In A Heugh – The Strategic Influence of a Breakwater

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Introduction

The historic town of Hartlepool is situated on the North East coast of England. It can be divided into two areas: the Hartlepool Headland and 'West Hartlepool'. The old part of the town is the Hartlepool Headland, a rocky peninsula which is exposed to the rough conditions of the North Sea (Figure 1). On the southern end of the Headland is the Heugh Breakwater (pronounced 'yuff'). To the west of the Headland is the newer part of the town: 'West Hartlepool' (Hartlepool Bay) which is lower lying and relatively sheltered from the stronger prevailing wind and waves. In between these areas is Victoria Harbour, a historically important Port first thought to be established in the 1300s (Page, 1928).

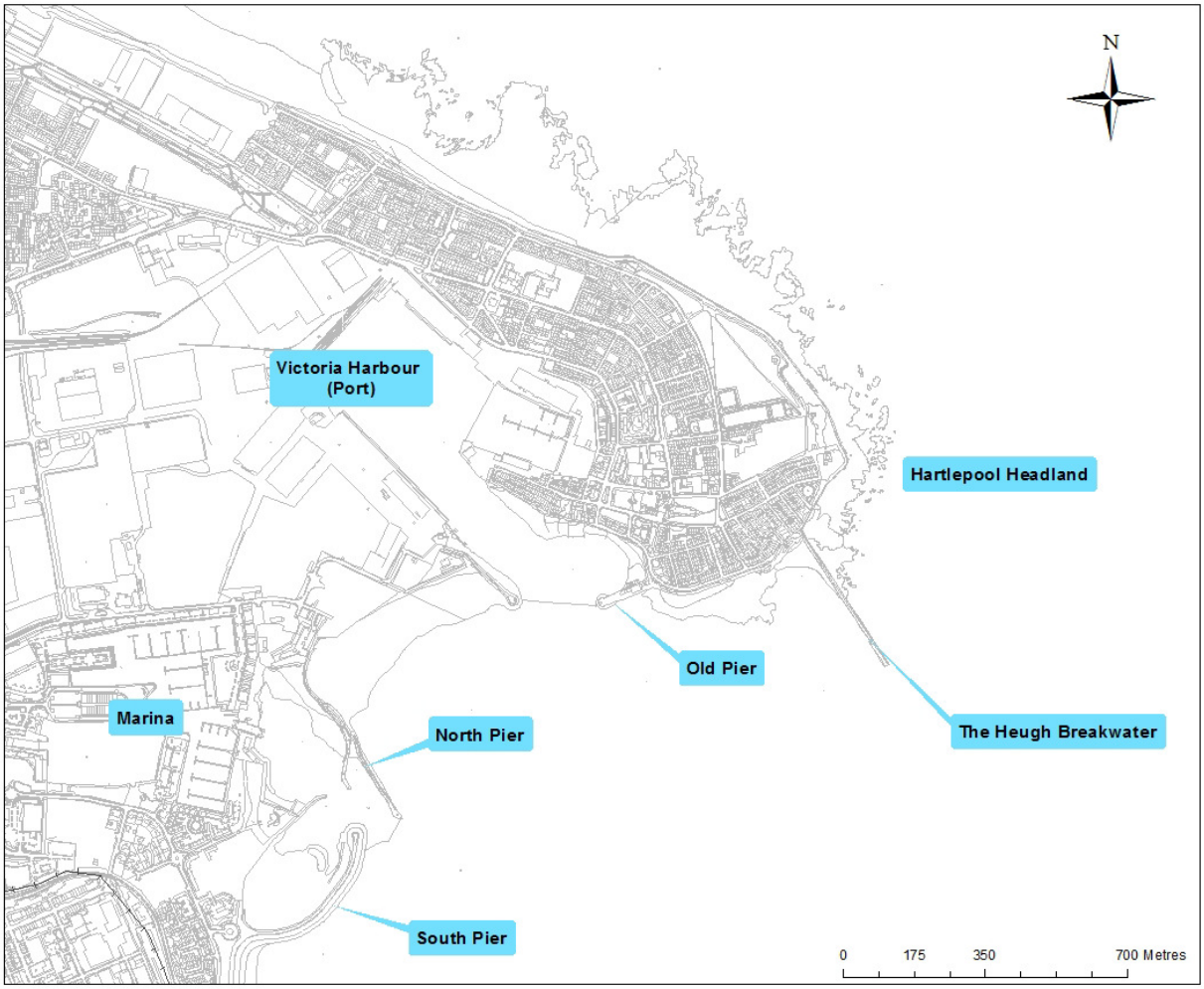

Figure 1: Map of the Hartlepool Headland. Source: Reproduced from the Ordnance Survey Mapping with the permission of the controller of Her Majesty's Stationery Office. Crown Copyright Reserved. Licence No.100026791.

Coastal defences have been in place for many centuries along the Hartlepool frontage, protecting local residents, residential and commercial properties and maritime assets from the clutches of the

North Sea. Defences on the Headland date back to medieval times and have been updated since. As the importance of the Port increased, several Piers or Breakwaters were also constructed to reduce the strongest waves propagating across Hartlepool Marina and maintaining access for vessels. In particular the Heugh Breakwater, a vertical blockstone structure, was constructed in 1853 (Atkins, 2006). The current structure is *ca.* 400m long and extends from the Headland into Hartlepool Bay in a northwest-southeast orientation, sheltering Hartlepool Bay and the entrance to Victoria Harbour to the west. The Breakwater is observed to give particular protection to the area of Block Sands situatedin the lee of the structure, where significant sand deposits are present.

The Heugh Breakwater epitomises one of the key issues associated with the management of the Hartlepool frontage, identified initially in the second Shoreline Management Plan (North Tyne to Flamborough Head), also known as SMP2 (Royal Haskoning, 2007) and currently taken forward in more detail through the Hartlepool Strategic Appraisal Report (StAR) (Mott MacDonald, 2013). Under current flood and coastal erosion risk economic analysis, residential and commercial property benefits are relatively tangible and easy to value. However the value of the defences themselves, both as historical assets and their wider influence (in terms of sheltering effects on other sections of the coastline) are harder to establish, and thus it is harder to gain funding support.

This paper will consider how we can re-examine the importance and value of the Heugh Breakwater in the wider strategic context of coastal management in Hartlepool. The first part of this paper will consider the history of the Breakwater and briefly how it was originally designed and constructed (from the limited records available). Secondly this paper will outline the protection that the Breakwater provides to areas of Hartlepool Bay and therefore the potential wider benefits that it could be argued to offer. Finally, the future of the breakwater will be considered along with the implications for the future management of the Hartlepool coastline if it is not maintained.

The Heugh Breakwater

History

Under the Hartlepool Pier and Port Act of 1851 the Heugh Breakwater was originally constructed for the Hartlepool Port and Harbour Commissioners to establish and control the ferry between Hartlepool and the new town of West Hartlepool (Port and Harbour Act 1855). It was proposed that the profits from this were to be used to maintain the Breakwater due to it's exposure to wave and tidal action from the North Sea. However with limited profits it proved difficult to mitigate against all damages.

As historical accounts collated by Page (1928) indicate, funding and maintenance for structures such as Piers and Breakwaters in Hartlepool has always been difficult to obtain. For example there are records of attempts to gain funding from the Government for the Old Pier (see figure 1) in 1657, 1662, 1665 and 1804 (and in 1662 a similar petition was referred to the Lord Chancellor) (ibid); however all attempts were declined by the Government. The Old Pier was briefly repaired between 1721 and 1732 by Mayoral support. In the 18th Century, trade in Hartlepool declined and the harbour was allowed to fall into disrepair. The severe storms of 1810 removed a significant part of the ruined Old Pier. Again support was sought and declined from the House of Commons, despite the fact that Hartlepool was the only safe harbour between Sunderland and Bridlington. Three years later an Act aimed at improving the Port and Pier of Hartlepool was passed which provided that part of a toll should be devoted to the maintenance of the Old Pier. Unfortunately, the amount raised by the toll was not significant enough to rebuild the Old Pier completely.

In the same way, the integrity, length and function of the Heugh Breakwater has been adjusted in response to available funding (Hartlepool Headland Protection & Improvement Act 1885). In 1870 repeated damage led to the loss of nearly one-third of the length of the Heugh Breakwater, with subsequent abandonment following destruction of its composite replacement end in 1877. After repair and reconstruction by the Port the Breakwater suffered significant damage as the result of the infamous North Sea storm surge in 1953 (Figure 2). The surge not only caused significant wave and

overtopping impacts for the Breakwater but the severity of the storm meant that the swimming pool in the lee of the structure at Block Sands suffered significant wave damage and was subsequently abandoned. Remains of the swimming pool can still be seen on the foreshore today.

Figure 2: Overtopping damage to the Heugh Breakwater caused during the North Sea Storm Surge of 1953.

Current day and future

In the current day, the outer third of the Breakwater is in very poor condition with cracks and damage to the blockwork and undermining of the toe (as inferred from walkover investigations and diving and boat based surveys by Mott MacDonald (2013)). This damage means that the structure is at serious risk of collapse by wave loadings and overtopping. PD Ports who own the Heugh Breakwater and are responsible for its condition are considering letting the outer third collapse (*ca.* 130m) in a controlled manner and only maintaining the remaining two thirds (*ca.*270m). It is likely given climate change and predictions for increased sea levels and storminess in the future that the Heugh Breakwater will become increasingly exposed to wave action and will suffer increased damage, with an increased maintenance burden on PD Ports.

Figure 3 presents an image of implusive overtopping occurring at the Heugh Breakwater in 2008. This is a common occurrence and will only become more common in the future with increasing requirements for maintenance and repair. It is understood that PD Ports will maintain the Breakwater as long as it is necessary to provide shelter for vessels entering and leaving the Port; this is likely to continue for the foreseable future given the Port's development plans. However, there is no certainty or obligation and so alternatives should be sought.

Figure 3: Waves breaking over the Heugh Breakwater in 2008. Source: nearthesea.co.uk

Breakwater design

Vertical Breakwater design in the 1800s often involved the use of rock rubble for the core and blockwork sides (Allsop, 1996). The Heugh Breakwater structure is very typical of this time and is *ca.* 4m high (from toe to crest) resting on bedrock at 1mOD and *ca.*10m wide. Over the nearshore stretch of the Heugh Breakwater, the structure is built directly onto the Permian Magnesian Limestone wave cut platform which is common around the seaward side of the area surrounding Hartlepool's Headland. The foundations for the last 1/3 of the structure (approximately 130m) are uncertain but thought to be laid upon 'softer' sandstone. Therefore the outer third of the Breakwater is not only in worst condition (from visual surveys undertaken by Mott MacDonald) but it also has the most vulnerable foundations. The first 250m of the Breakwater is thought to have been constructed using masonry blocks with a rubble core. The remaining section of concrete blocks was completed in 1870. The rest of the scheme was never completed due to lack of funding (Atkins, 2006).

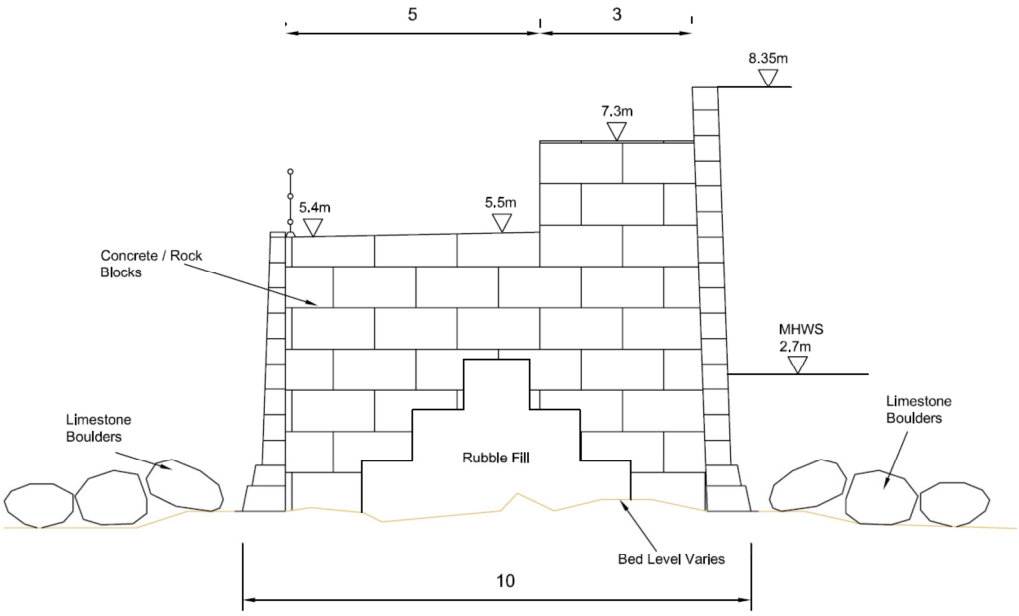

Figure 4: The Heugh Breakwater vertical blockwork structure

Failure

The core structure of the Heugh Breakwater has existed in some form since the mid 1800s, despite the damages sustained in the 1870s and 1953. Allsop *et al.* (1996) describe three stages of a life of a Breakwater: construction, initial service and extended service. Essentially Allsop *et al*. state that if a Breakwater survives the first 5 years following construction then it is likely to continue for up to 50 years further, not withstanding accelerated damage and minor failures. Therefore the Heugh Breakwater could be defined as carrying out 'extended service' to protect the Port and Hartlepool Bay.

The mode of failure of the Breakwater is likely to be removal of individual blocks by wave loadings, particularly where mortar fill between blocks and previously repaired cracks has degraded. Pressure waves between blocks and within cracks could then cause high internal forces impacting on surrounding blocks. Without significant repair or maintenance it is unsafe and vulnerable to sudden collapse.

Realistically the 400m long structure is unlikely to fully collapse at once, particularly considering that two thirds of the structure is in relatively good condition; however once it is exposed it will then become increasingly vulnerable to further breaching and collapse given the rough wave climate it is exposed to. Because the remaining two thirds of the breakwater is rubble core rather than block work it is likely to collapse more quickly than the end third. It is likely that rubble remains of any such collapse would be left *in situ* due to the high cost of removal, unless there was a considerable safety risk. The remains would also provide a degree of short term shelter by wave attenuation and would eventually be abraded away. Rubble remains would be unlikely to subside due to the hard nature of the limestone foundations on which the Breakwater sits (apart from the end third where there are softer foundations).

Ultimately contingency plans need to be produced if PD Ports decide that the Heugh Breakwater is no longer a key asset for their business and it is left to collapse. These plans should outline the various options for management and funding requirements; in particular the potential Environment Agency Flood Defence Grant in Aid (FDGiA) contributions towards the structure need to be understood by highlighting its importance for the wider community.

Reassessing the value of the Heugh Breakwater

Strategy development

The 2006 Hartlepool Coastal Strategy Plan was developed to outline the potential options for the future management of the frontage and identified coastal erosion along the frontage as a key risk, particularly with ageing defences vulnerable to failure (Atkins, 2006). The need for a review of the Strategy was partly initiated by the adoption of the Shoreline Management Plan (North Tyne to Flamborough Head (Royal Haskoning, 2007), also referred to as SMP2. The SMP2 recommended that a more detailed review was required to cover the area between North Sands to Newburn Bridge, including the Heugh Breakwater. It was also necessary to review and extend the Strategy with changes in funding and sea level rise guidance and best practice.

A Strategy Appraisal Report (StAR) has therefore been developed by Hartlepool Borough Council in partnership with Mott MacDonald. The StAR identifies the need for key capital schemes, particularly at the Headland that need to be implemented over the next 100 years to manage the risks to local people and the developed, natural and historic environments from coastal erosion.

Under SMP2 the policy for the majority of the Hartlepool coastline is Hold the Line for the next 100 years. Purely in terms of coast protection, the SMP2 recommends in the medium term to abandon the outer end of the Heugh Breakwater, taking into account the additional pressure and hence cost associated with the defence of other areas (Royal Haskoning, 2007).

Historic value

The Hartlepool coastline boasts many historic features both in terms of flood and coastal erosion features (for example the Town Wall Scheduled Ancient Monument, Sandwell gate, shown in Figure 5a) and the Heugh Breakwater Gun Battery Scheduled Ancient Monument (SAM), which is the only remaining British World War One Gun Battery in the UK (also shown in Figure 5b). Throughout the development of the StAR it has been difficult to assign a value or benefit to these assets to consider the economic case for maintenance and upgrade. However estimates of historical assets have been made and Partnership Funding Scores in accordance with new Environment Agency guidance have been calculated based on the cost of defences directly protecting the assets behind them (Mott MacDonald, 2013).

Specifically, the Heugh Breakwater is considered to have significant historic value. However as with the other historic assets, it is difficult to account for the benefits of maintaining the structure. It is particularly difficult given that the Breakwater is perpendicular to the coast and under the current funding regime it is considered to offer no direct protection to the assets on the majority of Headland, with the exception of the lee of the Breakwater at Block Sands. If it were allowed to fail either in part or completely this is likely to alter the approach to management of the frontages to the west and south.

Figure 5: Other Historic Assets along the coastal frontage at Hartlepool include: a) Sandwell Gate which lies in the lee of the Heugh Breakwater and b) the Heugh Breakwater Gun Battery.

Without understanding the benefit the Breakwater provides to these frontages it is difficult to see how justification for maintaining the Heugh Breakwater can be made within the current funding application guidelines. Instead '*funding to preserve the existing extent of the Heugh Breakwater would have to be obtained from sources, other than coast protection; reflecting the broader benefits which might be shown to accrue'* (Royal Haskoning, 2007). In order to form a comprehensive argument for funding from the FDGiA process or from external providers, it is necessary to consider and justify the wider benefits of the Breakwater; this is considered in the next section.

Assessing the wider benefits

The Heugh Breakwater has been assessed to consider the influence the structure has on the local wave climate and the potential changes to the wave climate arising from a lack of maintenance. In particular the end third of the Heugh Breakwater is in a poor condition and an assessment was needed to consider the potential impact on the local wave climate if it collapsed. Numerical wave modelling utilising the SWAN model along the Hartlepool coastline, undertaken by HR Wallingford (2011), considered several scenarios with waves approaching between 0 degrees and 150 degrees, these included:

1. Existing position of Piers and Breakwaters, for current day conditions.
2. Removal of all Piers and Breakwaters, for current day conditions.

3. Reducing the length of the Heugh Breakwater by a third, for current day conditions.
4. Removal of the outer third of the Heugh Breakwater and removal of the North Pier, for current day conditions.
5. Reducing the length of the Heugh Breakwater by a third and assuming a 100 year allowance for sea level rise (as per Environment Agency 2011 guidance).
6. Removal of the outer third of the Heugh Breakwater and removal of the North Pier and assuming a 100 year allowance for sea level rise (as per Environment Agency 2011 guidance).

The worst case wave heights were considered to originate from the North (0 degrees) and North East (30 degrees). Key outputs for a 0 degree wave direction are shown below in Figures 6-10.

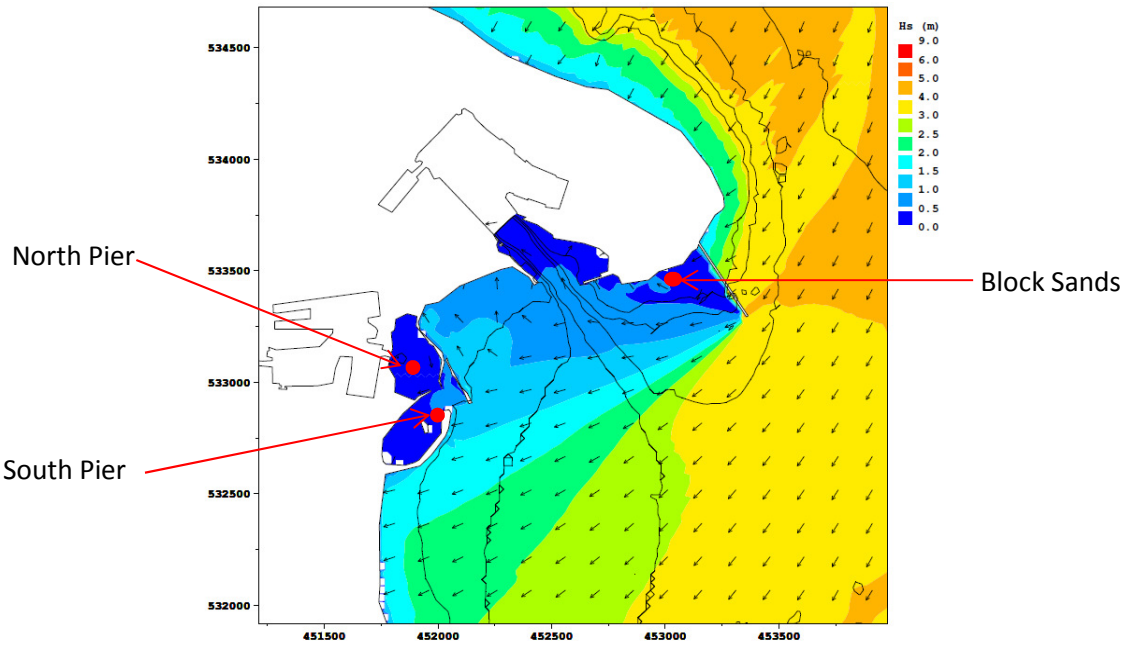

Figure 6 Wave climate with existing position of Breakwaters and piers (Dominant 1 in 1 year wave direction is 0 degrees). Source: HR Wallingford, 2011 (Red dots represent points of interest for change in wave heights as shown in Figure 10 below)

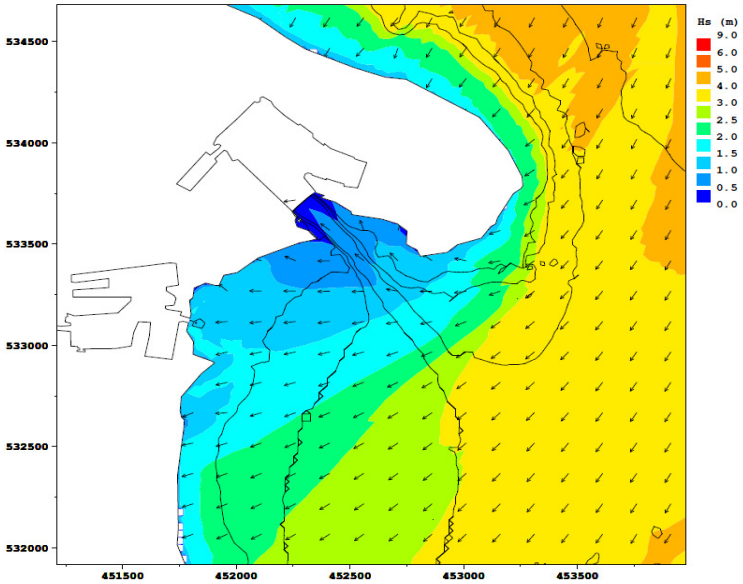

Figure 7 Wave climate with removal of all breakwaters and piers (Dominant 1 in 1 year wave direction is 0 degrees). Source: HR Wallingford, 2011

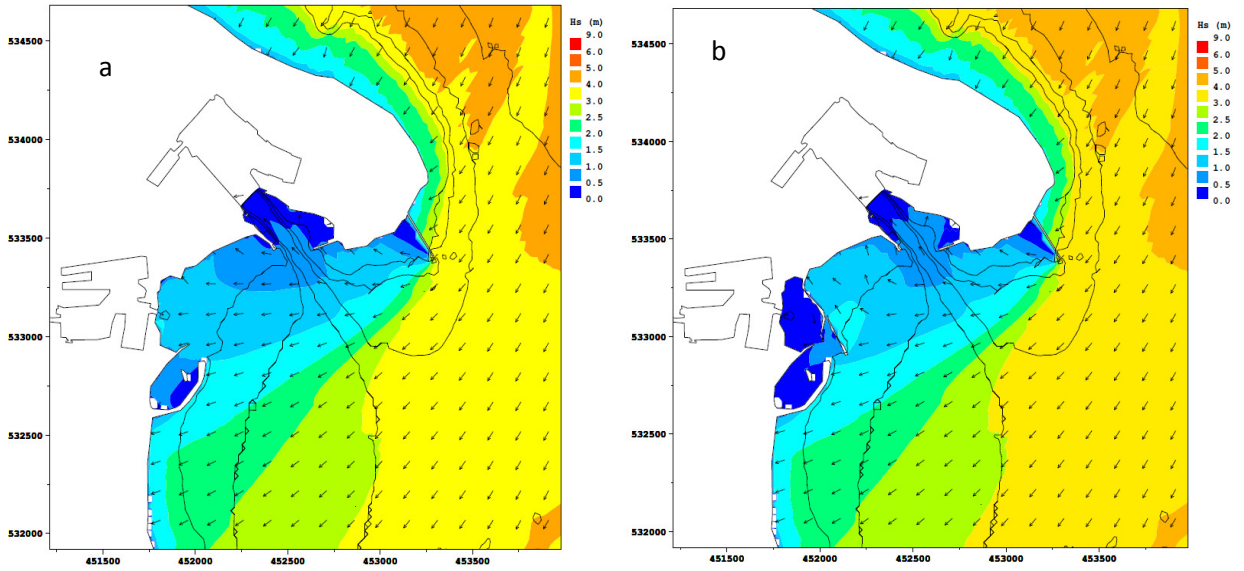

Figure 8a) Wave climate with removal of 1/3 of Heugh Breakwater (*ca.* 130m) and North Pier (Dominant 1 in 1 year wave direction is 0 degrees). 8b) Wave climate with reducing the length of the Heugh Breakwater by 1/3rd *(ca.* 130m) (Dominant 1 in 1 year wave direction is 0 degrees. Source: HR Wallingford, 2011

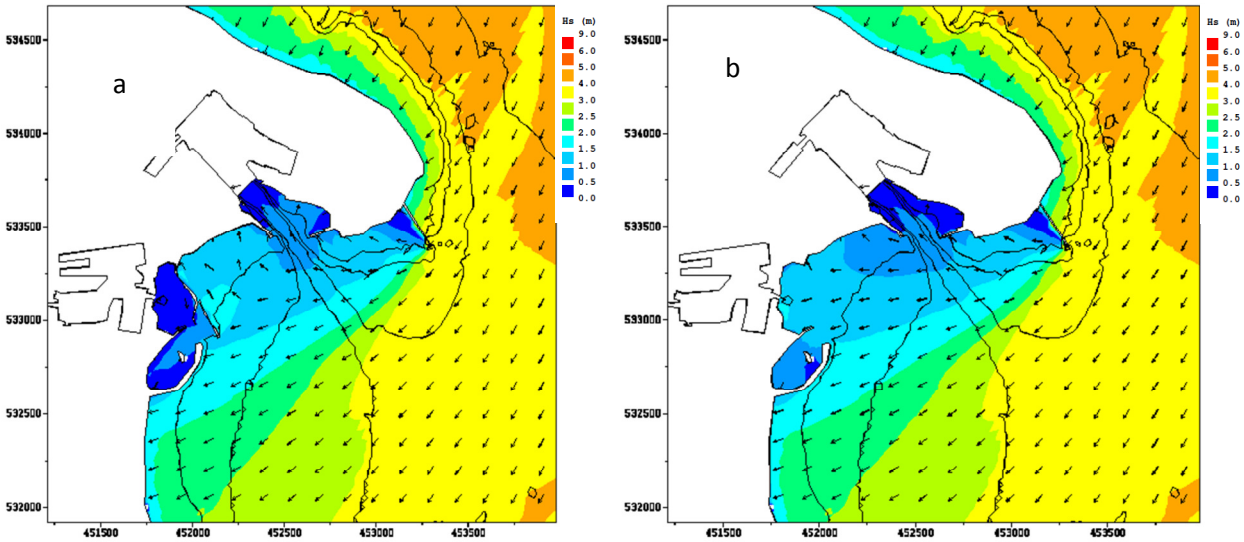

Figure 9a) Wave climate with removal of 1/3 of Heugh Breakwater(*ca.* 130m) with sea level rise b) Wave climate with removal of 1/3 of Heugh Breakwater(*ca.* 130m) and North Pier with sea level rise (both 1:1 year wave conditions from offshore direction 0° and water level = 6.0 m CD). Source: HR Wallingford, 2011

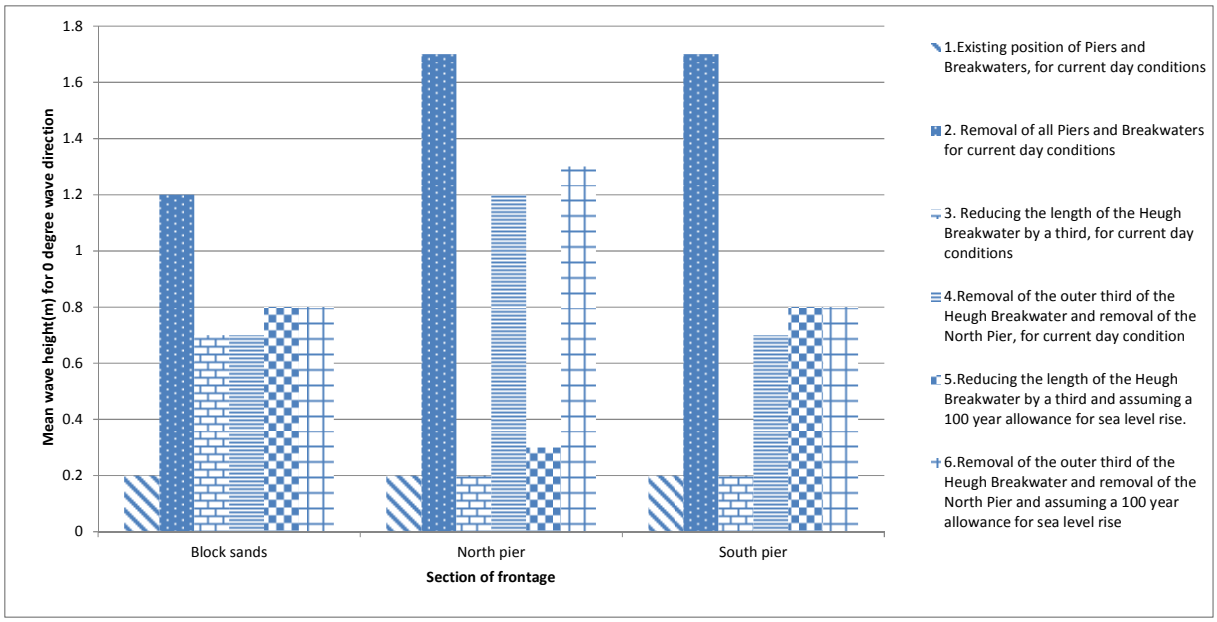

Figure 10: Changes in wave heights at Block Sands, North Pier and South Pier under each scenario (red dots for locations of each area are shown in figure 6)

The results suggest that if maintenance of the Heugh Breakwater ceased and it was allowed to fail this could alter the entire management approach required for the other coastal frontages within Hartlepool.

A strategic approach to benefit assessment

It is proposed that the benefit of a Pier or Breakwater such as the Heugh Breakwater can be considered with a more strategic approach.

The value of the assets which could currently be lost over 100 years if the defences were left to collapse (i.e Do nothing) has been assessed. Adopting a 'Do nothing' approach would mean the cessation of all maintenance and capital works. This is an unrealistic theoretical scenario used as a baseline for evaluation purposes across the wider benefit cost assessment. This includes the value of residential and commercial properties as well as infrastructure, services and tourism that could be lost and the year they might be lost. In particular, the loss of the breakwater could significantly impact tourism where visitor attractions at Block Sands and also the Marina would diminish due to reduced access for small boats. These values have then been discounted back over 100 years from current prices to calculate Present Values (PV) of benefit for each section of the frontage.

The costs of works required to protect the 'benefits' within each section of the frontage were then calculated over the next 100 years for two scenarios 1) assuming 2/3rds of the Breakwater is maintained and 2) assuming the Breakwater is no longer there. Costs have been estimated and optimised using contractor information and recent costs of construction of similar works.

The additional costs required for works if the Breakwater was to fail completely can then be estimated by the difference between the costs of works for each section of the frontage if the Breakwater is maintained (in 2/3rds) minus the costs of works needed for each section of the frontage if the Breakwater was no longer there (i.e it collapsed completely and 'disappeared').

For simplicity in this example it has been assumed that if wave heights increase by a factor of 3 (as a result of collapse) that overtopping and damage to the structures could also increase three fold; thus funding requirements to repair more damage to the structures in the lee of the Heugh Breakwater would also need to increase. This assumes a linear relationship between wave height and damage (and therefore cost of repair) but in reality impacts could be rather worse.

This is a very crude approach to assessing the value of the Heugh Breakwater, however as demonstrated by the modelling outputs, the assessment clearly shows that the value of the Breakwater in protecting other frontages is significant (Table 1). In this table Victoria Harbour and Middleton Strand have been excluded from the frontage, as the assets are privately owned and would not attract FDGiA funding.

Table 1: Outline of potential benefits

Section of frontage	**Present Value of Benefits i.e assets at risk under a Do nothing scenario (£)**	**PV Costs. Projected costs of capital/maintenance works over next 100 years (assuming 2/3rds Heugh Breakwater maintained) (£)**	**PV Costs. Potential investment needed over the next 100 years if Heugh Breakwater collapsed in 2013 (£)**	**Additional costs on other sections of the frontage required if Heugh Breakwater collapses (£)**
Block Sands	14.1 million	1.5 million	4.5 million	3.0 million
Town Wall*	9.1 million	1.9 million	5.7 million	3.8 million
Marina (North and South Piers)	33.4million	7.2 million	21.6 million	14.1 million
South Pier to Newburn Bridge	3.6 million	0.4 million	1.2 million	0.8 million
TOTAL	**60.2 million**	**11.0 million**	**33.0 million**	**21.7 million**

**Courtesy of Scott Wilson (2011).*

A more detailed assessment could be undertaken into the potential increase in wave forces on the different structures, as a result of the collapse of the Heugh Breakwater; this would give greater understanding of the proportional potential increases in maintenance that may be required and increases in capital works and costs to be sought under the Partnership Funding system.

According to this assessment, the increased revenue required over the next 100 years to maintain the other frontages if the entire length of the Heugh Breakwater collapsed in 2013 is £21.7 million. This value can be solely equated to the Heugh Breakwater; however it should be recognised that collapse of the entire structure is unlikely to happen immediately.

The value of the Breakwater will be an underestimation of the total strategic value, given that only part of the frontage has been assessed (Victoria Harbour and Middleton Strand have been excluded). The Port is very important for the local economy and the Heugh Breakwater is very important in maintaining access to the Port. Whilst the Heugh Breakwater is recognised as an important historical asset this assessment has not considered the historical value. Therefore overall value of the Breakwater is likely to be significantly higher.

Conclusions and recommendations

The paper has explored, through the thinking of the SMP2 and the Hartlepool StAR, the difficulty in maintaining an individual structure such as the Heugh Breakwater which has no simple, quantifiable 'benefit' value. This paper has attempted to estimate the value of the Breakwater depending on the potential increased works required in other areas (sheltered by the Breakwater) if it was to collapse.

It can be argued that instead of the Heugh Breakwater being considered as an individual feature within economic assessment, it should be considered in terms of the wider benefits its brings to the larger coastal system of Hartlepool Bay. As the modelling results show and as the SMP2 warns, the loss of the Heugh Breakwater could have significant impacts on other structures, in terms of their wave exposure and long-term sustainability. Even in times of austerity, it may be more cost effective to maintain the Heugh Breakwater given its wide ranging dissipative effect on the local wave climate in

Hartlepool Bay than to focus on maintaining long lengths of defences in the lee of the structure. However it should be noted that the Heugh Breakwater will not safeguard all defences against all wave directions and an important balance is needed to be achieved between maintaining the different structures to manage the coastal frontage in the long term.

It is therefore recommended that more consideration of the inherent value of coastal structures which protect further than the local assets (whether Breakwaters or Piers) should be recognised and considered within the FDGiA process and guidance, for the benefit of the wider coastal zone.

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