0:0 Unit Overview

Demonstrate comprehensive understanding of how interacting natural processes shape a New Zealand geographic environment involves:

- critically analysing the **interacting natural processes** and how they shape the **environment**
- integrating comprehensive supporting case study evidence.

2 *Interacting natural processes* refer to **processes that operate together to shape the environment** and may include **how natural processes operate at different rates** and **different scales** to create **variations (spatial and/or temporal)** in the geographic environment.

3 *Geographic environment* refers to the features and characteristics of a specific area large enough to allow for the study of several interacting natural processes.

Key Concepts to be covered in this unit.

- **Environments**
- **Features**
- **Processes**
- **Interactions**
- **Spatial Variations**
- **Temporal Variations**

0:1 Definitions of Key Geographic Concepts

Geographic Concept: Processes

Natural processes are natural events that occur in a sequence whereby one event causes another event to occur or change. Natural processes occur above, on and below the earth's surface. Processes can vary in time and space. Processes vary in magnitude and frequency.

Geographic Concept: Interactions

Involves elements of an environment affecting each other and being linked together. Interaction incorporates movement, flows, connections, links and interrelationships. Landscapes are the visible outcome of interactions. Interaction can bring about environmental change.
IE: An **interaction** is the way one thing or process affects another.

0:2 High Order Natural Processes

Natural processes can be divided into six high order (main) natural processes. These high order natural processes can further be divided into sub- natural processes:

Geomorphological: Processes that build the land. (Faulting, Folding, Volcanism)
Climatological: Processes that determine weather patterns. (Heating & cooling, expansion & contraction, Weathering, Solution, Oxidation, Salt Crystalisation, Hydration, Corrosion, Frittering, Evaporation, Insolation, air pressure, temperature, precipitation, humidity, wind, frost, Aeolian processes of saltation, surface creep & suspension.), Glaciation (Movement of ice over landscapes.)
Bio geographical: Processes whereby the life cycle provides the catalyst for new life. (Plant growth)
Fluvial: Moving water (river erosion, transportation and deposition)
Hydrological: Processes pertaining to the water cycle whereby water moves between air, water bodies and land. E.g. Wave action (refraction, reflection, diffraction, abrasion, attrition, corrosion, hydraulic pressure, quarrying, chemical weathering, longshore drift, currents, plunging, surging and spilling waves, swash, backwash.)
Pedological: Processes involved in the formation of soil types. (horizons, patterns, leaching and weathering, decomposition)

1:0 Muriwai Coastal Environment

I will cover:

- ✓ **Definition of coasts**
- ✓ **Muriwai's location**
- ✓ **Characteristics of Muriwai's environment**
- ✓ **Skills (Precis Maps, 14 point Grid References, Measuring Slope Angle)**

Go over **definition of coastal environment** – meeting of land, water and air

Geographic Concept: Environments

May be **natural** and/or **cultural**. They have particular characteristics and **features** which can be the result of natural and/or cultural processes. The particular characteristics of an environment may be similar to and/or different from another.

Teachers may choose additional concepts that may connect with the local environment or the circumstances of their students. Such concepts must be geographic in nature; **they must have a spatial component**.

Spatial components relate to how features are arranged on the Earth's surface. For example, an understanding of 'environments' will be supported by students also developing an understanding of additional concepts such as **location**, **distance** and **region**.

1:1 Defining the coast

- *Where the land meets the sea.*
- *Parts of the coast are being eaten away by erosion processes. Parts are being added to by deposition processes. In many parts erosion and deposition alternate with the seasons.*
- ***Littoral Zone:*** *On land it includes the furthest* point the sea can affect, as well as those areas where sand is blown from beach deposits. At sea, it includes the furthest point that land based processes can influence. (E.g. where river flows cease to dump sediment on the seabed.) However, due to rising and falling sea levels the littoral zone is constantly changing.

Natural features are phenomena in a geographic environment that result from natural processes over time. Geographic environments are **spatial areas** where different natural features exist in different places that are constantly being changed by natural processes. Geographic environments are classified by **dominant** natural processes that operate within them. E.g. Coastal environments have features mainly shaped by Coastal processes.

Muriwai Beach is a coastal environment that is dominated by **wave processes.** (**Process classification method:** Wave process dominated systems, Tidal process dominated systems, River process dominated systems)

1:2 What are the characteristics of the Muriwai coastal environment?

Task 1: Identify the main elements that occur in this environment that make it unique and describe them. Then **categorise** them according to land, air and water.

Task 2: Read the information under **1:3** below. (Also see Muriwai Field Guide) Break the information on the Muriwai coastal environment down into **Inputs (Elements), Processes (Actions) and Outputs** (Landform features and patterns) - (*see examples below*)

	INPUTS	**PROCESSES**	**OUTPUTS**
Meaning	The elements needed that give an environment its characteristics	The actions that occur in the environment which transfer energy	What results from the processes in terms of physical landforms or patterns or change.
Coastal examples *(note only a few given)*	Sand Rock Waves Plants Wind	Wave Action Wind Action Weathering Vegetation Growth	Headlands Caves Stacks Beaches Sand dunes

Location
Muriwai is located on West Coast of the Auckland region, latitude & longitude coordinates: **36.8167° S, 174.4167° E**
Being located on the Tasman Sea, Muriwai receives westerly and south westerly 40% of the time (usually over 11 knots). 70% of the time these winds blow onshore. Thus it is a high energy coastal system with typical wave heights over 1.5 metres from trough to crest. There are swells all year round, and storm waves with heights up to 3 metres.

The Headland: Otakamiro Point has a Gannet Colony, Wave Cut Platform (Fisherman's rock), blowhole, caves, stack (Motutara Island), joints, cliffs, notch and visor. Also some honeycomb weathering present. The headland is vegetated with Flax, Pohutukawa, and Kawakawa etc.

Muriwai Beach: Muriwai beach runs for 60 km south to north from Otakimiro Point to South Head of the Kaipara Harbour.
Muriwai has a high sediment supply with black ironsand from Mt. Taranaki (Heavy minerals: ilmenite and titomagnetite) Holocene (recent). Volcanic based sediments from the Waikato river. Awhitu sands: whitish grey sand which originates from Pleistocene. Also sediments that comes from dunes inland.
Muriwai has a Surf zone 200-500 metres wide because of its low gradient. Muriwai is Mesotidal, with a 3 metre tidal range. Muriwai has no berm so swash waves often run against the foredune during high tides.
Muriwai is a high energy, dissipative beach

Maori Bay: Ironsand beach. The beach is steeper than Muriwai. Has cliffs with debris below. The cliffs have pillow lava formations as well as Waitakere group sedimentary rock types: volcanic origin with a mixture of scoria, andesite, conglomerate rock. (The coastline south of Maori Bay has the same characterisitcs: E.G. **Pillow Lava Bay** & **Collins Bay**) **Mercer Bay** between **Piha** & **Karekare** has caves, stacks, cliffs, arches, dunes.

The Dunes
Muriwai has a dune system running parallel to the beach. Fore dunes , including fore dunes and hind dunes. Inland there are ancient dune ridges. There has been considerable human modification of the dunes, including the Golf Course and Woodhill Forest on the eastern and northern margins. The vegetation on the fore dunes include spinifex and pingao grass. Further back you can find the introduced Marram grass and native species such as Karo and Toi Toi. There is also a wetland by **Okiritoto Stream** which passes through the dunes.
Heights of the dunes range from 3 metres opposite the Golf Course to 10 metres near the Surf Life Saving Tower.

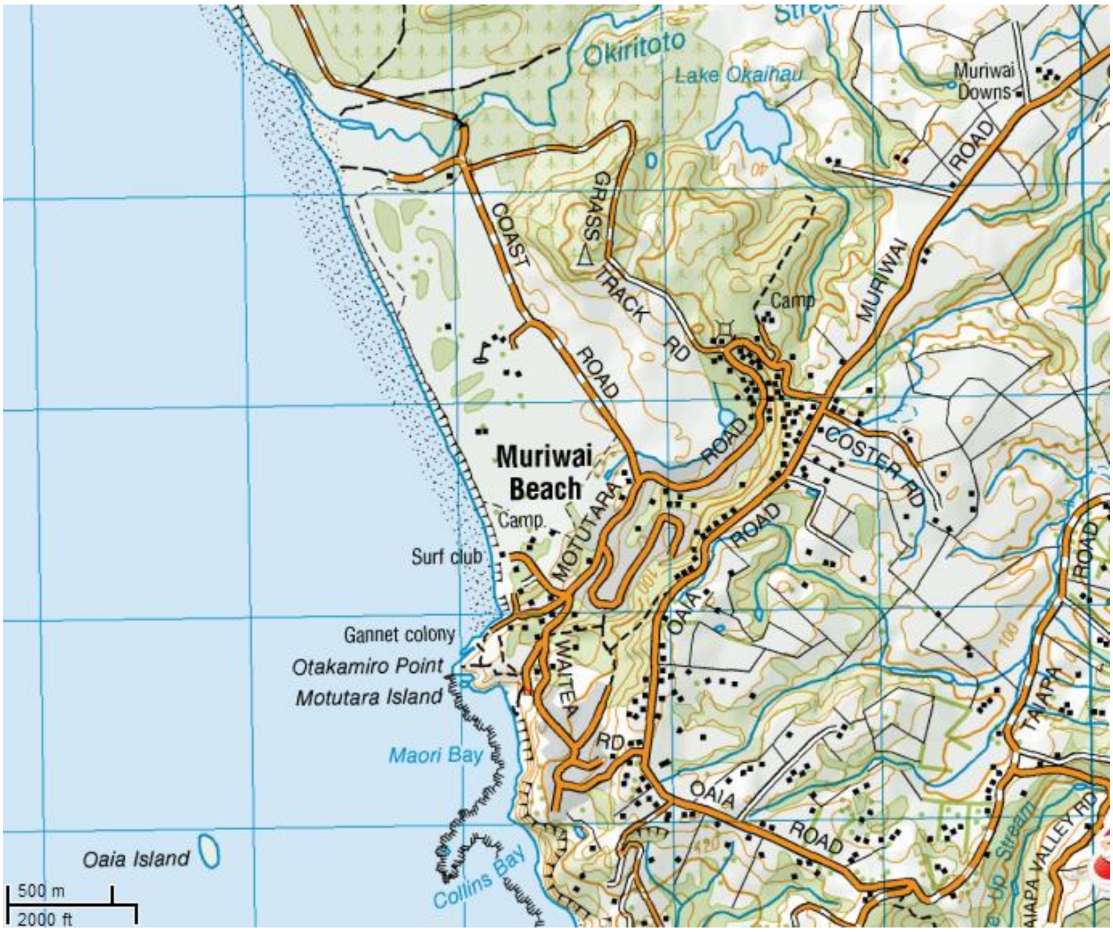
Okiritoto Stream is 3km north of Otakamiro Point is the main drainage catchment. Further back is **Lake Okaihau.** There is also a smaller stream which drains out at the southern part of the beach.

Oaia Island: An extinct volcano off the coast off Maori Bay.

Cultural Features
- 64 ha Muriwai golf course
- Roads
- Buildings including the Café at Muriwai village
- Playground
- Car parks
- Sea wall & Gabion Baskets
- Surf Life Saving tower
- Sand Fences
- Camp ground
- Regional park 183 ha

1:3 Precis Map from a Topographic Map of Muriwai

Activity: Draw a map showing the spatial variation of features at Muriwai. Present the students with a topographical map with no key. This will help students get familiar with the layout of the Muriwai Geographic environment. The video on the link below is helpful in learning how to draw a Precis Map. **http://www.youtube.com/watch?v=mKIlwunIQEc**



What the specific environment is like?

Task: 1. Students must learn to draw an annotated map of the Muriwai environment from memory. The map must show the main features there.
Task 2: Go online and identify the coastal features and their characteristics from photographs (or in the field). The class could be divided into groups. Each group has to find images of the different elements/categories that exist at Muriwai: e.g. hydrology, waves, geology, vegetation, cultural, wind, & sediment.
Task 3: Identify the **spatial variation** or how these elements vary in different parts of the environment. For example where is it steepest? Where is it windiest? Where do the highest waves occur? Where is the vegetation most dense? How does the sediment differ? Draw annotated maps to show this.

1:4: Fourteen Point Grid References

Watch Video on how to read a 14 point Grid Reference:
http://youtu.be/7w_PuHapDFU

1:5: Calculating Slope Angles

Watch video on how to calculate slope angles:
http://youtu.be/_0CxodQT0h8

Then we will practice using a topographic map.

2:0 Processes

- **Identify the main processes** that occur in this environment. Such processes should be agent based so that the way energy is transferred is easy to see and can be broken down into stages. E.g. wave action, wind action, tectonic action and vegetation growth. Then **categorise t**hese processes by scale (*See example below*). Select at least 4 to study in depth that are important in this environment.

LARGE SCALE	MEDIUM SCALE	SMALL SCALE	SUB-PROCESSES
Hydrological *(only this example given)*	Wave Action	Wave transport Wave Erosion Wave Deposition	Long shore drift Hydraulic Action Beach Sorting

- For each process identify **how it works or operates** as a series of related steps or actions and their outcomes. First this happens, then this and then that.

- How does each process affect another process? **How do they interact?**

- How do the processes interact to **produce specific features?** What is the role of each process and how important is it in the formation of this?

- What **role do these processes** play in causing the **spatial variations** in the environment? Link how the processes act differently in different parts of the environment to the variations in the elements. Why are some features here and not over there?

2:1 Geomorphology and the Coastline

Watch Youtube Video: Coastal Processes at Muriwai Beach Part One.
http://youtu.be/VyrTFNA2Ljo

Watch Youtube video on sediment and its origins.
http://youtu.be/HHcFiI8rx_g

I will cover:

- ✓ **Mohs scale of hardness**
- ✓ **Geomorphology and the shape/ structure of the coastline**
- ✓ **Geology & sediment**
- ✓ **Geomorpholgy and its impact on the spatial variations of coastal topography in Auckland's west coast**

Key ideas:

1. *Geomorphological processes build up the land which is later modified by its interaction with various erosion processes to produce coastal features.*
2. *The hardness of the rocks effects the way the coastline is eroded.*
3. *The geology of the coastline itself is a source of beach sediments.*

Key terms:
Greywacke: Hardened sandstones and mudstones that make up New Zealand's mountain core.

Igneous: Rock formed when magma cools and solidifies below the Earth's surface rather than being ejected to become volcanic rock.
Ignimbrites: Superheated gas and ash spills over the countryside to settle in valleys and depressions as welded rocks.
Plutonic: Rock material that forms at depth with slow cooling and crystallisation.
Sedimentary: Eroded fragments of rock laid down by water and wind, often in distinctive layers. Some sedimentary rocks may have been organically deposited.

Geomorphological processes include:

- ✓ **Rock formation** is a process whereby sand and mud deposited into the sea bed were, by the pressure of subsequent layers, consolidated into the Waitemata series of sedimentary rocks with strata of differential hardness of coarse hard sandstone and fine grained weaker greywacke mudstone.
- ✓ **Tectonic processes**
- ✓ **Folding**
- ✓ **Faulting**
- ✓ **Volcanism**

2:2 Mohs' Scale of hardness

The resistance of rocks to erosion (their **hardness**) can be measured on Moh's scale of 1 to 10. Most rocks are combinations of minerals and will be harder or softer depending on the combination of minerals and their structure.

Mohs' scale
1 Talc
2 Gypsum
3 Calcite
4 Fluorite
5 Apatite
6 Orthoclase
7 Quartz
8 Topaz
9 Corundum
10 Diamond

A classification of New Zealand rocks based on **hardness** would be:

- Soft, easily eroded, **sedimentary** rocks composed of compressed alluvial material or lightly compressed volcanic ash. 1 to 3 on Moh's scale.
- Harder sedimentary rocks that have been **indurated** (hardened by greater pressure). 5 or 6 on Moh's scale.
- Resistant volcanic rocks such as lahars containing boulders, or welded **ignimbrites** or **conglomerates** (mixtures of finer volcanic material and heavier stones and boulders). 6 or 7 on Moh's scale.
- **Igneous rocks** that have melted at depth and cooled into rock either at the surface (e.g. volcanic material such as **basaltic** and **andesitic** lavas), or cooled underground (**plutonic**, e.g. granite). Around 7 on Moh's scale.
- **Metamorphic rocks** (altered by pressure and heat at depth) such as gneiss or shist. These are generally very hard rocks but not always; for example mica forms in layers like thin sheets of plastic that are easily separated.

2:3 Geomorpholgy & Shape of the Coastline

Rank	Country	Coastline (km)
1	Canada	202,080
2	Indonesia	54,716
—	Greenland	44,087
3	Russia	37,653
4	Philippines	36,289
5	Japan	29,751
6	Australia	25,760
7	Norway	25,148
8	United States	19,924
9	New Zealand	15,134
10	China	14,500

Source: CIA World Factbook

Coastal **topography** is usually a reflection of the hardness of rocks combined with the availability of sediments. The shape of New Zealand is largely defined by more resistant rocks at its points. Rapid **uplift** of the land also plays a part in shaping coastal relief in some places.

Isostatic uplift has occurred:

- Along the east coast of the North Island- characterised by raised beaches and marine terraces.
- On the Wellington peninsula; cliffs uplifted and small streams and hanging valleys created.
- In the South Island, raising the Southern Alps (building the Canterbury Plains with sediments derived from the greywacke core)

New Zealand is a young country geologically so the processes of coastal erosion, transportation and deposition are working to straighten our coastline.

The structure of the coast

The alignment of rock structures relative to the shoreline has considerable bearing on the nature and therefore distribution of coastal features.

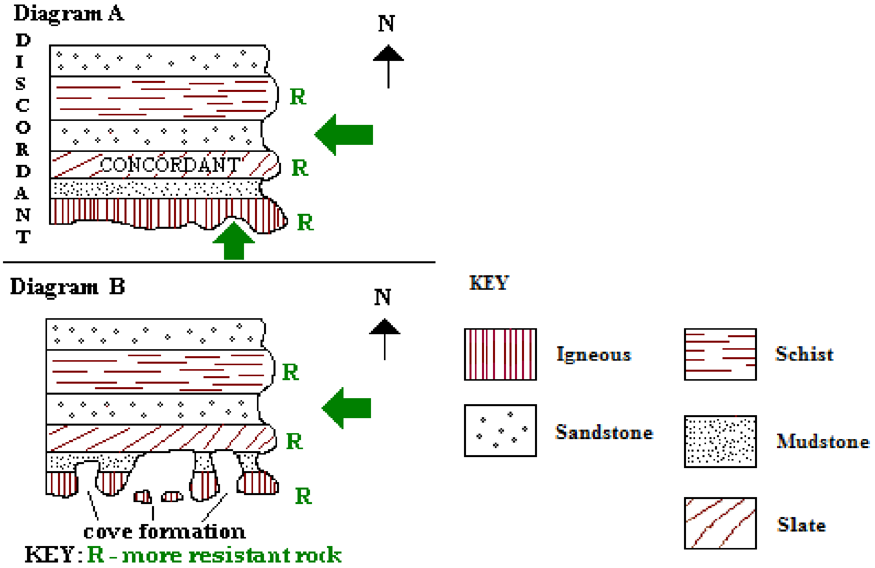
There are two types:

- The **Atlantic type (discordant)**, where bands of rock run transverse to a coast- the Marlborough Sounds.
- The **Pacific type (concordant)**, where bands run longitudinal to the coastline- not very evident in New Zealand.

The diagram below shows how various alignments of rock structures present either relatively resistant of weak rocks to wave attack and some of the resulting effects.

In diagram A the bend of the coast allows the waves to attack rocks of different resistance, exposed by their discordant alignment, and others to pound against the more uniform, concordant stretch of coast.

On the eastern side a coast of headlands and bays develops. Meanwhile, to the south, a series of coves, broad bays, and islands form.

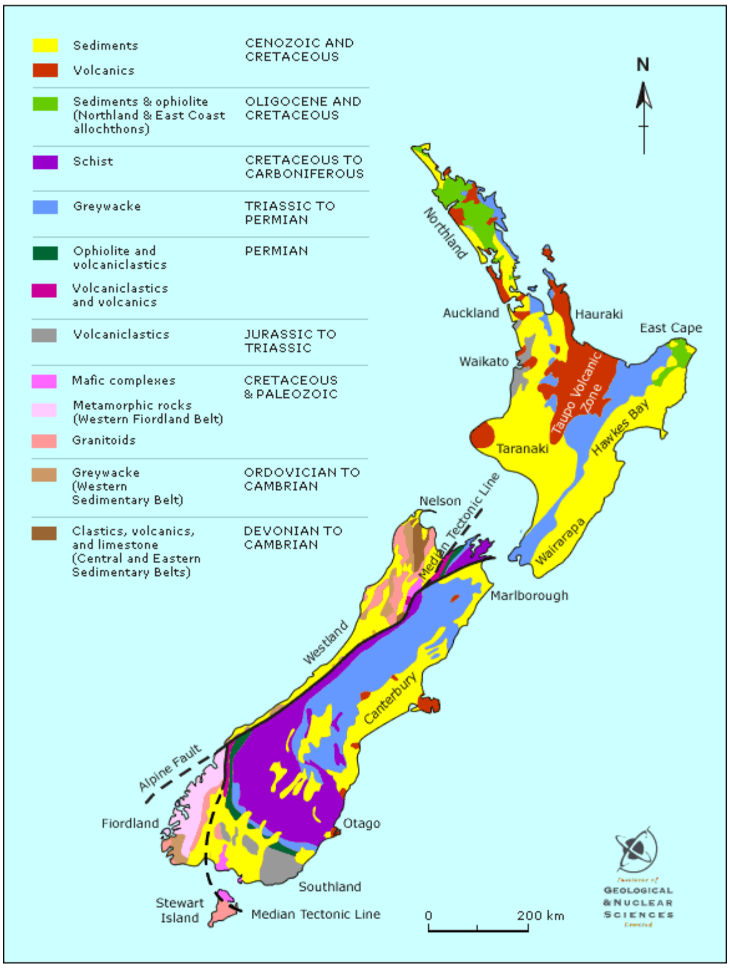


2:4 Volcanic activity and origin of beach sediments

Volcanism located on the Plate margin (Indo-Australian & Pacific plates) has supplied the North Island's coastline with a range of igneous sedimentary materials such as Pumice, Silica and Titomagnetite. Rivers and Glaciers have transported Greywacke resulting in coarser, grey coloured sediments on South Island beaches.

- Volcanic activity in Auckland has created a basaltic lava coastline.
- Banks Peninsula's much older volcanic geomorphology is an example of a typically arcuate coastline, long subject to the processes of fluvial erosion and subsequently inundated by both sinking of the volcanoes and by the eustatic rise in sea level.
- The west coast has more soft sedimentary rocks and sediment than the east coast. (Quarternary and Tertiary)
- On the East Coast, the geology has more hard, erosion resistant rocks than the west coast. (e.g. This combined with uplift of land (up or down) relative to sea level has often created indented coastlines. (Precambrian & Paleozoic hard sedimentary, Volcanic, Metamorphic and Plutonic rocks)

New Zealand geology



- http://www.nzpam.govt.nz/cms/images-old/minerals/maps/New%20Zealand%20Geology%20full%20screen/image_view_fullscreen

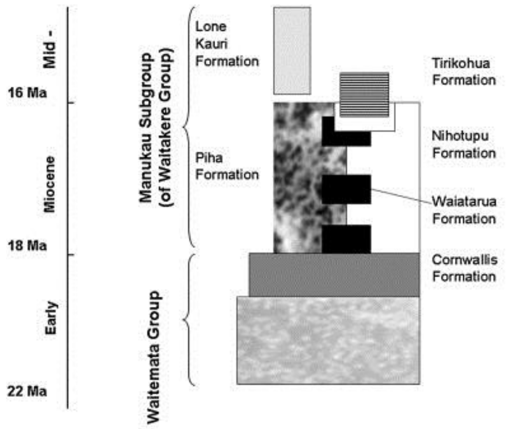
2:5 The impact of Geology on the Spatial Variations of coastal topography of Auckland's west coast.

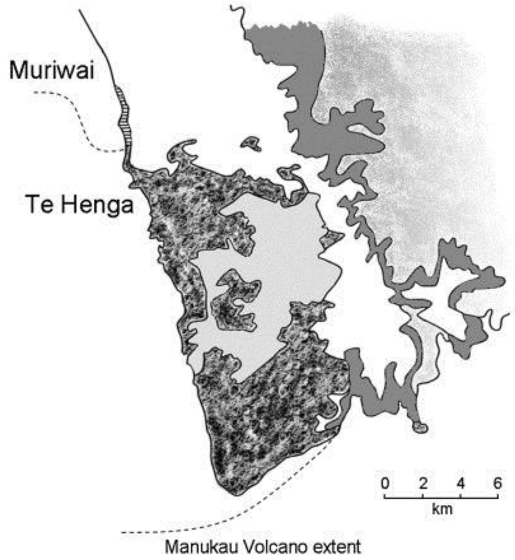
More ancient **andesite** volcanoes in the Waitakeres originally formed underwater by what was then a large offshore volcano. (This is evidenced by the presence of pillow lava at many west coast beaches. **Pillow lava** forms underwater.) This causes differential erosion when **andesite** and **conglomerate** rocks layers alternate with soft rock layers.

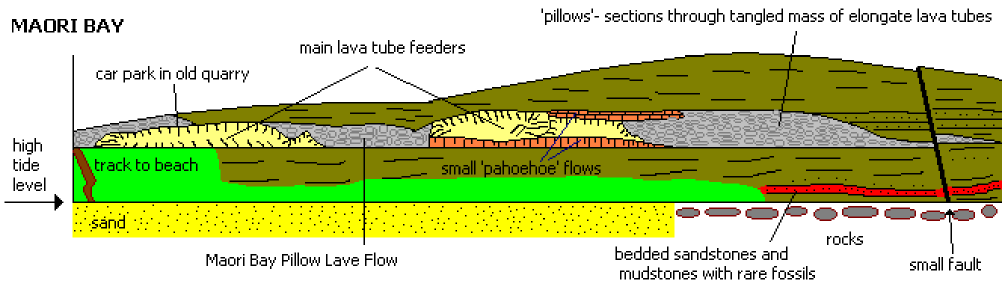
On Auckland's west coast, the harder volcanic rocks have resulted in cliffs and headlands, while places with softer sedimentary rocks have eroded into bays where beaches form.
Otakamiro Point and Maori Bay have conglomerate rocks made from a mixture of andesite, scoria & pumice. There are also beds of sandstone and siltstone. These rocks are of moderate hardness.

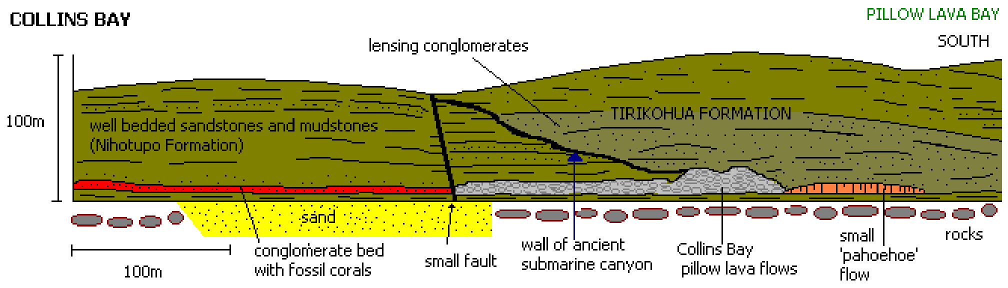
Breccia (mixtures of broken rock) and conglomerates from past eruptions underwater are also found. These igneous rocks are harder and fracture into columns or pillows if the formation is a pillow lava formation. However, the **Tirikohua formation** rocks at Otakamiro point are coarse volcanic material that has formed a more resistant headland.

These igneous rocks eventually weather to soft red-brown clays and characterise the cliffs of the area. The hardness of the rock, and the jointing that is characteristic of such igneous material, means that erosion features like stacks, caves and blowholes characterise the landscape. (There is an arch at Mercer Bay)









3:0 Tidal range and processes *Beguely pages 98-111*

I will cover:

- ✓ **Tidal range**
- ✓ **Tidal currents**
- ✓ **Tidal processes and spatial variations**
- ✓ **Ocean current circulation and spatial variations**

A **tide** is actually a wave with a very long wave length (about 1500km). Tides are caused by the effects of **gravity** from the **sun** and the **moon**, particularly the moon, which is much closer to the earth and about a quarter of the earth's mass. The gravitational pull of the sun and moon create a bulge in the oceans. The high point of the bulge produces high tides and the low point produces low tides.

- ❖ When the sun and the moon are lined up together with the earth then **spring tides** are created (higher than usual).
- ❖ **Neap tides (**lower than usual) occur when the sun and moon are at right angles to the earth.
- ❖ Most coasts have a **Semi-diurnal tidal pattern**, where there are two daily high and low tides every day.
- ❖ Some coasts, because of particular combinations such as the patterns of sheltering headlands and current and river processes, may have **diurnal** (one high and low tide per day, e.g. New Orleans) or **mixed** (one main high tide and low tide with a smaller high and low tide, e.g. San Francisco) tidal patterns.

Tidal range is the difference between high tide and low tide during the cycle of the tides.
Factors that cause changes from place to place in tidal range are as follows:

- The tidal range becomes greater as distance from the centre of an oceanic circulatory system becomes greater. (The main factor)
- The shape of the coastline- A straight, open ocean coast has less range but bays and estuaries tend to have higher tidal ranges.
- The depth and shape of the sea bed, which can focus the volume and energy of a wave to produce higher tidal ranges in places.
- The continental shelf- The wider the continental shelf, the higher the tide will be because the tidal wave crest has more time to concentrate into a higher wave.
- Extreme climatic events such as cyclones can drastically alter tidal levels. When air pressure drops 40 millibars below the average, the sea level can rise by an equivalent number of centimeters. When this increase in sea level combines with a high tide, low lying coastlines can be flooded. When storm winds blowing onshore are added to the mix, a **storm surge** can cause water levels to be 10-15 metres higher than normal.

Classifying coasts by tidal range:
Microtidal coastlines have a tidal range of less than 2 metres. E.g. Eastern Australia and Southern New Zealand.
Mesotidal coastlines: 2-4 metres (e.g. Muriwai is a **mesotidal** about 3 metre tidal range)
Macrotidal coastlines: 4-6 metres (e.g. North West of the north island of New Zealand, Britain)

Measuring tides:
High and low water: The highest and lowest tide levels recorded during any tidal cycle.
Mean high water (MHW): The average level of all high waters recorded at a particular point.
Mean high water springs (MHWS): The average height of the high water occurring at the time of spring tides.
Mean low water (MLW): The average height of the low waters over a 19 year period.
Mean low water (MLW): The average height of the low waters occurring at the time of the spring tides.
Mean range of tide: The difference in height between high water (MHW) and mean low water (MLW).

The width of the **intertidal zone** is decided by a combination of tidal range and gradient. Wide intertidal zones form on less steep, macrotidal coasts. Narrow intertidal zones are usually created on steep, microtidal coastlines. The higher the tidal range, the more drying of **substrate** can occur. The more drying occurs, the more Aeolian transportation of sand grains landward up the beach, and the more rapid the dune formation. **Salt crystals** also have more time to form on macrotidal coasts and rocks such as granites can be severely weathered by this crystallization process.
Wave action is affected by tidal ranges. Coasts characterized by notches at the base of cliffs are usually microtidal so wave breaking and its energetic impact is concentrated to form such erosion features. By contrast, macrotidal coasts are affected by waves over a wider area but the impact is less, as is the level of wave erosion.

3:1 Tidal currents and processes

Tidal current are caused by the rising and falling of water with the tides. A rising tide is called the **'flood tide'** and a falling tide is the **'ebb tide'**.
Tidal currents *move sediment* back and forth. The velocity of tidal currents is greatest at the halfway points between rising or falling, and this is therefore when the most sediment transport occurs. Current speed is zero at **slackwater** (high and low tide), so naturally the greatest **deposition** of sediment occurs at this time.
Whether transportation or deposition occurs depends on the relationship between particle size and velocity.
Since the same amount of water is flowing in and out on the tides then, if one tide is shorter than the other, its current will have the dominant effect. (e.g. if

flood tide takes 3 hours to come in and the ebb tide takes 8 hours to go out, then the flood tide would flow much faster. In this case the dominant flood tide current would carry far more sediment to land than would be taken out by the ebb tide.)

The **morphology** (shape) of the seabed is also affected by the velocity of the tidal processes. Where there are high current velocities, phenomena such as ribbons of sand and furrows tend to point in the same direction; where current velocities are low, phenomena such as ripples form at right angles to the flow. However, at very high or very low velocities, the bed may be smooth.

3:2 The effects of Gravity and Tidal Processes on spatial variations of the coast

Tidal flows are not usually of major significance in shaping the coast as the transportation of water and sediment is reversed every 24 hours. However, tidal currents can be increased when their flow is channelled, e.g. Cook Strait.

3:3 The effects of current circulation on spatial variations of the coast

New Zealand's west coast circulation of currents is linked to the East Australian current, which affects the North Island at North Cape.

- The flow divides to become the southward flowing East Auckland and West Auckland currents.
- The west wind drift south of Tasmania also directs the flow of the East Australia current eastwards towards Fiordland.
- It divides to become the northward- flowing Westland current and the eastward flowing Southland current.
- At times the Westland current may flow all the way up the east coast of the North Island, displacing the variable West Auckland current coming from the north.

4:0 Wave Processes

I will cover:

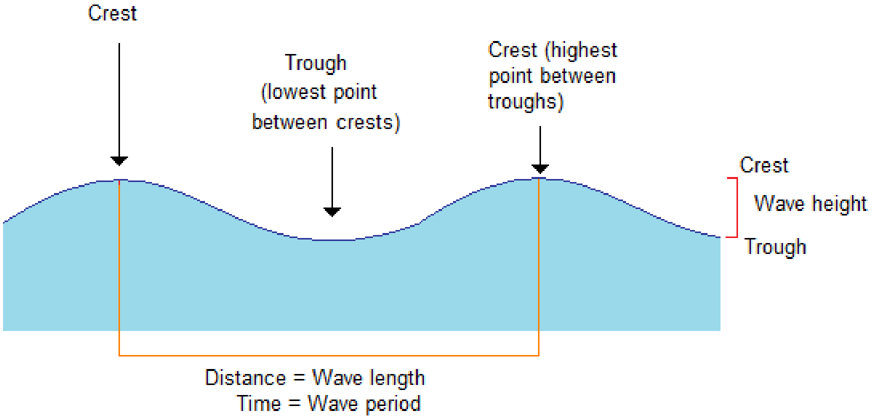
- ✓ **Wave characteristics and motion**
- ✓ **Wave refraction, diffraction and reflection**
- ✓ **How waves break**
- ✓ **How waves form**
- ✓ **Spatial variations of the operation of wind & wave processes in New Zealand.**

Watch Youtube videos on Ocean Waves and Erosion
http://youtu.be/m4bHsa1w0yI
Waves and Longshore Drift
http://youtu.be/sTDsQNXwn04

4:1 Wave characteristics and motion

Each wave has a **crest** and a **trough** exists between each wave. The distance between wave crests is called the **wave length** and the measurement from the bottom of the trough to the top of the wave crest is the **wave height**. The time it takes for wave crests or troughs to pass a fixed point is called the **wave period**.

Characteristics of waves



Ocean waves are ***not*** moving masses of water. In fact, a wave represents *energy being transferred*. E.G. The way energy transmitted by wave motion is similar to that sent through a rope held at each end. By jerking the rope at one end it can be made to undulate and can be snatched from a loose attachment at the other end, yet no part of the rope will move forward.
Since wave molecules move in a circular motion, the waves are called **oscillatory waves.**

Give an example of a student rolling under carpet. The student represents the moving energy. The carpet is not moving. Compare to sound waves and radio waves.

Wave length can be calculated from observations of wave periods:
*(**Extension activity:** Page 63 Beguely)*

$$L=\frac{gT^2}{2\pi}$$

L= wave length
G is the constant 9.81 m/s (acceleration due to gravity)
T is the wave period in seconds
Is 3.142 (ratio of circle circumference to diameter)

Velocity of deep water waves

$$C=\frac{gT}{2\pi}$$

Shallow water waves

Wave length **$L+T\sqrt{gd}$**
Wave velocity **$C=\sqrt{gd}$**

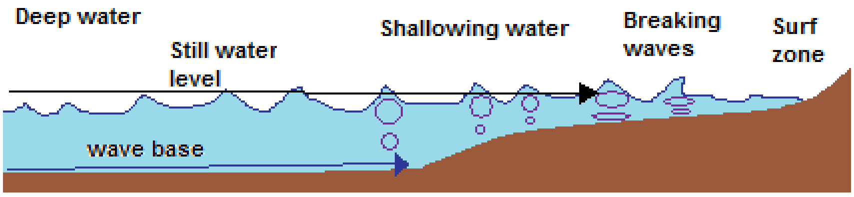
Field Work: Calculate wave lengths and velocity at the beach

Since waves are usually generated by wind energy there is a certain depth below which surface waves do no affect the water below. This is called the **wave base.**

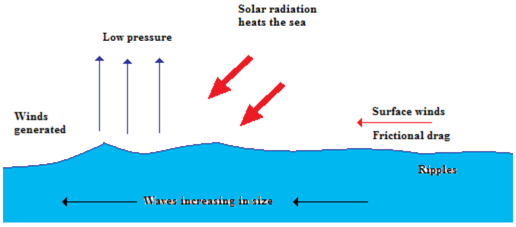
Deep water waves are oscillatory waves that move through water above their wave base. Waves are formed by the energy of the wind blowing over long ocean distances. **(Fetch).** Energy passes through wave particles in an orbital motion.
Shallow water waves are waves moving through water less deep than their wave base.

The **motion of particles** beneath the surface in deep water are **orbital**, but the diameter of these circles becomes smaller as the distance from the surface increases.
The velocity of a wave is not affected much by the depth of water until the depth is half the wavelength. As the depth falls below the wave base, friction with the sea bed begins to slow down the wave and change its characteristics. If the height increases and the length decreases, then the wave becomes steeper. At the ***break point***, the deep water orbital motion of the particles has become **ellipitical** and the currents generated by this movement in shallower water can lift and carry sediment. The landward- moving upper part is accelerating and the seaward moving lower part is decelerating. When this happens the wave becomes a **translatory wave.** Eventually the velocity towards the land exceeds the velocity of the wave form and the water rushes beyond the wave, translating the ***potential energy*** into ***kinetic energy*** as the wave breaks. This is how waves work on beaches and against cliffs and cause coastal erosion.

(When the depth becomes <u>one twentieth</u> of the wave length the wave behaves differently)



4:2 How waves form



1. **Activity: Using the notes below construct a flow diagram showing wave processes from their generation to when they break.**

When the wind begins to blow over a still surface, the friction forms small **capillary waves**, with very small wave periods. As distance increases these waves lengths and periods increase, becoming larger and larger sets of waves. **Sea waves** are those created within a storm area, but when they move outside the limits of the storm they become **swell** or **free waves**. Swell waves may travel thousands of kilometres before reaching a shoreline.
When high wind velocities combine with a long fetch (e.g. Pacific Ocean) then large waves (20-25+ metres high) will be experienced. In an area of ocean generating waves, such as in a storm system, chaotic wave structures are created, with different wave lengths and wave periods. These waves get sorted out after they leave the generating area because those of long wave length travel faster than those of short wave length. The process of wave sorting as the waves move away from the storm area is called **dispersion.** The separation of waves of different periods produces swell waves, and this process gives rise to a **wave train**, which are waves with long wave lengths preceding waves of shorter wave length. This process of dispersion, with waves travelling thousands of kilometres across vast oceans, creates great surfing conditions on many coasts of the Pacific or Atlantic oceans. However, in enclosed seas such as the Black Sea or the Mediterranean the limited fetch means that long and short waves often stay together to produce choppy conditions.
Surf beat is a <u>change in water level in the surf zone</u> with the water level rising and the surf zone growing wider when a group of large waves come in. Conversely, the water level lowers and the surf zone shrinks when a group of smaller waves come in. These larger and smaller groups of waves moving in the same direction combine to increase wave height. (Called **Superposition** or **Constructive Interference**)
However, when the wave crest and the wave trough coincide as the wave trains meet the wave height is lessened **(Destructive Interference).**

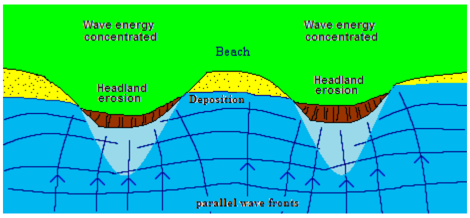
Activities:

2. Create a systems diagram to show how wind waves are formed.
3. Explain how constructive interference (superposition) and destructive interference can make waves larger or smaller by the time they reach the shore.
4. Explain how fetch may influence wave conditions.
5. Draw a weather map which would give great surfing conditions at Muriwai.

4:3 Wave refraction, diffraction and reflection

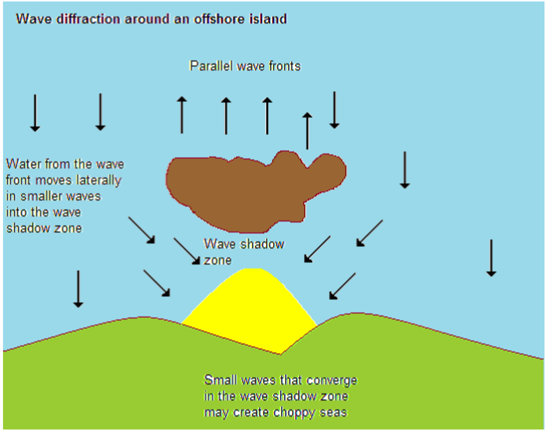
Wave refraction

Wave refraction refers to the process by which waves undergo a change of direction as they approach headlands and beaches.
This happens when an **incident wave** (uninterrupted by any obstacles) reaches its wave base along *only part* of the wave front. This often happens as a wave approaches a headland since the headland' shallows reach some distance out to sea.

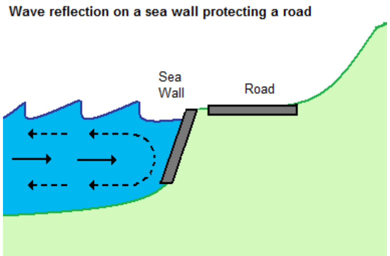


This refraction of the wave's energy happens because the **shoaling** (shallowing) makes the wave slow down in that place (but the rest of the wave front moves on at the same speed that it was moving at before the water shoaled).
<u>Outputs of refraction:</u> The concentration of wave energy on headlands increases erosive potential, causing headlands to have cliffs, arches, stacks, and stumps. Wave energy is reduced in intervening bays, where eroded material is deposited to form beaches.

Diffraction: When waves bend (diffract) around each end of an obstacle. (e.g. an offshore island or when waves enter a bay through a narrow inlet.)The obstacles slow the wave front but allow water to escape laterally into the protected area.



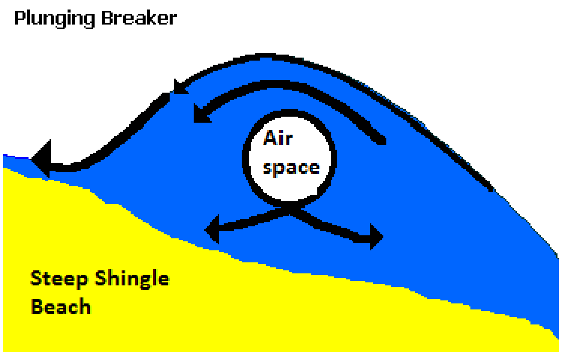
Reflection: The reversal of a wave by an obstacle, e.g. a sea wall. When waves approaching the shore (**incident waves**) meet waves that are reflected back off the beach or a sea wall (**edge waves**), they may move at right angles to the shoreline. This can raise the height of the breakers, thus increasing the impact of waves on the coast.



4:4 How waves break

There are three ways in which a wave breaks.

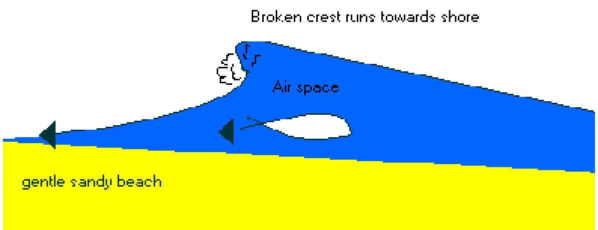
1. **Plunging breaker**: The crest moves forwards and downwards to enclose an air space for an instant between the wave and the broken water. These occur most frequently when slow waves approach a steep beach. The **swash** (up-beach movement) is not as strong as the **backwash** (Down beach movement).



- Intermediate gradient: about 5 degrees
- Steep fronted waves
- Crest curls over and crashes down
- Plenty of foam
- Shallower water
- Wave height/ depth + 0.8-1.1

2. **Spilling breaker:** Most of the breaking water is directed up-beach. Shores with a low angle of approach for waves tend to have spilling breakers with a lot of foam. Spilling breakers tend to lose a lot of their energy in a process called **dissipation.** (Which happens in an area of the beach called the **dissipative domain**.)

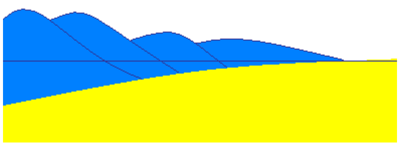
Spilling Breaker



- Low gradient shores: < 2 degrees
- May be steep waves
- Water from the crests 'spill' down the wave fronts
- Plenty of foam
- Deeper water
- Wave height/ depth =0.5-0.8

3. Surging breaker: These do not break fully and so have little foam associated with them. They are low energy waves in which the crest collapses instead of curling over.

Surging breakers



- Steep gradient: > 10 degrees
- Low waves
- Crest collapses
- Little foam
- Deeper water
- Wave height/ depth = 1.1+

For both plunging and surging breakers even greater reflection will occur off hard obstacles like cliffs, and the reflected waves from these may travel at right angles to the shore. When they meet incoming incident waves their troughs and crests can combine, creating an undulating effect. On the other hand, if reflected waves the same height and wave length and velocity meet incident waves going the opposite way, then the water may simply seem to be going up and down but not going anywhere. **(**Called a **Clapotis)**

4:4 Spatial variations of wind and wave processes on the New Zealand coast.

Modern New Zealand is more influenced by wave, gravity and tidal processes than it is by fluvial processes.

- New Zealand's island chain is affected by wave fronts with large fetch from every direction.
- The prevailing winds affecting the west coast create a strong wave regime. The protected east coast has a balance between wave and tidal processes. Strong surge and currents also influence the east coast.

Wind processes

Wind is created by changes in air pressure. High pressure air is drawn towards low-pressure zones. Water level is also higher in low pressure conditions and low in high pressure conditions.

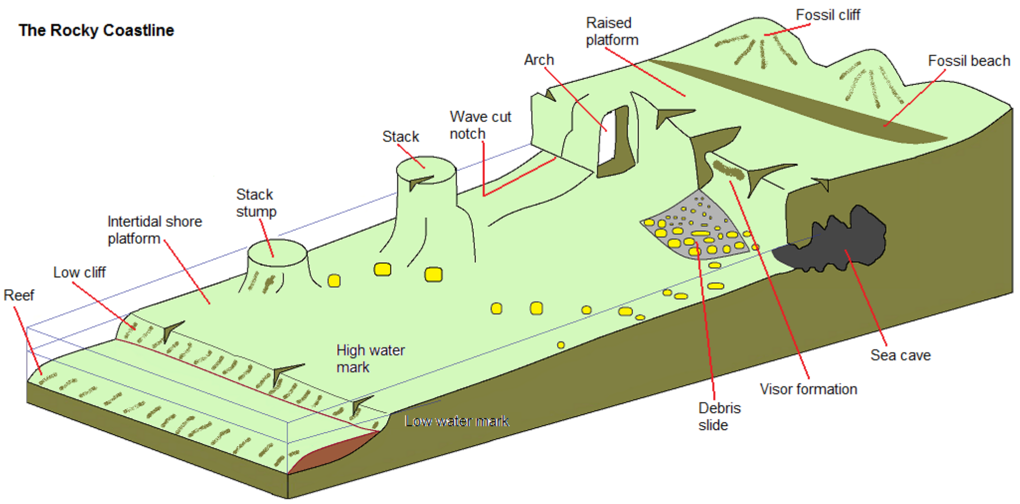
In New Zealand changes of water level in response to air pressure changes are not usually over 30cm, but a combination of storm surge and winds and high tide can caused very high sea levels. Wind is the active agent in wave formation.

- Given enough fetch and duration of the wind at a certain speed, waves are created.
- Westerly winds prevail between 30 and 70 degrees latitude, and New Zealand's main land mass stretches approximately 34-47 degrees south.
- New Zealand has a highly energetic wave regime, dominated by west and south west storm waves.
- The west and south coasts are high wave energy windward coasts.
- South of East Cape is a high wave energy lee coast (prevailing southerlies produce driven, deep-water waves).
- Sheltered coastal areas exist at: -west Wellington and Marlborough Sounds. –the northern sections of the South Island's east coast peninsulas. –the coast from East Cape to North Cape. This is also a protected, low wave energy lee shore.
- Hydrological processes affect the distribution of coastal features mainly through wave energy, with waves either being destructive (cliff erosion, platforms, arches, stacks, caves, headland recession) or constructive (longshore drift, spits, bars, tombolo, straightening coastline).
- The type of wave (plunging, surging, breaking) determines whether the beach profile is steep or flat.
- Aeolian processes, rainfall, hydraulic action by waves and rivers and the effects of currents along the coast have also shaped the littoral zone.
- Protected coastlines, such as eastern coasts or inside harbours, erode less rapidly (waves have less fetch).

5:0 Operation and Interaction of erosion processes (Mainly wave action) with Geomorphology to produce geomorphological features/phenomena at cliffs and headlands

I will cover:

- ✓ **Cliff retreat, formation of arches, caves, & stacks**
- ✓ **Wave cut platforms**
- ✓ **Spatial Variations in natural processes at the cliffs and headlands at Muriwai/ Maori Bay**
- ✓ **Interactions at the cliffs and headlands at Muriwai/ Maori Bay**



Key Terms:

Weathering breaks down rocks on the spot. No movement is involved in weathering. Two types of weathering are chemical weathering (changes the chemical composition of the rocks) and mechanical weathering. (Involves physically breaking the rocks into fragments) E.g. water enters the rocks, freezes & thaws.

Erosion is the breakdown and transport of rocks by a *moving force*.

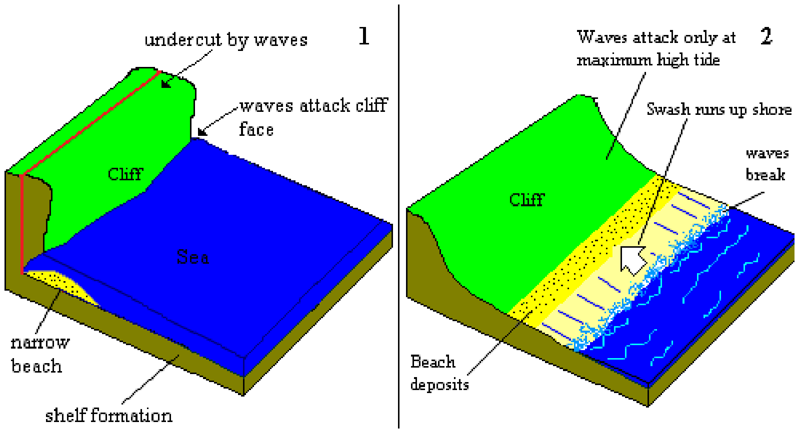
Mass movement is the down-slope movement of material by the force of gravity.

5:1 Cliffs

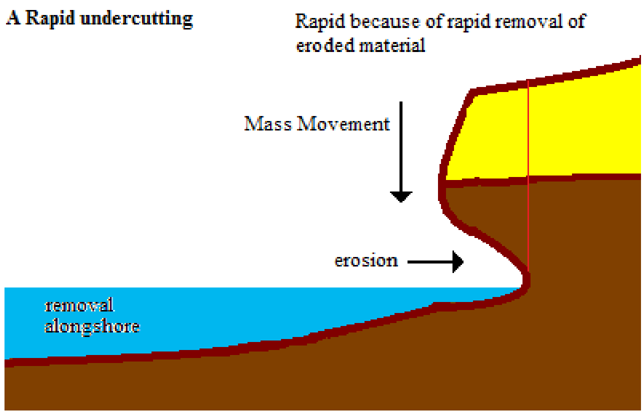
Most cliffs are a product of **coastal erosion**. Their steep faces are usually devoid of significant vegetation and often with **debris** piles at their base are clearly erosion features. (But where cliffs plunge directly into deep water, swell waves do not shallow as they approach and consequently they do not break. Most of their forward energy is reflected back with little erosive work occurring on the cliff face.)

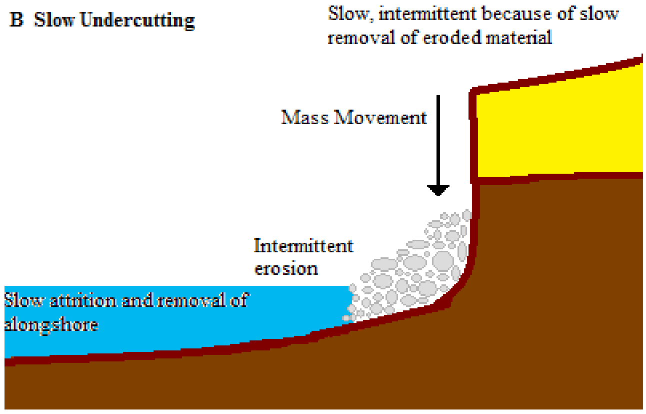
Processes shaping cliffs:

- **Glacial processes** in the past may have given the coastline a very steep aspect by creating sheer-sided **U shaped valleys**. E.g. Fiordland
- **Faulting** may have raised the coastline on a steep fault plane relative to sea level.
- **Hydraulic action** (Also known as wave quarrying), is when a wave breaks onto a cliff, it traps a large amount of air behind it. The air is forced into cracks in the cliff with an immense amount of pressure. When the water retreats, the air is released from the cracks and a decompression takes place, weakening the cliff. Over time, the cliff can be weakened to the point at which a small storm will be enough to cause it to collapse.
- **Abrasion**. Bits of rock and sand in waves grind down cliff surfaces like sandpaper. (UK- different from NZ textbooks)
- **Attrition**. Waves smash rocks and pebbles on the shore into each other, and they break and become smoother. (UK- different from NZ textbooks) (Further breakdown occurs through **attrition processes** such as **abrasion** (detached blocks of rock rub against each other, rounding and reducing each other) and **corrasion** (particles of sand or sediment further abrade rocks). (NZ textbooks)
- **Solution**. Acids contained in sea water will dissolve some types of rock such as chalk or limestone.
- The **frequency and energy of waves:** Without a lot of high energy waves, eroded debris would not be transported away and would instead protect the base of the cliff from further erosion.

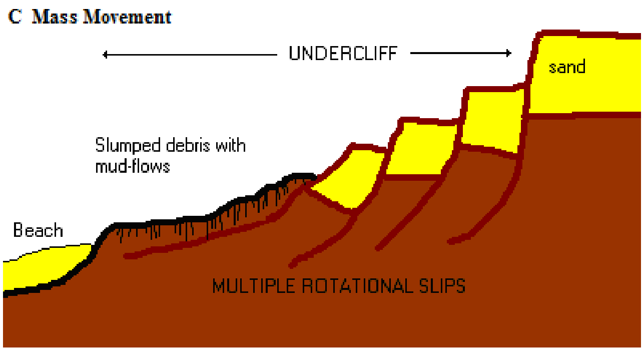


- **Cliff Retreat** is where a cliff is cut back is by the formation of a **notch** at the base of the cliff. These notches progressively undermine the cliff until it collapses, leaving a pile of debris at the base of the cliff.





The 'main' cliff may be 100 plus metres inland. At the base of the **undercliff** (debris), under-cuttings by waves will form a 'secondary' cliff.

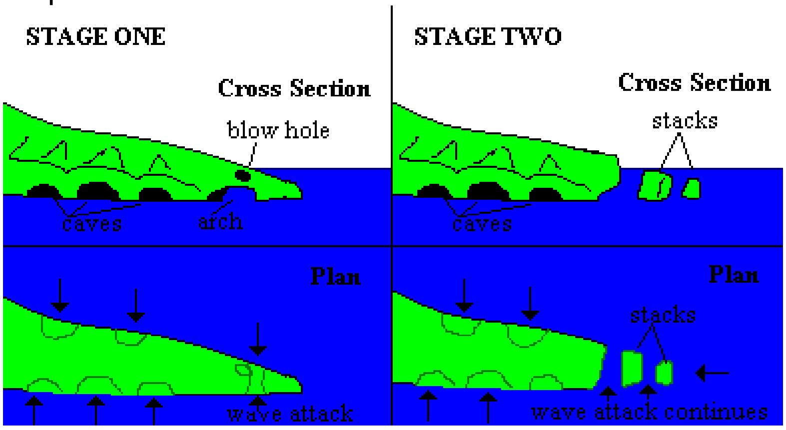


E.G. The notch at the base of the rear of the stack (Motutara Island) has been shaped by wave refraction around the stack focussing the energy of waves at the rear. Reflection of wave energy off the adjacent cliffs will also have contributed to this notch forming process. Spatial variation of the erosion processes on the cliff and stack are also visible in the harder layers of conglomerate rock that project out from the surface of the cliffs and stack.

Little evidence of cliff collapse or rocks broken from the cliff or stack is visible on the platform or around the base of the stack. The powerful wave environment, with its very strong currents and eddies, causes wave and current transportation of eroded material, which is soon broken down to finer sediments. These sediments join the littoral flow of sediment northwards along the beach and some will be deposited on the beach itself or on the offshore bars. (There is plenty of evidence of cliff collapse at nearby Maori Bay)

- When the **geology** of a cliff is varied, (e.g. when hard basalts or andesites intrude into softer sandstones or siltstones), then the process of **differential erosion** may occur. The weaker rocks erode more quickly and **caves**, **arches**, **blowholes** and **stacks** may form. Differential erosion also occurs where there is a structural weakness in the rock such as a **fault**. The crushed rock along the fault line combined with the fault itself makes the rock more vulnerable to hydraulic pressure, quarrying and abrasion by eroded material.

  Caves and blowholes, arches and stacks are usually formed in the sequence shown below:



A number of features can result from the **interaction of these processes**. Weaknesses develop and caves may be formed by wave action. Sometimes a cave roof partially collapses leaving a blow-hole from which spray shoots up at high tide. Sometimes complete collapse along the line of the cave forms an inlet in the headland; or adjacent caves may join forming an arch. Finally, erosion may detach the end of the headland, leaving a **stack**.
The headland (Otakamiro Point) at Muriwai has all these features. (Except for an arch, but there is an arch at Mercer Bay, further south.)

Activities:

1. Explain why cliffs are obviously erosion features.
2. Write a few paragraphs to explain how the process of differential wave erosion can result in the spatial variation of cliff features.

5:2 Wave-Cut Platforms/Shore Platforms

When the process of cliff retreat occurs, a **shore platform** may form.

Types of shore platforms

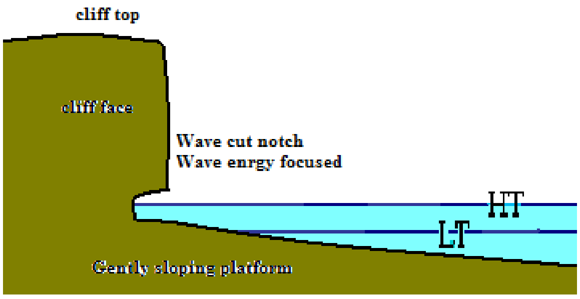
1. Sloping

In New Zealand these are called **high tide benches. 5-15 metres wide.** They end at low tide level at an escarpment that drops 3-4 metres deep. They usually form on harder rocks, e.g. Andesite cliffs of west coast.

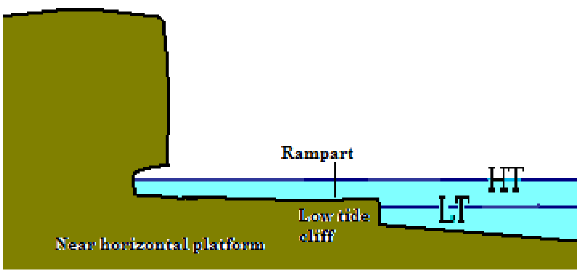
2. Near horizontal:

These often have a wave cut notch at the cliff base (high level tide) and low cliffs at the low tide level. In New Zealand these are called **broad intertidal platforms.** They take shape in softer sandstones and siltstones. They have a gentle slope from cliff to low water level. They have an escarpment which drops 4-6 metres at low tide level. Cliffs can retreat very rapidly because of wetting and drying effects but vertical planation is slow because the porosity of the rocks means that there is a high level of water saturation. **Subaerial weathering** occurs when the rocks of the platform dry out at low tide. These platforms are very broad and can be over 100 metres wide.

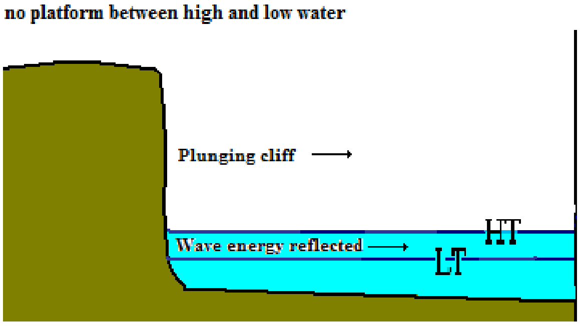
Sloping shore platform profile



Near- horizontal shore platform profile



Plunging cliff profile:
no platform between high and low water



Main factors causing shore platform types

1. ***Rock type and structure**:* The degree of ***permeability*** of rocks controls the amount of air that can enter and cause ***chemical***, ***subaerial*** weathering rather than ***mechanical***, ***subaqueous*** weathering, which occurs when air is forced into a rock by hydraulic pressure to gradually break it apart. The degree of **jointing** and the alignment of joints in rock is also significant.
   Vertical joints on the east coast where marine sediments predominate in cliff and platform structures are not as significant because they are asymmetrical and often reinforced by limonite (hydrated iron oxides and hydroxides) accumulations. Erosion of these platforms is more determined by the horizontal or tilted bedding associated with these sedimentary structures and the platforms have a more rounded aspect with harder beds protruding alternately, in some places near vertically. At Muriwai regular and irregular **joints** formed in the rock as it cooled. As tectonic uplift occurred, it was exposed at the surface, making the work of hydraulic action and wave erosion easier at the shore platform edge. This is clearly seen in the angular pattern of the edge of Flat Rock. The finer matrix of ash and other volcanic material binding the conglomerate rock together also makes the frittering process easier, creating the smoothed and hollowed shapes of the cliffs.

2. ***The power of waves***: Since shore platforms slow down wave momentum there is a limit to how wide they can develop, since high wave energy is needed to create the wave cut notch and erode the base of the cliff. The width of a shore platform can be extended by wave erosion, which would create a negative feedback and slow down cliff retreat. On the other hand, weathering down of the platform creates more depth for waves, but there is also a limit to how deep the weathering can lower the platform (because waves cannot erode past a certain depth).
   Wave energy is rarely strong enough to seriously erode the massive rock structure of a cliff face unless joints are present to allow hydraulic pressure to be focused. This is evident on Auckland's west coast at Muriwai where the most severe mechanical erosion is in the jointed edges of the shore platform. However a **visor** is evident in the cliff from salt spray weathering and the alternation of wetting and drying. Direct wave attack does have a role to play in the morphological development of platforms but it is more effective on the edges of the platform rather than at the cliff face. Hydraulic and pneumatic pressure within joint planes is more significant at the cliff base. **Caves** and **blowholes** are also formed by direct wave action, although they are also often a result of the pattern of jointing in the rock. The formation of these phenomena contributes to the breaking up of the shore platform at its edges.
3. ***Tidal range**:* A high tidal range means there is more time for drying out of the platform. Around the New Zealand coast there is a tidal range of up to 4 metres. The platforming process is generally affected by components from **subaqueous** (high tide) and **subaerial** (low tide) processes:

- **Saturation of rocks**- the more saturated a rock remains, the more resistant it is to atmospheric weathering. Therefore shore platforms occur in the zone where tidal action keeps the pores of the platform rock saturated most of the time, strengthening the rock and limiting the wetting and drying cycle which weathered the cliff back.

- **Wetting** and **drying processes**- In the drying cycle at low tide the small particles at the surface of the rock are subject to changes in temperature as well as expansion and contraction associated with drying and wetting, and so are weathered away from the surface. The process of spray-splash weathering easily breaks down the surface of lightly bonded sedimentary rocks such as the Waitemata sandstones. This process is responsible for cliffs remaining steep and retreating all around the Waitemata Harbour as well as places on the West Coast. In some soft rocks, such as mudstones, cliffs have been estimated to retreat up to 30cm a year.
- **Salt weathering** (through **salt crystals** forming in gaps) may accelerate the wetting and drying process. In some places sea spray causes salt to get into gaps in the rocks. This can result in **honeycomb weathering.** There is some evidence of this just below the gannet colony at Otakamiro Point.

4. **Biological erosion** by such things as algae and small marine creatures that inhabit the rock shelf.
5. **Chemical processes can deeply erode rock platforms like limestone if the w**ater table is slightly acidic. Solution produces sharp pinnacles of limestone called **lapies** low down in the intertidal zone. In tropical seas with microtidal or mesotidal ranges, these features become very large and are called **visors**.

E.G. The platform remnants around the stack (Motutara Island), as well as the one at fisherman's rock, have been eroded at the edges by wave and hydraulic action by compression of air and water at the adjacent blowhole.

Activities:

1. Create detailed structured overviewed to illustrate the main factors determining the shape of shore platforms.
2. Draw simple diagrams to illustrate the differences between the two main types of shore platforms in New Zealand.
3. Explain how the interaction of refraction, hydraulic action and geological processes can lead to the formation of caves, arches and stacks.

5:3 Spatial Variations in natural processes at the cliffs and headlands at Muriwai/ Maori Bay *(Field Guide pages 33-37)*

Wave and current erosion processes at the headland - Otakamiro Point, Motutara Stack, Flat Rock, Fisherman's Rock

- At the shore platform edge wave erosion occurs, especially in jointed rocks.
- At the base of the cliff a slight notch is created by wave attack.
- At the cliff face the waves create salt spray, which results in the mechanical weathering process of haloclasty (the 'frittering process). Wave action is also significant in the 'frittering' process because of the alternate wetting and drying that occurs with the alternation of tides on the shore platform and at the cliff face.
- Some attrition and abrasion occurs on the shore platform, at the cliff face and at the platform seaward edge, but it is not as significant as the wetting and drying processes.
- Differential erosion occurs because the harder volcanic rocks of the headland resist erosion more and are left as headland promontories, stacks, etc. compared to the softer rocks like the Awhitu sandstones

Waves and current transportation of sediment at the headland

- Maximum transportation away from the headland towards the beach is a normal result of wave refraction focusing wave energy on the headland and alongshore currents being driven by prevailing westerly and south westerly winds.
- Material accumulates in the protected caves.
- At high tide, the cliff face also reflects wave energy, which carries eroded material away.

Waves and current deposition at the headland

- Little deposition occurs here except in sheltered areas because of strong wave action and an offshore rip current that often travels along the northern edge of the point.

Aeolian erosion processes at the headland

- Aeolian weathering and erosion of surface material loosened by salt crystallisation and wetting and drying effects occurs. The wind plays a part in the drying effects. Both cliffs and shore platforms are affected.

Aeolian transportation processes at the headland

Aeolian transportation occurs briefly when fine material is carried from the rock surface into the water, although most movement of frittered materials probably happens because of wave action.

Aeolian deposition processes at the headland

- Aeolian deposition does not occur in this environment except in very minor and temporary ways.

Field Work Activity: Go to Muriwai. Students have to take photographs of the features mentioned above. Back in class they must make annotated power points using their photographs that explain the spatial variations of the processes according to the bullet points above.

5:4 Summary of Interactions at the cliffs and headlands at Muriwai/ Maori Bay *(Field Guide pages 18-28*)

Headland- the interaction of wetting-drying, wave action, volcanism, chemical/salt weathering, hydraulic/ wave action, jointing, and sediment transportation help create the cliff/stack, cave, platform environment.
Headland to nearshore- the interaction of cliff and platform erosion, longshore transportation of sediment and deposition at the beach.
Nearshore to headland- the gradually shallowing nearshore creates wave refraction that causes caves, arches and stacks. E.g. Motutara Stack and Oaia Island
Headland to backshore- the headland supplies eroded material for the dunes, but not much; as most of it is ancient.

6:0 Beach Processes:

I will cover:

- ✓ **Beach Sediments and sediment sorting**
- ✓ **Summer and Winter Profiles**
- ✓ **Long shore Drift, swash and backwash**
- ✓ **Formation of spits and bars**
- ✓ **Sediment Budget Model and other models**
- ✓ **Rip currents, beach and surf zone processes**
- ✓ **Spatial Variations in beach processes at Muriwai**
- ✓ **Summary of interactions between beach processes at Muriwai**

6:1 Beach Sediment characteristics

Beach sediments:

- ➢ Range in ***size*** *f*rom huge boulders to tiny sand grains.
- ➢ Spherical to rod **shaped** particles.
- ➢ **Source:** Organic matter such as shells (**Calcium Carbonate**) and corals, or weathered rocks and mineral matter, such as silca, quartz and feldspars. Silica, Quartz and Titomagnetite (ironsands) have volcanic origins. **Silica** is the most common mineral found in the earth's crust. (See the green sand beach in Hawaii that originates from a volcanic mineral Olivine.)

The nature of these materials affects the **permeability** of the beach surface (the ability of water to drain through it). For example a gravel beach may absorb most of the swash with very little backwash; hence the beach is built up with a steep gradient. On the other hand, a beach with much silt or clay in the sediment may have a stronger backwash and a shallower profile.
The **energy characteristics** of a beach usually determine **sediment characteristics**. On a high wave energy beach **abrasion** may shape pebbles and rocks and gravity will sort them by size. Little of the finer material remains as it is carried away in **suspension** in the water and deposited in low wave energy beach environments as sandy beaches.

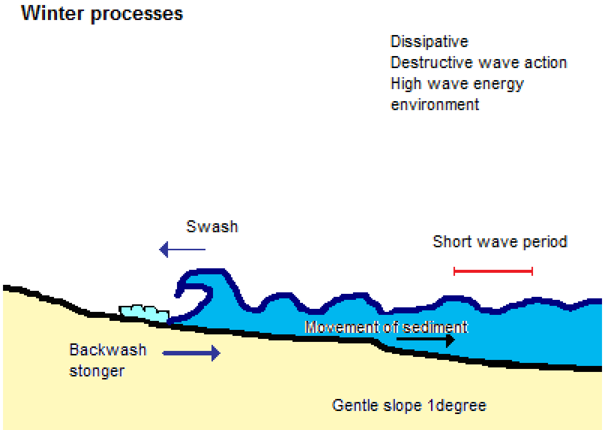
Beach sediments can also be described according to their **sediment sorting**. A sediment with grains of mostly source material would be ***well sorted.*** Beach gravels are often well sorted and show uniform characteristics.
A sediment with a mixture would be ***poorly sorted***, especially from short, swiftly flowing rivers which emerge at the coast.

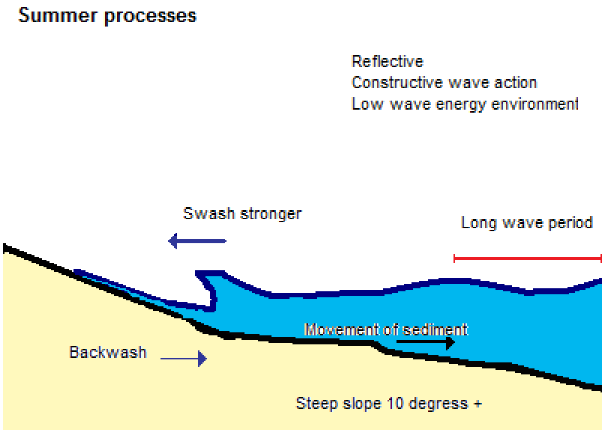
Generally, the coarser the sediment, the steeper the slope. More exposed beaches tend to have lower slope angles and sheltered beaches tend to be steeper.

Particle Type	**Particle Size**
Boulders	265 mm plus
Gravel	2-265 mm
Sand	0.0625-2 mm
Silt	0.0039-0.0625 mm

6:2 Summer & Winter profiles *(Beguely pages 85)*

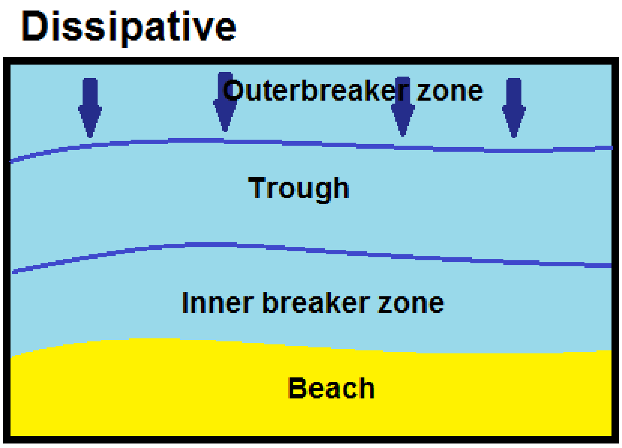
In **summer conditions** when wave energy is low, the beach may have a steeper gradient (10 degrees) which reflects wave energy back to sea. This reflection is associated with the longer time interval between waves. Because of the longer time interval the **backwash** does not interfere with the **swash.** Since the energy of the swash is greater than that of backwash there is more sediment carried up the beach than back to sea. Such summer conditions operated through **constructive waves**, which build the summer profile of the beach, with a **berm** marking the edge of the swash zone.
In **storm conditions**, particularly **winter**, **destructive wave** action dominates to develop a smaller gradient on beaches. Slopes under 1 degree tend to absorb wave energy but enable waves to travel further up the beach, often eroding frontal dunes. The wave period is much shorter so the backwash meets the swash before it has a chance to carry material landward resulting in seaward migration of sediment, which reduces the slope of the beach. Such destructive wave action causes a **winter profile** which may be characterized by **ridges**, **bars** and **gullies** parallel to the shore at low tide level.
(NB: The model shown below is based on European beaches)





Muriwai itself, like most of the west coast beaches, does not conform to the model of European beaches (which have summer and winter profiles). Muriwai is typical of southern hemisphere west coasts, which get **high energy waves all year** and have little variation from season to season. The west coast swell wave environment that Muriwai is part of tends to produce what is called a **modally dissipative beach**. This means the Muriwai beach profile ***always*** resembles the 'winter' profile. Around 90% of the beach's material will be held in offshore bars, since the beach remains in a permanently 'eroded', although stable, state. Strong winds blowing onshore may also interact with higher tides to cause a marked rise in water level, resulting in greater and regular wave erosion of the foredune.

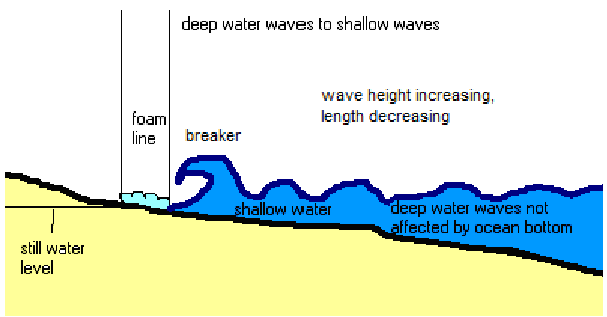
(NB: Muriwai is more like the Australian model shown below)



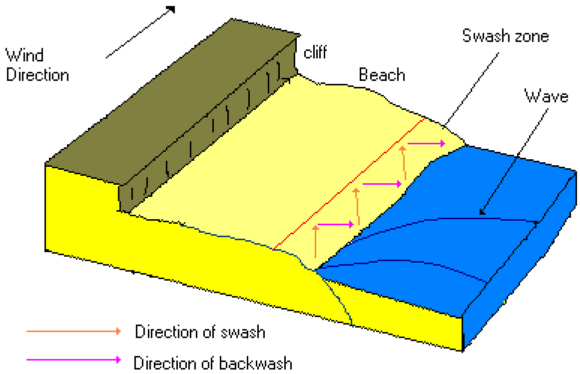
Activities:

1. Explain why summer beach profiles tend to be steeper than winter beach profiles.
2. Explain the relationship between constructive and destructive waves and the movement of sediments to build summer and winter profiles.

6:3 Beach Processes: Longshore drift, swash and backwash *(Beguely pages 85-87)*



Beaches show variation from one end to the other as well as with a cross sectional profile. Currents moving along the shore have much to do with these variations and include the formation of a **longshore current** and the movement of sediments by **longshore drift**. Material like **foam** and **fine sediments** is carried by surface currents alongshore and a **longshore current** occurs when waves approach at an oblique angle to the shore, creating a **zig zag** current motion along the beach. When sediment is transported in the littoral zone by this mechanism, it is called **longshore drift.** (also known as **littoral drift**) Sediment is also transported along the beach through **swash** and **backwash**. **Swash (**the action of waves travelling up a beach after the wave has broken**)** pushes material up the beach and then **backwash/ gravity** (the return flow of water down the beach) drags it back down the beach face. Sediment drifts along the beach face in a zig zag fashion when waves are breaking at an angle to the beach, so this process is called '**beach drift'**. Beach drift occurs at the beach face where wave steepness is low.



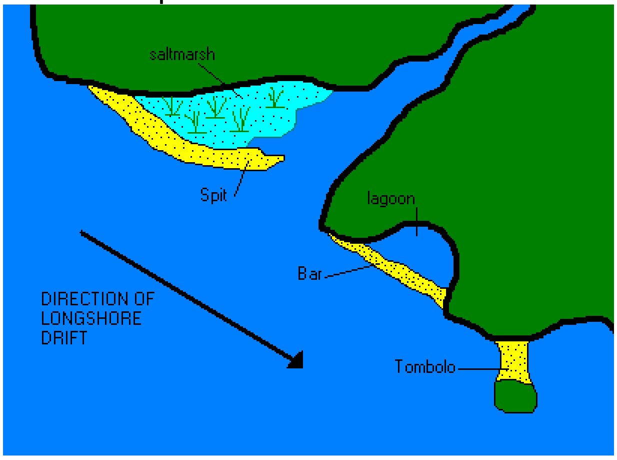
Even along a shore where waves break parallel to the coastline there can still be longshore drift and transportation. This is because the onshore movement of water in breaking waves still has to be balanced by an offshore flow of water so a circulation of water occurs. As part of this circulation of water, **circulation cells** develop, usually between rips. Further out from shore longshore transportation of sediment (longshore drift) occurs where wave steepness is high below the breaker zone.

There are ***variations*** in **swash** action (thin sheet of water that runs up the beach) due to the ***interaction*** between **incident waves** and **long (infragravity) waves.** (**Long waves** are other waves generated by wave groups breaking in the surf zone and tend to have a long wave period of over 30 seconds). During winter, the distance swash from incident waves travels up a dissipative high wave energy beach depends mainly on the wave height and less on the beach slope. During summer, on a reflective beach, beach slope will play the dominant roles in limiting swash travel.

Backwash can play a big part in the formation of the gradient of the swash slope but is itself controlled by the size of beach sediments. On a beach with **coarse sediments** such as gravel or pebbles the volume of the backwash is restricted by **percolation** of the water through the sediments. This has the effect of causing a steeper slope to maintain the beach equilibrium between swash and backwash, such as gravel beaches. By contrast, on a saturated, fine sand beach where little water is lost by percolation, the amount of backwash will still be a large proportion of the swash so equilibrium is maintained by a flat beach, such as on West Coast' iron sand beaches. An interesting feature of backwash that can be observed at low tide is the formation of rhomboid (diamond shaped) patterns in the ripple marks on the sea bed.

As material is moved alongshore by the drift process it may be trapped just inside a bay to form a **baymouth bar**, or it may accumulate around the corner

of a headland to form a **spit.** Spits form when the coastline changes direction suddenly away from the path of the longshore drift.
Cuspate coastal forms and **tombolos** may develop when two longshore drift currents meet from opposite direction. The island attached by the tombolo (which is the sand accumulation linking the island to the shore) refracts waves to create a convergence of longshore drift as well as a wave shadow zone in which sediment accumulates to form the tombolo. The island is tied to the mainland to become a peninsula. One example of a land tied island can be seen at Cape Maria Van Diemen in Northland.



Cuspate forelands may develop when the island is large and well offshore, as is the case with Kapiti Island and the cuspate Paraparaumu beach.
When longshore drift meets submarine canyons, which carry sediment into deep water beyond the reach of wave action, sand may be lost permanently from the coastal system. Under normal circumstances longshore drift will carry material out of a beach system but will also replenish it from another beach system so that the beach remains in equilibrium. Such equilibrium is easily upset, however, when human processes (such as dredging for marinas or canal developments, or sand mining) limit the amount of sediment that can be replaced. Severe erosion of sandy coasts can then occur.
To conserve beach deposits for coastal protection, authorities halt the longshore movement by building **groynes** offshore. The groynes act as a barrier to physically stop sediment transport in the direction of longshore drift. This causes a build-up of the beach on the groyne's updrift side. Secondly, groynes interrupt the tidal flow forcing the tidal current further offshore beyond the groyne end. This slows the tidal current inshore causing the deposition of heavier sediments and encouraging the beach to grow in size.

Activities:
1. Describe the process which leads to both longshore drift and beach drift.
2. When would swash and backwash not be involved in beach drift?

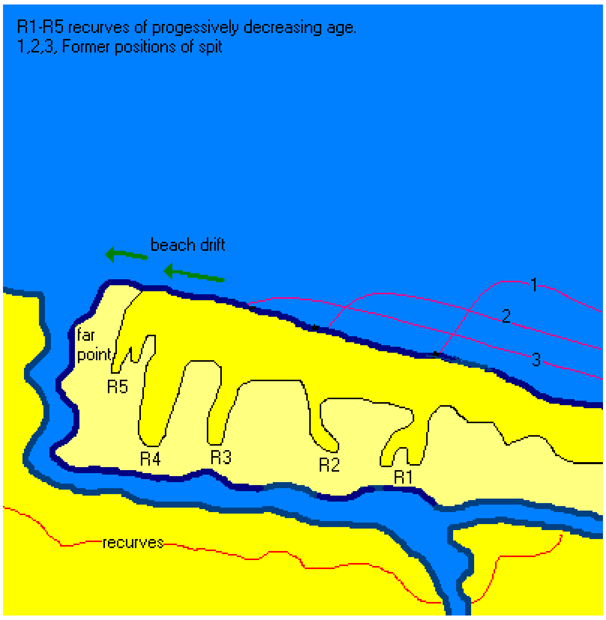
Waves and longshore drift at Muriwai *(Field Guide pages* 23-25)
In the short term, wave action and current scouring and transportation of sediments in longshore drift may change the shape of bars from parallel to the coast to transverse.
Kaipara Harbour’s North Head and South Head have a straightened coastline stretching from Muriwai northward. Because of the high iron content of the

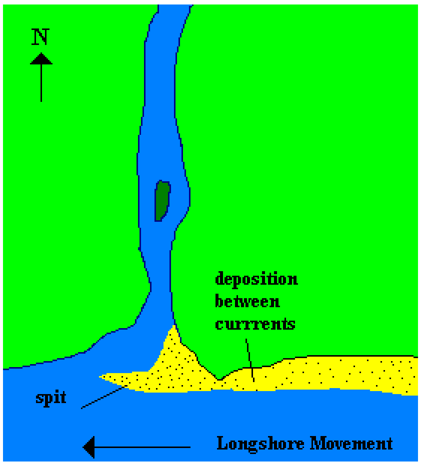
black titomagnetite sands in this region, iron pans have formed that prevent water draining away from the marsh areas.

Coastal currents and sediment supply at Muriwai
The amount of sediment supplied to the inshore and foreshore zones from coastal currents moving northward also has a significant effect on the backshore and dunes. As sediment supply varies, so do bar and beach formation vary.

6:4 Beach processes: Spits and Bars *(Beguely pages 81-83)*

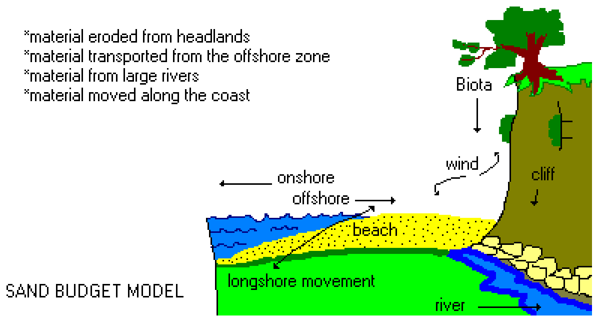
Many coasts are made of marine sediment deposits created by marine processes. On many gradually sloping coastal areas waves may break before reaching the beach and deposit sediment in the breaker zone to build up an **offshore bar**. These may be very long and end up enclosing lagoons, such as many do on the west coast of the South Island. Over long periods of time, wave and Aeolian processes can move the bar landward, creating lagoon and marsh landscapes and eventually transforming it into a sand dune beach landscape. The Northland coastline has been straightened by sand bars which began life as offshore bars produced by the strong prevailing westerlies and Ninety Mile Beach has been pushed by Aeolian transportation inland to connect the string of volcanic islands which make up its core. Ninety mile beach shows a typical sequence of newer dunes enclosing marshes and lakes between them. Kaipara harbour's North Head and South Head have a similar structure with a straightened coastline stretching from Muriwai. Black **titanomagnetite** sands in this region have formed, which prevent water draining away from the marsh areas. Harbours like the Kaipara are now undergoing high rates of sedimentation from rivers, especially since people have caused deforestation, which has led to accelerated erosion.
Spits develop as a response to longshore drift transportation of sediments rather than offshore wave and current processes. For example, Farewell Spit, is up to 20 metres high, kilometres wide at low tide and 30 km long. Material for the spit is derived from wave attack processes on the adjacent cliffed coastline of the West Coast. These sediments have been moved northward and eastward by longshore drift and then deposited in the lower energy environment past the headland.
Salt marshes often develop in the area between the spit and the shore, and are produced by the deposition of fine sediment in slack water. Salt-resistant plants colonise these areas and help to trap more sediment.


R1-R5 recurves of progessively decreasing age.
1,2,3, Former positions of spit
beach drift
1
2
3
far point
R5
R4
R3
R2
R1
recurves

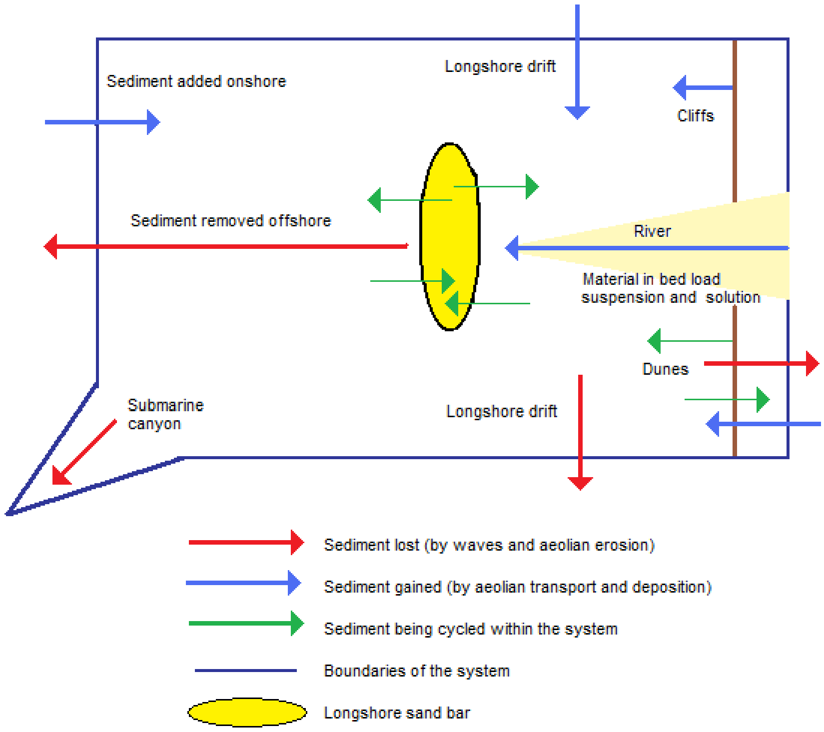

N
deposition between currents
spit
Longshore Movement

6:5 Models of coastal systems **Text:** *Beguely pages 3-7*

BEACH SORTING AND BEACH SLOPE



Sediment budget model



Losses > Gains = Erosion environment

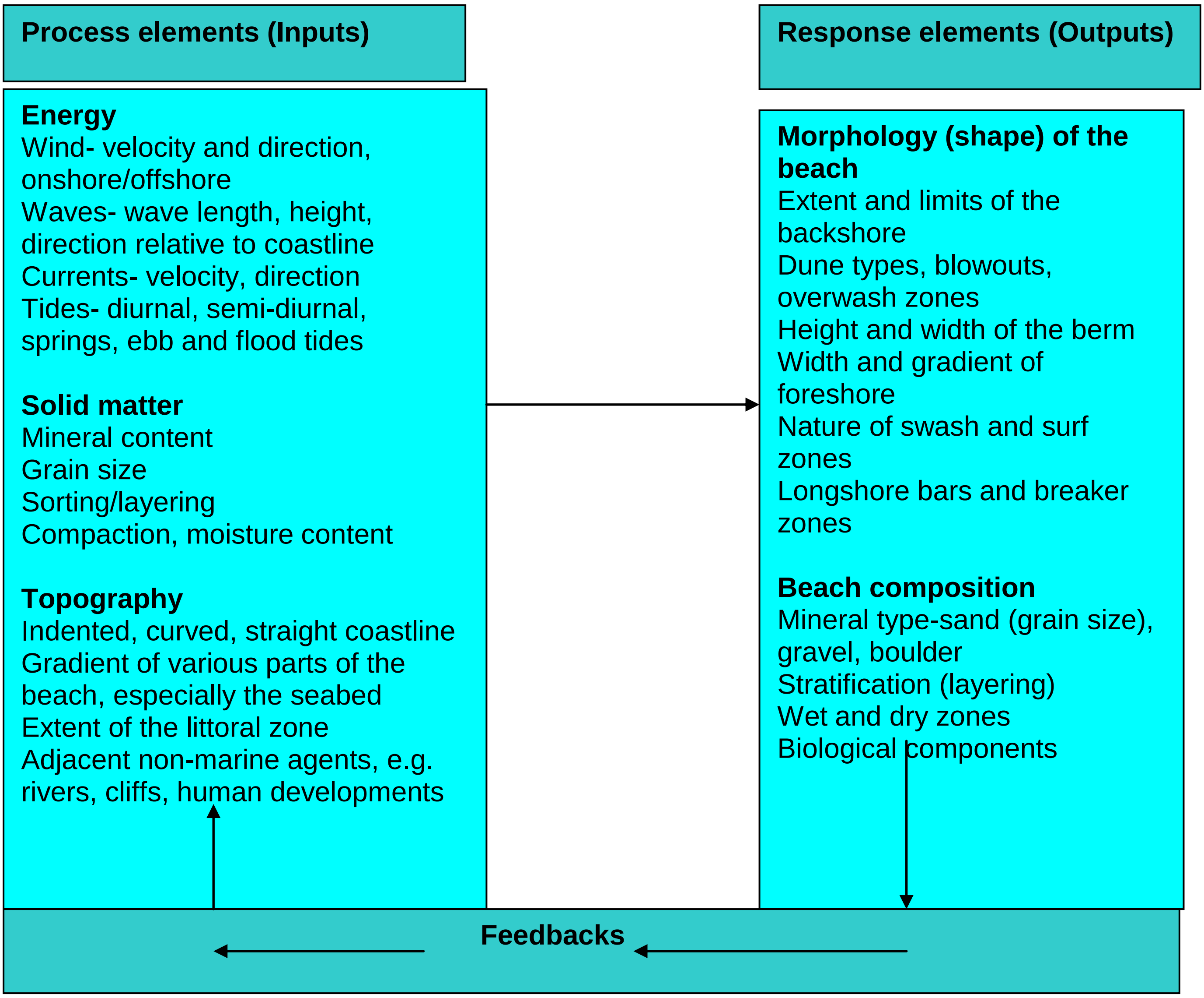
Gains> Losses = Deposition environment

Activities:

1) Look at the sediment budget model and the process response systems model. Think of a beach you know and attempt to adapt each model by drawing your own version of it for that particular beach.
2) Write an essay explaining the sediment budget model.

Process response system model

This model combines systems diagram with flow models (e.g. sand budget model) and shows response elements such as cliffs, width of beach, sand dunes, are the result of processes such as coastal erosion and saltation, which are driven by the energy of wind and waves.



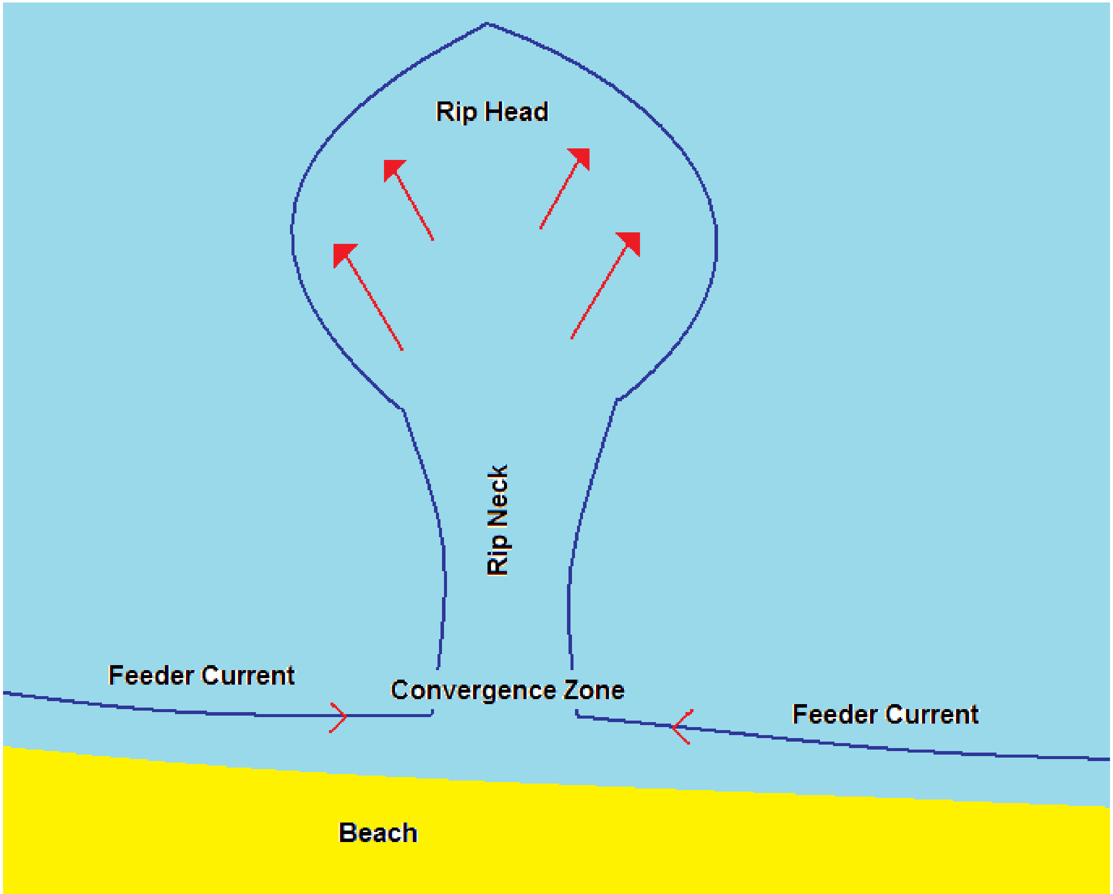
6:6 Beach Processes: Rip currents, beach and surf zone processes.

Rip current formation *(Beguely pages 87)*

Water flows along the shore until it reaches a flow from the other direction and then moves out to sea as the concentrated flow of a **rip current**, which goes through the surf zone and past it. These circulatory cells result in the formation of 'beach cusps', usually developed symmetrically along the beach. Rips have 3 aspects:

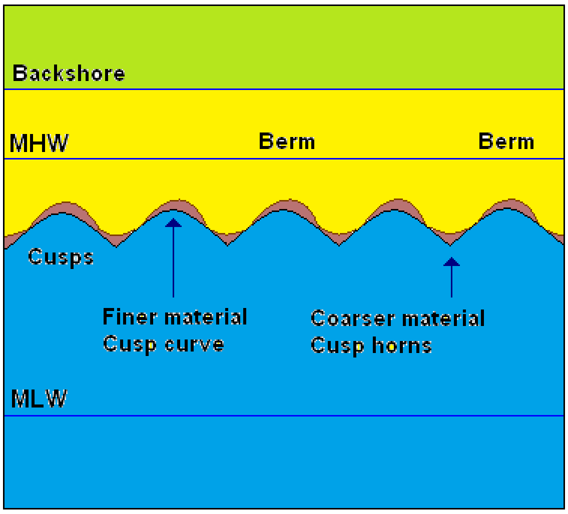
1. **Feeder currents** moving alongshore within the surf zone.
2. **A convergence zone** where two of these currents meet and form a **'rip neck'** or narrow fluid channel for the water.
3. **A rip-head**, which is an expanding area seaward where the rip gradually loses its velocity as its energy is dissipated.

Generally, as wave height increases, the number of rips on a beach decreases and vice versa.



Cusps

The structure of a gravel beach shoreline may be flat and straight (**rectilinear**), which tends to reflect wave energy, creating **edge waves**. The resonance between incident waves arriving at the shore and those reflected back from the shore tends to result in the formation of **cusps**. (A series of regularly spaced ridges on a foreshore spaced by crescent shaped troughs) Cusps form when water flows along the shore until it reaches a flow from the other direction and then moves out to sea as a concentrated flow. Cusps may also form around natural hollows and ridges on the beach surface. Cusps tend to have finer material in the cusp curve and coarser material on the cusp horns.



http://www.ozcoasts.gov.au/conceptual_mods/beaches/wdb.jsp

Scientists have described 5 patterns of swash circulation.

In mild weather conditions:

- Circulation may simply oscillate back and forth weakly.
- Swash may flow away from the horns of the cusps and flow out as rips in the cusp embayments- this tends to preserve the cusp shapes.
- Swash may flow towards the horns of the cusps with rips forming opposite the cusp horns- this process tends to erode the cusps and cause deposition between them.

In storm conditions:

- A sweeping pattern that carries a lot of material alongshore occurs.
- A swash jet may form, which results from a build-up of pressure as powerful backwash retards incoming swash until the swash then moves very quickly up the beach as a narrow jet.

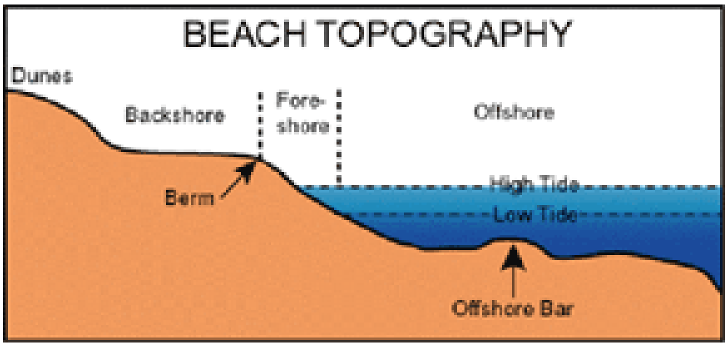
Beach and surf zone processes *(Beguely pages 89-91)*

Dissapative: A gradual dispersal or loss of energy.
Dissapative beach: One in which waves break and lose most of their energy before reaching the beach face.
Dissapative domain: The area of a beach in which spilling waves tend to dissipate their energy.
Reflection: The process by which wave energy is returned seaward. Wave energy is reflected back off an obstacle into a small harbour or confined area, creating unstable conditions when the reflected waves meet the incoming waves.
Reflective beach: These beaches have steep gradients, Wave energy is not absorbed in a broad surf zone with bars and gentle gradient so most of the incident wave energy is reflected from the steep beach face below the berm.
Berm: A ridge usually located high on a beach face and marking the limit of normal swash action.

Activities:

1. Draw a diagram to show how a rip forms. Include the phenomena associated with the rip and the processes that are associated with it and lead to its formation: cusp horn, neck, channel scouring, longshore current, longshore drift, rip current, head, rip current, head, waves, current flow, circulation, convergence
2. Draw a flow diagram to show the traditional understanding of how beach cusps are formed.

6:7 Spatial Variations of beach processes at Muriwai



http://www.ucmp.berkeley.edu/education/dynamic/session2/sess2_beach.html

Wave and current erosion in the nearshore zone- bars and gullies *(Field Guide pages* 34)

- Bar and gully forming processes are the result of associated currents, creating gullies (holes) and separating bars by alongshore and rip currents respectively.
- Wave action; incident waves approach at an angle to the beach and create alongshore currents and rips and a strong swash/ backwash effect, eroding material from the beach, especially in winter, and restoring sediment in summer.

Waves and current transportation of sediment In the nearshore zone- bars and gullies *(Field Guide pages* 35)

There is a present pattern of:

- More loss by northward drift alongshore and in the inshore zone.
- Loss by greater backwash than swash in the foreshore area.
- Destructive wave action dominating over time, so backwash meets swash before it has time to carry sediment further landward into the intertidal drying zone is that Aeolian transportation can occur up the beach. This is because the wave period is much shorter in winter wave conditions.

This loss is a reversal of the previous accumulation of sediment from material being carried north to the beach from the southern Taranaki and Waikato source areas. (Rivers that have been dammed, mining of sand, and the reduced flow of the Waikato River could all be the causes of the loss. Or is global warming a factor, with rising sea levels?)

Waves and current deposition in the nearshore zone- bars and gullies *(Field Guide pages* 35)

- Associated currents.
- Wave action; incident waves approach at an angle to the beach and create alongshore currents and rips and a strong swash/ backwash effect, eroding material from the beach, especially in winter.
- Currents create gullies (holes). Backwash meets swash before it has time to carry sediment further landward into the intertidal drying zone,

so Aeolian transportation cannot occur up the beach to the dune. This is because the wave period is much shorter in winter wave conditions.

6:8 Summary of interactions between processes at Muriwai Beach

Nearshore-the interaction of wave action, rip formation, currents, longshore drift, etc. result in the bar and gully formations.

Headland to nearshore- the interaction of cliff and platform erosion, longshore transportation of sediment and deposition at the beach.

Nearshore to headland- the gradually shallowing nearshore creates wave refraction that causes caves, arches and stacks. E.g. Motutara Stack and Oaia Island

Nearshore to backshore/ back dunes- wetting and drying in the sub-aerial low tide zone reaches the backshore by Aeolian transportation and results in dune formation. (Aeolian deposition)

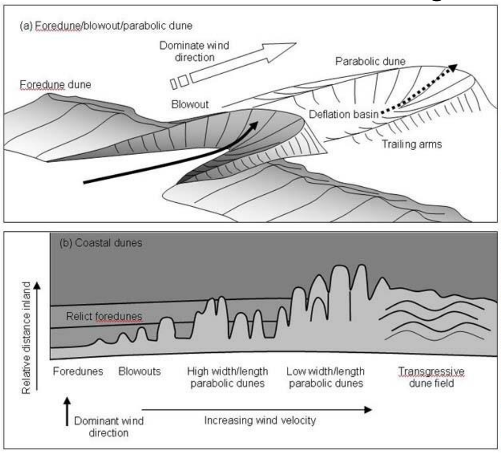
7:0Dunes & Aeolian Processes

I will cover:

- ✓ **Types of dunes**
- ✓ **Dune formation**
- ✓ **Aeolian transportation and deposition processes**
- ✓ **Dune ecology**
- ✓ **Temporal variations of processes in the dunes at Muriwai**
- ✓ **Spatial variations of processes of the dunes at Muriwai**
- ✓ **Interacting processes at Muriwai's dunes**

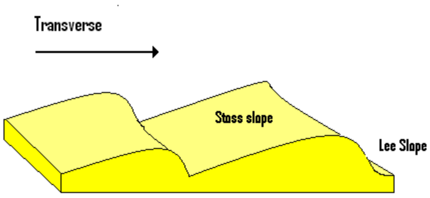
7:1 Types of dunes

Parbolic dune: U-shaped mounds of sand with convex noses trailed by elongated arms are parabolic dunes. These dunes are formed from blowout dunes where the erosion of vegetated sand leads to a U-shaped depression.



http://www.nature.com/scitable/knowledge/library/coastal-dunes-geomorphology-25822000

Transverse Dune: Sand ridges with a gentle windward slope whose line follows the prevailing direction.



A Barchan Dune is an arc-shaped sand ridge, comprising well-sorted sand.

Sand dunes are often found on bars and spits. They mark the limit of marine processes on land.

Blowouts

These are depressions in the sand that are cup- saucer- or trough-shaped. They are caused by wind erosion of an existing sandy substrate.

There are three characteristics of blowouts:

- Depositional Lobe; where sand from the walls and deflation zone is being deposited
- Deflation zone/basin; where sand has been scoured out. Often these reach the water table or the basal material (rocks). Both these factors prevent further erosion and revegetation often occurs.
- Erosional walls; margins of the blowout.

An incipient foredune will often form across the throat of a blowout, reducing sand inundation and allowing revegetation.

Also see:

http://www.doc.govt.nz/publications/conservation/native-plants/pikao-or-pingao-the-golden-sand-sedge/coastal-sand-dunes-form-and-function/#parabolic

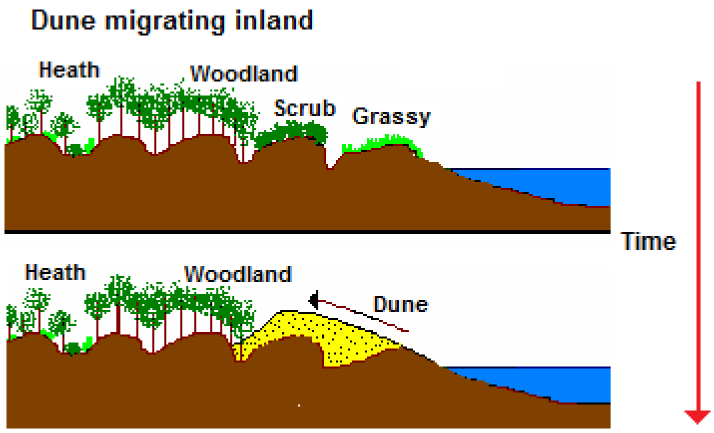
Migratory Dunes

Transgressive dunes are also known as mobile or **Transgressive Dunefields**, and sand drifts.

Transgressive dunefields will are generally located where wave energy is high and sand supply is or was moderate to high, or where significant coastal erosion has occurred.

Transgressive dunefields can be unvegetated, partially vegetated or completely vegetated (relict) and the dunes often have a sinuous/fish scale shape.

Good examples of transgressive dunefields can be found in Northland,Farewell spit, Manawatu-Wanganui region and Raglan. Often these have been stabilised with marram grass planting.



7:2 Dune formation *(Beguely pages 92-96)*

Sand dunes are an accumulation of sand grains which are deposited by the wind.

How do sand dunes form?
Wind carrying sand along the beach and depositing it in heaps around obstacles. E.g. grass, driftwood.

Why are they important?
They protect inland areas from wave action. They are also sensitive to change.

Conditions required for dune formation:

- Wide area of land for sand to accumulate (cliffed coasts don't have sand dunes.
- Strong prevailing winds so Aeolian transportation can carry dry sand from the beach face and berm and beyond.
- Sand grains must be small enough to be moved by Aeolian transportation. There must be a steady supply of sediment from rivers or cliff erosion.
- Colonising vegetation which stabilises the dunes. Dunes without stabilising vegetation (free dunes) may migrate big distances. E.g. in deserts. This can happen at coastal dunes causing loss of farmland. This was prevented at Muriwai by the planting of Woodhill Forest.
- Dune formation requires a beach with a low gradient and a large tidal range. This is so large areas exposed at low tide can dry out and saltation and Aeolian transportation can occur.
- Must be a suitable climate (not too wet) for this drying out to occur.

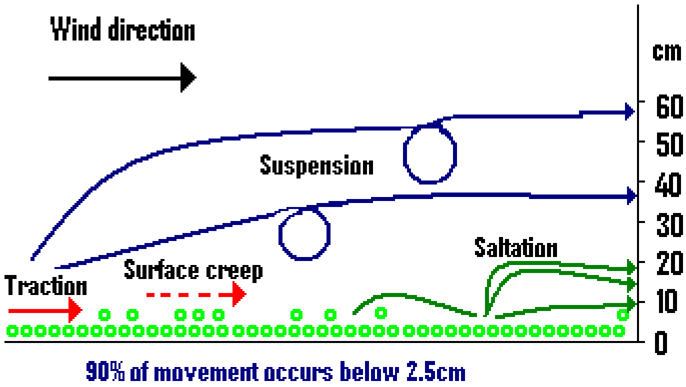
Dune systems
A dune system develops with the formation of at least one **foredune ridge** with an adequate supply of sediment to maintain it.

- When sediment supply is equal to sediment loss the dune system remains in equilibrium.
- When sediment supply is interrupted then **Aeolian erosion** (**blow-outs** caused by deflation) and **storm wave erosion** (resulting in **washovers**) reduce the dunes. Sand from blowouts often forms typical desert-type dune forms with a crescent like **parabolic dune** shape.

7:3 Aeolian transportation and deposition processes

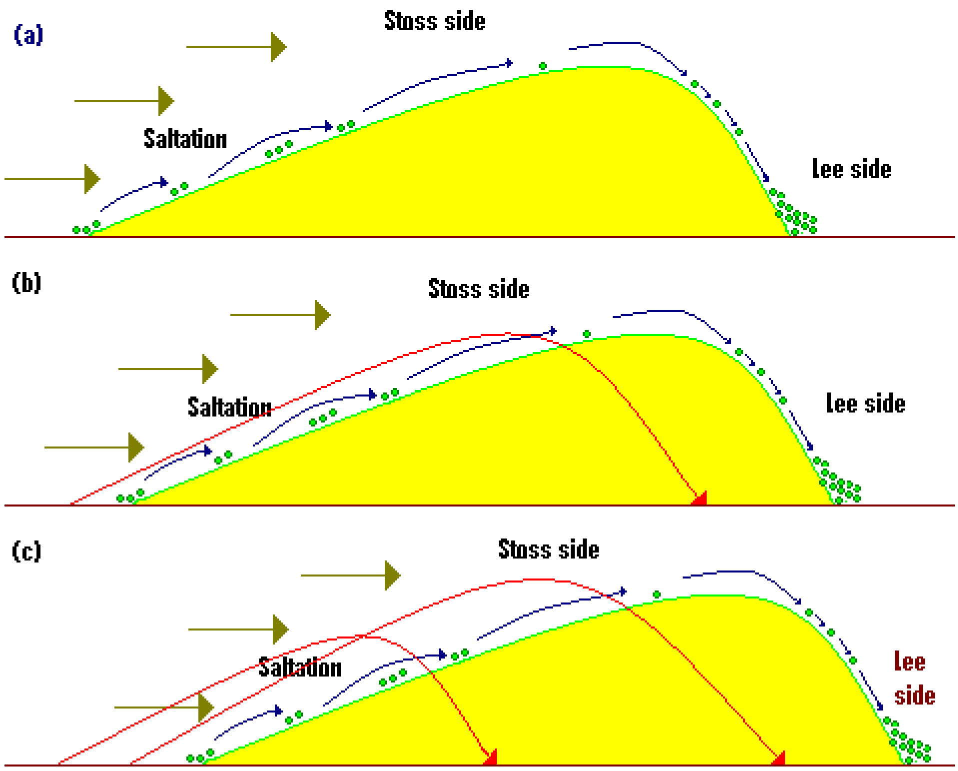
(Beguely pages 89-91)

Cloze activity



kinetic energy, **embryo dune, saltation x2,** ***cross bedding,*** **surface creep, aeolian processes, deposition, fluid threshold velocity,** ***stoss slope,*** **impact threshold velocity, embryo dunes, lee, shadow dune**

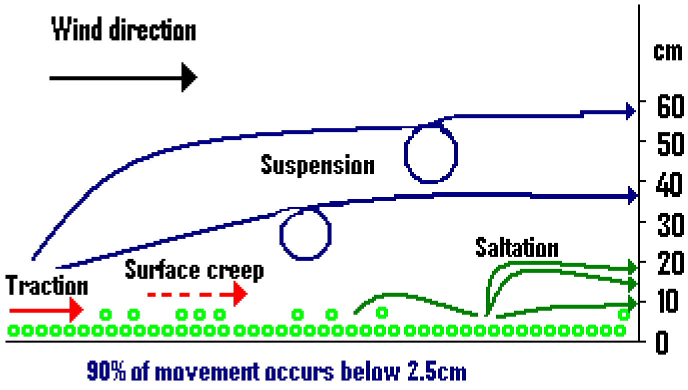
_________ refer to the action of wind. Wind action involves the creation of pressure slopes, the action of _________ and the action of storm waves.
Sand will not be moved by wind until the _________ is reached. The wind velocity required depends mainly on the particle size of the sand. However, very fine particles are more resistant than expected because the fine particles bind together.
Particles may be carried in the air in suspension or may advance by rolling along the surface in a process known as_________ . However, the most common means of transportation is a process called _________ . In the process of saltation sand grains are blown into the air briefly then fall back under gravity to strike other grains. _________ is released, which lowers the threshold for other particles to move as well as for the original particle to bounce back up. The lowered threshold velocity caused by impact is called ________________and means that once Aeolian transportation has begun, it can continue at lower wind speeds.
A drop in wind velocity is need for _________to begin. (Forming an ________) Obstacles, such as driftwood, may accumulate sand on the lee side and a _________may form. This is followed by an embryo dune as vegetation begins to colonise the mound. _________ may merge laterally to form dune ridges and foredunes along the back of the beach.
The classic dune shape is shown below with a gradual upwind slope (_________) and a steep downwind slope in the _________of the dune. If dunes move, whether gradually, by avalanche effects, or by a combination of the two, then _________of old angled stoss and high angled lee surfaces may occur.



Answers

Aeolian processes refer to the action of wind. Wind action involves the creation of pressure slopes, the action of **saltation** and the action of storm waves.

Sand will not be moved by wind until the **fluid threshold velocity** is reached. The wind velocity required depends mainly on the particle size of the sand. However, very fine particles are more resistant than expected because the fine particles bind together.



Particles may be carried in the air in suspension or may advance by rolling along the surface in a process known as **surface creep**. However, the most common means of transportation is a process called **saltation**. In the process of saltation sand grains are blown into the air briefly then fall back under gravity to strike other grains. ***Kinetic energy*** is released, which lowers the threshold for other particles to move as well as for the original particle to bounce back up. The lowered threshold velocity caused by impact is called

impact threshold velocity and means that once Aeolian transportation has begun, it can continue at lower wind speeds.
A drop in wind velocity is need for **deposition** to begin. (Forming an **embryo dune**) Obstacles, such as driftwood, may accumulate sand on the lee side and a **shadow dune** may form. This is followed by an embryo dune as vegetation begins to colonise the mound. **Embryo dunes** may merge laterally to form dune ridges and foredunes along the back of the beach.

The classic dune shape is shown below with a gradual upwind slope (***stoss slope***) and a steep downwind slope in the ***lee*** of the dune. If dunes move, whether gradually, by avalanche effects, or by a combination of the two, then ***cross bedding*** of old angled stoss and high angled lee surfaces may occur.

7:4 Dune ecology *(Beguely pages 95-96)*

Dunes provide an unfriendly environment for most plants:

- The substrate of sand is often mobile.
- Water drains away quickly (except at **wet slacks** where the water table meets the surface)
- There is a high salt input.
- Strong drying winds.
- Hot ground temperatures.
- There is little organic content in the sand.

Despite these conditions salt tolerant pioneering plants colonise shadow dunes at high tide level to form embryonic dunes then marram grass and others take over from them to begin foredune development. These plants are largely **xerophytic** (dry loving) with extensive root systems to gather water and thick shiny leaves to conserve water. These are then replaced by grassland communities. Slack water communities have bog or marsh vegetation. All these plant communities are very vulnerable since they are based on sand. If blowouts occur, the plant communities may allow breaching by higher than normal waves during storms and flooding of lowlands. Removal of vegetation on foredunes may result in steep scarps forming in the foredune and subsequent breaching. However, dune scarps do develop normally during winter because of high energy waves, but sand is replaced during summer by the processes of constructive wave action and Aeolian transportation. In effect, the dune system and longshore bars are acting as a reservoir from year to year. This helps keep the beach in a state of dynamic equilibrium. Human interference in these processes by recreational use of the dunes often has to be counterbalanced by the use of **geotextiles** to trap sand again and fences designed to reduce wind flow and cause deposition of wind-blown sediments.

Activities:

1. Construct a flow diagram to illustrate how Aeolian erosion, transportation and deposition processes **interact** to form coastal dunes and their phenomena.
2. Construct a diagram or write paragraphs to explain how wave processes **interact** with Aeolian processes to keep dune systems in equilibrium.

7:6 Spatial variations of processes on the backshore and dunes at Muriwai *(Field Guide pages* 34-37)

Spatial Variations in wave processes and the dunes

Wave and current erosion of the backshore/ back dunes

- The frontal dunes at Muriwai have been undercut as part of the erosion cycle of the beach, and the effect of the high tidal range (mesotidal), occasional high storm surges and strong wave action and currents that carry material from dunes back to bars in the near shore and offshore zone.

Waves and current transportation at the backshore

- The present pattern (since the 1950s) is of more transportation away from the dune and foreshore than wave and Aeolian transportation towards it, resulting in a net loss of over 1 metre per annum of the frontal dune.

Waves and current deposition at the backshore

- There is some deposition to the beach and backshore in summer with constructive waves, but the beach is in a long-term erosion phase and more is lost in winter because of destructive wave action.

Spatial Variations in Aeolian processes and the dunes

Aeolian erosion processes in the near shore zone- bars and gullies

- Aeolian weathering and erosion occurs as the wind dries the substrate at low tide on the foreshore zone and carries or entrains sand particles up the beach to the foot of the frontal dune.

Aeolian erosion processes at the backshore and dunes

- Aeolian weathering and erosion occurs as loosened or exposed sand on the dunes is picked up and carried or entrained. Deflation hollows/ blowouts are formed in places where there is little protective vegetation but not where there is ground cover.

Aeolian transportation processes at the backshore and dunes

- Aeolian transportation occurs a great deal in this zone, especially when the surface sand is exposed and loosely compacted or disrupted. The sheltered lee of the dune sees least transportation of sand. The method of transportation (traction, surface creep, saltation or aerial suspension) depends on the wind speed, type of sand and the fluid impact threshold.

Aeolian transportation processes in the nearshore zone

- Aeolian transportation occurs on the foreshore as the substrate dries out and weathers to fine, loosely aggregated particles.

Aeolian deposition processes at the backshore and dunes

- Aeolian deposition occurs when transported sand grains meet resistance such as plants like marram grass or pingao, designed to cause sand to accumulate, or when wind sped drops and fluid impact threshold is lowered to the point where transportation ceases. This particularly happens in the lee dunes.

Aeolian deposition processes in the near shore zone

- Aeolian deposition may occur in the foreshore zone if the wind drops while particles are being entrained or saltated towards the fore dune area between low and high tide.

7:7 Operation and Interactions of processes on the backshore and dunes at Muriwai *(Field Guide pages 20-22)*

At Muriwai Wave and Aeolian processes have built up an ancient dune landscape inland and remnants have been left in the Awhitu sandstones behind the beach.

Operation of processes that form dunes

Aeolian erosion, deflation and blowouts at Muriwai.

This process occurs on the foreshore, backshore and in exposed areas of the dune system. It occurs as a normal extension of the wetting and drying process on the sub-aerial section of the beach between tides. It also occurs on the part of the beach close to the frontal dune that is most exposed to the drying effects of the sun after high tide, and at exposed gaps in the dune ridge top. Wetting has a compacting effect on the sediments and drying is usually accompanied by a temperature increase that sees an expansion of particle sizes and gaps between them. The drying process makes the sediment more vulnerable to wind erosion.

The dominant **westerly**, and **south westerly**, onshore winds often (over 40% of the time) exceed 11 knots. This is necessary for the process by which beach sediment is moved across the surface. During Cato's study in the 1980s the 'critical shear velocity' of 10.64 knots (5.47 m/s) for unconsolidated iron sands was exceeded 67% of the time at Muriwai.
Saltation and the aerial suspension of finer sediments also occur. In exposed places where air is funnelled the process of deflation causes blowouts to form. Examples can be seen all the way along the dune ridge facing the sea and in the dune areas behind.
Blowouts also occurred around the old surf tower, and attempts were made in 2005 to limit them with geotextile mesh netting before the decision was made to crane the surf tower back.

Aeolian transportation at Muriwai
In the past, after Maori and European occupation has stripped the protective vegetation from the hind dune areas, extensive migration of dune sand occurred up to 4km inland of Muriwai beach. Woodhill Forest was a management response to prevent this **Aeolian transportation** by **saltation** and **suspension**. The dense cover of marram grass and spinifex over many dune areas prevents Aeolian transportation, as the grass and spinifex over many dune areas prevents Aeolian transportation, as the grass traps the sand. However dunes can still be built up as the plants respond to being gradually buried by growing upwards. This process has been largely responsible for the unstable height the dune has reached at the southern end of the beach.

Aeolian deposition at Muriwai
When wind speed is reduced by vegetation impeding its flow, or in the lee of dunes, sand grains are no longer moving in the process of surface creep, they no longer saltate and/ or they drop out of suspension. Sediment then accumulates in that place to form dunes, to be a part of their migration or to build them up.
All of these processes have been evident in the past, and they have been most evident during the period of human occupation that saw protective vegetation removed from old dunes. Aeolian processes are now limited once more by plantings to manage them, including Woodhill Forest and dune stabilisation programmes.
The use of geotextile mesh netting to trap windblown sand has increased dune size. As dune height and steepness increase, so does wind speed and Aeolian transportation.

Washover at Muriwai
Washovers may occur at very high tides by normal wave action or during storms. Waves wash over the dune ridge in exposed places, ponding sediment behind the frontal dune. This may later dry out and be carried inland by Aeolian transportation.
Breaching of the frontal dune by waves has been seen as a major problem by managers in the past and has been a focus of much dune management,

including sea walls and planting systems. Such approaches see the dune as a line of defence, but in this particular high energy, dissipative beach environment washovers may need to be seen as a natural part of the coastal system, which simply requires a wider hazard zone and less human interference.

Summary of interactions of processes on the dunes

Backshore/ backdunes - the interaction of Aeolian erosion, transportation (saltation) and deposition result in the dune landscape, blowouts, migrating dunes, etc.
Between processes from location to location:
Headland to backshore- the headland supplies eroded material for the dunes, but not much; as most of it is ancient.
Nearshore to backshore/ backdunes- wetting and drying in the sub-aerial low tide zone reaches the backshore by Aeolian transportation and results in dune formation. (Aeolian deposition)

8:0: Temporal Variations over geological time

I will cover:

- ✓ **Beach Equilibrium**
- ✓ **Glaciation, Uplift and Changing Sea Levels**
- ✓ **Global Warming: its causes and predicted effects on the coast**
- ✓ **Long term Temporal Variations in natural processes in Auckland and Muriwai/ Maori Bay(climate and geomorphology)**

- How has the environment shown **temporal variations** (changes over time). This may be over millions of years (geologic time), hundreds of year (recent time) now (present time) or the future. Which parts are showing changes in erosion and deposition?
This could also include summer and winter profiles.

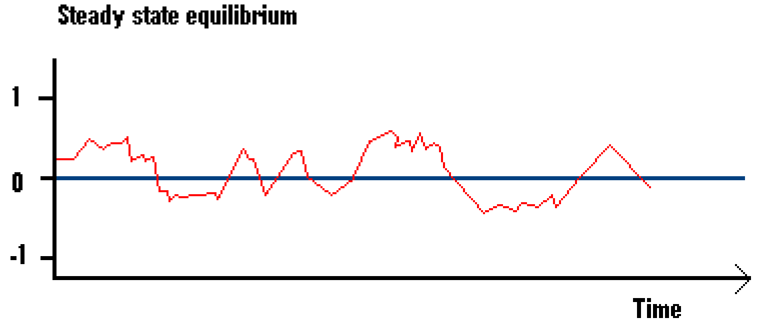
8:1: Beach Equilibrium

Beach Equilibrium *(**Text**: Beguely pages 6-7)*
The word equilibrium refers to a state of balance. Energy is being put into the coastal system from both natural and human sources, and like all environments the coastal system is trying to stay in equilibrium.

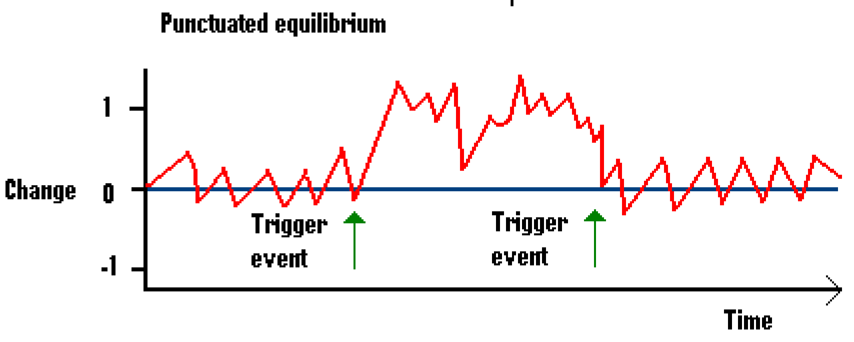
There are three main types of equilibrium which can be represented on a graph:

1. **Steady state equilibrium.** This describes a situation where most change that occurs is regular, seasonal change throughout the course of a year, e.g. from summer to winter. Little real change occurs over

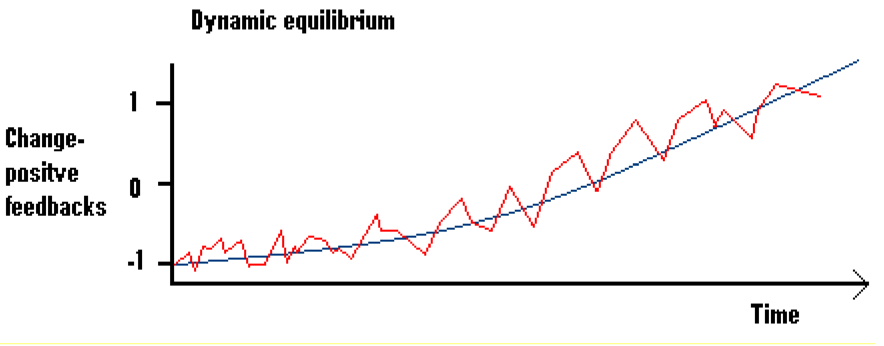
long periods of time. On average, wave and wind conditions stay much the same.



2. **Punctuated equilibrium.** This happens when an environment switches between more than one state of equilibrium from time to time. A major storm event with its associated storm surge, or a series of tsunami can have drastic effects on aspects of the coastal environment for some time, e.g. sediment supply, although eventually the coast will revert to its former state of equilibrium.



3. **Dynamic equilibrium.** This involves more gradual, long term change, during which the coastal environment is constantly adjusting and adapting. This will be the situation if global warming causes a gradual rise in sea levels over the next century.



8:2 Glaciation, Uplift and Changing Sea Levels (*Beguely pages 31-32, Natural Processes pages133-137)*)

Source: Thornton, GNS website

The Geological Timescale and New Zealand's Coastline

Era	Period	Epoch	Age (million years BP)	Events
Cenozoic	Quarternary	Holocene	0.01	Humans established. Flandrian transgression Latest Ice Ages begin. Subduction and renewed uplift in the NZ region.
		Pleistocene	1.63	
	Tertiary	Pilocene	5.28	
		Miocene	23.8	
		Oligocene	34.3	NZ mostly under sea. Modern mammals, whales, dolphins appear.
		Eocene	55.5	60M BP sea floor spreading the the Tasman Sea. NZ being eroded down.
		Palaeocene	65.0	
Mesozoic	Cretaceous Jurassic	Age of Reptiles	144.2	85M BP NZ starts separating from Australia. Flowering vegetation appears. 130M BP collison forces NZ land mass up against
	Triassic		208 248	Ammonites, dinosaurs and first mammals begin.
Palaeozoic	Permian	Age of Amphibians		First reptiles develop.
	Carboniferous		290 354	300-130M BP volcanoes and sediments deposited in the NZ region.
	Devonian Silurian	Age of Fishes	417 443	370M BP collision and uplift in the NZ region.
	Ordovician Cambrian	Age of Invertebrates	490 540	500-380M BP volcanoes & sediments deposited in the NZ region. Hard-shelled anilmals appear.
	Pre-Cambrian		540-4.6 Billion	Soft-bodied organisms appear Multi-celled organisms appear

Long term sea levels do not remain constant because of the processes of ‘eustasy’ and ‘isostasy’.

Eustacy is the rise or fall of the sea level relative to the land. It is often associated with periods of glaciation (sea level drops as water is locked into ice caps and glaciers) and periods of warming (sea level rises as the ice melts).

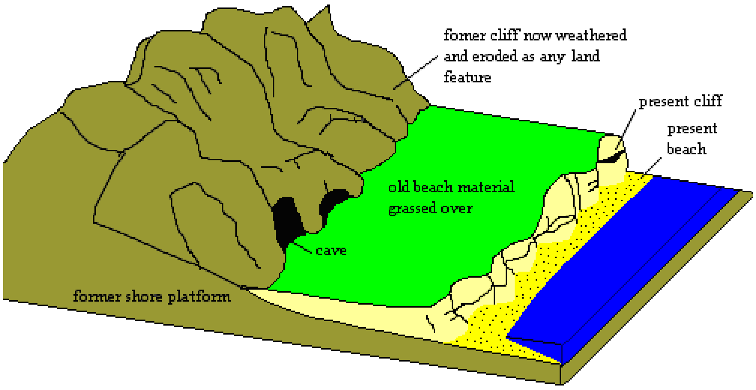
Isostasy, is the rising and falling of the land, which causes a ‘relative’ change in sea level. Isostasy is the tendency of the Earth’s crust to maintain an equilibrium; IE: if one part of the Earth’s crust is depressed another will rise to make up for it, or, when pressure is released from one area of the crust, it will begin to rise toward its previous level.

The main reason for both eustatic and isostatic changes in land and sea levels is **glaciation**. During the ice ages, the ice accumulates to thousands of metres depth on the continental areas. The weight of the ice depresses the surface, causing glacial isostacy. When the ice melts during **interglacial** warming periods the surface begins to rise toward its former equilibrium position. Of course, as the ice melts the sea level also rises, so eustacy occurs also.

When the rate of land uplift is the same as the rate of sea level rise, then the sea level relative to the land remains the same- this is called **sea level stillstand.** The same effect occurs when ice makes the land subside and the sea level drops at the same rate. When eustatic changes are faster than isostatic changes, coastlines are submerged. When the reverse occurs, coastal emergence is the result.

Most of the landforms associated with eustasy and isostasy have been created by alternating glacial and interglacial periods during the geological Quaternary period, which includes the Pleistocene epoch (1.8 million years BP- 10,000 years BP) and the Holocene epoch (10,000 years BP to the present). Many fossil shorelines occur above present day sea levels and are often called **raised beaches.**

Raised Beach

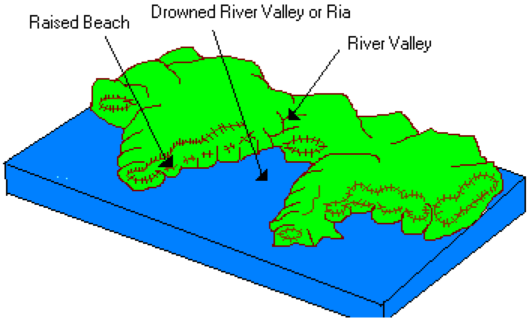


The evidence for changes in sea levels includes wave process eroded landforms (e.g. cliffs and shore platforms), set clearly above the existing sea levels, deposited forms such as ancient beaches or coral reefs above or below present-day sea levels, ‘misplaced’ fossil organisms, such as shellfish, and even human archaeological remains, such as submerged houses or port facilities.

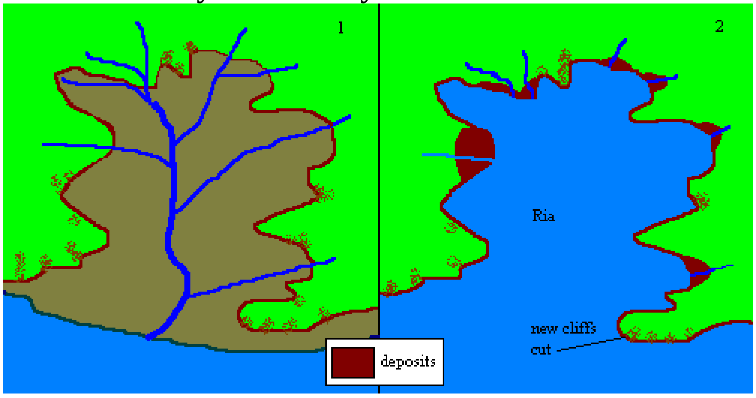
When sea levels drop and more land is exposed this is called **regression.** When the sea levels rise and more coastal land is covered, the process is called **transgression**. Regression is associated with the **emergence** of the coastline (raised beaches). Transgression is associated with the **submergence** of the coastline. (Ria, drowned river valleys, Dalmatian coasts) The ‘**Flandrian transgression’** (rise in Sea Levels after the last glacial maximum), resulted in valleys being filled with sediment from longshore currents as sea levels rose. Many of these valleys are now sand filled estuaries and harbours around the coast of New Zealand.
After a rise in sea level, river valleys along the coastline are drowned by the rising waters but keep the tributary shape of the drowned river pattern. These are called **ria** coastlines. Glacial erosion produces straight, deep, **U shaped valleys**. When sea levels rise and glaciers melt, these valleys are submerged by rising sea levels. These are called **fiord** coastlines. (e.g. Norway, Pantagonia, Fiordland)

Glacial deposition features often result in unstable coasts with many bars and spits and projecting features like drumlins and roche moutonee. In New Zealand, the west coast has some of these phenomena, but most of the debris has been redistributed by strong wave action to form long beach and lagoon systems.

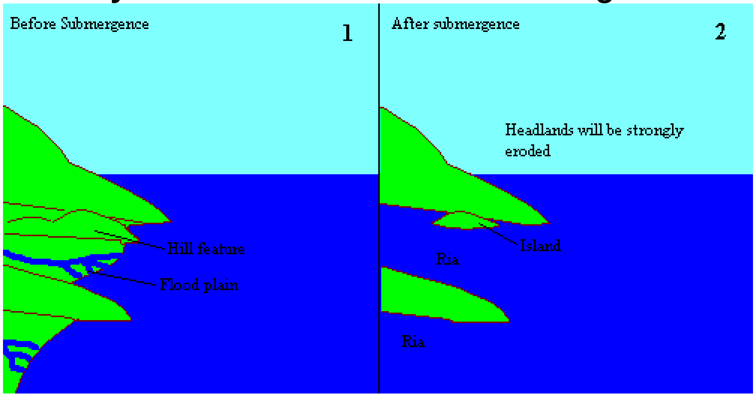
Ria



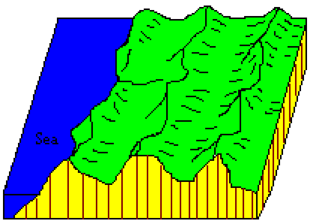
Rias formed by river valleys



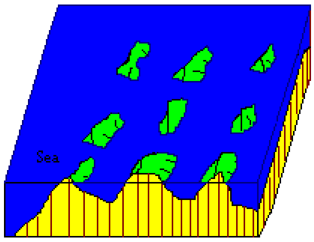
River systems before and after submergence



Dalmatian coasts before and after submergence e.g. Adriatic Sea

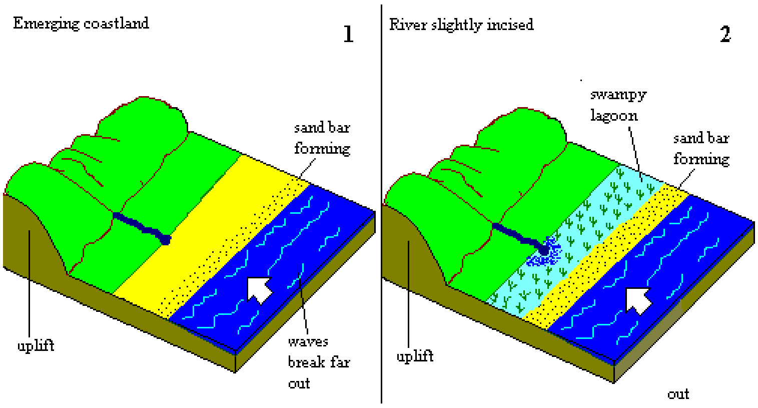


Before sea level rise



After sea level rise

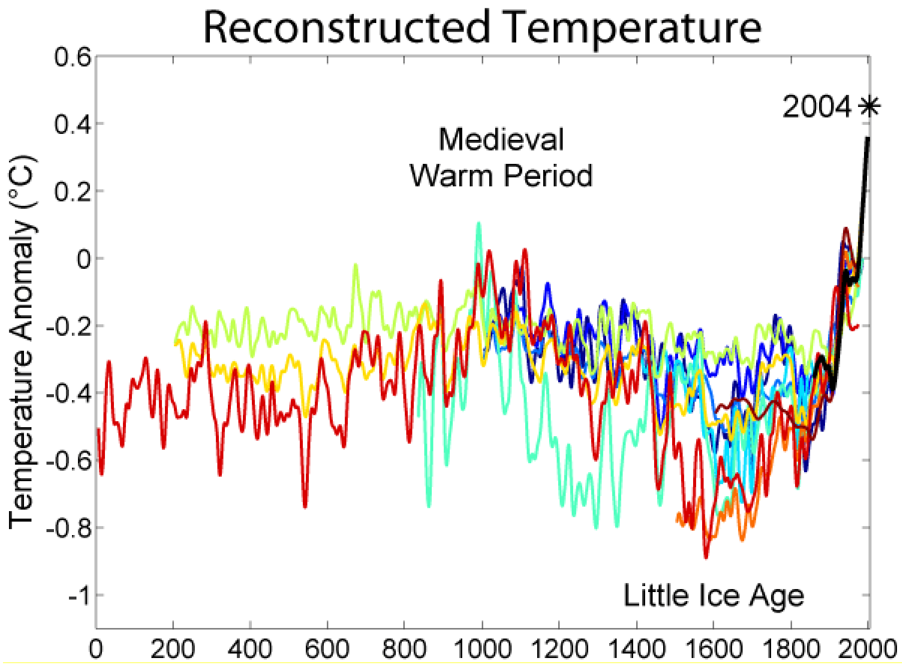
EMERGENT COASTLINES

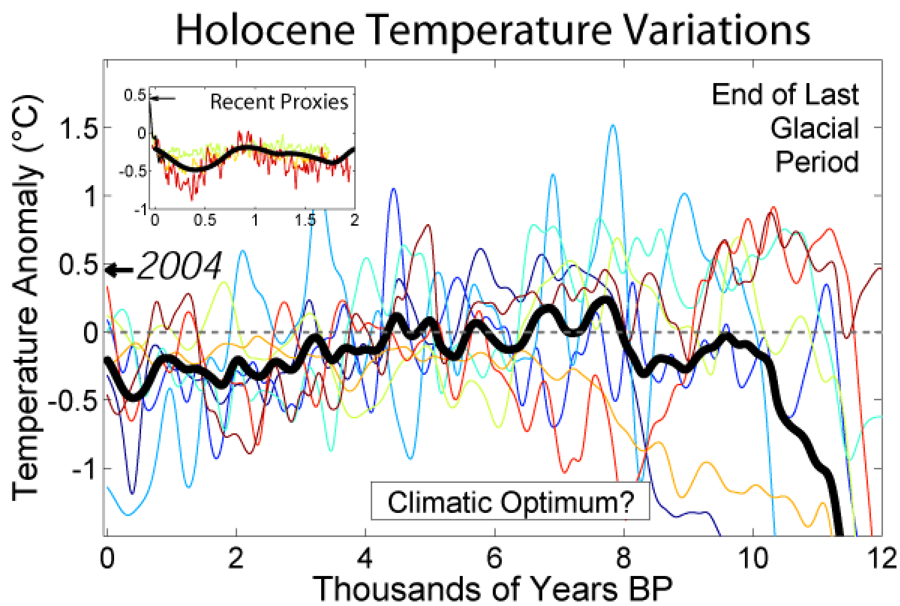


Modern Dating Techniques: *(Background information for teacher Beguely page 32)*

Upon the death of an organism, radioactive decay of Carbon 14 occurs, with a half life of close to 6000years. For example, if the amount of Carbon 14 was half what would be expected in modern organisms, the fossil might be 6000 years old. However this method had had to be calibrated with measurements from tree ring research to make it more exact. It is also unreliable after 20,000 years because of its short half life, and the tests cannot be carried out on material older than 60,000 years. In older material dating is uranium performed.

8:3: Possible causes of Global Warming and its predicted effects the coast





During the last century, worldwide temperatures rose by over half a degree above the Earth's average temperature of 15 C. Some climate models suggest that this could rise to a 2 C increase by AD 2100.
Some climate scientists think global warming is caused by natural variations in solar variation rather than the result of human activity. (Called **anthropogenic global warming**) Most scientists are convinced the rise is mostly attributable to human activities. The "standard" view of climate change

has come to be defined by the reports of the **IPCC. (International Panel on Climate Change)**
http://en.wikipedia.org/wiki/Global_warming_controversy

The potential effects of global warming are also debated. Will global warming cause a steady rise in average temperatures around the world or will a point be reached where an equilibrium is maintained as humans adjust their outputs of atmospheric pollutants? Will the changes be mostly beneficial or harmful?

Rising sea levels: Causes

- The warming and expansion of the oceans and seas. This is estimated to contribute about half of the observed increase in sea levels- models are used to predict rises of about half the expected increase.
- The melting of small ice caps and glaciers. It is estimated this could contribute 44% of any increase. Hard data are available for this from the study of mountain glaciers.
- The melting of the Antarctic and Greenland ice sheets. Moderate estimates calculate 0% from this because of compensatory ice accumulation in the interiors.
- The increased surface and ground water. These would only contribute about 6%.

Predicting the future

- Some experiments using models show a possible rise in sea level over the next century of up to 50cm (faster than that recorded for last century).
- Even if we were to cut back emissions, sea levels would continue to rise because of thermal inertia. We can expect a greater frequency of high intensity storms as well as other effects.
- The damage from flooding and increased coastal erosion alone could cost billions of dollars worldwide.
- Fishing industries could be damaged.
- Tourism venues and industries could be damaged.
- Coastal agriculture could suffer by flooding and salt water intrusion.
- Heavily populated, low lying islands and delta plains could suffer enormous losses of life and income.
- Huge social and economic costs could be incurred for new or enhanced coastal protection systems.
- Land could be lost to coastal erosion.
- Sediments could be redistributed changing the shape of beaches and offshore bars, spits etc.
- Wetlands, home to endangered species, could be submerged.
- Industry, agriculture, transportation and the whole infrastructure of coastal cities could be affected.

8:4 Long term Temporal Variations in natural processes in Auckland (climate and geomorphology)

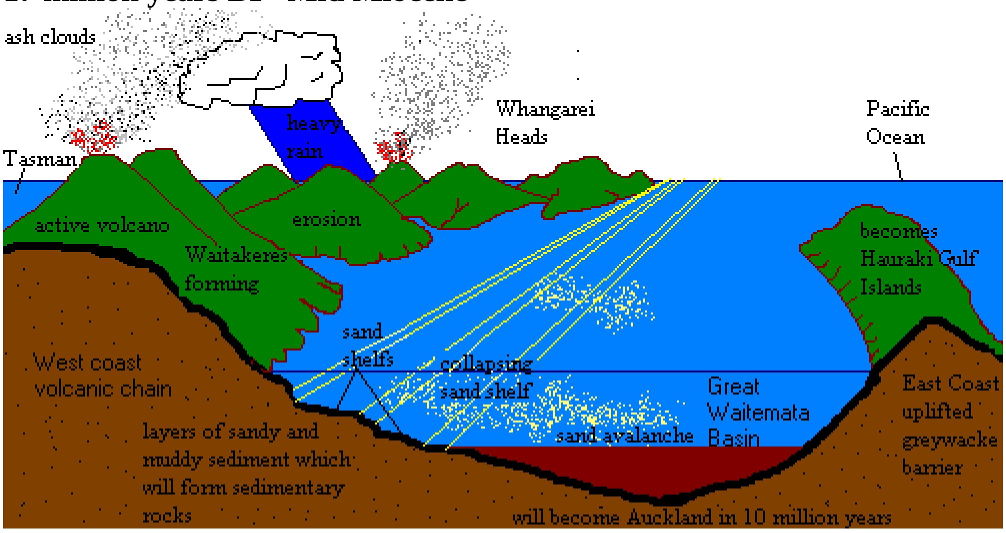
Today

The Auckland region is dominated by the sea. The exposed west coast, pounded by high energy waves generated across a large fetch of the Tasman Sea, has been moulded to a sweeping curved plan that reflects the erosive power of the ocean waves. The east coast has a lower energy wave regime. On both the east coast and the west, large and small estuaries interpenetrate the land, so that no one place in the Auckland region is more than a few kilometres from salt water.

Pre-historic Processes forming the Auckland region coastline

The diagram below shows the main geomorphological processes that shaped present day Auckland.

17 million years BP- Mid Miocene



Geomorphological Processes

22-15 million years ago (early Miocene)	**-** Formation of the Waitemata Basin - Volcanic activity erupting lava and ash **-** Volcanic islands grow offshore from the Waitakere Ranges and the present day western coastline. -Formation of volcanic dykes. -Bedding of sedimentary rocks. -Earth movement uplifts sea floor to shallow depths. Submarine channels and canyons were eroded into the raised sea floor and cut deeply into the rock formation. This coincided with volcanic eruptions. -Area uplifted above sea level during final stages of the Waitemata eruptions.
14-10 million years ago (middle Miocene)	**-**The Auckland region is now above sea level and is eroded down.
9-8 million years ago	**-** Land was broken into huge blocks which moved

(late Miocene)	relative to one another. South of Auckland, the Hunua ranges and Coromandel Ranges were two blocks that were elevated, whereas in between, the Firth of Thames block was lowered. The Waitakere Ranges and Auckland area was a single block elevated to a height between the Hunuas and the Manukau lowlands and was tilted northwest.
7-2 million years ago (Pliocene)	-Erosion removed a large quantity of softer rocks (Waitemata sandstone) that covered the area but the harder rocks (conglomerate and lava flows) of the Waitakere Ranges have been more resistant to erosion.
2 million years ago (Pleistocene)	-Dune sands consolidated to form sandstone rock.
8000 years ago	- Sea has eroded sloping hillsides south of Muruwai to form a cliffed coastline.

Climatological Processes

22-15 million years ago (early Miocene)	**-** Rise in sea level meant that the Auckland region was under the sea. - Warmer temperatures than present prevailed as evidenced by reef building corals.
2 million years ago (Pleistocene)	**-**The world's climate experienced a number of drastic coolings which brought about a series of Ice Ages. During each Ice Age, a large proportion of the earth's water was frozen on land as ice, and sea level dropped. When temperatures rose again, the ice melted and sea levels returned to about their present level. Auckland's coastline was significantly shaped during this era.
20,000 years ago	**-** The last Ice Age with sea levels 100 metres lower than present.
8000 years ago	- Temperatures warmed and sea level returned to the present level.

Pedological Processes

22-15 million years ago (early Miocene)	**-** Sand and mud beds built up on top of each other to form sandstone and mudstone (Waitemata sandstone) - Volcanic debris led to pebbles, grit and mud sitting on top of the bed of sandstone and mudstone (Parnell grit) - Material compacts to form two rock types:

	• Nihotup (older)- pillow lavas, beds of sandstone and mudstone and pebbles • Tirikohua (younger) – volcanic conglomerates, pumice and viscous lava, grit and coarse sandstone. - Further beds of sandstone embedded on top of Parnell grit. - Volcanic conglomerates, pumice and ash supplied as material.
2 million years ago (Pleistocene)	**-** During normal sea levels black sands, rich in iron, were washed onto shore and subsequently blown inland to form a thick layer of dune sands.
20,000 to 8,000 years ago	**-** North of Muriwai vast quantities of sand have been deposited by the sea to form a 3-5 km wide belt of sand dunes behind the 50 km long Muriwai Beach.

Temporal Variations from Geomorphological interactions with climate change and waves at Otakamiro Point and Maori Bay.

At Maori Bay Pillow Lava Flow

Volcanic activity operating over a long period of time, produced a viscous lava which moved as a series of connecting tubes.

- Contact with wave action caused a radical pattern of joints or fractures on the lava as it spread across the sea floor.
- The pillow lava spread across the sea floor and built up over time. With a change in sea level this pillow lava became exposed in the cliffs above Maori Bay.

At the intertidal platform

- A return to present sea level has exposed the cliff to wave attack.
- Volcanic activity and uplift has creates coastal cliffs, made up of rocks of varying resistance to wave attack.
- Wave attack erodes softer rock and attacks the cliff leaving the more resistant rock. As the width of the platform increases the waves become shallower and less able to attack the cliff, leaving a platform.

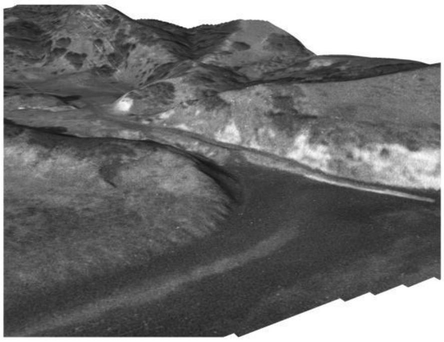
At Otakamiro Point

- Volcanic activity and uplift has created coarse sedimentary rock.
- A return to present sea level from the last Ice Age has enabled Otakamiro Point to establish itself as part of the coastline.
- Wave energy has eroded the cliff and sloping hillside to form a cliffed coastline and to create a point where the most resistant rock has prevailed.

8:5 Temporal variations of processes on the dunes at dunes at Muriwai

About 3000 years ago the most recent phase of deposition began to produce the landscape of the modern beach and foredune in the Muriwai-Kaipara area. However, about 2000 years ago a trend of coastal erosion began, and the inland sand dunes were already stabilised before people arrived.
The rate of coastal retreat has been up to **1.4 metres** a year in recent times. The MHWS (mean high water springs) has also moved closer to the foredune, and this creates more possibilities for erosion. It is thought that low frequency edge waves running at right angles to the beach do the most damage in undercutting the frontal dune. This undercutting is followed by slumping, and the detritus from the slumps is soon redistributed on this high energy dissipative beach.

Muriwai is a **mesotidal** (about 3 metre tidal range), dissipative beach, but much of the wave energy in recent decades has been going into the dune face with sediment being removed to the inshore zone or offshore. The frontal dunes have been modified in order to maintain a protection barrier for reserves and recreational features inland.



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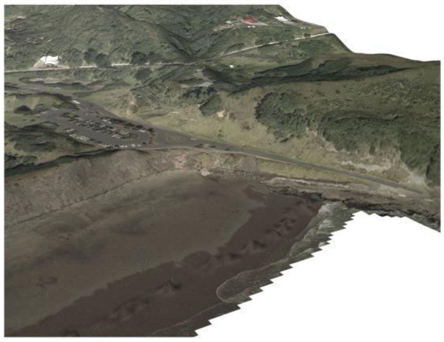


2006

Since the 1960s this area has experienced significant dune erosion and has retreated about 50 metres at the southern section of the beach. This process seems to be related to large scale sediment transportation process changes. There have been various attempts have been made to halt this loss. Early protection of the dunes, access road and front edge of the carpark has involved placing large boulders and gabion baskets beneath the access road, planting marram grass over the dunes and building solid wooden seawalls across the dune face. These seawalls were demolished soon after by wave damage from severe storms.
Since the erosion is likely to continue into the foreseeable future, management plans are likely to focus on an adjustment to nature rather than attempts to control it.
By 2009 the beach front had eroded so far back that parts of the carpark began to collapse into the sea. The area has now been reshaped by pulling back/retreating the carpark over 50m (from the seaward edge), excavating the fill material used for the carpark, pulling out sections of the stormwater pipe as

required, reshaping remaining dunes, planting them with pingao and spinifex and recreating the natural gully that was formerly there.


2005


Early erosion of bank, storm water pipe undercut and dislodged from bank. June 2006

2008

Newly excavated and reshaped area 2009

2010

9:0 How and why is the whole environment being modified at the present time and is likely to be changed in the future?

See Temporal Variations notes for more on how natural processes are likely to change the environment in the future.

- **Link t**hese changes to changes in the processes. Why have these changed over time? What is modifying the environment at the present time? Are these changes related to human actions? Could people's actions cause changes in the future?

9:1 Process modification of natural processes in coastal environments

Activities:
Construct a continuum which shows the extent by which human modification of natural features and natural processes can exist in an environment. Place the modification (e.g. build a sea wall) on the appropriate continuum.

no modification — **Human modification of natural features** — significant modification

no modification — **Human modification of natural processes** — significant modification

Students rearrange the notes into this table.

Modification	Processes modified	Examples
Breakwater	Barriers may change the impact of wave energy by deflecting energy away from a particular place, or by directing it to a specific site.	e.g AT Half Moon Bay Marina and Pine Harbour

Human developments threatened by coastal erosion at Muriwai
Coastal/ wave erosion threatens the southern end of the beach, including the **car park**, the **storm water outlet**, the **surf clubhouse**, the **beach parking area** and the northern end of the **golf course**.

Southern car park area
The area of the southern car park was originally a gully with a natural waterway that drained part of the Muriwai Stream catchment area. This gully has been piped and filled in, and the current car park has been built over. The gully had been mostly infilled by 1953 and completed by the 1970s.
There has been no road access onto the beach since the 1920s. There used to be wooden steps along the front of the car park area, but these were taken away because of regular wave erosion threatening them.
Hard engineering solutions in the form of shoreline armouring works were built to protect the access road from wave erosion. These included large boulders, walls, sloping concrete faces and gabion baskets, the latter two of which remain intact although the gabions are slumping.

To the domain, the golf course and the area of the frontal dune and back dunes
The Domain comprises the most southern 600 metres of this area and includes the surf club building and tower (removed in October 2005), the main visitor car parks, parkland, toilet facilities and the Muriwai motor camp. The Muriwai Golf Course occupies most of the reserve area south of the Okiritoto Stream, along about 1.5 km of foreshore. The golf club has lately relocated 200-250 metres inland at the southern end to pre-empt threatened erosion and sand migration on to the greens in that area. The front and back dune areas stretch from the area north of the southern car park to the mouth of Okaritoto Stream, a distance of 2 km.
The council's management plans for the front and back dune areas include establishing native sand-binding grasses on the eroding dune face then creating wind erosion buffers after erosion has been halted. The northern end of the golf course is considered at risk and is also to be moved inland.
A high frontal dune mostly backs the beach, on average about 6-8 metres high although higher than 14 metres in some places. The width of the foredune has been greatly reduced by wave erosion in the last 40 years. In places the high dune has actually been removed by coastal erosion, human modification and/ or wind erosion causing deflation/ blowouts.
There is little or no vegetation on the eroding seaward face of the frontal dune, which has a steep gradient (35 degrees) that can become near vertical after severe erosion. Just inland the topography is hummocky- reflecting the major wind erosion and blowouts in the past.
This area is now largely grassed, although there are patches of trees and shrubs. Most plantings are exotic species, although there are also areas of native ground cover and shrubs that have re-established naturally or have been planted. Maori and exotic **Ice plants** and **pingao** occur.

Modifications of Tidal Processes
Tidal effects may be modified by the **planting of vegetation** which can slow or re-direct water flow.

- ✓ The transfer of wave energy through deep water waves cannot be modified, but the creation of artificial barriers, such as **breakwaters**, may change the nature of the impact of wave energy by deflecting energy away from a particular place, or by directing it to a specific site.

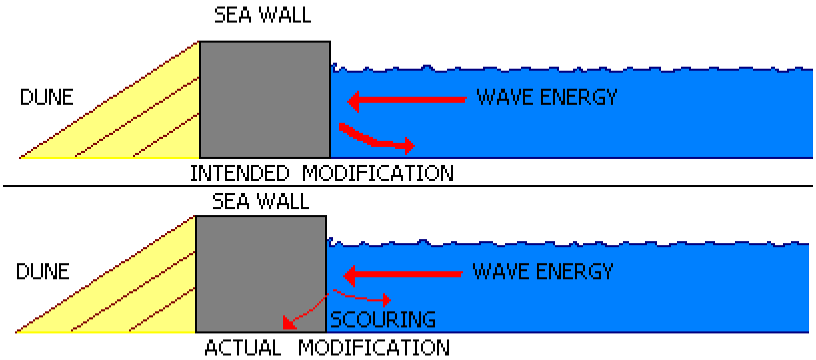
Modifications of Wave Processes

- ✓ Waves in shallow water may be affected by **dredging** of the ocean bottom. Unless dredging is continuous, this would only be a short term modification as the wave energy processes would adjust to the changing conditions of the ocean bottom and seek to establish an equilibrium.
- ✓ Refraction processes may be modified by the creation of **breakwaters** and **groynes**, which will affect where and how waves break.
- ✓ Waves in shallow water may be affected by the building of **groynes** which may protect loss of sediment from a beach. The problem with this is one beach may be protected, yet eventually an adjacent beach may be destroyed by sediment being removed from it.
- ✓ Effects of wave quarrying may be modified by protection of geomorphological features and the way they are shaped, e.g. cliff protection measures by **groynes**, **fencing** and **wire nets** holding rock material stable. The process of wave quarrying would still occur, but would act against the artificial barrier rather than the coastal feature, so the rate and magnitude of the effects of the process would be reduced.
- ✓ Abrasion effects may be modified by the building of **rock walls** to protect existing coastal features. Abrasion would still occur against the artificial barrier, but coastal features would be protected.
- ✓ **Large rocks** can be placed on a beach, to protect the beach frontage and thereby reducing transportation of material.

At the headland, no attempt has been made to modify the shore platforming, cliff erosion or cave formation processes except at the beach itself.
At the beach, the wave refraction and reflection processes that follow the shape of the headland have caused considerable wave erosion and undercutting of the southern car park and threatened the road down to Flat Rock.

- The response has been to build **gabion basket structures** and a **sloping concrete wall** along the base of the small cliff that the road follows down to the beach. The **gabion baskets** and **concrete wall** seemed effective, but much damage had already occurred to the **temporary defences**. There is evidence of older temporary works that have been demolished by wave action, and now (2012) the current gabion basket defences have to be protected by **large boulders**.
- **Protective wooden and iron structures** and **stacks of boulders** have also been used to protect the water pipe that drains the immediate catchment above and the lower end of the southern car park.
- Hard structures have been put in place to modify the wave erosion of the southern car park, but long term plans promoted by the **ARC** and **Rodney District Council** are to let nature take its course and engage in *managed retreat from the hazard.*

✓ Erosion of coastline may be slowed down by the building of **sea walls**. Sea Walls are designed to reflect wave energy back to sea. However wave energy can scour underneath the sea wall and still eventually erode the coastline. The reflection caused by sea walls can also cause the loss of sediment at a beach.



✓ **At Muriwai Sea walls** and small **groynes** have been tried in the past but to little effect. The sea wall was constructed to reflect wave energy. In response, the wave energy scoured underneath the sea wall and still attacked the dune.

Modification of adjacent beaches and rivers

✓ The erosion or deposition of beaches can be modified by control over the source of beach material, such as **damming rivers**, building **groynes** etc.

The southern end of Muriwai beach may have been in a dominantly erosive state for thousands of years. This area has shown a recent trend for rapid shoreline recession, with erosion of the frontal dune backwards averaging 1-1.5 metres per year.
It is possible that this greater coastal erosion is linked to global warming patterns and/ or changes in the sediment supply of the region. For example, the **damming of the Waikato River** may have reduced the availability of material to build up the beach. However, more than one researcher has noted that there seems to be a worldwide trend for erosional retreat of sandy coasts.

Modification of weathering processes on the cliffs and headland

- ✓ Weathering effects may be reduced by protection measures such as **planting vegetation** on cliffs.
- ✓ Mass movement can be modified by **cliff support measures** preventing cliff collapse.
  At Maori Bay there are retaining walls at the top of the cliff protecting the car park and homes.

Modification of processes on the dunes and backshore

- ✓ Erosion of sand dunes by people can be managed by the construction of **walkways** between dune systems from car parks to the dune front. This can accentuate **funnelling**, where the wind is channelled through a narrow gap, frequently increasing erosion on the sides of the dune. Extensive dune stabilization works from the early 1900s until recently emphasized the building of a large frontal dune and revegetation with exotic **marram grass.** The resulting high, steep dune has required ongoing management and intervention to maintain. Increased **recreational pressures** at the southern end of the beach had initiated serious wind erosion problems by the early 1950s. To protect the dunes a **wire fence** was erected to stop people trampling over the dune system. **Walkways** were constructed between the beach and the main car park. This accentuated saltation through wind funnelling where the wind was channelled through this narrow gap, increasing erosion on the side of the dune.

- ✓ Saltation, suspension and surface creep can be hindered by the use of **4WD vehicles on the beach.** Heavy vehicle traffic may also compress the sand surface and reduce the amount of sand that can be saltated towards the dune face, further reducing the frontal dunes. There is an entrance for vehicles to the beach just before Okiritoto Stream. From that point towards South Head Muriwai is a designated “road”.

- ✓ Saltation, suspension and surface creep can be enhanced by the **removal of vegetation** and lead to the **migration of dunes** inland. Plants bind the sediment to the foredune.

- ✓ Saltation can also be hindered by the planting of vegetation, particularly **Marram grass (French species)**, or natives species such as **Spinifex** and **Pingao grass**.

History of dune management in New Zealand

It is not known how much Māori influenced the active dune lands, but their fires may have opened up more land to sand movement. From the mid-1800s, settler farmers cleared and burnt sand-binding native grasses, shrubs and small trees near the coast in order to run sheep and cattle. They removed the natural vegetation cover, allowing dunes to migrate inland.

The first NZ Forest Act of 1874 was largely in response to concern about the increase in coastal dune invasions. However, little was done and the dunes continued to advance.

By 1880 estimate suggested that there were 40,000 hectares of drifting coastal sand in New Zealand. By 1909, the area was thought to have increased to 120,000 hectares. It is uncertain if the growth was entirely due to farming practices – research has shown that dune lands also had natural periods of expansion over the late Holocene (last 10,000 years), so some of the growth may have been natural.

Today dune lands are seen as unique ecosystems, but in colonial New Zealand there was a fear of drifting sands. Sand blew about in coastal areas, encroaching onto pastures.

From the 1870s, the threat to productive land was recognised but little was done. In 1908, the government passed the **Sand Drift Act**, but it wasn't until 1913 that the Public Works Department made its first efforts in sand stabilisation. In places around the coast farmers had already taken things into their own hands and planted introduced marram grass (*Ammophila arenaria*) to stabilise the dunes. By 1873 James Stewart reported fully grown trees buried by dunes and in the Kaipara dunes of 90 metres tall.

The Department of Lands was the first government agency to tackle what was seen as the sand problem. The botanist Leonard Cockayne published repor a report in 1911 that included a section on how the French had stabilised dunes on the Gascony coast with extensive planting. Cockayne advised the government to stabilise sand at the point of supply – the coast. Cockayne pointed out that only continuous vegetation cover would solve the problem, and that this should also be commercially valuable.

The **planting of Woodhill Forest** was a major modification to prevent sand migrating inland.

By 1924 only 65 hectares of marram had been planted at Woodhill. During the economic depression of the 1930s, the Public Works Department took over the sand-stabilisation project. With 80,000 registered unemployed at their disposal, gangs of men lived in camps, planting marram grass, and other exotic species around New Zealand.

In 1932 planting of marram grasses began in earnest, with lupins and eventually pine seedlings following. In Woodhill there were 4 camps of 20-30 men per camp working all year around, with supplies being brought in from neighbouring farms and plants supplied from a Nursery also in what was then a barren wasteland of sand dunes.

By 1951, when the New Zealand Forest Service took on the job, 9,000–10,000 hectares of dunes had been planted in marram grass and yellow tree lupin (*Lupinus arboreus*), and 3,800 hectares of forest had been planted. The Forest Service mechanised the planting of marram grass and radiata pine (*Pinus radiata*), greatly increasing the areas they could cover. By the 1970s, they had a standard approach:

1. Build fore dunes, using barriers such as mānuka fences and radiata pine prunings.
2. Plant marram.
3. Sow yellow tree lupin.
4. Plant radiata pine on the coastal edge.
5. Plant commercial forests in the lee of the shelter achieved.

From the 1960s to the 1980s, the Forest Service established pine forests in large areas of Northland, Auckland, Waikato and Manawatū dune lands. These forests have been the largest factor in the reduction of New Zealand's active dune lands.

http://en.wikipedia.org/wiki/Woodhill_Forest

Change to planting native species

Many exotic plants have invaded dune lands. Marram grass has been planted extensively, and has also spread naturally. It has stabilised dunes, but has also replaced native plants such as pīngao (*Desmoschoenus spiralis*) and spinifex (*Spinifex sericeus*).
Plants can also alter the shape and extent of dunes. Marram is a very effective sand binder, creating dunes that are steeper and higher than those covered in pīngao and spinifex. Pīngao actually needs sand movement to

survive, so it does not grow on well-stabilised dunes, and is now found mainly on fore dunes (closest to the sea).

Replacing pīngao with marram grass has also changed the habitat of the native katipō spider, which is now considered to be a threatened species.

More recently, however, they have developed a more sustainable frontal dune using mechanical reshaping and **revegetation with native sand grasses**. This has been very successful at the mouth of the Okiritoto Stream, where stable **spinifex** dunes have been established.

http://www.teara.govt.nz/en/dune-lands/2

The **golf club** has been trying to stop sand blowing over fairways and greens and the planting programmes seem to have been largely successful in this. However, in the past, **toilet blocks** have been threatened by high steep dunes that promised to slump and inundate the toilet area. The dune fronting the main car park area in the 1980s had become particularly unstable because of its height and steepness. This was caused by the use of **sand fences** to control sand drift, which trapped the sand at the summit. This modification prevented the process of landward migration but created a danger of slumping. It had long been known that both wind seed and the rate of Aeolian transportation increase as surface steepness increases. The cure was making the sickness worse.
Cato suggests three main options regarding the foredune and it's management:

1. Continue stabilisng the dune, which will probably simply maintain the erosion trend.
2. Stop dune stabilization completely, which will result in some predictable and some unpredictable changes to the beach and its processes.
3. Actively promote dune destabilization so that the normal process of inland transportation of sand could resume.

9:2 Natural causes that may cause modification of the Muriwai coastal environment

A recent theory put forward by the **ARC** and **Rodney District Council** in a joint document suggests that this erosion is related to the movement of quanta (slugs) of sand- that move up the coast on a regular periodical basis. Each period during and between slugs could be several decades. In the periods of time between slugs erosion occurs, but when the slug arrives a period of deposition occurs.
This theory seems to fit with the fact that the beach was in equilibrium until the 1960s, and it then went into an erosion phase. Beach profile data and field

observations also seem to show that erosion decreases north. Net sediment transport along the west coast is northward, so it could be that sand eroded from the south of the beach is being deposited further north.
The erosion of the southern end of the beach suggests that sediment supply from the south is not balancing the transportation of sediment to the north. This may be related to the large scale movement of sand up the west coast being blocked by obstacles such as headlands, river mouths and the tidal inlets of estuaries.

SKILLS THAT NEED TO BE COVERED

As well as the content there are several geographic skills required that could be examined. These should form part of your teaching.

- Drawing a geographic map of an environment using mapping techniques such as the use of a frame, arrow, appropriate colour, key, scale (may need to be an estimate but must be provided) and title (where it is and what showing). These can be easily abbreviated – many use the term FACKTS.

- Drawing a cross section of part of the environment or a feature using standard techniques such as frame, direction, scale, colour, labels and title.

- Being able to annotate maps or diagrams. This means to put simple notes by the appropriate spot that allow analysis or explanation to occur. It is more than being able to label.

- Being able to write essays. While they are not marked on their structure it is a good habit to provide a simple introduction (what you intend to cover), body and conclusion. Use of a plan helps an answer to flow which gets better marks.

- If an essay asks to include maps or diagrams then you draw them where appropriate to your answer and refer to them in an answer. These can be very simple and do not have to have all the mapping/diagram techniques.

- Know the requirements to analyse. You must say **WHY or HOW** something happens not just describe it. Not ‘the waves erode the headland to form a cave’ but ‘the waves slow down when they approach a headland and are directed onto the end of it where energy breaks it down to form a cave.’