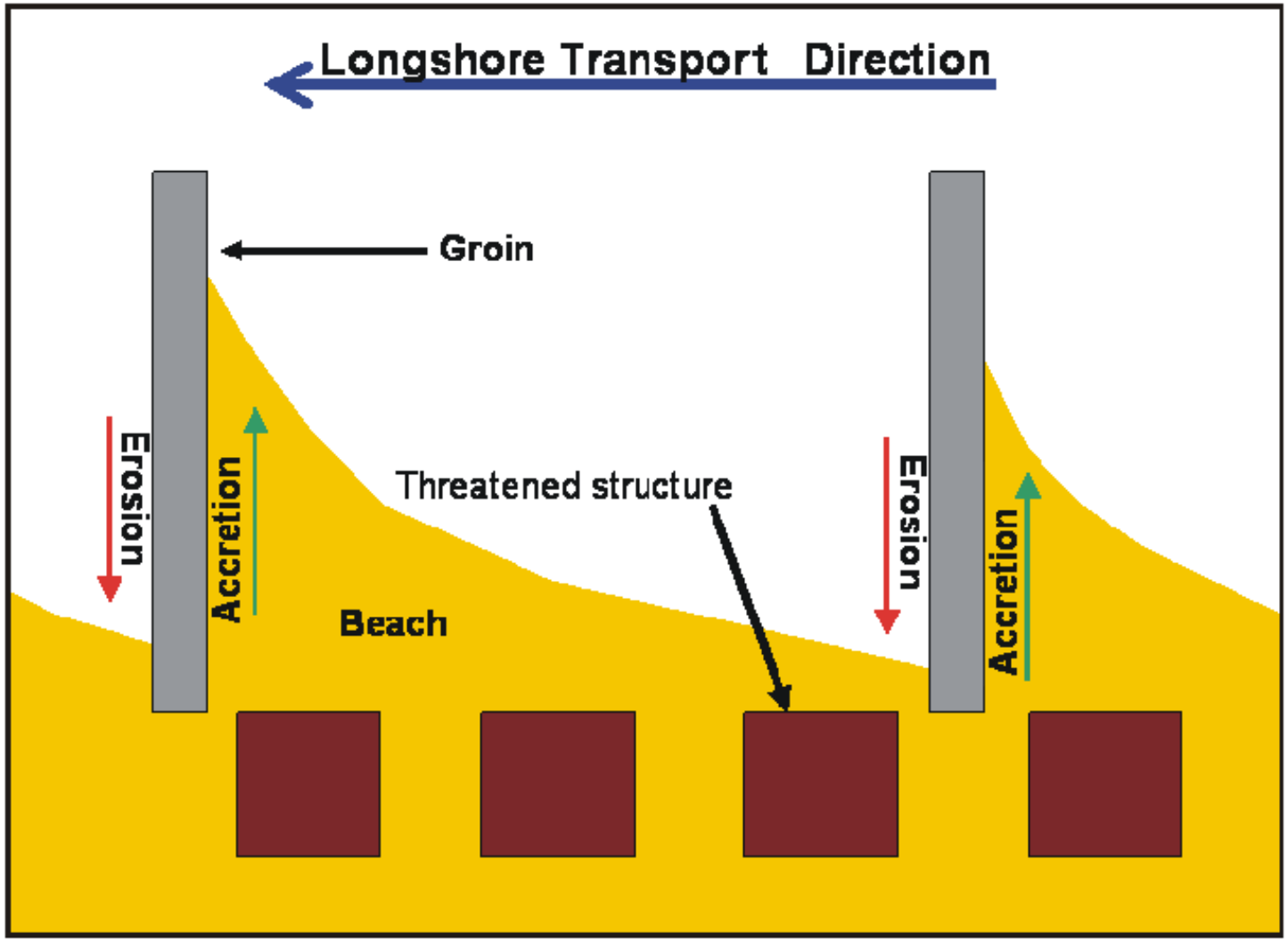
Sediment Transport and Coastal Processes

Groin - shore perpendicular structure, installed singly or as a field of groins, designed to trap sand from the littoral drift system





Sediment Transport



Sediment Transport

Gabions – Boulders and rocks are wired into mesh cages and usually placed in front of areas vulnerable to heavy to moderate erosion.



Sediment Transport

Longshore bar - offshore ridge or mound of sand, gravel or other loose material running parallel to the shore which is submerged (at least at high tide) and located a short distance from the shore.



Sediment Transport

Beach nourishment - the restoration of a beach by the mechanical placement of sand on the beach for recreational and/or shore protection purposes.



Sediment Transport

Sand spit- low tongue of land or a relatively long, narrow shoal extending from the land.



Sediment Transport

Tombolo - the combination of an offshore rock or island which is connected to the beach by a sand spit




THANK YOU