

The Taw-Torridge Estuary: Geomorphology and Management

Report to Taw-Torridge Estuary Officers Group

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EXECUTIVE SUMMARY

Intention

This report presents a study of the Taw-Torridge estuary and its adjacent coast. The aim is to provide a detailed explanation of the components and function of this complex geomorphological system upon which future management decisions may be based.

The study relies upon two distinct modelling approaches: development of a conceptual model of the estuarine system and application of a series of computer-based models. The first approach offers an interpretation of the form and function of the Taw-Torridge system based upon available knowledge compiled from maps, charts, aerial photos, site visits, previous studies and a specially commissioned bathymetric survey. The second approach uses a top-down modelling procedure that defines the theoretical equilibrium form of the estuary under a number of different scenarios and compares this with the actual morphology. This allows, for example, the impact of future sea level changes or of managed realignment to be assessed in a quantitative manner.

Conceptual model: Open coast

The conceptual model concluded that the open coast of Bideford Bay is dominated by a counter-clockwise tidal gyre that re-circulates sandy sediment northwards along the nearshore and coast with a southerly return in the offshore zone. This re-circulatory system explains the continued northerly movement of sediment along the coast despite the lack of any sediment inputs to the Bay, or of massive erosion of the coast. The orientation of the coastline of the Northam Burrows and Saunton Sands is such that it presents an oblique angle to incoming westerly or south-westerly waves. This forces a northerly longshore current that augments the tidal gyre and transports sediment northward along the coast: a morphology known as drift alignment. The study found however that this drift alignment was slowly changing due to erosion of the coast, so that the orientation is becoming more parallel to incoming waves. This reduces the volume of northerly drift, which could, eventually, cease altogether: a process known as swash alignment.

Conceptual model: Tidal delta

The Taw-Torridge estuary presents a major obstacle to the northerly movement of sediment along the open coast and, equally, the longshore movement of sand also tends to restrict the entrance to the estuary. This mutual antipathy is overcome by a complex

morphological development: the tidal delta. The outer or ebb-tide delta is formed by the Bideford Bar; sand waves move along this Bar from south to north during extreme storms. These sand waves arrive on the Saunton Sands where they attach themselves to the upper shore, forming the pronounced headland known as Airy Point. From here some of the sand is moved, by wave action, further north into the tidal gyre, while the rest is moved by flood tide currents along the estuarine shore via Crow Point and into the outer Taw-Torridge estuary. Here the sand is temporarily deposited in a flood tide delta which is located along the Instow shore, before moving seaward on ebb currents to rejoin the outer ebb delta. This circulatory system is not, however, sediment-tight since some sand is deposited in the outer estuary so keeping pace with sea level rise that has averaged 2.8mm per year over the past century. This sand accretion represents a loss to the circulatory system in Bideford Bay and explains the gradual re-orientation of the coastline towards a swash alignment in which less sand is circulated.

Conceptual model: the Pebble Ridge

The Pebble Ridge along the Northam Burrows shore is a minor component of this overall coastal system. It seems likely that the cobbles entered the system as recently the 16th and 17th centuries, possibly emanating from major landslips at the Gore. The cobbles are subjected to the same northerly drift as described above, so that there is a loss at the distal end of the spit, possibly entering the extensive gravel spread along the southern shore of the estuary, but no corresponding input at the southern end. The Pebble Ridge is therefore losing sediment at a rate of up to 5000m³ per year and thus it appears to have a finite life. However, records indicate that the Pebble Ridge is itself re-orientating counter-clockwise towards a swash alignment so that northerly drift and thus loss of cobbles is progressively reducing.

Conceptual model: the Estuary

The conceptual model of the Taw-Torridge estuary concluded that both the Taw and the Torridge are still in the process of adjustment to the rapid rise in sea level after the last glaciation, during the Holocene period. This is quite distinct, for example, from estuaries on the eastern coast of Britain, where rapid adjustment took place in the early Holocene. The difference between the two lies in the relative lack of muddy sediment along the Atlantic coast of southwest Britain. The Taw, in particular, has a wide valley floor that is only slowly filling due to this lack of muddy sediment. This infill proceeds in a seaward direction starting at the inner reaches of the estuary. The study concludes that the leading edge of this progressive infill has now reached Penhill Point having passed by Barnstaple some two or three hundred years ago, causing siltation of its once prosperous harbour. The siltation of the outer estuary is likely to be extremely slow since here the channel bed is over-deepened by the former river channel incised here when sea level was more than 15m below its present level some 8000 years ago.

The Torridge, in contrast to the Taw, has a very narrow valley floor and its steep valley sides constrain the width of the estuarine channel so that it is much deeper than the corresponding sections of the Taw. Here again, relative lack of muddy sediment means that the estuary is still adjusting to existing sea levels and the predicted increase in the rate of sea level rise will retard this process even more.

Regime model

The quantitative modelling of the estuaries of the Taw and Torridge provided additional information to complement that developed in the conceptual modelling stage. The basic model employed was a regime model. This defines the relationship between tidal volume and channel size using a sample of west coast estuaries and this relationship was then applied to the Taw-Torridge system. The results indicate the form that the estuary would take in response to existing tidal conditions, assuming that sufficient time, sediment and space were available: a theoretical condition that nevertheless allows the existing behaviour of the estuary to be assessed. The results showed that the equilibrium channel in the Taw would be much narrower than its valley in the section between Penhill Point and Barnstaple, would fill the existing valley (defined mainly by artificial defences) in the Chivenor reach, and would be significantly wider (by 50%) than the existing channel in the outer, mouth section. Upstream of Barnstaple the model suggests that the equilibrium channel is much wider than the existing channel implying that some stress is already exerted on tidal defences here. In the mouth of the estuary the over-deepened channel means that the tidal discharge is contained within a much narrower section than predicted by the model. Nevertheless, since any further increase in depth is not possible, any changes in the tidal discharge (for example due to sea level rise) would result in a change in width. This was shown by running the model in reverse to predict what changes would have occurred in theory over the past century when sea level rise was around 2.8mm per year. The model results showed that the channel would have widened by 1.04m per year, a result extremely close to the actual change of 1m per year in the outer estuary. Thus the outer estuary is seen as being extremely sensitive to changes in tidal discharge, in contrast to the inner estuary where the wider valley allows room for channel expansion. In the central section, that is the Chivenor reach, the model results suggest that stress on the defences may be an existing problem that will be exacerbated in the future.

In the Torridge estuary, the model results show that the equilibrium width is approximately equivalent to those of the existing channel suggesting that the estuary is in regime. However, this is contradicted by the depth data that shows the Torridge channel is much deeper than would be expected for an equilibrium estuary. In fact the model results show that the cross sectional areas of the existing channel are almost twice the size that would be predicted for an equilibrium state. Clearly the Torridge is still slowly adjusting to the Holocene rise in sea level, inhibited by the lack of sediment. Equally clearly, the predicted increase in the rate of sea level rise will not lead to an increase in channel size in the Torridge but will, instead, merely reduce the rate of infill.

Regime model: sea level rise

The study went on to predict the response of the Taw-Torridge estuary to the rise in sea level over the next 100 years, put at just under 1m by Defra. The results indicate that, taking the over-deepened channel mouth into consideration, the estuary mouth will increase its channel width by between 360m (the error term here for the model being +/- 100m) by the year 2100. At Chivenor the increase is predicted to be 119m (+/- 33m) and at Barnstaple 61m (+/-17m). For the Torridge, results are more difficult to interpret given the existing depth of the channel. If the present channel were in equilibrium the model

predicts that sea level rise over the next 100 years would result in channel widening of 157m at Appledore; 47m at Bideford; and 25m at the R. Yeo, again with 28% error margins. However, these increases are unlikely to occur due first to the depth of the channel here and the fact that the valley sides constrain the channel from further widening.

Regime model: managed realignment

A further set of model predictions were made to define the response of the estuary to proposed managed re-alignment of the flood defences. The proposed realignment sites were at Bishops Tawton, Anchorwood Marsh, Home Farm Marsh, Horsey Island, Northam Burrows on the Taw and Hallspill and Tennacott on the Torridge. The tidal volume that would enter these areas if flood defences were to be realigned would mean an increase in the tidal volume of the estuary channel and a corresponding increase in its size. However, the model predictions show that these increases in channel width would be modest (i.e. <10m) for most of the proposed sites. For the Horsey Island realignment however, a 33m increase in width at the mouth of the estuary is predicted while, on the Torridge, the Hallspill realignment would result in a potential width increase of 27m at the R Yeo outfall. It is interesting to note that these predictions for managed realignment must have acted in reverse during times of reclamation when the reduction in tidal volumes would have caused channel narrowing. For example, the reclamation of the Horsey Island site began in 1833, a period when accretion was noted on the shore at the lighthouse, south of Airy point, implying channel narrowing here. By 1860, however, this accretion had reversed to erosion, perhaps in response to the increase in sea level, an illustration of the sensitivity of this area of the estuary to changes in its tidal volumes and the rapidity with which such change can occur, an example that may inform management practices in the future.

Meander model

The prediction of channel width in the model assumes a symmetrical response on both banks, but this is not observed in reality since estuarine channels, in common with their fluvial counterparts, meander between banks causing problems for management and flood defence. In order to provide some estimate of this asymmetry, a meander model was developed for the study that incorporated the channel response to both tidal and fluvial discharges and their predicted increase over the next 100 years. The results showed that under existing conditions meanders in the Taw do not impinge directly on either bank, but that after 100 years of sea level rise the increase in meander amplitude will cause stress on the estuarine channel banks north of Penhill Point and at Home Farm Marsh. These impacts will be exacerbated by an increase in fluvial discharge over the same period. On the Torridge, due to the more restricted valley widths, meander bends have a greater impact on channel banks. Under existing conditions the predicted meanders impact both banks of the estuary south of the Torridge Bridge although in reality channel training on the Bideford reach has effectively removed these. Interestingly, as sea level rise occurs, these meanders south of the Torridge Bridge become less marked and bank stress would be reduced mainly due to the increase in meander wavelength under these conditions. Nevertheless, immediately north of the

Torrige Bridge meanders will cause increased impact on both banks both due to sea level rise and fluvial discharge increases over the next 100 years.

Management issues

Although the intention of the study was to provide the basis for management of the estuary rather than offer management advice itself, some consideration was given to the probable status of the estuarine flood defences over the next 100 years as a result of sea level rise. At the moment, flood defence crest levels along the estuary protect against floods with a return interval of 1: 200 years, the study concludes that, unless major upgrading takes place, by 2055 this defence standard will have fallen to 1: 2 years and that, by 2100 the defences will be overtopped on most spring tides. In addition, defences will become under increased stress due to the impacts of channel widening and meander bend development as outlined above. Increased crest heights will be necessary in order to maintain defence standards, although, where possible, realignment should also be considered.

Three other management issues were briefly considered in the study. These were the erosion at Crow Point, sand accretion on the Instow foreshore and the erosion of the Pebble Ridge. The study observed that the existing spit and dunes at Crow Point may have developed in the 19th century as the result of the construction of a stone weir, possibly a fishing weir. This structure has now vanished and the dunes in its lee are being rapidly eroded. The study concluded that this was an inevitable development and, since the dunes here are ephemeral features, would result in no geomorphological changes to the estuary. The sand accretion on Marine Parade, Instow was seen as part of the ongoing process of sand circulation around the tidal delta. The wind-blown sand accretion on the Instow foreshore and road has probably been exacerbated by sea level rise resulting in higher inter-tidal levels. This circulation of sand around the tidal delta of the Taw-Torrige estuary is an important process helping to maintain the entire system as described above, and the sand accretion at Instow is a vital component of this circulation. The study suggested that management should consider moving the sand back to the estuary inter-tidal zone but to the south of Instow where it will continue in the circulation pattern.

The management of the Pebble Ridge is more complex particularly in view of the multiple use of the land behind the ridge including the landfill site. If nothing is done it seems likely that the ridge will gradually deteriorate allowing increased flooding of the Burrows area. This would be geomorphologically acceptable, but would involve loss of use of the Burrows for recreation, change of conservation status and would necessitate removal of the landfill site. Present management consists of rock armouring of the northern extremity combined with some replacement of material along the ridge after severe storms. The study concluded that this maintenance was both costly and, in the long term, unsustainable. Maintaining the ridge in its present form involves prevention of the long term geomorphological development which was shown to be towards a swash alignment that would eventually reduce northerly drift of the cobbles and thus increase the lifespan of the ridge. The study suggested that this process could be enhanced if the northern end of the ridge were to be held in place by rock armour but the southern end

were to be allowed to move landwards, thus increasing the counter-clockwise re-orientation of the shoreline and encouraging a swash realignment..

Conclusion

It is emphasised that the intention of this study was to provide a coherent geomorphological model of the Taw-Torridge estuary and coast upon which local planning and management decisions could be based. The work has attempted to do this and to provide appropriate quantified estimates of change over the next 100 years as a result of climate change. It is acknowledged however, that the Taw-Torridge estuarine system is an extremely complex one and that the basic model resulting from this study should be seen as only the first stage in the process of understanding this important and beautiful area.

Questions for Participation:

Our coast is a dynamic system and change is inevitable. We are looking at the changes that will happen over the next 100 years. To do that we need to have a concrete understanding of the changes that have happened previously and see whether they can be explained by the scientific model or if they expose any anomalies.

What memories do you have about various parts of the estuary that have changed?

Are there areas of erosion or build up that you have some evidence of within the estuary?

Do you have access to other data that supports or otherwise the scientific model of the estuary presented above?

Do you have any direct evidence of change that you can bring along and share? (photographs, old charts, published work).

Are there any cultural practices that you have know about that have changed or altered with the environment?

What memories do you have about the landfill site at Northam?