Coastal Landscapes

Suggested Case Studies/exemplification

Case Study	Exempifies	Case Study Detail	Notes
Cornwall	1.Rocky coastline	**Bedruthan steps**, Cornwall Geology: Middle Devonian **Slates** an Staddon Grits (Old resistant **sandstone**)	
Northumberland	1. Coastal plain (sandy coast)	**Bamburgh Beach**, Northumberland	
Baltic Sea	1. Concordant coastline 2. Haff coastline	Long spits of sand form lagoons behind e.g. **Coronian lagoon**	
Dalmatian coast, Croatia	1. Concordant coastline 2. Dalmatian coastline	Formed by **faulting** and **rising sea levels** since the end of the last ice age	
West Cork, Ireland	1.Discordant Coastline 2.Rias	Rock strata meets the coast at **90 degrees** in **parallel** bands Weaker rocks (limestones) have been eroded creating long, thin bays (rias) in-between the mudstones and old red sandstones Especially resistant rocks remain as detached islands, such as **Clear Island**	

Jurrasic coast:	1.Marine erosion dominated coastline 2. Concordant coastline 3. Resistant Limestone coastline 4. Seaward dip 5. Folding 6. Discordant coastal features 7. Clay coastline unconsolidated. not resistant) 8. Natural Arch 9. Sedimentary chalk headland 10. Stack & stump sequence 11. Jointing 12. Cliff formation 13. Rockfall at St Oswalds bay	Located on the **Jurassic Coast World Heritage Site** (awarded by UNESCO in 2001) Mouth of the cover has strong **seaward dipping Portland limestones** Easier to erode **Wealden sediment** (deposited c.124 million years ago) around can be found either side of the bay **Steeply dipping** chalk forms that back of the cove (73 million years ago) Sea **eroded** through limestone creating a cave through which you can see the **Lulworth crumple,** an excellent example of folding (**limestone and shale strata** folded due to **African** and **European Plate** colliding 30 million years ago) At **Kimmeridge Bay,** unconsolidated **Kimmeridge Clay** (exposed at low tides) erodes easily Comprised of **layers** of mudstones, thin shales and resistant yellow-brown dolomites Natural arch (**Durdle door)** hard **Portland Limetone** exploited by erosion of weaknesses between vertical layers of rock Wealden beds behind more easily eroded **The Foreland** is a **sedimentary chalk** headland, South of Studland Erosion and weathering (chalk is a limestone vulnerable to weathering) formed features including **Old Harry** - a stack , as well as a cave, arch and other features. **Durlston Head** - made of Portland and **Purback limetone.** Created steep cliffs (e.g Peveril Point) The limestone is **jointed**, and so is more easily exploited Occurred April 2013 (see below)	
Eden estuary of Fife, Scotland	1.Coastal plain (estuarine coast) 2. Importance of vegetation	An example of a **Special Area of Conservation (SAC)** Restoration of the salt marsh from bare mudflat has taken place, providing ecosystem services including: **Wildlife benefits:** high tide refuge for waders; breeding sites for a range of birds; feeding ground for geese; fish spawning / nursery; marine invertebrate habitat; specialist plants; Insect / amphibian habitat; or as part of the **wider estuarine function**: shoreline stability; sediment accretion; wave attenuation, flood, storm and coastal protection; nutrient/organic matter source; absorbing excess water run-off; pollution trap and water filtration; recreation, education and leisure.	
Lands End, UK	1. Rocky coastline 2. Resistant granite coastline	Eroded only 10 cm in one century	

South Coast of England	1. Longshore drit	Dominant wind and wave direction from the west to the east determine direction of LSD	
Pembrokeshire coastline, Castlemartin	1. Landforms of coastal erosion 2. Marco-tidal coastline	Pembrokeshire coast is 420km long and inclcies 60 Geological Conservation Sites, 40% has been granted SSSI status Various geology- mostly sedimentarty inc. sandstone and mudstone, whilst periods of volcanism led to intrusive and extrusive igneous deposits Landforms of erosion: found mostly along the concordant streets of coast at Castlemartin due to faults in limestone here though **macro-tidal** so no wave cut notches present Caves present in limestone cliffs at **Stackpole Head** Natural arches: **Green Bridge of Wales** - carboniferous limestone and, at its base, thinly bedded rock strata have been cut out along joint planes. 24 metres high and 20 metres across. The limestone strata dip inland (northwards) Stacks: **Stack Rocks**, 36m above mean sea level Blowhole**s: Devils´s cauldron** It is a 45 metre deep shaft, 55 metres at its greatest width, which is exposed to the sea by an arch 18 metres high and 21 metres wide **Vertical cliff**s due to limestone (e.g. South Pembrokeshire- 45/50m high) **Wave cut platform** present in Manorbier bay, exposed Old Red Sandstone- tilted by compression	
Coastal deposition	1. Examples of coastal deposition	Swash-aligned beaches: Bay head beach: **Morfa Harlech (Wales)** Drift aligned beaches: Spit: **Orford Ness (Suffolk)** Recurved spit: **Spurn Head (Holderness coastline)** Tombolo: **Lindisfame (Northumberland), or Loch Eriboll (Scotland)** Cuspate forelands: **Dungeness (Kent)**	

St Oswalds Bay, Dorset	1. Chalk coastline 2. Mass moveent- Rockfall	29/30th April a 90m area of cliff failed Removed part of coastal path and left a large fan of debris which extended onto the sea **(a talus cone)** **Porus chalk** was started after preceding rainfall (**antecedent conditions**), increasing pore water pressure and decreasing stability Chalk 95% calcium carbonate- susceptible to **carbonation** and **solution** opening weaknesses and fissures in the rock (creating **solution hollows**) Intense **folding** led to a 115 degree **seaward dip**- encouraging a **sliding** motion **Conjugate joints** also encouraged slippage 120m tall- **steep** cliffs have more **stress** **Lack of vegetation** on cliff face, exposure to full force of south-westerly waves and winds also has an impact- creating slight **undercutting**	
Aldborough, Holderness	1. Mass movement- topple	NE facing Avering 20m **high** cliffs Comprising of **Skipsea Till and Withernsea Till** Topple movements are sudden and **frequent** **Stepped cliff profile**	
Nefyn Bay, 2001	1. Mass movement- translational and flow	Jan 2001, a period of heavy rain led to a **translational landslide** (which degraded into a **mud flow)** due to weak geology (clay, silt and glacis-fluvial outwash deposits) plus **seepage erosion** due to juxtaposition of sands over a **less permeable** clay layer 2 cards swept of the cliff leading to 1 **fatality**	
Holbeck Hall, North Yorkshire	1. Mass movement- rotational slide	1993 landslide- **1million tonnes of cliff failed** cutting the 60m high cliff back by 70m Created **semicircular promontory** 200m wide Causes: 140mm **rainfall** in the 2 months previously, pore water pressure build up, poor drainage and the geology (Glacial Till resting on Scalby Mudstone and Moor grit- old sandstones) Destroyed Holbeck Hall **hotel** at top of cliff	
Emergent coastlines	1. Landfroms on emergent coastlines	**Raised beaches** and **relict/fossil cliffs** e.g. **Westward Ho! in Devon**, beach 5m above current sea level; in Western Scotland, terraces are found at 8m, 15m and 30 metres above present sea level. **Fossil caves** in **King´s Caves** in **Arran**, an islands of the West Coast of Scotland (sandstone)	

Submergent coastlines	1. Landforms on submergent coastlines	Rias: e.g. **Milford Haven in Pembrokeshire** Estuaires e.g. **River Thames** Fjords: e.g. **Milford Sound, New Zealand,** Fjards: e.g. **Strangford Lough in Northern Ireland** Dalmatian coasts e.g **.Croatia**	
2013 North Sea storm surge	1. Coastal flooding 2. MEDC Storm surge 3. Impacts of flooding	**Cause**: Succession of major storms inc. storm Xavier due to low pressure weather system brought by powerful jet stream across the Atlantic 5-6 December **2013intense low pressure** (976mb deepening to 968mb) (A 1 millibar reduction in air pressure allows sea level to rise by 10mm.) **Shape of the coastline** (North Sea funnels storm surges towards London and Amsterdam), **reduction in depth towards the south** and strong **Northerly winds** increased heigh of surge **UK Impacts:** Strong winds (gusts of over 200km/hr in Scotland), mean elevations attained were 4.96–5.53 m in Lincolnshire, 5.16–6.11 m in North Norfolk ***Social impacts*:** Coastal flooding (14000 homes affected) and forced evacuation, Hemsby (Norfolk) cliff erosion meant several properties collapsed into the sea, bridges were shut (e.g the Humber Bridge) and2 people died Hull and along the Humber estuary 2010 residences flooded There was localised cliff slippage, collapse and subsidence of sea walls and promenades and extensive damage to access ramps, chalets and beach huts on the soft rock cliffs between Weybourne and Happisburgh Vegetated dunes in North Lincolnshire (Fig. 2B) and North Norfolk were severely cut back The Thames Barrier was closed to protect London ***Economic impacts:*** Cost of damage was calculated at £100 million, **Netherlands impacts**: Storm surge of 3.74m above the mean sea level on the Frisian coast (In Germany, but right on the Dutch boarder)	

Phillipines (LEDC)	1. LEDC coastal flooding 2. Socio-economic impacts of flooding 3. LEDC coastal management	**167,000 hectares** of coastland - about 0.6% of the country's total area -- projected to flood Water levels projected to rise between **7.6 and 10.2** cm each decade. High level of **poverty** and **inequality** (90% of wealth is controlled by 15% of the population). Natural **ecosystems** in Manila bay e.g. **mangroves** and **sea grass** have been destroyed by pollution, over exploitation and siltation. Estimated **losses of $6.5 billion** a year without adaption costs. Urban areas around Manila Bay, such as **Cavity City** and **Las Pinas**, are estimated to be **destroyed** with a 1m rise in sea level. **2.3 million people** could be affected, 62% of them in **Metro Manila.** **San Fernando** is also threatened, by 2012 some estimates suggest the city will lose 300 buildings, and 283,000m2 of beach. **Property loses** are estimated at $2.5 million and there will be social **amenity losses** of schools, churches and beach. 130 fishermen earn $12 a week- alternative employment will be hard to find (welfare loss of $168,000 a year) Small **breakwaters** of **rip rap** constructed to protect government buildings and infrastructure for e.g. San Agustin, at a cost of $21,000	

Bangladesh (LEDC)	1. LEDC Storm surge 2. Factors affecting flood risk 3. Climate change and flood risk	**Vulnerable** area-l**ow lying** land (1-3m), river discharge from Ganges and Brahmaputra, delta made of **unconsolidated** sediment, **shape** of Bay of Bengal concentrates wave energy further north 2007 category 4 storm **Cyclone Sidr -**heavy rain, strong winds (223km/hr), storm surge (6m high) Eye of the storm crossed the coasts near Sundarbans mangrove forest around 9.30pm on 15 November Coastal districts/offshore islands had highest **impacts** **US$ 29.6 million** damage to roads, embankments, sluice gates and riverbank protection Destroyed more than 7000 **shrimp farms** in Satkhira, Khulna, Bagerat and Patuakhal- estimated loss of $36 million One quarter of the **biomass** cover (2500 sq. km) of Sundarbans mangrove forest damaged Generally mitigation measures a success- only 3,000 dead (embankments, early warning systems) Problems of coastal defences included: Embankments and Polders did not provide the enough heights to prevent overtopping of cyclone storm surge. Many trees are planted in the surface layer of embankments and polders, and were then blown down breaking embankment. Maintenance for the structures has scarcely been executed. Illegal habitation on the structures. Cyclone shelter capacities were inadequate for the population of the service area. Without shelters, many livestock animals died during the disaster. Many people neglected cyclone warnings, which resulted in many deaths. The Sunderbans forests helped reduce some impacts, but 71% of Bangladeshes coastline is now retreating by as much as 200m a year . One cause of this is for shrimp farming (accounting for 25% of mangrove forest loss globally)	
Chittagong	4. Coastal management	A Coastal Climate Resilient infrastructure Project (2012) supported by the Asian Development Bank (ADB) aims to ´climate-proof´ the area. The project involves: -Improving road connections, **raising embankments** too 60cm above normal flood levels -Creating new market areas with sheds on **raised platforms** -Constructing 25 **tropical cyclone shelters,** taking account of sea level rise -Training in **climate resistance** and **adaption** measures A Environmental Assessment and Review framework was used, rather than EIA as its a series of small projects Positives- poverty alleviation (10%), environmental enhancement e.g. tree planting May 2015 the **IFDA (International Fund for Agricultural Development)** a UN agency rated progress as satisfactory Disturbance of people and habitats during construction, 200 household relocated	

Kiribati	1. Contemporary sea level change	Kiribati consists of 33 islands (32 atolls and one raised coral island) 100% of the population live less than 1km from the coast In some places, **sea level is rising** by 1.2 cm a year (four times faster than the global average) It could **disappear** within the next 50 years Rising sea levels are causing **salt water intrusion** and affecting the nations ability to **grow crops** In 2014 the president purchased 20KM2 of land in one of the **Fijian Islands** The government has announced a ´migration with dignity´ policy to allow people to apply for jobs in nearby countries such as New Zealand The population are likely to become ´environmental refugees´	
Akosombo Dam, Ghana	1. Cuases of coastal recession	Constructed primarily for the generation of HEP, and also used for fishing, transportation, farming and tourism Approximately 99.5% of the river drainage basin is **blocked** by the dam Reduction of **fluvial sediment** supply from the Volta Rive Impacts/responses: Construction of dam has **accelerated shoreline retreat** In 1965, **coastal defences** built in the region of Keta to attempt to halt recession Keta Sea Defence constructed between 2001-2002 (included **offshore breakwater** and **seven headland groynes** as well as **beach nourishment)**. Evidence in 2006 suggested groynes were **not long enough** and beach material was being lost **Togo** and **Benin** down the coast are likely to suffer **negative** impacts from about 71 million m3/a to a little as 7 million m3/a Constructed on the **Volta river in 1964**	
The Nile delta	1. Causes of coastal recession	**Aswan High Dam** completed in 1968, Problems: River **discharge fell** (35 billion cubic meters to 10 billion cubic meters) and **sediment fell** from 130 million tonnes to 15 million tonnes due to water withdrawals for industry, cities and farming behind the dam, sediment being trapped by the reservoir and the dam Increased **erosion** rates Surface **salt crust** in Kafr el-Sheikh (used to wash off during floods) Now 25-80% farmers **profits** spent on fertilisers Heavier demand of water use upstream, predicted 70% decrease in the amount of Nile **water** reaching the Delta (responsible for 60% of the countries food supply and densely populated (4,000 people per square mile)) **Future**: Heavier demand of water use upstream, predicted 70% decrease in the amount of Nile water reaching the Delta, I m rise in sea level will cause 20% of the Delta to be lost Area is responsible for 60% of the countries food supply	

Californian Coastline	1. Causes of coastal recession	1,250 miles of diverse ocean coastline inc. sandy coasts and rocky cliffs 21 major rivers 85% of the coastline experiences erosion **Coastal development** has been accompanied by significant investments in public infrastructure, including roads, airports, and harbours. Retreating in response to continuous **sea level rise** over the past 18,000 years **El Niño** events acerbate the problem as they bring **large storm waves due to elevated sea levels** (e.g. 2006/2007 Winter beach erosion on 29 beaches along the California, Oregon and Washington coasts was 76 percent above normal) Reduction in rainfall during El Niño means the **coastal rivers produce little sand**	
The Maldives (LEDC)	1. Coastal erosion 2. Coastal conflict 3.Sustainable management 4.Soft engineering 5.ICZM	**97% of inhabited islands are experiencing coastal erosion** Maldives holds a range of coastal **ecosystems** including coral reefs, seagrass beds, lagoons, beaches, and small areas of mangrove. Maldives **depends** entirely on the coastal and marine ecosystems as the asset base of the national economy. **Tourism,** the largest contributor to GDP, is based wholly on the health and attractiveness of Maldives's coastal features Some development activities, such as harbour dredging and land reclamation, permanently change the natural environment and substantiall**y damage habitats** Construction of **new artificial islands such as Hulhumalé** means isolated islands are ignored Sustainable management of traditional income sources such as fishing and resources such as mangroves are overlooked to protect areas important for tourism Mangroves for the Future (MFF) - endorsed by the Government in 2011 Working in small atolls including Baa Atoll, Noonu Atoll and Haa Dhaal / Haa Alif Atolls Ensures at least one ICZM model in each province Educates on the importance of maintaining mangrove swamps	
Deltawerken/ Deltaworks, Netherlands (MEDC)	1. Flood prevention 2. Megaproject 3. Hard engineering	Constructed after 1953 **North Sea Flood** in which 8,361 people in the Netherlands died and 9% of farmland flooded Completed 1997, cost of **$5bn** Comprised of laying **13 dams,** including barriers, sluices, locks, dikes and levees within and around the **Rhine-Meuse-Scheldt delta** Provides flood protection, drinking water and irrigation **Successful**: Risk of flooding reduced to 1 in 4,000 years Except for the Oosterschelde and Westerschelde, all the estuaries were closed. Channels, streams and coves became silted up and mud flats and shallows caved in. Saltwater fish died (saline water become fresh) and birds moved away. Gradually, other species replaced them. Isostatic rebound is causing the Netherlands to sink and so dikes may need to be strengthened and raises barriers currently open, closed.	

Varela, Guinea Bissau (LEDC)	1. Coastal Erosion 2. Coastal Flooding 3. Coastal management 4. Soft engineering	**Rapid** rates of coastal erosion Loss of trees and infrastructure, as well as a tourist resort built in 1980´s Caused by **rising sea levels** (10cm since 1950) and loss of **mangrove forests**, especially around **Kabrousse,** which act as natural barriers **Biodiversity** is at risk (e.g. marine turtles and manatees depend on mangrove forests and sea grass beds which have been shrinking) **Coastal activities** which provide a large source of income are now under threats (e.g. tourism, fishing and commerce) Pilot site for United National Adaption to **Climate Change in West Africa project (UNESCO, 2012)** Encouraging implementation of **ICZM,** inc. Mangrove restoration and afforestation	
Thames Barrier (MEDC)	1. Flood defences	Build in 1984 Protects **1.3 million people** and **£275 billion worth of property from North Sea storm surges and exceptional high tides** Successful but will need to be increased by 2070, which is 40 years later than planned according to Thames Estuary 2100	

Holdernes s (MEDC)	1. Sub-aerial processes dominated coastline 2. Coastal erosion 3. Factors affecting coastal recession 2. Coastal management	One of Europe's fastest eroding coastlines 1m a year, average 4km lost since Roman times Average annual rate of erosion -2 metres per year. Causes: bedrock is made up of **till** (unconsolidated boulder clay) and waves have a **long fetch** over the north sea- NE direction, **small beaches** offer little protection as waves **destructive**, **sea level rise** a further threat This material was deposited by glaciers around 12,000 years ago. **Skipsea**: Series of Gabon cages built by the local landowner Groynes are locally effective, acceptable visually and development of low lying land has now been possible Gabions protect only small area, erosion occurring either side at Skipsea. **Hornsea**: Holiday resort with a promenade and hotel frontage. Groynes repaired at a cost of 5.2 million. Old sea wall has been raised slightly. Sand dunes in the south beach were planted with trees. **Mappleton**: 1991 a scheme costing 2.1million, supported by EU funding, was put in place including 2 rock groynes and rip rap. Blocks of granite were imported from Norway for the sea defences. Cliff between the two groynes has been stabilised through landscaping and vegetation cover. Substantial beach has been retained. Groynes have been attributed to causing increased erosion at Great Cowden, 3km down the coast. **Withernsea:** A resort town, protected by groynes and a sea wall. A curved sea wall has been built. Rip rap and beach nourishment also protect the wall, a total cost of 6.3million. Will hold the line, protecting seasonal jobs at the resort and halt falling house prices. Costs have limited the length of the sea wall and rocks have reduced access to the beach. Views are limited. There is a problem of wave noise. **Spurn Head**: After a series of storms, the damage was to costly to manage so left unmanaged from 1995 Growing costs of annual protection were saved. The community of lifeboat men had to move out in 2012.	

Happisburgh (MEDC)	1. Coastal erosion 2. Coastal management 3. Coastal conflict	Village in North Norfolk, population of 2400, **sparsely populated** and high levels of **rural deprivation** **30** properties disappeared since 2000 After an CBA, it was decided that the **'no active intervention'** approach would be used, however work to move the **existing granite sea defences** a hundred yards back towards the crumbling cliffs should give the village a little more **time** Residents of Beach Road have all lost their homes By 2105 shoreline will recede by a further **200m. T**his would mean: 50 more homes lost, caravan site lost and other property loses including the village church totalling £6 million Losers: House values are very low so residents cant afford to move Government provided £5000 to residents to assist with the with £1000 for **relocation** **Campaigning** by **CCAG (Coastal Concern Action Group) to** raise support for residents Received £3million as part of **Pathfinder** Rising costs of hold the line avoided	
Blackwater Estuary (MEDC)	1.Soft engineering 2. Coastal conflict	**Managed realignment** began in 2002 by Essex Wildlife Trust (owners) Arae of international wildlife importance Problem of ´**coastal squeeze**´ due to old sea wall 3.5 km sea wall built 300-400 year ago very expensive to maintain **CBA** showed not worth maintaining since soil quality and land value was low **5 breaches in the wall** made, opening up **80 hectares of land for flooding** Creeks dug behind to promote formation of **saltmarsh habitat** These mudflats and salt marshes will provided sustainable protection for the **future**, absorbing **higher seas** and **storm surges** Habitat created for Brent geese and lapwigs as well as marine invertebrates West Mersea oyster fisherman concerned about hydrodynamic impacts which could increase sedimentation RSPB concerns of food risk and habitat change	
Thursaston, (MEDC)	1.Soft engineering 2. Unsuccessful coastal management	Little human development; **Low value** land **SSI** (Site of Special Scientific Interest) Cliffs susceptible to erosion (weak sandstone and boulder class, bedding layers have **seaward dip**, susceptible to **sub-aerial weathering** and mass movements) Introduction of **drainage pipes** Cliff erosion continued and drainage pipes fell out	

Thailand (LEDC)	1. Impacts of coastal erosion	Reliance on tourist beaches which are being rapidly eroded According to the Department of Marine and Coastal Resources, Thailand loses about 5-20m of shore each year along its 2,677km coast. In 2012, constant pounding by waves battered a seawall to pieces at Surin Beach in Phuket	