

Building coastal resilience to sea-level rise and storms in the UK

What steps can decision makers both locally and nationally take to make coastal populations and businesses more resilient to sea-level rise and climate change?



**Living With Environmental Change
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The Living With Environmental Change Partnership brings together 22 public sector organisations that fund, carry out and use environmental research and observations. They include the UK research councils, government departments with environmental responsibilities, devolved administrations and government agencies. The private sector is represented by a Business Advisory Board.

Important towns, cities and energy infrastructure are located in the coastal zone. With climate change these assets are under increasing threat from sea-level rise and intermittent storms. Storm surges are particularly dangerous due to their extreme water level and large waves. Strengthening and raising the height of sea defences is an immediate option, but how do we identify when, where and whether to take such actions, and what alternatives can be considered to increase our resilience to climate change?

What causes changes in sea level?

Changes occur when:

- Climate change leads to melting of land-based ice (eg Greenland and Antarctica) and permafrost, thermal expansion of seawater, and solid earth responses to changing ice distribution.
- Patterns of sedimentation, abstraction of groundwater or underground resources, oceanographic or climatic phenomena (eg El Niño) and tectonic movements lead to local or short-term changes.
- Storms characterized by low pressure and high winds create a temporary addition to the predicted tide – a storm surge.
- Increased rainfall is transmitted to the coast through runoff and river flow that combines as it progresses downstream.

What threats can arise?

Threats from sea-level rise, storms and reduced sediment supply do not operate in isolation:

- Beaches and saltmarshes can naturally reduce wave energy at the coast providing they have sufficient sediment (gravel, sand or mud).
- Sea-level rise will increase the extreme level of storms in the future due to a rise in the average level of the sea. Similarly, storm surges accompanied by high wave energy increase the potential for coastal erosion and beach loss.
- Engineering interventions (eg sea defences) designed to reduce erosion in one location can cause problems for the adjacent coast.
- The expansion of coastal settlements, industries and infrastructure exacerbate the problems. Human activity at the coast often conflicts with the natural dynamic processes of disturbance, response and recovery, leading to a phenomenon known as “coastal squeeze”.

What information is available to help identify areas prone to future flooding?

Decision makers can draw on a range of research to help inform them about future risks in specific areas including:

- Projections of sea-level rise due to climate change to 2100.
- Longer term projections of sea-level based on analysis of past trends in sea-level and temperature.
- Models of coastal flood risk that:
 - Take account of land surface height variations, location and height of sea defences, and beach slope and its extension into coastal waters.
 - Incorporate water level height (eg tide plus surge) and include additions to floodwater volume from wave overtopping of sea defences and river flow.
- A Flood Hazard Rating based on water depth, velocity and debris that enables decision makers to assess the threat to human life.
- Flooding decision-support tools that help identify tipping points where the extent and depth of flooding would exceed the capacity of current management and resourcing and identify where building of future infrastructure should be avoided. These tools can provide a basis for dialogue between stakeholders about when/where/whether future interventions should be implemented.

Projections of storm magnitude and frequency, storms tracks and wave climate are more difficult because of natural variability in such phenomena.

What do we know about the risks of future flooding from sea-level rise and storms?

Flooding due to storm surges, wave overtopping and high river flows may combine to increase flooding. This means that:

- Areas adjacent to sea defences are more prone to flooding from wave overtopping, while those alongside tidal rivers are at greater risk from higher flows.
- The risk of flooding from extreme events is likely to increase because a storm surge is added to the higher tide levels due to sea-level rise. This doesn't require storms to be generated more frequently nor for storms to be more severe.
- Events with the same joint probability of combined wave height and extreme water level can cause different flood extents and depths because higher waves increase overtopping locally, while higher extreme water levels generate more widespread inundation.

How can decision makers plan for the future?

Sea-level rise leads to tipping points at which the extent of flooding greatly increases, requiring a step change in management strategies and resourcing. Decision-support tools such as ARCoES can:

- Help identify critical thresholds of sea-level rise and storm magnitude at which current strategies need to be reconsidered.
- In combination with economic modelling, support decision making on optimum times and locations for investment in defences.
- Help identify locations that are less well suited for coastal development and for the next generation of energy infrastructure.
- Identify locations where new energy infrastructure (eg tidal lagoons) may be built to both generate energy and reduce flood risk.

Can working with natural processes and sediments increase coastal resilience?

Effective coastal decision making relies on understanding the appropriate timescales and spatial extents of natural system behaviours.

Hard engineering may not be the only solution to sea-level rise and climate change:

- "Healthy" beaches and coastal wetlands have sufficient sediment supply to respond favourably to sea-level rise or to recover quickly from storms.
- Promoting healthy sediments leads to enhanced coastal resilience, and is an essential precaution in the absence of a good understanding of coastal response to sea-level rise.
- Working with natural processes at the coast enhances dynamic resilience to sea-level rise and storms.
- Beach recharge is an established method for adding sediment to the coast, and this is often dredged from the seabed. Innovative sea defence through "Landscaping" works with natural processes to reduce coastal erosion and flood risk, simultaneously creating new habitats and environments. The economic benefits of these new places and habitats may substantially offset the cost.
- A key challenge is to build public confidence in natural solutions.

What are the messages for decision makers at local and national levels?

Locally, decision makers need to:

- Understand and assess future flood depths, velocities and extents due to combinations of sea-level rise, storm surges, wave overtopping and high river flow.
- Recognize that sea-level rise increases the frequency of dangerous extreme water levels.
- Quantify and map flooding caused by different combinations of wave height and extreme water level that have the same joint probability.
- Identify tipping points at which flooding increases greatly, thus requiring a step change in management strategies. These thresholds may be explored using incremental projections of sea-level rise in a decision-support tool (eg ARCoES).
- Examine the viability of innovative sea defence by Sandscaping and working with natural processes to reduce coastal erosion and simultaneously create habitats and environments.

Nationally, decision makers need to:

- Based on probabilistic projections of sea-level, assess the relative costs of both depth-damage and the implementation of resilience measures, to identify the optimal time for investment in energy assets to build resilience to future sea-level rise and storms.
- Explore projections of flooding and erosion to identify vulnerable coastal locations that are less well suited for the next generation of energy infrastructure.
- Consider the implementation of tidal barrages as a means for combining energy generation with enhanced sea defence capability.

Further information

This note was written by Professor Andy Plater and Dr Jenny Brown. It draws on the Adaptation and Resilience of Coastal Energy Supply (ARCoES), a research project identifying the challenges facing the future security of the UK nuclear energy sector and coastal energy supply in northwest England and north Wales. The project is funded by the Engineering and Physical Sciences Research Council as part of the Adaptation and Resilience in a Changing Climate programme.

Useful resources:

ARCC website: <http://www.arcc-network.org.uk/>

ARCoES website: <https://www.liverpool.ac.uk/geography-and-planning/research/adaptation-and-resilience-of-coastal-energy-supply/>
ARCoES Decision-Support Tool: <http://arcoes-dst.liverpool.ac.uk/>

UK Climate Projections:

<http://ukclimateprojections.metoffice.gov.uk/>

Regional projections of 21st century sea-level rise in northern Europe:

http://www.int-res.com/articles/cr_oa/c064p015.pdf

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