The Exe Estuary

Enquiry 1: How can flood risk and habitat change be managed most effectively in the Exe Estuary?

Context and Learning Aims

Pupils will be supported in and outside of the classroom to:

• Recognise the social, economic and environmental importance of the Exe Estuary at a range of scales from local to global;
• Understand how rising sea levels and the increased frequency of severe storm events caused by climate change are already impacting on the Exe Estuary;
• Describe and explain the concept of coastal squeeze and its implications for the Exe Estuary;
• Explain ways in which the coast has been managed in the past as well as approaches to managing it in the future;
• Identify from a range of resources locations within the Exe Estuary at greatest risk of flooding as a consequence of climate change;
• Understand that with limited funds difficult decisions have to be made about the management of the coast and that some locations will take precedence over others for scarce resources;
• Know what is meant by compensatory habitat and why it will be required in the Exe Estuary in the future;
• Undertake an evaluation of ten flood management sites in the Exe Estuary in order to identify both their risk of flooding and suitability for the creation of new wetland through compensatory habitat schemes;
• Appreciate the range of stakeholders who are likely to be impacted by coastal management decisions within the Exe Estuary;
• Draft and produce a report recommending two sites as compensatory habitat within the Exe Estuary which clearly describes and explains the decision making process.
Learning and teaching activities and curriculum progression

**Key Question 1.1: How has flooding impacted upon Devon in recent years?**

As an introduction to this investigation show the pupils the film in **Resource 1.1 How does flooding affect us** which provides a context to river and coastal management locally as all of the images are based on flooding events over time in Devon with the most recent being in February 2014. The pupils can now be encouraged to produce a concept or mind map of the issue of flooding and in particular the social, economic and environmental impacts that it can have. Many of these are evident in the film but what else can the pupils add? Do they have any personal experiences to contribute? Encourage the pupils to talk about cause and effect and to use the connective which means that to link together social, economic and environmental factors on their concept map e.g. the flooding of farmland degrades the soil and reduces biodiversity and is directly linked to falling incomes and destitution in rural areas. Another example might be the destruction of railway lines e.g. at Dawlish leading to direct economic impacts in terms of falling revenue from tourism and the isolation of much of Cornwall. Encourage discussion and make a list of all the impacts mentioned on the whiteboard. Working in pairs the pupils can classify each impact into one of three categories: social; economic and environmental. This could be done via colour coding or by using a Venn diagram. Challenge the pupils to consider whether any of the impacts can be said to belong exclusively to just one category? Are there any which are not linked in some way to one of the other categories?

**Key Question 1.2: What are the key geographical features of the Exe Estuary?**

An important aspect of this investigation is for the pupils to appreciate how dynamic the coast is at the Exe Estuary. Provide each pupil with a copy of **Resource 1.2**. This investigation introduces a key concept of coastal management, termed coastal squeeze which today has major ramifications for how coastlines around Britain will develop in the future. The objective of the investigation is for pupils to fill in all of the information required on **Resource 1.2**. This can be achieved in one of two possible ways:

- **Resource 1.3** is a PowerPoint which supports the pupils to recognise and explain what coastal squeeze is. Essentially this is about recognising that the inter – tidal land between high and low tide will be reduced or ‘squeezed’ as sea levels rise, particularly if ‘hard’ engineering schemes such as sea walls are built to prevent the flooding of inland areas. The PowerPoint can be used to identify and explain the key aspects of coastal management in the and around the Exe Estuary with pupils adding their own notes to the relevant sections of **Resource 1.2**.

- Alternatively **Resources 1.4 – 1.11** can be printed out and placed around the room. Pupils can then move around the room with their blank copy of **Resource 1.2**, collecting key information as they go. A timer, bell or buzzer alarm can be used to demarcate periods of time e.g. 2 minutes after which they must move on to the next resource. It is really important that the pupils do not merely copy everything but are supported through modelling to identify and select the most relevant information for the task they have to complete. Once the allocated time to access all of the resources has been used then the pupils can swap sheets with a partner to compare information and add anything which they have missed.
As a summative piece the pupils can annotate key information about the inter-tidal zone on Resource 1.4. It may be useful here to revisit the PowerPoint again to highlight the main characteristics and particularly the slides in Resource 1.9 – 1.12. The important thing is to support the pupils to understand the influence of rising and falling tide levels on the variety of habitats which are created within the inter-tidal zone e.g. mudflats; salt water marsh; rock pools etc. The richness of the inter-tidal zone along the Exe Estuary is the prime reason why it has been designated as being of such ecological importance on a national and global level. As a plenary activity consider dividing the group into two sets A and B. Give each set of pupils one minute to talk as much as they can about what they have learned about the Exe Estuary and then swap. Pupils in set B must attempt not to repeat anything which the first group mentioned.

Key Question 1.3: What happens when the coast gets squeezed?
In this enquiry the pupils begin to consider what some of the implications of coastal squeeze might be in the future for the Exe Estuary. They can consider the possible environmental effects of a reducing inter-tidal zone on biodiversity, especially wading birds which are both resident in the estuary and visit during migratory flights from other parts of the world; as well as risks of flooding and damage to human settlements during storm conditions. An important thing for the pupils to reflect upon here is the potential loss of valuable habitat – the very habitat that is the reason why the Exe Estuary has received so many designations as a protected environment. Before moving on ask the pupils to consider whether building sea walls and other ‘hard’ engineering projects such as rock armour or revetments to reduce the risk of flooding as sea levels rise will be likely to make the issue of coastal squeeze better or worse? Can the pupils explain why? The PowerPoint in Resource 1.13 can be used to take the pupils through the process of the coast becoming squeezed through the combined impact of sea level rise and the construction of hard engineering coastal defences. Using a copy of Resource 1.14 the pupils can then create their own sequence of diagrams to explain coastal squeeze using key geographical terms and vocabulary in the smaller box. The pupils can then write a short explanatory piece of narrative to summarise their key points in the space below.

Key Question 1.4: Why is climate change likely to make the problem of coastal squeeze worse?
This enquiry can begin by providing each pupil with a copy of Resource 1.15 which shows the level of temperature change (anomaly) which has occurred globally since 1850. Spend some time discussing this with the pupils and then encourage them to describe the pattern of variation over time. Descriptions should include dates and temperature changes and the main overall trend compared with exceptions to this trend at particular time intervals. In general there has been a consistent increase in global temperatures since 1850 despite the fact that between 1880 -1910 and 1940 -1950 a small decrease occurred. Total temperature change of the atmosphere is 0.8C. Take time to discuss with the pupils what they think some of the implications of such a change in temperature might be? What do they already know about changes in the environment attributed to climate change e.g. melting glaciers?
**Resource 1.16** encourages the pupils to now make the link between global temperature change and sea level rise as well as being able to understand the causes of severe storms. The PowerPoint in **Resource 1.17** enables the pupils to access the information they will need to complete **Resource 1.16**. This could be presented as a memory challenge with the pupils not being able to make any notes during the PowerPoint and then filling in **Resource 1.16** using their own understanding. In addition the film in **Resource 1.19** can be used an aide to remembering the key points. As a plenary the pupils can use the Five Steps to a Storm flash cards in **Resource 1.18**. Distribute at random a class set of these flash cards making sure that those pupils nearest to each other do not have all the cards they need e. pupils in one corner of the room could be given all ‘river’ cards. Once distributed the pupils must mingle and swap cards until they are in groups of five with a full set. Then they need to stand with the cards in the correct order.

As an extension piece or homework activity, the pupils can use **Resource 1.20** which shows both the European and global scale of recent relative sea level change. Do spend some time discussing with the pupils that sea level rise is a complex process and many factors, not just climate change, can be contributing to it e.g. isostatic adjustment where land in some parts of the world is still rising as a result of the retreat of ice sheets following the last Ice Age. Also sea levels tend to fluctuate normally during the course of the year e.g. as ice is formed at the poles during winter. Using the maps ask the pupils to:

- Describe the general pattern of sea level rise – the overall trend;
- Identify areas which are experiencing the largest and least rates of sea level rise;
- Consider which areas might be most vulnerable to sea level rise. This can either be locally within Devon or on a global scale.

Important points here for the pupils to consider include:

- In general most of the world is experiencing an average sea level rise of 3mm a year, which is predicted to increase to 10mm per year by 2100.
- The indication is that northern coastal regions are experiencing the least annual increase whereas the seas closer to the equator appear to be rising more significantly;
- In Europe the data appears to indicate that southern countries are experiencing a greater rate of sea level rise whereas to the north of the continent there is evidence of a decrease in sea level. This is because of isostatic rebound. The land in Northern Europe was affected more by the weight of covering ice sheets during glaciation but is now bouncing back.
- Overall areas most at risk are those with the largest average annual sea level rise which also happen to be low-lying, coastal areas or islands. Low lying countries like Bangladesh and Pacific Island States like Tuvalu are most at risk on a global scale as they have limited financial resources to deal with flooding.
Key Question 1.5: What is the risk of flooding in the Exe Estuary?

The purpose of this investigation is to enable the pupils to consider the potential impacts of a 1m sea level rise on five Exe Estuary communities – Exmouth; Dawlish Warren; Starcross; Topsham and Lympstone. These scenarios are shown in Resource 1.21 – 1.25. It is important to emphasise to the pupils that a sea level rise of 1m is possible within their lifetimes. This serves to emphasise how coastlines will change as sea levels increase. Divide the pupils into groups of 3 or 4 and provide each group with one of the communities. They can then place the resource at the centre of a larger A3 piece of paper which will allow them to annotate the photographs with notes. What significant changes do they observe? Label key features that can be seen. The pupil’s annotations should identify what is being affected e.g. a car park or housing estate and also suggest what the impacts of this might be on the local community – think social, economic and environmental consequences. Encourage the pupils to discuss this and then give each group the additional information about their community in Resource 1.26. What other implications of sea level rise arise from this information? Take feedback from each group as to the effects that they feel their community will have to cope with if sea levels rose by 1m. Is there one community which the pupils feel will be worst affected? The PowerPoint in Resource 1.27 can be used if desired to summarise the key points.

Resource 1.28 and 1.29 are both kml files which require a connection to the Internet and for Google Earth to be downloaded. In Resource 1.28 the possible effects of a 1 metre sea level rise on the Exe Estuary can be explored by clicking on the different tabs on the left. By checking each height the level of the sea can be slowly increased and the impact of this on the coastline observed. Resource 1.29 contains an extreme storm surge simulation – but not one that is likely in the lifetime of the pupils! Finally the pupils can consider the extreme flood level scenarios in Resource 1.30. These can be used to stimulate discussion about the future. Are the pupils concerned? Do they feel it is their issue to do something about now or should it be left to people in the future to sort out? How are people going to adapt their lives in the future as sea levels rise? What is it going to mean for where we build new houses and businesses? What are the implications for the design of houses? What about the people and their homes and businesses along the coast that are going to be flooded or destroyed by cliff collapse and land slides? Do we have a responsibility as a community for these people or should they just be left to their own devices? The pupils could be supported here to design a future-proofed house which may be needed to cope with future sea level rises. Alternatively the pupils could suggest modifications to an existing house to make it more resilient to increased flooding. What features would these houses need? How would they look or function differently to houses built now? The pupils could design their house and then compare it with images produced by professional architects at http://www.building.co.uk/analysis/batten-down-the-hatches/3092556.article

Key Question 1.6: How vulnerable to flooding are the key coastal management sites in the Exe Estuary?

In terms of the most recent flood management proposals the Exe Estuary is divided into 12 key sites. In this exercise pupils will study ten of these sites working in groups of two or three. Each group is to be given a number of resources pertaining to their site from which they need to gather evidence about its vulnerability to potential flooding. Some will be more straightforward than others e.g. the more built up and heavily populated areas of Exmouth,
Starcross and Topsham. Each group needs to be given the Ordnance Survey map of their site together with an aerial photograph and photographs taken on the ground. Emphasise to the pupils that each resource is a source of evidence that will help identify the characteristics of their place and what the consequences might be if there was any flooding. To help pupils think about the different types of land use that might exist at each site the exercise in Resource 1.31 (and organised into a PowerPoint in Resource 1.32) is a useful way of assisting thinking that can be applied to each of the ten locations in the Exe Estuary.

In particular the pupils can be challenged to think about whether they attach greater ‘value’ to some kinds of land uses than others. How do we measure ‘value’ anyway? Is it always a financial measure or is there value in things which do not have a monetary price? This is important preparation for the decision making exercise which comes later.

Information to give the pupils about each site is contained in the following resources:

Resource 1.33: Ordnance Survey map extract
Resource 1.34: Aerial photographs
Resource 1.35: Terrestrial photographs
Resource 1.36: Background information

Each group now needs to write a description of the possible vulnerability to flooding of their key site using the template in Resource 1.37. A model for the pupils of what a completed description might include using this template for a hypothetical site is included in Resource 1.38.

For whole class introductory and plenary sessions all of the Resources 1.33 – 1.38 are assembled into location sets in the PowerPoint Resource 1.39.

To broaden the scale somewhat and to help the pupils think about the whole area of the Exe Estuary both the Google Earth images in Resource 1.40 and the Ordnance Survey maps in Resource 1.41 extrapolate from the current rate of sea level rise hypothetical scenarios of flooding in and around the Exe Estuary 3000 years into the future. These are all contained in the PowerPoint Resource 1.42. Explain to the pupils that in the PowerPoint they are going to see a series of images and they will need to identify the areas of the Exe Estuary most at risk of potential flooding. The pupils can then use copies of the maps and Google Earth images to identify and shade in red on their copy of Resource 1.43 those areas of the Exe Estuary most vulnerable to flooding in the future. They can then add to this the locations of the ten management sites they worked on in their groups’ earlier and label them and shade in blue.

Alternatively each pupil can lay a piece of tracing paper over copies of the resource slides in turn and draw the height of the water at 1m; 2m intervals and so on. As the pupils work through all 10 slides the extent of the flood water will increase. The pupils can then create a chloropleth map by using a range of colours to represent the different layers (heights) of flooding. A grading of colours is most appropriate for showing a trend. The pupils could use different shades of blue – light to dark or dark to light or they could create a ‘danger map’ through using a red based colour range. It is important that the pupils include a key for their chloropleth map. A group work option is to encourage the pupils to produce a layer each. If this is done on a separate piece of tracing paper for each layer then it is important that that the first is coloured the darkest so it is not covered up by the additional wider layers. The last slide will therefore be the lightest colour with the darker layers showing through from below.
At the end of the enquiry invite feedback from the group and encourage discussion and debate. In terms of the most severe flooding scenario in Resource 1.44 which management site was seen to be most vulnerable and which the least? The risks at each site can be identified using a range of categories which are outlined in the template in Resource 1.45 (PowerPoint Resource 1.46). The pupils can work in groups using this template to decide collectively on the level of risk for each category in the table – whether it is high, medium or low. As a group they need to be able to compromise and discuss ideas given that each site may have different risks and individual members of the groups may have different opinions.

Now the pupils will need to summarise their findings to the rest of the group in order of priority 1 – 10. It is important that this is done thoroughly as it will provide the basis for a future decision on flood management in the Exe Estuary. Feedback by each group needs to include information on locational characteristics and what the main impacts of flooding might be. Pupils can be encouraged to answer these questions for their site: Is my site likely to erode or flood? What and who would be affected if it does flood? Each pupil can work on their own copy of Resource 1.47 (PowerPoint Resource 1.48) to add key information about each site as groups present their findings. At the end of the presentations the pupils will have summarised the vulnerability of each of the ten coastal management sites.

**Key Question 1.7: How can we manage the Exe Estuary?**

The film in Resource 1.49: The Exe Estuary: living with a changing coast has been produced to help people understand better the topic of managing the estuary in the future and the differing perspectives of stakeholders around the estuary. Encourage the pupils to watch the film and to identify different stakeholders and consider the reasons why they hold the views they do. Which management strategies shown in the film have they come across before e.g. in their spider diagram? To assist with the pupil’s thinking on management strategies they can carry out the card sort activities in Resource 1.50 (PowerPoint Resource 1.51). The key points to make to the pupils are that:

- The existing flood defences are being reviewed in the light of recent weather events;
- The Environment Agency is generating a long term strategy to manage flood risk around the Exe for the next 100 years and will be looking for long term solutions at the 10 locations within the Exe as well as at Dawlish and Dawlish Warren. For more information see https://www.gov.uk/government/publications/exe-estuary-flood-and-coastal-erosion-risk-management-strategy;
- Existing defences can be repaired and improved if partners agree and sufficient funding can be found;
- Due to the large number of existing hard engineering structures such as sea walls and revetments coastal squeeze will have a significant impact on the Exe Estuary as sea levels rise as a consequence of climate change;
- As a result of coastal squeeze, large areas of internationally important wetland and saltmarsh will be lost and under UK and European Law new areas of habitat will have to be found somewhere to replace them;
- There is not enough funding to protect all areas of the Exe from increasing future flood risk;
- Scientists predict future sea level rise, more severe southerly storms and periods of heavy rain, which will affect our coast. Other impacts of climate change, including water shortages and increased temperatures are also predicted.
In total there are 15 cards in Resource 1.50 which need to be cut up and given to groups of pupils to allocate to the correct box on the template – description; advantages and disadvantages. Allow the groups of pupil’s time to discuss different options and feedback. Check understanding through questioning before moving on. Which of the strategies do the pupils feel would be most and least effective?

Key Question 1.8: How can we maintain the natural balance of the Exe Estuary?

In this activity pupils are given the task of identifying which two areas of the sites 1-10 should not receive any funding for flood management and be allowed to convert to wetland conservation areas. It is important for pupils to understand that if the Environment Agency approves hard coastal defences in some parts of the Exe Estuary e.g. to protect people’s houses, then the loss of inter-tidal habitat that will occur through coastal squeeze, will need to be reinstated elsewhere as compensatory habitat. Open the PowerPoint in Resource 1.52 and work through the slides with the pupils. Take time to address the questions raised and seek the opinion of the pupils. This PowerPoint seeks to support pupils to understand the controversial nature of almost all environmental management decisions – costs and benefits/ winners and losers over issues such as new railway lines or wind farms. It is no different when it comes to decisions about the future of the Exe Estuary.

Working individually pupils need now to prioritise the list of ten sites in order of importance 1-10 justifying their decisions as they do so using their previous investigations and conclusions. Resource 1.53 and 1.54 (slides 9 and 10 from the PowerPoint presentation) can be printed off and projected to assist with this task. The pupils also need to think about the suitability of each site for conversion into wetland e.g. if it is open farmland on the one hand or heavily built up on the other. Summative notes by pupils can be made on a copy of Resource 1.55 which can then be written up on the templates provided in Resource 1.56 and Resource 1.57.

A final task is for the pupils to produce a draft consultation report on the areas they feel could be managed differently in the future to create two new wetland habitats. There is an ‘official’ template provided for them to do this on in Resource 1.58 and Resource 1.59 although some pupils may wish to create their own report structure. The pupils will have generated a good deal of structured work and thinking up to this point which now needs to be synthesised and presented coherently. Key areas which the pupils should consider in their consultation report are:

- An introduction to the Exe Estuary;
- Assessing areas of value, highlighting the areas of the estuary that must be conserved and protected;
- Identifying prime areas most suitable for conversion to wetland habitat which could be allowed to flood in a managed way;
- Addressing public concerns – trying to persuade people that many processes and stages of thinking have been involved before arriving at a decision – though nothing is final yet!

As an extension activity pupils could be challenged to create web content or a communications briefing for the general public covering the major points and decisions.
Sample Resources from Enquiry 1. The complete set of resources supporting learning in this enquiry are available on the accompanying DVD and online at www.licco.eu

Resource 1.4

The inter-tidal zone

1) Label the following areas:
   Pools
   Mudflats
   Marshland
   Upland

2) Draw on the high and low tide levels.
   Colour the vegetation and shade the soil layers — the bigger the trees the better the soil.
   EXT: Where would the following animals live and why?
   Crab, snail, otter, fox, fish

What is an inter-tidal zone?

Resource 1.15

How does climate change make the coast more vulnerable?

Credit: Andy Schindler www.outdoorlearningforschools.co.uk

What does this graph show?
This graph shows the how much change in temperature there has been since 1860. Whilst it has only been a small amount, there seems to be a clear pattern. Note the graph does not give the temperature but the change in temperature.

Describe how the temperature has changed over the last 150 years?

Credit: Andy Schindler www.outdoorlearningforschools.co.uk
Resource 1.21

Exmouth

Credit: Andy Schindler www.outdoorlearningforschools.co.uk and www.google.com/earth/

Resource 1.22

Dawlish Warren

Credit: Andy Schindler www.outdoorlearningforschools.co.uk and www.google.com/earth/
Resource 1.33

Location: East of the Clyst

Credit: © Crown Copyright and database right 2013 Ordnance Survey license number 100024198

Resource 1.34

Location: East of the Clyst

Credit: www.google.com/earth/
Resource 1.34

Location: **West of the Clyst**
### Identifying Risk

It is expected with continued climate change and sea level rise, areas of the Exe will experience more flooding and flood damage.

Each area of the Exe is different. Using your knowledge of your site identify whether you think there is a risk and at what level.

For example an area identified near the river with buildings may have a HIGH risk of damage to property.

<table>
<thead>
<tr>
<th>What is the risk?</th>
<th>High/Moderate/Low</th>
<th>Evidence/Explanation</th>
<th>Why do you think this is a risk?</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damage to property and businesses</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Threat to people</td>
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<tr>
<td>Damage to transport lines (roads and rail)</td>
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<tr>
<td>Damage to farmland</td>
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<tr>
<td>Damage to recreational areas, parks and football pitches</td>
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<td></td>
<td></td>
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<tr>
<td>Damage/loss of habitats and wildlife areas</td>
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<tr>
<td>Damage to coastal cliffs</td>
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<tr>
<td>Erosion of beach</td>
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</tbody>
</table>

In summary, the main risks are ______________________ because _______________________.

Credit: Andy Schindler [www.outdoorlearningforschools.co.uk](http://www.outdoorlearningforschools.co.uk)
Resource 1.47

What are the risks? Summary Sheet

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Resource 1.55

Prioritising the sites

You are required to prioritise the areas in terms of importance and suggested order of protection. Help the planners by justifying your choice

<table>
<thead>
<tr>
<th>Location</th>
<th>Priority</th>
<th>Reason/Justification</th>
<th>Suitability for Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy Bay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Maer</td>
<td></td>
<td></td>
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<tr>
<td>Exmouth</td>
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<td></td>
<td></td>
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<tr>
<td>Lymstone</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>East of the Clyt</td>
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<td></td>
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<tr>
<td>Clyst St Mary</td>
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</tr>
<tr>
<td>West of the Clyt</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topsham, Countess Wear and Exminster Marshes</td>
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</tr>
<tr>
<td>Powderham and the Kenn Valley</td>
<td></td>
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<tr>
<td>Starcross and Cockwood</td>
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</tbody>
</table>

Key terms: habitat, settlement, population, environment, coastal squeeze, space, flooding, cost, businesses, houses, infrastructure, railway, A-roads, Meterway, river, meander, wetland, saltmarsh, birds.

Credit: Andy Schindler www.outdoorlearningfrorschools.co.uk