CUCKMERE PATHFINDER GROUP
COASTAL PROCESSES REVIEW

COASTAL PROCESSES PANEL REPORT

April 2011

1. The Coastal Processes Panel

1.1 The Cuckmere Pathfinder Project is working with the local community to reach a consensus on how best to manage change in the Cuckmere Estuary. It has commissioned an Options Impact Study to provide technical advice on how the estuary might develop if nothing is done and the implications of the management options being considered. As part of the study a small team of specialists in coastal geomorphology (the Coastal Processes Panel) was convened to consider the coastal processes occurring at the mouth of the estuary and the constraints they might place on these management options.

1.2 The members of the Panel are listed in Appendix A. They were provided with information about the Cuckmere Estuary and the studies relating to it, as listed in Appendix B, and met at a Coastal Processes Workshop on 21st March 2011 together with observers from the Pathfinder Project (also listed in Appendix A). This report sets out their findings, based on the information provided together with their background knowledge and professional judgement. It reflects the considerable uncertainties there are about the processes taking place at the site and the effect these could have, in particular on the timing of future changes. Nevertheless the Panel expects that the main features of these changes are likely to be generally as described.

1.3 A more detailed discussion of the existing conditions at the mouth of the estuary is included in Appendix C.

2. Information provided to Panel

2.1 The information provided to the Panel is limited, particularly with regard to:-

- the volume of material in the beach and how it varies;
- the rate of movement of the beach and the volume needed to sustain it when it moves back;
- the sources of sediment supplying the beach and the rate (if any) of this supply;
- the condition and likely lifetime of coastal defence structures, particularly the groynes and training walls

2.2 An inappropriate breaking criterion has been used in the wave analysis, which has led to the heights of the waves reaching the beach being over-estimated. As a result the risk of conditions that could damage the beach occurring has also been over-estimated.

2.3 The uncertainties associated with some of the key conclusions, such as time-scales and beach movements, have not been properly identified. This is likely to lead readers to have more confidence in the figures quoted than they deserve.

2.4 Despite the above, the Panel agreed with the overall description of conditions at the mouth and on the beach, of the processes taking place there, and of the roles played by the beach/training structures and the shingle recycling. They also agreed in general terms with the description of the changes likely to occur in response to the options considered, although noting that the timings and extents of these changes

could vary depending on circumstances (such as the occurrence of extreme events). Finally, they emphasised that successful predictions can only be made by understanding what has happened in the past and noted the value of the Historic Trend Analysis in this respect.

2.5 The Panel confirmed that although the available information is limited, any new information is very unlikely to change the overall understanding of what is happening now at the mouth and on the beach, or what is likely to happen in the future. It is therefore unnecessary to delay any decisions so that such new information can be collected.

3. Existing conditions and historic development

3.1 The Cuckmere system is effectively a pocket beach, i.e. one that is held in position and has its alignment determined by the cliffs on either side.

3.2 The dominant wave direction and the alignment of the coast mean that the general movement of sediment (long-shore drift) is from west to east, although storms from the south-east can reverse this trend temporarily.

3.3 At present there appears to be very limited amounts of new shingle reaching the beach. The cliffs to the west are a potential source but they are not retreating very rapidly and the volume produced is small. Some material might be carried along the coast from further west, although there is little evidence for this and little material is brought on-shore, suggesting that any such transport is likely to be mostly sub-tidal. The cliffs to the east are retreating but most of the shingle they produce moves east away from the beach.

3.4 There is no sign of significant volumes of material being moved onto the beach from offshore. In the area below the toe of the shingle the bed is formed of pebbles and cobbles cemented together, is covered with vegetation and does not appear to have material moving across it. These conditions are unlikely to change significantly in the future. There might be temporary increases in the rate of supply, for example if any local cliff collapses occur, but they are unlikely to be sustained. Sea level rise might lead to increased cliff erosion but the volume of shingle produced is likely to remain relatively small.

3.5 The top of East Cliff is retreating at a rate of about 0.3m/yr but the cliff toe is receding more slowly, leaving a series of prominent chalk buttresses as it retreats. These act like groynes and help retain shingle at Cuckmere that might otherwise move eastward along the toe of the cliffs towards Eastbourne.

3.6 The historic maps show that the East Beach moved back about 100m over a period of about 130 years, i.e. at a faster rate than the East Cliff. The rate was more rapid in the first part of this period, when the beach line was close to the cliff line, and slower in the second part when it was behind the cliff line. A wooden groyne at the east end of the beach (not mentioned in the reports, perhaps because it is largely covered by shingle and rarely visible) suggests that at one stage material was being lost at this point. With the East Beach in its present position little material is likely to be lost in this way, although if the cliff toe starts to retreat more rapidly than the beach a new groyne might be needed in a similar location to hold the beach material in place.

3.7 The historic maps also show the river mouth has been at a number of places along the shore, consistent with a sequence of west-to-east movements under the influence of longshore drift with occasional breakthroughs at the western end. This sequence ceased once the training walls were built.

3.8 It is noticeable, however, that the mouth seems never to have been further to the west than it is at present. Although this could be because the circumstances leading to a breakthrough further west have never arisen, it might be because there is hard ground (i.e. solid rock) underlying the West Beach that is high enough to prevent such a breakthrough happening. This would be worth investigating as it could affect the future behaviour of this part of the system under some of the options being considered.

3.9 Finally, the historic maps show that over the last 70 years the West Beach has moved back much less than the East Beach, suggesting that it is being held in its current position through the interventions that have taken place (including training wall/groyne construction and regular recycling of material from the mouth to the West Beach).

3.10 It is the combination of these interventions that is important. At present the training walls prevent the mouth from moving and limit its maximum width; the recycling removes material from the channel so keeping its bed relatively low and improving the river's drainage characteristics (in particular reducing flood levels upstream of Exceat Bridge and so reducing the risk of damage to property there); the material removed is placed on the West Beach increasing its volume and reducing the risk of it being over-washed during a storm; the groynes and the West Training Wall help to keep the West Beach material in place, slowing the west-to-east longshore shingle movement caused by the wave climate and beach orientation that leads to the mouth filling up again.

3.11 As there is no significant input of new material to the system, the current configuration of the mouth and the West Beach will only continue for as long as the training walls and groynes remain effective and regular recycling continues. If the training walls deteriorate, the channel mouth could move, which would affect the location, scale and frequency of the recycling operations. If the recycling ceases the channel will be infilled, affecting flood risk upstream. At the same time the volume and crest level of the West Beach will fall, affecting its location and orientation as well as the risk of flooding to the land behind. If the groynes deteriorate shingle will move from the West Beach to the mouth more rapidly, again affecting the scale and frequency of the recycling effort and the flooding risks further upstream.

4. Management options considered – general comments

4.1 When assessing impacts on the mouth and the beach the management options being considered by the Pathfinder project can be grouped into three main categories:-

- Baseline option – doing only what is needed to avoid increasing the flood risk to property (the Environment Agency's preferred approach, effectively a Do minimum option).
- Managed realignment – deliberately breaching some or all of the existing flood defence banks so tidal flooding will occur in selected areas (Options A, B and C envisage different degrees of intervention).
- Hold the line – continuing to maintain or improve the existing flood defences (Options D, E and F again reflect different degrees of intervention).

4.2 There are two further options that could be considered but are not included in the current list:-

- Full Do nothing – stopping all management actions immediately, including those at the mouth and beach.

- Adaptive management – a step-by-step approach based on setting out a long-term vision without prescribing in detail the scope or timing of the actions needed to achieve it. This approach is suitable when there is some uncertainty in the outcome of each step, since the next one can be adjusted to take into account the results that actually occur.

5. The Full Do nothing and Baseline options

5.1 The Full Do nothing option will lead to an uncontrolled set of changes at the mouth and along the beach, which may have significant consequences within the estuary and upstream of the Exceat Bridge. The first change will be that material moving to the mouth will not be recycled, so it will become increasingly blocked and the West Beach increasingly starved of material. The increased blockage will interfere with drainage from the estuary, raising water levels upstream at low tide under normal conditions and throughout the tide during severe floods, so increasing the risk of flooding both downstream and upstream of the Exceat Bridge. The continuing loss of material from the West Beach will reduce its volume and crest level, so increasing the risk of wash-over during severe storms and flooding of the land behind. These changes are likely to happen fairly rapidly (within a few years).

5.2 This situation (increasing blockage of the mouth and reducing volume of the West Beach) is likely to continue for some time, although for how long is difficult to predict partly because it will largely be driven by severe storms but also because it will be influenced by the remnants of the training walls and groynes (and so will depend to a degree on their current condition). In due course the West Beach will get so low that a wash-over occurs and the shingle is moved inland. The western end is partially protected by the cliffs and private defences below the Coastguard Cottages (including a timber breastwork) so may not move so far, with the result that the West Beach could in effect rotate about its western end, gradually turning to face to the south-east. Although it could still provide a measure of protection to the shoreline in this position, nevertheless there is a risk that some erosion could take place if the breastwork is overtopped or outflanked.

5.3 The situation will also be affected by the rate at which the river defences deteriorate. If they are not maintained, in due course they will breach, flooding the land behind and greatly increasing the flowing in and out of the mouth on each tide. This will increase the system's flushing capability (to the extent that it could become self-cleansing) and so lower bed levels and improve drainage from the estuary. The increased water surface area and reduced blockage at the mouth will result in lower water levels during severe floods, so reducing the flood risk upstream of the Exceat Bridge. The time taken for this to happen is impossible to estimate without detailed information about the condition of the defences and even then will be subject to a wide margin of error.

5.4 Initially the mouth is likely to stay in its current location as the channel is constrained by the flood banks and training walls. As more material is lost from the West Beach (lowering crest levels there and infilling the mouth), and as the flood banks and training walls deteriorate, it is possible that an easier route to the sea will open up and the mouth switches to it. This route could either be to the east, outflanking the Eastern Training Wall, or possibly to the west if the beach has moved inland and the flood bank has failed (unless the beach there is underlain by hard ground as discussed earlier). In either case the increased flushing that will occur once the flood banks have failed will help increase the mouth's stability.

5.5 In the long term, once the flood banks, beach and training structures have decayed or been removed, the estuary will have reverted to a more natural condition. The loss of the flood banks means the cubature (the volume of water flowing in and out on each tide) will be much greater than before, which will result in the mouth being wider and deeper than it is now. Initially it will probably stay in roughly its present position since the relict channel will restrict its movement sideways. The mouth will still be flanked by a barrier beach, although it is likely to be further inland and lower than at present unless there has been a major input of new shingle, which is unlikely. Its exact location is uncertain but assuming the long-term average rate of movement remains the same as before the beach could have moved perhaps one to two hundred metres inland in one hundred years. Sea levels will be higher than at present so the lower crest levels mean the beach is likely to be over-washed more frequently, which will re-distribute the material but not remove it. The East Cliff will have receded, although possibly not as much as the beach. As long as the private defences protecting the Coastguard Cottages remain in place, however, any retreat of the West Cliff should be minimal. These defences may need to be extended northwards as the West Beach moves back and the higher ground forming the edge of the valley is exposed.

5.6 The difference between the Full Do nothing and the Baseline (Do minimum) options is that in the latter case the Environment Agency will continue to maintain the training walls and groynes and to recycle material regularly until the river defences fail and the mouth becomes self-cleansing. This will avoid the increased flood risk upstream of the Exceat Bridge due to the mouth being blocked that will occur under the Do nothing option. There is also a suggestion that the Environment Agency might remove the training walls and groynes on Health and Safety grounds once they have deteriorated, which could accelerate the development of fully natural conditions. In all other respects the long-term outcome of the two options is likely to be very similar.

6. The Managed realignment options (Options A, B and C)

6.1 The main difference between the Managed realignment and the Baseline (Do minimum) options is that in the first case the location and timing of breaches through the flood defences are planned whereas in the second they are not (in effect the Baseline option could be re-named as Unmanaged realignment). This means that any changes resulting from Managed realignment options are likely to be more predictable and to happen more rapidly.

6.2 As far as the mouth and the beach are concerned, the difference between the three Managed realignment options will depend largely on the increased tidal flows through the mouth associated with each of them. In practice the topography of the area means that Option A would provide most (perhaps 80%) of the extra tidal storage volume theoretically available downstream of the Exceat Bridge. Option B would provide most of the remainder while Option C would provide little if any more. The implications of this are that Option A would provide a very good chance of the mouth developing into a stable, self-cleansing feature fairly rapidly once the flood banks have been breached. The chance would be slightly improved if Option B is implemented and the development might be a bit more rapid, while implementing Option C would have little further effect.

6.3 The result of all three options would be that the Environment Agency would be able to reduce, and probably stop, their re-cycling of material from the mouth to the West Beach earlier than under the Baseline (Do minimum) option. If the mouth does not

become fully self-cleansing some re-cycling might still be needed but the frequency and effort involved would be very much less than at present with Option A and less again with Options B or C. The consequence of this is that the West Beach would no longer be sustained in its present position and would move, probably quite rapidly. It would remain attached to the high ground at the edge of the valley, possibly moving northwards slightly but probably pivoting to face closer to the south-east as well. Any such movement could be constrained by features below the existing beach, such as old breastworks, hard ledges or similar. Access from high ground onto the beach should remain possible under most circumstances although artificial re-grading of the beach profile might be necessary on occasion. Its crest level would probably fall, increasing the risk of over-washing during a severe storm and flooding the land behind, although this will already be open to tidal flooding as the defences will have been breached.

6.4 There are two further points worth noting in relation to the Managed realignment options. The first is that although there will be a major increase in the system's flushing capacity when the defences are first breached, this will reduce in time as sediment accretes in the flooded areas, raising bed levels and reducing the storage volume available. The rate of this reduction will depend on the rate of accretion. The second is that the condition of the beach in general and of the West Beach in particular could be improved by importing shingle and depositing it below the Coastguard Cottages. Although this might be expensive and could raise environmental issues, nevertheless it would compensate for the effective loss of material that will result when the beach moves across relatively low ground and lengthens as it realigns.

7. The Hold the line options (Options D, E and F)

7.1 The three Hold the line options all assume that the defences will not be breached in the future and imply that if any breaches do occur they will be repaired. As a result the estuary's cubature will not increase significantly, the mouth will continue to be prone to blocking and the Environment Agency (or some other organisation) will need to continue to maintain the training walls and groynes and the regular recycling of material from the mouth to the West Beach.

7.2 The effort required to do this and the risk of the West Beach being over-washed during a severe storm will increase as time goes by and as sea levels rise and storms become more frequent. The consequences of over-washing will be more serious than with the Managed Realignment options, since the land behind will not normally be open to tidal flooding. Again importing shingle and depositing it below the Coastguard Cottages could improve the condition of the beach, since this will increase its overall volume, although this could also increase the rate of movement of material from the beach into the mouth and so increase the re-cycling effort needed to keep the mouth clear.

8. West Beach revetment options

8.1 The Panel was not fully clear whether the aim of the West Beach revetment options being considered is to prevent the West Beach from being breached, as stated, or to protect the Coastguard Cottages from being affected by the loss of the beach (presumably through erosion of material at or behind the point where it currently meets high ground). In practice none of them are likely to be particularly effective, since although they may absorb some of the wave energy reaching the beach they will not absorb it all, so the shingle will still be able to move as the mouth re-adjusts.

In addition wave reflection would probably lead to increased scour immediately in front of them. The construction of rock groynes buried in shingle could help but only if the shingle is imported from elsewhere, since this would increase the overall volume of the beach. This shingle would still be able to move, however, and the groynes could become isolated and no longer effective as the mouth re-adjusts.

8.2 It is important to note that although there is a risk that the West Beach will be over-washed, and this risk will increase with time whichever of the estuary management options is selected, nevertheless it is unlikely to disappear completely. The most effective way of reducing the risk of over-washing would be to allow the beach the freedom to respond to the wave climate reaching it, rather than trying to fix it in one position. The next most effective approach would be to increase its volume by importing shingle from elsewhere, although this could be subject to cost and environmental issues.

8.3 The security of the Coastguard Cottages depends more on the maintenance of the existing defences preventing the erosion of the cliff beneath them than on the current alignment of the West Beach and possibility of it being over-washed. If the beach is allowed to re-align there may be some erosion of the high ground along the edge of the valley and if this appears to be happening, or there is real concern that it might happen, then it would be more appropriate to extend the existing defences towards the north (i.e. along the valley edge) rather than trying to fix what is an inherently mobile feature.

9. Other issues

9.1 The previous discussion has focused on the impact of the estuary management and other options being considered on the mouth and the beach, rather than on the impact of what happens at the mouth and the beach on the options. It has also focused on the stability of the West Beach, as the least stable part of the frontage, without saying much about what will happen to the East Beach. In practice either of the two beaches could be over-washed, although the risk of this happening to the West Beach is much greater than to the East Beach. If it does occur the land behind would be flooded, which might have limited impact for the managed realignment options but could be of more concern if the area is to be protected against flooding. Since the total volume of the beach is unlikely to change significantly (unless shingle is imported as discussed earlier), the risks of over-washing and associated flooding are likely to get higher as sea levels rise and storminess increases.

9.2 Concern has been raised about the Environment Agency's access to the mouth if the West Beach has been over-washed, and therefore its ability to clear the channel and recharge the beach. This could be an issue; however it should not be too difficult to re-build the access using the plant that will clear the channel should this be necessary. Alternatively it may be possible to bring plant along the East Beach.

9.3 Finally, the Panel's suggestion that an Adaptive Management approach should be adopted is repeated. This would apply in particular to the Managed realignment options, providing the best way of dealing with the inevitable uncertainties associated with them, but also to any extension of the defences for the Coastguard Cottages. It would involve developing whichever scheme is selected in stages rather than all at once, with sufficient time between each stage to allow the consequences to be identified and the next stage adjusted to take them into account.

APPENDIX A

THE COASTAL PROCESSES PANEL AND WORKSHOP

The members of the Coastal Processes Panel were:-

Alan Brampton	Technical Director, HR Wallingford
Uwe Dornbusch	Coastal Technical Specialist, Environment Agency
Callum Firth	Professor, Environment & Technology, Brighton University

The Coastal Processes Workshop took place at the University of Brighton on Monday 21st March 2011 and was attended by the above together with:-

Richard Young	Director, RYE Consultancy (Non-technical Chairman)
Scott Ferguson	Technical Director, Capita Symonds
Andy Arnold	Team Manager, East Sussex County Council

APPENDIX B

DOCUMENTS PROVIDED TO COASTAL PROCESSES PANEL

Topic key

R Relating to the Panel's Review (i.e. scope of work, questions to be answered etc)

T Relating to the Technical aspects of the Review (i.e. the coastal processes, the options considered and their likely impacts etc}

Document	Topic
First e-mail (25Feb11)	
Attachment 1 (e-mail from Adrian Davies dated 24Feb11)	
Option Impact Brief (for full study)	R
Options Analysis Tables (to be completed from CP Review Report)	R/T
Second e-mail (03Mar11)	
Coastal Processes Review Proposal	R
Coastal Processes Workshop; Draft Agenda	R
Third e-mail (03Mar11)	
Prediction of Extreme Wave Heights (R1163)	T
Assessment of Inlet Stability (R1174)	T
Shingle Modelling Report	T
Fouth e-mail (03Mar11)	
Historical Trend Analysis (HTA) and Channel Regime Assessment	T
SEA Environmental Report; Non Technical Summary	T
Appendix 6; Rejected Scenarios	T
Appendix 7; Scenario Description Tables	T
Fifth e-mail (03Mar11)	
SEA Post-adoption Statement	T
EA Information Leaflet March 2009	T
Sixth e-mail (09Mar11)	
Attachment 1 (e-mail from Ray Traynor dated 08Mar11)	
SEA Environmental Report; Full	T
Appendix 1; Relevant Plans and Policies	T
Appendix 2; Consultation Proforma	T
Appendix 2; Summary of Consultation Responses	T
Appendix 3; Citation	T
Appendix 4; List of Species	T
Appendix 5; Cultural Heritage	T
Appendix 6; Rejected Scenarios (as above)	T
Appendix 7; Scenario Description Tables (as above)	T
Appendix 8; Environmental Assessment Tables	T
Attachment 2 (e-mail from Ray Traynor dated 08Mar11)	
EA Final Brochure 2007	T
Seventh e-mail (14Mar11) - Comments on Review Proposal (by e-mail)	
From Scott Ferguson (04Mar11)	R
From Adrian Davies (11Mar11)	R

APPENDIX C

FURTHER DISCUSSION OF EXISTING CONDITIONS AT CUCKMERE

Note: This Appendix was drafted by Alan Brampton of HR Wallingford but has been reviewed and agreed by the other members of the Coastal Processes Panel.

1. Information provided to Panel about coastal processes

There have clearly been problems in obtaining and analysing information on the evolution of the beaches at Cuckmere Haven so that the quantification of both hydrodynamic processes and morphological changes is less complete than for many other parts of the South Coast.

The reports available on local wave conditions seem to have assumed an unusually high value for the significant wave height at breaking over the water depth. This has resulted in greater nearshore wave heights being predicted than would normally have been estimated. The resulting estimates of exceptionally severe wave heights, with return periods as great as 30 years, are correspondingly larger than usually would have been predicted. This in turn has meant that the modelling of the response of the shingle barrier beaches to such extreme events can be expected to have over-estimated the extent of the landward retreat of the beach crest during such events. The extent of such predicted retreat would have been further increased by a corresponding over-estimation of the wave period likely to accompany such large waves. The wave period over wave height ratio used in the modelling of the beach profile response also seems higher than that deduced from wave measurements made off Seaford (in 1983/1985). In summary, the estimates made of the potential for beach retreat at Cuckmere during severe storms seem likely to be over-estimated, and may have raised greater concerns than actually warranted.

There is little in the way of quantified information on recent rates of beach volume changes or of any recent landward movement of the beach face.

Calculations of net longshore drift rates along the barrier beaches have been carried out by numerical modelling, resulting in estimates of greater than 25,000 cubic metres/ year at the western end of the barrier, dropping to zero at the eastern end. However, these calculated drift rates are noted as being dependent on there being sufficient volumes of sediment available for transport. However, the rates of supply of new shingle to the barrier beaches and of any losses of sediment from them are unknown. However the protection of many of the chalk cliffs and the erection of barriers to longshore drift, for example the harbour breakwater Newhaven and the terminal groyne/ outfall at Seaford, seems likely to have reduced the historic natural rates of supply from further west. As a result, the rates of sediment transport along the beaches from west to east might have been over-estimated by the numerical modelling. It has not been possible to obtain detailed survey data or information on recycling volumes to help calibrate/ verify the calculations of drift rates

A notable omission in the reports provided to the Panel is any assessment of the functional performance and likely residual lifetime of the various groynes and training walls. These structures both reduce the longshore transport rates and any tendency of the river mouth to shift. Such assessments are normally provided when the future development of beaches is being predicted. A further point is that the reports do not mention at least two timber structures largely buried below the crest of the beach; one at the western end of the West Beach (near its junction with the West Cliff) and one at the eastern end of the East Beach. Both structures are likely to affect the movement of shingle and other processes at these locations.

2. Description of current behaviour of coastline

The important aspects of the behaviour of the coastline at Cuckmere from the viewpoint of the future evolution of the estuary are:

1. Any landward movement of the barrier beaches;
2. The longshore movement of shingle into the channel at the estuary mouth;
3. Lateral movements of the position of the estuary (river) mouth.

These points are now dealt with in turn.

Landward movement of barrier beaches either side of the estuary mouth

As well as any short-term beach retreat ("roll-over") of the beach in storms there is a long-term process of beach retreat which has been demonstrated (if not well quantified) by analysis of historical maps. This retreat is largely caused by rising sea levels and changes in wave environment and sediment supply. The beach is also likely to be affected by the slow retreat of the cliffs on either side of the valley, although this inter-relationship is likely to be complicated and hence it difficult to predict how the cliffs retreating will affect the beach evolution.

As stated earlier, the modelling of the beach profile response to severe storms has probably been over-conservative, although there is always a risk that such natural barrier beaches will be over-topped by waves arriving at high-tide. Nevertheless, this modelling does suggest that the beach west of the estuary mouth is the more likely to suffer over-washing and retreat in extreme events.

In the medium to long-term, i.e. over 20 to 50 year or longer, this retreat may become noticeable, particularly if the present recycling of sediment from the channel back to the western beach is reduced and eventually halted; if this happens the landward migration will become much more rapid. Over a much longer period, the beach will retreat back into the estuary which becomes wider, and with lower underlying land levels, than at the present beach location. The reports and data available at present do not allow an estimate to be made of how quickly the barrier beach will retreat over the three time epochs specified, or to judge how feasible it might be to control such retreat, for example by the addition of additional shingle during beach recharge schemes. However, it seems likely that left to natural processes alone, the two beaches would both retreat and separate, i.e. resulting in a wider estuary mouth. This in turn would require realignment of the flood embankments that meet the rear face of the barrier beaches.

Longshore movement of shingle into the estuary mouth

The important second aspect of future beach behaviour is the movement of shingle from the beaches into the channel between the training walls at the estuary mouth. At present, tidal flows through this channel are not sufficient to scour out such infill. This infill means that under flood conditions the channel will not drain water out of the estuary as fast as it arrives from upstream, so the Environment Agency presently remove the shingle from the channel mechanically to reduce the risks of flooding upstream of Exceat Bridge. As they excavate the shingle from the channel and the ebb tide delta, they use it to recharge the beach west of the estuary mouth, so reducing the risks of that beach both being over-washed in storms and gradually retreating in response to rising sea-levels. The rate at which shingle travels into the channel, mainly but not exclusively from the beach to its west, is reduced by the presence of various groynes and training structures. The apparent placement of excavated shingle only onto the western beach coupled with the presumed arrival of extra shingle from the west and the construction of groynes has led to the face of the western beach apparently lying further seaward than that of the eastern beach.

If the channel cleaning and shingle recycling back to the western beach were to be halted there would be a loss of shingle from the western beach into the channel, raising the invert level and increasing the risk of flooding upstream following heavy rainfall. The loss of material would also

increase the risk of the western beach being over-washed and retreating. This process would be more severe and happen more rapidly if the groynes and training walls were left to deteriorate.

Lateral movements of the position of the estuary (river) mouth

At present the historical pattern of changes in the position of the estuary mouth is constrained both by the training walls and by the reduction in the volume of water entering the estuary during each tide caused when the flood defences were built. The training walls provide the primary constraint of any movement of the mouth of the estuary, and while these continue to function, there is little risk of any major shift in the position of the mouth.

However, if these structures are not maintained, and especially if there is an increase in the inter-tidal areas in the estuary, then it is likely that the estuary mouth will move. In similar situations elsewhere, e.g. at Pagham Harbour, and in the past in the Cuckmere estuary, there has been a gradual shift of the mouth eastwards. This occurred at a time when there was a supply of sediment from the west, however, which appears to be no longer available at Cuckmere. As a result the mouth could well remain at its present location for a relatively long period of time. At some stage it could become blocked and a new mouth formed, either to the east or the west, although there appears to be no evidence from the available maps that the estuary mouth has ever been much further west than it is at present. This **may** be because of some geological control, e.g. a chalk outcrop extending from the west underlying the western beach and estuarine sediment deposits that prevents the channel being formed much closer to the Cable House and Coastguard Cottages than it is today. This, however, is speculative and would need to be investigated further, particularly in view of concerns that a retreat and perhaps eventual loss of most of the west beach might threaten properties on that side of the estuary, however unlikely this seems based on historical records.

3. Effects of severe weather conditions

The modelling carried out to predict wave and water level combinations as an input to assessing the effects on the coast of severe weather conditions was carried out by ABPmer (2005).

This involved a simplified transformation of offshore wave conditions, as predicted by the Met Office wave model between 1988 and 2004, to a nearshore location where the bed level was 5m below ODN. As previously noted, the report has chosen an unusually high ratio for the wave height to still water depth at the point that the waves break. The result has been that their predicted wave heights at this location are greater than we would have expected, with a maximum predicted H_s of 6.3m in a water depth of 8.5m, i.e. a ratio of 0.74. Most field experiments suggest that this ratio is about 0.6 when using significant wave heights (see Thornton and Guza, 1982).

The wave height probability distribution at this location was then extrapolated to estimate extreme wave heights, i.e. with a return period of up to 30 years. No explicit mention of the possibility of the wave height probability distribution being limited by the restricted depth of water at the inshore location has been found.

The report goes on to assign both appropriate (mean down crossing) wave periods (T_z) and still water (or tidal) levels likely to occur at the same time as these large wave heights. For the former, the report has assumed a wave steepness of 1/19.6 (or 0.051) which is lower than we would have expected based on the wave measurements made at Seaford in 1984. As a result, the predicted T_z values might be larger than expected.

A potentially greater concern is their rather confusing statement that the expected water level at the time that a large wave arrives has been estimated using “a conservative assumption of independence between wave height and water level”. In general, large waves along the South Coast are produced by deep depressions that can also create a large tidal surge, and hence higher than normal tidal levels. This means that some dependence between high water levels and large wave heights can be expected. To obtain a conservative estimate of the simultaneous occurrence of large waves and

high tidal levels, therefore, it is normal to assume a substantial, or even a strong dependency between these two quantities.

A preliminary review of their results for extreme wave heights and water levels suggests a complete dependency, i.e. the predicted wave height with a return period of **n** years will arrive at the same time as the tidal level with a return period of **n** years.

Overall, therefore, the table presented showing, for various return periods, the recommended values for the significant wave heights, their expected periods and the simultaneous water level is very conservative. While the occurrence of these combinations of values is perhaps not impossible, it seems very unlikely that they would occur.

Nevertheless, these recommended values for the extreme wave heights and periods were accepted without comment and used in a subsequent modelling study carried out by Babtie, Brown and Root (2005) to predict the short-term beach response in extreme storm conditions. We are not therefore surprised to find that the predictions of beach profile change produced by this modelling, even for lower return period conditions, do not correspond well to the measured beach profiles along the Cuckmere Haven shoreline. As an example, this modelling predicts beach crest levels reaching 8m ODN when the surveys indicate they are less than 6m ODN.

We have not been able in this brief review to check the modelling results thoroughly but feel confident that the predictions of beach profile changes that have been presented are pessimistic, and potentially substantially over-estimate the likely retreat of the barrier beach during a single storm event. This in turn may have caused greater concerns about flooding and erosion than may actually be the case.

4. Likelihood of river mouth becoming blocked

Attempting to predict the future development of entrances to estuaries or inlets that pass through a mobile barrier beach is notoriously difficult and inaccurate. The Cuckmere River mouth is no exception.

The mechanisms for shingle being carried into the bottom of the channel that runs through the barrier beach are clear, namely the longshore transport of sediments driven by waves breaking obliquely onto the barrier beach from either the east or the west. The available reports on and the general understanding of this stretch of coastline all indicate a predominantly easterly net transport of sediments driven by the waves approaching from the south-west sector. It is from this sector that winds approach more often and the long fetch lengths into the South-Western Approaches allow these winds to generate the largest waves.

The beach west of the entrance to the Cuckmere River appears to lie further seaward than the beach just to the east, and this will further intensify the tendency for shingle to move from the west to the east towards and into the entrance channel, The installation of various groynes and the training wall to the west of the entrance serve to reduce this eastward transport and retain sediment on the western beach; at the same time these structures reduce the amount of shingle that can reach and be deposited in the low-water channel that drains the estuary.

The tendency for any net longshore transport along the beach east of the entrance is much smaller; essentially this beach has rotated over the years to face the mean wave direction. However, there will still be occasions, e.g. in south-easterly storms, when shingle from this beach will be driven towards the entrance. The training wall to the east of the river mouth helps to prevent this material infilling the channel.

Calculations of the likely water velocities entering and more importantly leaving the estuary even during spring tides have been carried out by ABPmer for Jacobs Babtie, with a view to assessing whether any coarse sediment particles in the channel would be flushed out of it by the ebbing tide. This sort of calculation is always subject to error, as a result of imperfect knowledge of the

processes involved and uncertainty regarding the shape (i.e. width, depth and cross-sectional area) of the channel at some future date, following a period of infill. In this particular case, however, the calculations seem to very strongly indicate that if left to Nature alone, the present-day ebb tidal flows would not be able to remove shingle particles unaided.

In this context, therefore, the presence of the groynes and training walls that reduce the rate of transport of sediment into the channel, and the mechanical excavation of the sediment that is deposited in it are vital to preserving an entrance to the estuary. The training walls also reduce any tendency for lateral movement of the mouth of the estuary.

As the tidal flows would not, at present, be able to remove shingle from the established channel, it seems even more unlikely that they would be able to form a new channel through the barrier beach if the existing channel was partly filled with coarse sediment. In the short-term future, therefore, if the inter-tidal area of the estuary does not increase (as a result of managed or unmanaged breaching of flood embankments) then the only way to prevent its mouth being infilled will be to continue the mechanical excavation and removal of the deposited beach sediments. The need for such excavation may increase if the condition of the groynes and training walls deteriorate further.

If all management of the beaches and the entrance channel were to cease, it could be reasonably be deduced that in the short term the estuary would become more like a lagoon, with much restricted interchange of water with the sea. Fluvial flood water would infill the estuary much more rapidly than at present, leading to flooding upstream of the Exceat Bridge. Eventually, the flood waters would drain through any remaining part of the channel or simply permeate through the shingle beach. One possible outcome is that in due course the western beach is over-washed and breaches (unless there is a physical control preventing this), resulting in a small tidal inlet being formed in the area behind it until the flood bank separating this area from the lagoon also breaches and the channel diverts to this new route.