ABLE MARINE ENERGY PARK (MATERIAL CHANGE 2 – TR030006)

UPDATED ENVIRONMENTAL STATEMENT

CHAPTER 8: HYDRODYNAMICS AND SEDIMENT REGIME

Able Marine Energy Park, Killingholme, North Lincolnshire

www.ableuk.com

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BASIS OF REPORT

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8.1.0 Introduction

Development Consent Order Context

8.1.1 The Able Marine Energy Park (AMEP) Development Consent Order (the DCO) for the site, approved a harbour development with the associated land development, to serve the renewable energy sector. The harbour comprised a quay of 1,279m frontage, of which 1,200m is solid quay and 79m is a specialist berth formed by the reclamation of intertidal and subtidal land within the Humber Estuary.

8.1.2 The associated development for the above proposals that was consented by the DCO includes:

- Dredging and land reclamation;
- The provision of onshore facilities for the manufacture, assembly and storage of wind turbines and related items;
- Works to Rosper Road, the A160 and the A180; and
- Surface water disposal arrangements.

8.1.3 The assessment of impacts upon the Hydrodynamic and Sedimentary Regime associated with the consented scheme was initially reported in Chapter 8[1] of the Environmental Statement (ES) and in four supporting appendices that formed part of the DCO application ('the original ES'). The supporting appendices were:

- 8.1 - AMEP Estuary Modelling Studies Report (JBA);
- 8.2 - Review of Geomorphological Dynamics of the Humber Estuary (JBA);
- 8.3 - Assessment of the Effects of a Proposed Development on the South Bank of the Humber Estuary on Fine Sediments (HR Wallingford); and
- 8.4 - Able Marine Energy Park Dredging Plume Dispersion Arisings from Capital Works (HR Wallingford).

8.1.4 The following supplementary environmental information was issued during the examination of the project and Chapter 8 was re-issued as EX8.16: Chapter 8 Signposting Document[2].

- EX 8.5 - Validation of 3D Flow and Sediment Models used for Assessment of Impacts of AMEP on Fine Sediment Transport;
- EX 8.6 - Maintenance Dredge Variability;

[1] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR030001/TR030001-000312-08%20-%20Hydrodynamic%20and%20Sedimentary%20Regime.pdf

[2] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR030001/TR030001-001740-121012_TR030001_Leslie%20Hutchings%20of%20Able%20Humber%20Ports%20Limited.zip

- EX 8.7A - Modelling of Final Quay Design (Supplement to Annex 8.1 of the ES);
- EX 8.8 - Update to Longer Term Morphology Predictions in the Region of the Centrica and E.ON intakes and outfalls;
- EX 8.9 - Historical Review of Morphological Change North of HIT (2001–2010);
- EX 8.10 - Long-term Morphological Change at Embayment South of Quay;

[Weblink:https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR030001/TR030001-001613-OS-003_TR030001_Able%20UK%20Ltd_Supplementary%20Environmental%20Information_File%201%20of%202.zip]

- EX 8.14 - Hydraulic & Sediment Regime – Piled Structures;
- EX 8.15 - Effect of Moored Vessels on Flows; and
- EX 8.16 - Chapter 8 Signposting Document.

[Weblink:https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR030001/TR030001-001740-121012_TR030001_Leslie%20Hutchings%20of%20Able%20Humber%20Ports%20Limited.zip]

Consideration of Material Amendment

8.1.5 The proposed changes to the quay and dredging (the 'AMEP Amended Quay') are described in Chapter 4 (Description of Changes to Development) of this Updated Environmental Statement (UES).

8.1.6 The changes require a review of the predicted impacts of the proposed AMEP Amended Quay on tide levels, flow speeds, shear stresses, waves, deposition and erosion of sediments. This review is undertaken through modelling and desk-based assessment reported in this chapter, highlighting any changes to those impacts previously predicted for the consented scheme.

Purpose and Structure of Chapter

8.1.7 This chapter of the UES examines the likely changes to the hydrodynamic and sedimentary regime of the Humber Estuary in relation to the AMEP scheme based on the differences between the consented layout and the proposed material amendment. This principally relates to consideration of the amended quay layout.

8.1.8 The development of AMEP will cause an alteration of the local estuary shoreline and bathymetry, which may lead to changes to existing estuarine processes both in close proximity to AMEP and potentially further afield. This chapter of the UES evaluates the potential effects of the proposed amended quay design in terms of physical processes (for example changes to hydrodynamics, sediment transport, waves and geomorphology), compared to the consented layout, and these findings have been used to inform the impact assessment that is reported in other chapters of the UES.

8.1.9 The Humber Estuary is a dynamic estuarine environment with complex hydrodynamic processes controlling local and wider scale sediment transport processes. The nature of these hydrodynamic processes is determined by a range of factors including the local and general estuary morphology, wave climate, tidal range and freshwater inputs. Additionally, the Humber Estuary contains numerous man-made structures that change the flow and sediment patterns. The components of the consented scheme comprise a solid reclamation and quay that will protrude from the existing flood defence wall into the intertidal and sub-tidal area and dredging of the surrounding bathymetry for shipping access. The development will therefore result in an alteration of the local estuary morphology at Killingholme.

8.1.10 In summary, the material amendment comprises an alteration to the reclamation shape and a consequential change to the berth pocket. In addition, the assessment of the amended quay is undertaken against a Humber Estuary local channel and flats bathymetry that has evolved naturally since the previous assessment.

8.1.11 This Chapter of the UES includes consideration of the following:

- An updated assessment of the sediment plume dispersion from the construction dredging activities at the amended AMEP (see Technical Appendix UES8-1).
- Assessment of erosion rates for the amended volumes proposed to be placed at the HU081 and HU082 disposal sites (see Technical Appendix UES8-2).
- Updated modelling of the impacts of disposal of material at the HU081 and HU082 disposal sites on tides and waves and assessment of effect at Hawkins Point.
- Updated hydrodynamic modelling based upon the present-day bathymetry and the proposed AMEP Amended Quay.
- Sediment modelling to inform on changes to mud and potential sand transport for the proposed AMEP Amended Quay ; and
- A qualitative description of changes to wave impacts as a result of the AMEP Amended Quay.

8.2.0 Methodology

Changes in Legislation, Guidance and Planning Policy

8.2.1 There are no specific Directives or legislation governing solely the areas of hydrodynamics or the sedimentary regime. Legislation, guidance and policy documents are generally directed towards either the ecological, chemical or human environment.

8.2.2 Changes to the hydrodynamic and sedimentary regime have the potential to impact on these other receptors, and these effects are addressed in other chapters in this report, for example Chapter 10 on Aquatic Ecology and Chapter 14 on Commercial and Recreational Navigation. However, the Water Framework Directive recognises the link between hydromorphological characteristics and ecological quality by defining a series of hydromorphological quality elements that support the biological quality elements. These hydromorphological quality elements include parameters reflecting morphological conditions and tidal regime and, to comply with the Water Framework Directive, it is necessary for each parameter to achieve good status.

8.2.3 Further information on the requirements of the Water Framework Directive can be found in Chapter 9 on Water and Sediment Quality and in the supporting Water Framework Directive Assessment submitted with the Material Change 2 application.

National Planning Policy Framework

8.2.4 National Planning Policy Framework (NPPF) (June 2019) sets out the Government's economic, environmental and social planning policies for England. In relation to marine and coastal processes, paragraph 166 notes that in coastal areas, planning policies and decisions should take account of the UK Marine Policy Statement and marine plans.

Marine Policy Statement

8.2.5 UK Marine Policy Statement (MPS) (September 2011) provides the framework for preparing Marine Plans and for the decision-making by marine planning authorities. The MPS notes in Section 2.6.1.3 that as a general principle, development should aim to avoid harm to geological conservation interests (including geological and morphological features), including through location, mitigation and consideration of reasonable alternatives.

8.2.6 The MPS further notes in Section 2.6.8.6 that Marine plan authorities should seek to minimise and mitigate any geomorphological changes that an activity or development will have on coastal processes, including sediment movement.

East Inshore Marine Plan

8.2.7 AMEP lies within the area covered by the East Inshore Marine Plan (2014). Relevant policies include:

- Policy CC1 - Proposals should take account of:

  a) how they may be impacted upon by, and respond to, climate change over their lifetime; and

  b) how they may impact upon any climate change adaptation measures elsewhere during their lifetime. Where detrimental impacts on climate change adaptation measures are identified, evidence should be provided as to how the proposal will reduce such impacts.

- Policy BIO2 - Where appropriate, proposals for development should incorporate features that enhance biodiversity and geological interests.
- Policy DD1 - Proposals within or adjacent to licensed dredging and disposal areas should demonstrate, in order of preference:

  a) that they will not adversely impact dredging and disposal activities;

  b) how, if there are adverse impacts on dredging and disposal, they will minimise these;

  c) how, if the adverse impacts cannot be minimised they will be mitigated; and

  d) the case for proceeding with the proposal if it is not possible to minimise or mitigate the adverse impacts
- Policy ECO1 - Cumulative impacts affecting the ecosystem of the East marine plans and adjacent areas (marine, terrestrial) should be addressed in decision-making and plan implementation.
- Policy GOV1 - Appropriate provision should be made for infrastructure on land which supports activities in the marine area and vice versa.
- Policy GOV2 - Opportunities for co-existence should be maximised wherever possible.
- Policy PS3 - Proposals should demonstrate, in order of preference:

  a) that they will not interfere with current activity and future opportunity for expansion of ports and harbours

  b) how, if the proposal may interfere with current activity and future opportunities for expansion, they will minimise this

  c) how, if the interference cannot be minimised, it will be mitigated

  d) the case for proceeding if it is not possible to minimise or mitigate the interference
- Policy SOC3 - Proposals that may affect the terrestrial and marine character of an area should demonstrate, in order of preference:

  a) that they will not adversely impact the terrestrial and marine character of an area

  b) how, if there are adverse impacts on the terrestrial and marine character of an area, they will minimise them

  c) how, where these adverse impacts on the terrestrial and marine character of an area cannot be minimised they will be mitigated against

  d) the case for proceeding with the proposal if it is not possible to minimise or mitigate the adverse impacts.

Guidance

8.2.8 There are a number of plans and guidance documents that are of some relevance to the hydrodynamic and sedimentary regime; these are detailed below, and where appropriate are taken into account in this Chapter.

8.2.9 The Humber Estuary Management Scheme Annex D (Environment Agency, 2004) provides guidance on the noted effects of dredging and their significance in the estuary.

8.2.10 The Humber Maintenance Dredging Baseline Documents (ABP Humber Estuary Services, 2008 and 2014) provide information on the maintenance dredging regime including quantities and locations of disposed material in the estuary.

8.2.11 The Humber Estuary Coastal Habitat Management Plan (CHaMP) (Environment Agency, 2005) provides mechanisms for delivering flood and coastal defence schemes which comply with the requirements of the Habitats Directive.

8.2.12 The Humber Flood Risk Management Strategy: Planning for the Rising Tides (Environment Agency, 2008) set out the Environment Agency's strategy for managing the flood defences of the Humber Estuary over the next 100 years. An emerging policy, Humber 2100+, is being developed in response to new technical information.

8.2.13 The Humber Estuary Coastal Authorities Group Flamborough Head to Gibraltar Point Shoreline Management Plan (Scott Wilson, 2010) provides a plan for managing flood and erosion risk for the area of coastline encompassing the outer Humber Estuary. This plan details the development of a sustainable management approach and looks at the short, medium and long term.

8.2.14 The East Riding of Yorkshire Biodiversity Action Plan, the Lincolnshire Biodiversity Action Plan and the Hull Biodiversity Action Plan all aim to actively conserve priority habitats and species locally.

8.2.15 Guidance and best practice for the calibration and validation of hydrodynamic models used to simulate estuarine processes is provided by the Environment Agency technical report, Quality Control Manual for Computational Estuarine Modelling (Bartlett, 1998).

8.2.16 Guidance and best practice for predicting morphological change in estuaries is provided in the EA report, "Coastal morphological modelling for decision-makers" (EA, 2019).

Scoping Opinion

8.2.17 The Planning Inspectorate's comments relating to hydrodynamics and sediment are listed in Table 8-1 below.

Table 8-1: Scoping Opinion

Page & Paragraph No.	Scoping Opinion	Comments	Outcome	Reference within UES
4.2.1 Para 6.10	Wave Modelling	The Scoping Report proposes to conduct desk study assessment of changes to wave dynamics rather than conducting further wave modelling. The Scoping Report argues that the	Further wave modelling has been undertaken	8.4.0

Page & Paragraph No.	Scoping Opinion	Comments	Outcome	Reference within UES
		proposed changes represent a likely minor change in impact characteristics. The Inspectorate notes that the Humber Estuary is a dynamic environment, with complex hydrodynamic processes, as such small changes of this sort may result in substantial change to impact characteristics. The Applicant should make effort to agree the approach to wave modelling with relevant consultation bodies including the need for further wave modelling to account for the proposed changes.	with respect to disposal sites HU081 and HU082 to inform the updated ES.	
4.2.2 Para 6.6	Assessment Methodology	The Inspectorate welcomes the commitments made in the Scoping Report to update the assessment with relevant information and making use of available computer modelling to aid the assessment. The Inspectorate notes that the models proposed to inform the assessment are generally those that were used for the original ES and are now several years old. The Applicant should make effort to agree the suitable modelling techniques with relevant consultation bodies.	Latest versions of modelling software have been used along with updated bathymetry	8.2.0
4.2.3 Para 6.8	UKCP18 and sea level rise	The Inspectorate notes the commitment to updating the assessment of effects based on relevant information set out in UKCP18 guidance particularly in relation to sea level rise and Representative Concentration Pathways (RCPs). The Inspectorate is aware that the application of latest guidance may alter the findings of the original assessment. The Applicant should make effort to ensure that the approach to the assessment is agreed with relevant consultation bodies including the EA. The relationship between this assessment and the assessment of the Proposed Development's vulnerability to climate change should be explained.	New overtopping calculations of the quay have been undertaken using the EA's Humber Extreme Water Levels (2020) V2, 18th February 2021. Results are reported in Chapter 13.	Chapter 13 8.2.0
4.2.4 Para 6.9	Baseline assessment	The Scoping Report explains that updated information is available to inform the updated baseline assessment for estuary morphology. The Scoping Report does not explicitly state that this will be carried out. For the avoidance of doubt the Inspectorate considers that the	Latest versions of modelling software have been used along with	8.2.0

Page & Paragraph No.	Scoping Opinion	Comments	Outcome	Reference within UES
		baseline assessment should be updated and informed by the most relevant and up to date information available. The Applicant should make effort to agree the need for further sampling, if required, to inform the assessment with relevant consultation bodies including the MMO.	updated bathymetry.	
4.2.5 Para 6.12	Assessment of significance	The Scoping Report explains that the updated ES will focus on impacts to processes and not receptors therefore it is inappropriate to assign significance levels. The Inspectorate generally accepts this conclusion but points out that the EIA Regulations require an assessment of the 'likely significant effects'. The Applicant should ensure that impacts to processes likely to result in consequential effects for relevant receptors should be assessed. This would include consequential impacts to receptors reliant on habitats affected by process change e.g. intertidal mudflat and saltmarsh.	Likely significant effects are assessed in other Chapters of the UES.	Chapters 9, 10 & 14
4.2.6	Table 7	The Inspectorate notes the proposal in the Scoping Report to dispose of significant quantities of dredged material at the relevant disposal location (HU082). The Inspectorate considers that the updated ES should include information to adequately characterise the disposed material and its intended disposal location in order to inform a detailed assessment of the likely significant effects. The Applicant should make effort to agree the approach to the characterisation and assessment with relevant consultation bodies including the MMO.	This information has been provided.	See Technical Appendix UES8-2.
4.3.7 Paras 6.16- 17	Modelled impacts	The Inspectorate notes the intention in the Scoping Report to update the assessment in accordance with the approach undertaken in Chapter 8 of the original ES. The Applicant should make effort to agree this approach with relevant consultation bodies and if necessary, update the approach to modelling in order to be consistent with up-to- date methods of assessment.	Latest versions of modelling software have been used along with updated bathymetry.	8.2.0

Page & Paragraph No.	Scoping Opinion	Comments	Outcome	Reference within UES
Cumulative effects				
4.19.1 Table 6	South Humber Bank Energy Centre	The Scoping Report suggests that the South Humber Bank Energy Centre located approximately 7km from the Proposed Development is too remote for it to be assessed cumulatively with the Proposed Development. The Inspectorate does not agree and notes the comments received from the EA in particular the potential for wider scale impacts through the hydrological regime. The updated assessment of cumulative effects should include an assessment of likely significant effects with South Humber Bank Energy Centre. The Application should make effort to agree the approach to the assessment with relevant consultation bodies.	No hydrodynamic and sediment regime effects are predicted to impact the South Humber Bank Energy Centre	8.4.0
4.19.3 n/a	Middle Estuary developments	The Inspectorate agrees with comments received from Hull City Council that cumulative effects with major development proposed in the middle estuary should be assessed in the updated assessment. The Applicant should make effort to agree the list of other developments located within the middle estuary that should be included in the updated assessment with relevant consultation bodies.	There are no cumulative projects to be considered relevant to this topic.	8.2.0
In combination				
4.20.2 n/a	n/a	The EA have highlighted the need for the Water Framework Directive assessment to include other activities that impact the same receptor. The Inspectorate considers that in-combination effect assessment is more typically associated with the Habitats Regulations assessment process. However, assessing inter-related impacts to receptors is within the EIA process and should be assessed in the updated ES where significant effects are likely to occur. The Applicant may wish to address inter-related impacts within relevant aspect chapters to avoid a separate chapter of this sort in the updated ES.	There are no in-combination projects to be considered relevant to this topic. The placement of dredged material to HU081 and HU082 has been shown to have no effect on the	8.2.0

Page & Paragraph No.	Scoping Opinion	Comments	Outcome	Reference within UES
			ongoing coastal erosion at Hawkins Point and will also have no interaction with the proposed managed realignment further to the east.	

Additional Consultation

8.2.18 Following consultation on the PEIR, the following responses relevant to this Chapter have been received from the Environment Agency, MMO and CGEN.

Table 8-2: EA, MMO and CGEN comments on PEIR

Party	Comment	Outcome	Reference within UES
Environment Agency (EA)	EA - Paragraph 8.1.11 refers to a qualitative assessment of the amended quay on wave impacts, but no reference to any potential changes in wave climate arising from the proposed amendment to the dredge disposal. We require clarification that such an assessment will be undertaken.	Changes to waves arising from the dredge disposal at sites HU081 and HU082 are presented in Section 8.4.34	8.4.34
Environment Agency (EA)	Paragraph 8.2.16 refers to 2000 guidance on modelling morphological change. We would draw the applicant's attention to some more recent work undertaken as part of the iCOAST project. This can be easily accessed via .gov.uk via the following link: https://www.gov.uk/flood-and-coastal-erosion-risk-management-researchreports/ coastal-morphological-modelling-for-decision-makers	Updated in para. 8.2.16.	**Error! Reference source not found.**
Environment Agency (EA)	Paragraphs 8.3.3-8.3.5 and 8.4.15-8.4.24 set out the applicant's assessment of waves, including on overtopping via a qualitative assessment. The evidence presented uses the	An updated overtopping assessment for the quay is included in Chapter 13. Additional text provided in	Chapter 13 8.2.0

Party	Comment	Outcome	Reference within UES
	previous climate change guidance, but no additional narrative has been presented to explain how this would change with the latest guidance and updated estuary water levels used in the remainder of their assessments. In addition, we have been unable to locate the wind and wave rose diagrams setting out the dominant direction for both the amended quay and the disposal site. These were presented and discussed in recent meetings and should form part of future formal submission/s as they are key to demonstrating both the assessment done and therefore how the conclusions are met.	Chapter 8 relating to latest guidance. The relevant wave rose is presented in Chapter 13.	Chapter 13
Environment Agency (EA)	Paragraph 8.4.5 refers to Appendix U9-2 with regards the likely behaviour and erosion of the clay placed at HU082, this should be amended to read Appendix 8-2. Notwithstanding this error, paragraph 8.4.1 refers to 1M tonnes of clay that will be deposited at HU082 and an additional 1.1M tonnes that will no longer be required for beneficial use. Appendix U8-2 has been undertaken on the basis that previously an estimated 455,000 cubic metres would be placed at HU082, and now an assessment of 590,000 cubic metres has been undertaken. Can the applicant confirm the actual volumes they are seeking to dispose of at HU082 and how that compares to this assessment/future assessments which are expected as a result of commitments in para 8.4.6 . These will be key to understanding both the impacts on habitats in this part of the estuary as well as erosion and impacts on the defences as a result of this change.	Wave modelling has now been undertaken to inform on this point. See paragraph 8.4.34 and following paragraphs. Disposal is considered to both HU081 and HU082. For purposes of assessing potential impact on currents and waves the two sites have been simulated as being filled with dredged material to a level of -5.3 m CD. This is representative of a volume of 1.1 Mm^3 at HU081 and 1.6 Mm^3 at HU082. This is considered to represent a worst case scenario based on the existing marine licence permitting dredge arisings to be deposited at HU082 up to a level of -5.3mCD. The actual volume to be placed at these sites is subject to the dredging methodology and described in the Dredging Plan (Appendix UES4-2).	8.4.34 onward
Environment Agency (EA)	Paragraph 8.8.3 notes there are some potential acceleration of flows on the ebb tide on the downstream end of the quay. We request further clarification from the applicant as to their proposed mitigation to this potential impact.	The flow acceleration for the amended quay on the ebb tide is predicted to occur a slightly further inshore and over a smaller area than was the case for the consented quay. The increased ebb tide currents	8.4.26 onward

Party	Comment	Outcome	Reference within UES
		are in line with the AMEP quay and extends downstream for up to 500m on spring tides. Peak speeds on the ebb tide at South Killingholme Oil Jetty may increase by up to 0.3m/s and at the Immingham Gas Jetty by up to 0.1m/s.	
MMO	2.1. As discussed on the teleconference 23 April 2021, it was agreed that the Applicant would review the potential impacts on coastal and physical processes associated with: • The use of a cutter suction dredger (CSD) and subsequent split-hopper barge placement and its potential impacts on suspended sediment concentrations, following a similar method to that already used in the assessment of backhoe dredging and trailing suction hopper dredging, as summarised in the appendix "Sediment Plume Dispersion from Dredging"; and • Disposal of non-erodible material at HU081, following a similar method to that previously used in the assessment of disposal at HU082, as summarised in the appendix "Erosion of Placed Clay".	The use of CSD for the capital dredge and the associated use of barges for placement at HU081 and HU082 has been simulated and effects assessed (see Appendix UES8-1 and Section **Error! Reference source not found.** 8.4.1.) Changes to the flow and wave conditions associated with placement of dredged material at HU081 and HU082 are presented in paragraph 8.4.26 onwards (flows) and paragraph 8.4.33 (waves). The assessment of how glacial tills mechanically dredged by backhoe dredger and placed by barge at disposal sites HU081 and HU082 has been assessed and is presented in paragraph 8.4.1 and following paragraphs and in Appendix UES8-2).	Section **Error! Reference source not found.** 8.4.26 8.4.33
MMO	It was also agreed that the applicant would investigate mitigation associated with the disposal of non-erodible material, including: • the potential use of a CSD and subsequent split-hopper barge placement. The use of a CSD may help break up non-erodible material prior to disposal and consequently aid dispersal from the site; • appropriately dividing the amount of material disposed of at each site is a potential mechanism to aid dispersal from each site and reduce potential risk associated with safe navigation; and	The volumetric capacity of HU081 and HU082 assessed in the hydrodynamic modelling is a combined sum of about 2.7 Mm^3. Material that has been dredged by CSD and is placed at these sites will be more readily eroded and dispersed than material placed at the sites arising from BHD dredging. A combination of CSD and BHD may be used. Mitigation measures have been proposed in Section 8.5.2	**Error! Reference source not found.**

Party	Comment	Outcome	Reference within UES
	dispersal of non-erodible material from the disposal site will be monitored. If the formation of discrete mounds due to disposal via split-hopper barge appear to be hindering dispersal (as discussed in the appendix “Erosion of Placed Clay”), the subsequent use of a plough dredger to ‘cap’ the mounds and fill the adjacent troughs is a potential mechanism to aid dispersal and reduce potential risk associated with safe navigation.	where consideration is given to using HU082 preferentially for material arising from BHD operations and HU081 and HU082 in combination for placement from CSD operations. Any placement of material arising from BHD will likely occur after placement of material arising from CSD operations. Whilst a plough dredger could be used as a last resort to redistribute any high spots arising from disposal operations, extensive plough operations at the disposal site are not proposed.	
CGEN	The former power station is designated as a site for energy projects and as such the cooling water infrastructure and route remains viable for providing cooling water abstraction and discharge (subject to an environmental permit and other consents as necessary) for electricity generation uses in future. We note from the PEIR that there are predicted changes to the original assessment of accretion and deposition that accompanied the DCO. These changes to the consented project therefore have the ability to impact on the utility of the cooling water infrastructure in future. We are concerned that the changes will present additional / new impacts on the pipework that will affect its utility in the future. If you are able to provide additional environmental information prior to making the application – at the very least additional sensitivity analysis – we would be happy to review this.	Changes to predicted accretion at both the Uniper and CGEN cooling infrastructure are summarised in this UES.	8.4.8 8.4.12 8.4.16 8.4.20 8.4.67 – 8.4.68

8.2.19 Subsequent to submission of the PEIR and ahead of submission of the UES, further consultation meetings have been held between Able UK, its consultants, and the MMO and Environment Agency to present methods and results, and to discuss and take feedback on the hydrodynamic and sediment assessments for the UES. Further information regarding these meetings can be found within Chapter 5: Scoping and Consultation and the Consultation Report submitted in support of the Material Amendment application.

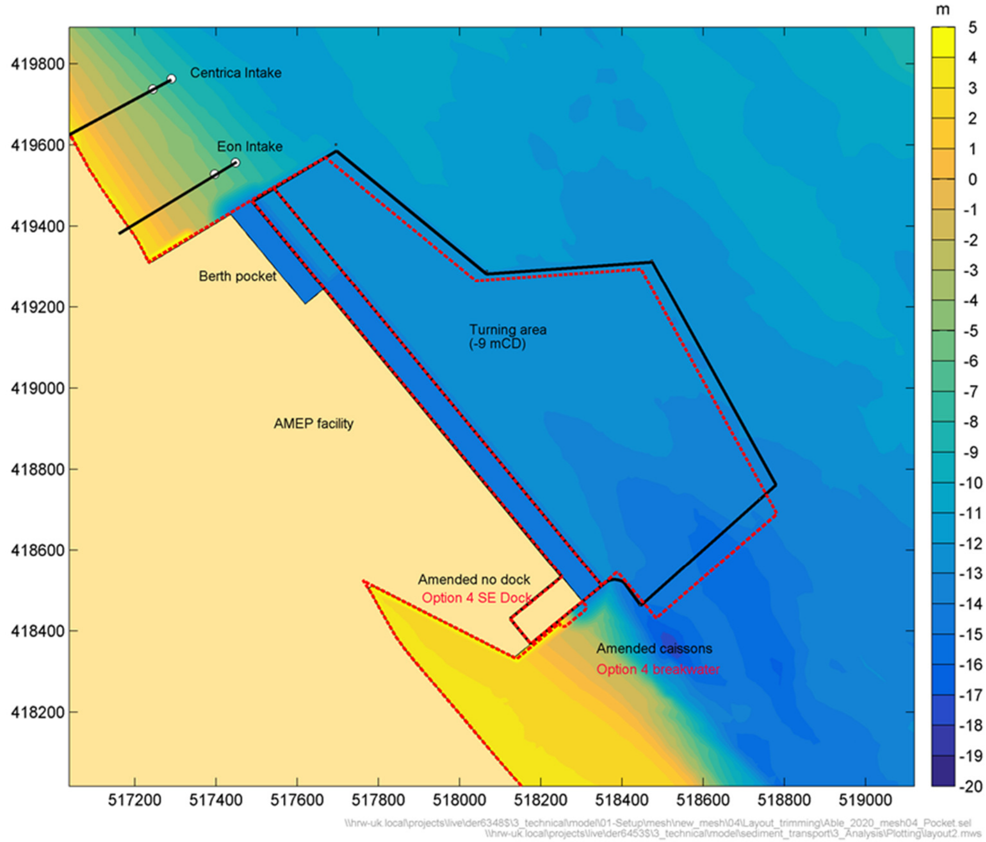
Assessment Methodology

8.2.20 An assessment of the effects of the AMEP Amended Quay on hydrodynamic and sedimentary processes has been carried out using appropriate numerical modelling tools. This section provides an overview of the modelling techniques utilised, which include hydrodynamic modelling, sediment transport modelling, sediment plume modelling and nearshore wave transformation modelling. The modelling has been used to simulate the baseline conditions in hydrodynamic and sedimentary processes in the Humber Estuary, and subsequently to determine and quantify the predicted effects of the AMEP Amended Quay on these baseline conditions. Detailed descriptions of the development of the original models are provided in JBA Consulting (2011a & b) and HR Wallingford (2011a & b), respectively Annexes 8.1, 8.2, 8.3 and 8.4 of the original ES. Updated models used in the present hydrodynamics and sediment studies are described below.

Study Area

8.2.21 As was used for the consented layout, the study area included in the model domain extends from Spurn Head to Trent Falls. The layout at the AMEP Amended Quay and associated dredging is shown in Figure 8-1, using up to date bathymetry data from Defra[3] . Also overlain on Figure 8-1 is the original model for the AMEP Quay (Option 4) for comparison. The red line is the original model and the black line the amended layout.

Figure 8-1: Comparison of AMEP Amended Quay layout (black line) with the original Option 4 layout (red line)



[3] https://environment.data.gov.uk/DefraDataDownload/?Mode=survey

Hydrodynamic Modelling

8.2.22 An investigation of the impacts of the AMEP on hydrodynamic processes within the Humber Estuary, and the changes arising from the amended quay design, has been carried out using computer modelling techniques.

8.2.23 A three dimensional (3D) hydrodynamic numerical flow model was constructed, calibrated and validated in order to simulate baseline flows within the estuary. The model grid extends from Spurn Head to Trent Falls.

8.2.24 The same model domain was used for assessment of the amended quay layout as for the consented layout (DCO model layout). Bathymetry was updated to reflect the present day.

8.2.25 Alterations to the model grid were made to incorporate the changes represented by the AMEP Amended Quay. Comparisons between the results of model simulations using this grid with those of the updated baseline model reveal the predicted effects of the scheme on estuarine hydrodynamic processes.

8.2.26 Figure 8-1 shows the proposed AMEP Amended Quay layout as compared with the DCO model layout (Option 4). The overall reclamation is slightly smaller with the AMEP Amended Quay than for the consented layout (3% reduction in reclamation area). The assessment of the AMEP Amended Quay layout used the TELEMAC modelling system and updated model bathymetry, to assess impacts to flows, water levels, cohesive and non-cohesive sediments.

Sediment Transport Modelling

8.2.27 The assessment of the AMEP Amended Quay used an up-to-date release version (V8P1R1) of the same TELEMAC modelling system previously used for the mud transport modelling and for the tidal flows for navigation assessment in the original ES, to assess the changes reported below.

8.2.28 For mud transport, the three-dimensional version of the TELEMAC code was used (TELEMAC-3D). The cohesiveness of mud, which is transported in suspension, means that additional processes are required in the model such as flocculation which leads to variable settling velocity of the suspended mud in both time and space. This leads to more complexity in the vertical profile of suspended concentration which cannot be modelled simply by assuming a Rouse profile (such as for sand transport) and hence a 3D model is required to model mud transport accurately. For sand transport, which is dominated by bedload transport, the two-dimensional depth-averaged version of the TELEMAC hydrodynamic model (TELEMAC-2D) was used.

8.2.29 It should be noted that all sediment transport models involve a high level of uncertainty, particularly when used for the purposes of estimating morphological change. Relevantly, at the conclusion of the Examination of the AMEP application in 2012, the Examining Authority observed in the '*Panel's Findings and Recommendations to the Secretary of State*'[4]:

'10.198 The problem that emerged very clearly for the Panel was not just the complexity of the proposals but the complexity of the environment itself. The River Humber is manifestly a very

[4] https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR030001/TR030001-002249-The%20Able%20Marine%20Energy%20Park%20Order%20201X%20Panel's%20Findings%20and%20Recommendations%20with%20Appendices.zip

complex and highly dynamic ecosystem.

10.199 At an early stage in the examination the applicant noted –

'The prediction of geomorphological impacts (which occur over decadal timescales) is not a precise science. When the Environment Agency commissioned an assessment of geomorphological change due to sea level rise in order to inform the Coastal Habitat Management Plan for the Humber Estuary, they obtained results from three separate numerical models; all provided different results with a significant range of impacts predicted.' [REP008, para 22.142].

10.200 We can be sure that the River Humber eco-system will change, with or without human intervention. Predicting the nature and extent of that change <u>with any degree of precision, however, seems to the Panel, to be a more-than-human skill'</u> (paragraphs 10.198 -10.200, underline added).

Significance of Effect

8.2.30 This chapter defines the predicted changes to the hydrodynamic and sedimentary regime of the Humber Estuary resulting from the AMEP Amended Quay. As these are changes to processes rather than impacts on receptors it is not appropriate to assign significance levels.

8.2.31 The approach adopted in this Chapter is to describe and, where possible, quantify any predicted changes. The implications of the predicted changes to the hydrodynamic and sedimentary regime are assessed in terms of the significance of the potential impacts on various environmental parameters (e.g. aquatic ecology, water quality, commercial fisheries, etc.) in the relevant chapters of this UES. Similarly, any measures that may be required in order to mitigate a potential impact on a receptor arising from a predicted effect on the hydrodynamic and sedimentary regime of the estuary are described in the relevant Chapters.

Sensitive Receptors

8.2.32 There are a number of receptors that may be affected by changes to the hydrodynamic and sedimentary regime. These include sensitive environmental receptors such as intertidal mudflat and saltmarsh habitats, and operational receptors including vessels navigating in the vicinity of AMEP, nearby port facilities (C.Ro Port Killingholme [the former Humber Sea Terminal], Humber Work Boats, South Killingholme Oil Jetty, Immingham Gas Jetty, Humber International Terminal, Immingham Outer Harbour [IOH], Immingham Bulk Terminal, Immingham Docks), Uniper and CGEN intakes and outfalls. These are shown in **Error! Reference source not found.**.

Figure 8-2: Details of AMEP location showing potential sensitive receptors

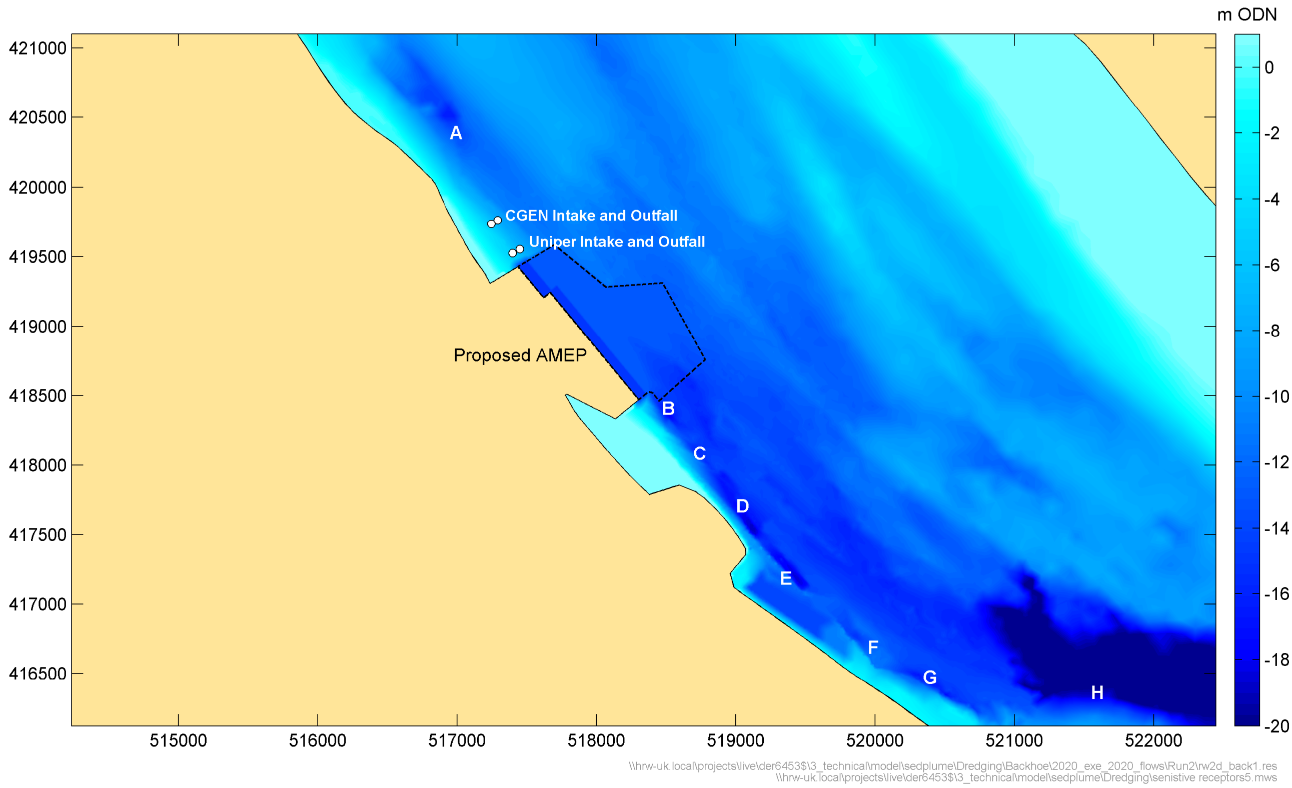


Table 8-3: Names of sensitive receptors shown in Figure 8-2

Letter	Name
A	Humber Sea Terminal
B	South Killingholme Oil Jetty (SKOJ)
C	Immingham Gas Jetty
D	Humber International Terminal
E	Immingham Bulk Terminal
F	Western Jetty
G	Eastern Jetty
H	Immingham Oil Terminal

8.3.0 Baseline Conditions

DCO Baseline (current and future)

Hydrodynamic Regime

Water levels

8.3.1 The Humber Estuary is a macro-tidal estuary with a spring tidal range of 6.0 - 7.0m at the site of the AMEP. High water levels increase further upstream as tidal flows are constricted by the narrowing estuary. Mean High Water Spring levels at Goole are 1.3m above levels at the estuary mouth at Spurn Head.

Currents

8.3.2 Currents within the estuary are dominated by the tide. Upstream, the monthly average freshwater flow rate at Trent Falls of 250 m^3/s has been estimated from Environment Agency data, with a variability of ±110 m^3/s (Townend and Whitehead, 2003). Observations of currents near to Killingholme used to calibrate the hydrodynamic model show that magnitudes can reach approximately 1.5 m/s offshore and 1.1 m/s in the nearshore zone during a modest spring tide (15th May 2010). Predictions of currents provided by the United Kingdom Hydrographic Office Admiralty TotalTide software, suggest ebb-flow dominance of current magnitudes throughout the middle estuary. Peak flows occur within the deeper channels of the estuary, with the greatest flow speeds of over 2.0 m/s occurring in Halton Middle, upstream of Killingholme between Halton Flats and Paull's Sand.

Waves

8.3.3 The wave climate at South Killingholme is dictated by the local fetch lengths over which the wave-generating force of wind stress can act. Fetch lengths across the estuary to the north bank are the shortest, with longer lengths upstream and downstream, leading to larger waves from these directions.

8.3.4 A still water level/wave height joint probability analysis study provides details of the prevailing wave climate at South Killingholme (ABPmer, 2007). An analysis of wave heights over a multi-year period highlighted the dominance of south-easterly waves, followed by waves propagating from the north-west in the direction of Hull.

8.3.5 For the consented scheme, the future wave scenario in relation to the existing adjacent defences, modelled a 1:200 year wave event based on the joint probability of wave height and water levels in 2033. This included a 0.21 m sea-level rise from 1991 levels based on the PPS25 guidance.

8.3.6 Wave overtopping calculations for the proposed quay were performed using values for water level, wave height and wave period specified in ABPmer (2007). Calculations were carried out for the consented scheme for a range of return periods (1:2-year, 1:5-year, 1:10-year and 1:200-year) joint probability events, with 100 years of projected climate change added (i.e. 100 years of sea level rise and increased wave heights) in accordance with PPS25. This assessment has been updated and is reported in Chapter 13 of this document, using the most recent Environment Agency data.

Bed shear stresses

8.3.7 The shear stresses experienced on the bed of the Humber Estuary determine the evolution of the morphology. Bed shear stresses are a result of both wave and current forcing, primarily through the friction they exert on the bed. The total bed shear stress consists of skin friction, form drag and the effects of sediment transport (via momentum transfer between grains). The stresses due to wave action are irregular and determined mainly by wind variability but also locally by ship wake. However the tidal currents within the estuary are far more predictable and regular. The large magnitudes of the currents in the deep channels of the estuary mean that their contribution to the bed shear stress dominates here. Wave-related bed shear stress is more significant in the shallower sub-tidal and inter-tidal areas.

Estuary Morphology

8.3.8 The sub-tidal bed of the Humber Estuary consists of silt, sand, gravel, boulder clay and chalk at different locations. In shallow subtidal and intertidal areas along the banks of the estuary the bed consists mostly of silt and fine sand. Particle size analysis of intertidal and sub-tidal bed material around the AMEP site has generally revealed surface sediments to comprise: muds on the upper intertidal areas; sandy muds on the lower intertidal areas, and; sandy muds, muddy sands or slightly gravelly muddy sands on the subtidal areas (IECS, 2010a)[5].

8.3.9 A site investigation involved the collection of multiple vibrocore samples from the site of the proposed scheme (Buro Happold, 2010)[6]. These showed a surface alluvium layer consisting of varied grain sizes, with median values equally distributed in the range 0.01mm to 0.3mm. A thin layer of sand and gravels was intermittently observed below this, with a thicker layer of stiff glacial till underneath, though this structure shows significant variation with location.

8.3.10 For the most part, the sub-tidal areas of the Outer Estuary (generally considered as the Estuary downstream of Grimsby) are predominantly sand. Further upstream more mixed sediments are typically found, often consisting of silty sand. On the lower intertidal the sediments generally consist of sandy silt, fining to silt at the higher levels.

Sedimentary regime

8.3.11 The water within the Humber Estuary contains very high concentrations of fine suspended sediment. On a given tide up to 1.2×10^6 T of sediment may be in the water column (Townend and Whitehead, 2003). Fluvial input amounts, on average, to 335 T of sediment per tide compared to the average tidal exchange of 1.2×10^5 T per tide at the mouth. Around 430 T per tide is deposited in the estuary with a net marine import of around 100 T per tide.

8.3.12 The sedimentation patterns are therefore dominated by tidal flow, with approximately only 3 percent of sediment entering the estuary originating from upstream. Much of the sediment entering the estuary from the mouth is returned to the sea on the ebb tide. However, a considerable amount is deposited across intertidal areas or shifted around sub tidally. An annual rate of infilling of between 2.6 and 6.6×10^5 m^3 has been estimated (ABP Research, 1999).

5 https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR030001/TR030001-000366-7.2%20-%20Water%20and%20Sediment%20Quality.pdf

6 https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/TR030001/TR030001-000368-7.4%20-%20Ground%20Engineering%20Interpretative%20Rpt.pdf

8.3.13 There is a large degree of variability in the suspended sediment concentration (SSC) throughout the estuary. The position of the turbidity maximum varies seasonally between Hull and Selby depending on the balance of freshwater/tidal water flows (Uncles et al, 1998) and the availability of sediment is governed by the hydrodynamic and sediment transport processes, including wave dynamics, tidal asymmetry and salinity-induced circulation. British Transport Docks Board measurements (BTDB, 1970) report a range within the middle and outer estuary between 300 mg/l and 1,900 mg/l. Further upstream in the Upper Estuary concentrations regularly reach 5,000 mg/l (Uncles et al., 1998). At times concentrations of up to 20,000 mg/l have been recorded in the system (ABPHES, 2008).

8.3.14 Maintenance dredge volumes in the Humber Estuary vary considerably from year to year. Between 1985 and 2007 the total mass of material dredged from and disposed into the estuary was in the range 9 to 17 million wet tonnes per annum (ABPHES, 2008). The Sunk Deep Channel (SDC) was originally dredged to allow deep-draught vessels to use deep-water terminals at Immingham. It experiences significant annual variation in accumulated sediment, requiring an annual maintenance dredging ranging from none to 9 million tonnes per annum between 1985 and 2007. Between 2016 and 2019 the average wet tonnage of sand disposed at disposal site HU080 under the licence for the Sunk Dredged Channel was 1,193,000 tonnes (Licence Return L/2014/00429/2). The quantities varied from a minimum of 920,000 tonnes in 2016 to a maximum of 1,431,000 tonnes in 2018.

8.3.15 Maintenance dredge material at the `Humber 3A` disposal site (also known as 'HU060') was mainly from material arising from dredging of Immingham Docks, jetties and terminals. Records showed significant variation here also, with disposals in the range 1-7 million tonnes from 1985 to 2007. The Humber Maintenance Dredging Baseline Document (ABP Humber Estuary Services, 2008) stated that there is no apparent trend in dredge volumes at Immingham. More recent maintenance dredging figures for years up to 2011 were also provided and analysed for the consented development. An update to the maintenance dredging figures (ABPHES, 2014) includes those updated figures plus figures for two further years (2012 and 2013). Between 2016 and 2019 the disposal to this site was under two licences (Licence Return L/2014/00429/2 – Immingham riverside berths and approaches, and Licence Return L/2016/00242/1 - C.RO Ports North Killingholme (Berths 1 to 6 plus approaches)). The assumed bulk densities of the materials placed under these two licences are different with the Immingham riverside berths reflecting a lower density deposit. The average wet tonnage of silt dredged from the Immingham riverside berths and approaches for the period 2016-2019 was 3,447,000 tonnes (this is locations B to H in Figure X-2-2). The quantities varied from a minimum of 2,965,000 tonnes in 2018 to a maximum of 3,913,000 tonnes in 2016. For the North Killingholme berths (location A in Figure X.2.2) the average dry mass of silt placed was 503,000 tonnes. The quantities varied from a minimum of 335,000 tonnes in 2018 to a maximum of 799,000 tonnes in 2016.

Hydrodynamics and sediment transport

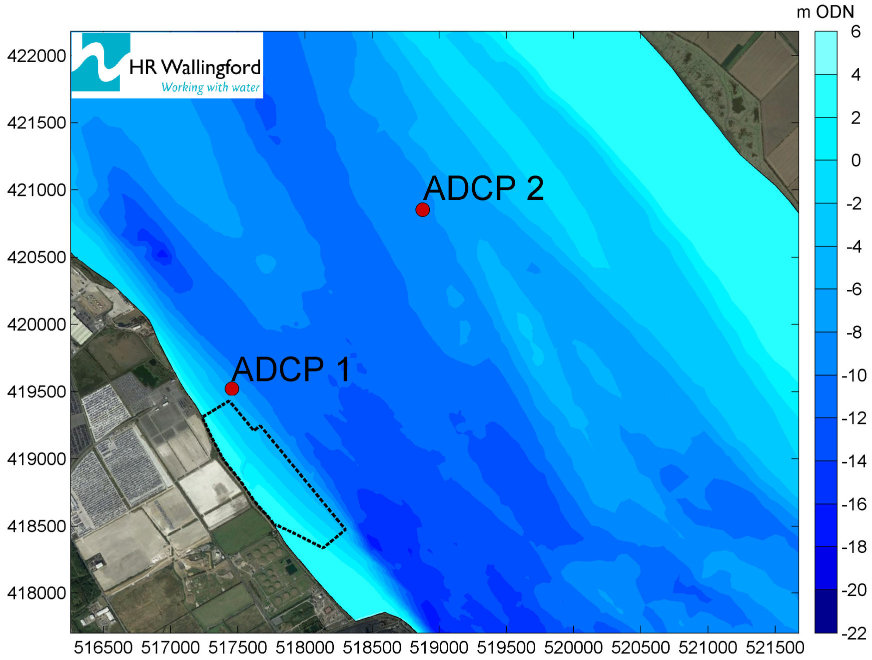
8.3.16 The future hydrodynamics and sediment transport was based on a typical spring-neap tidal cycle. Allowances for sea-level rise and future bathymetry changes were not used. Morphological change and changes to dredging requirements at sensitive receptors were calculated based on extrapolating the sediment transport results for a spring neap cycle up to a year.

Material Change 2 Baseline (current and future)

8.3.17 The assessment of the proposed material amendment used the TELEMAC modelling system and updated model bathymetry, to assess impacts to flows, water levels, cohesive and non-cohesive sediments. This is referred to as the updated baseline.

8.3.18 The existing TELEMAC-3D model was previously validated against the JBA model (EX8.7). The JBA model was validated against two bed mounted ADCP instruments (ADCP1 and ADCP2). These instruments were deployed concurrently (between 13 May and 2 June 2010) at two locations within the lower estuary, one near to the northern limit of the AMEP development (close to the Uniper Power Station intake and outfall) and the other on the opposite side of the estuary main channel (Figure 8-3).

Figure 8-3: Location of bed mounted ADCP instruments



8.3.19 Following the update of the TELEMAC-3D model to include the latest "2018" bathymetry (a composite of the most up to date bathymetry and LiDAR tiles available on the EA/Defra Portal, mainly 2018 with some 2017), a comparison of the updated baseline model and the model with the pre-2009 bathymetry was carried out. The comparison of the predicted water levels, depth-averaged current speed and direction at the ADCPs is shown on Figure 8-4 and Figure 8-5. The results from the calibrated JBA model are also shown on the plots. The predicted water levels from the updated baseline model are similar to the results with the pre-2009 bathymetry. The peak current speeds from the updated baseline model are higher by approximately 0.2 m/s at both the previous measurement positions. This is likely to be due to the changes in bathymetry (**Error! Reference source not found.**) since the measurements were taken.

8.3.20 Further recent grab sample surveys (Allen, 2020, Technical Appendix UES10-4) in the location of the AMEP showed sand content in nearshore subtidal samples being typically 30% and mud content typically 70% or more.

Sedimentary Regime

8.3.21 Between 2016 and 2019 the average wet tonnage of sand disposed at disposal site HU080 under the licence for the Sunk Dredged Channel was 1,193,000 tonnes (Licence Return L/2014/00429/2). The quantities varied from a minimum of 920,000 tonnes in 2016 to a maximum of 1,431,000 tonnes in 2018.

8.3.22 Maintenance dredge material at the `Humber 3A` disposal site (also known as 'HU060') was mainly from material arising from dredging of Immingham Docks, jetties and terminals. Records showed significant variation here also, with disposals in the range 1-7 million tonnes from 1985 to 2007. The Humber Maintenance Dredging Baseline Document (ABP Humber Estuary Services, 2008) stated that there is no apparent trend in dredge volumes at Immingham. More recent maintenance dredging figures for years up to 2011 were also provided and analysed for the consented development. An update to the maintenance dredging figures (ABPHES, 2014) includes those updated figures plus figures for two further years (2012 and 2013). Between 2016 and 2019 the disposal to this site was under two licences (Licence Return L/2014/00429/2 – Immingham riverside berths and approaches, and Licence Return L/2016/00242/1 - C.RO Ports North Killingholme (Berths 1 to 6 plus approaches)). The assumed bulk densities of the materials placed under these two licences are different with the Immingham riverside berths reflecting a lower density deposit. The average wet tonnage of silt dredged from the Immingham riverside berths and approaches for the period 2016-2019 was 3,447,000 tonnes (this is locations B to H in Figure 8-2). The quantities varied from a minimum of 2,965,000 tonnes in 2018 to a maximum of 3,913,000 tonnes in 2016. For the North Killingholme berths (location A in Figure 8-2) the average mass of silt placed was 503,000 tonnes. The quantities varied from a minimum of 335,000 tonnes in 2018 to a maximum of 799,000 tonnes in 2016.

Figure 8-4: Predicted water levels and depth-averaged current speeds and directions at ADCP1 location

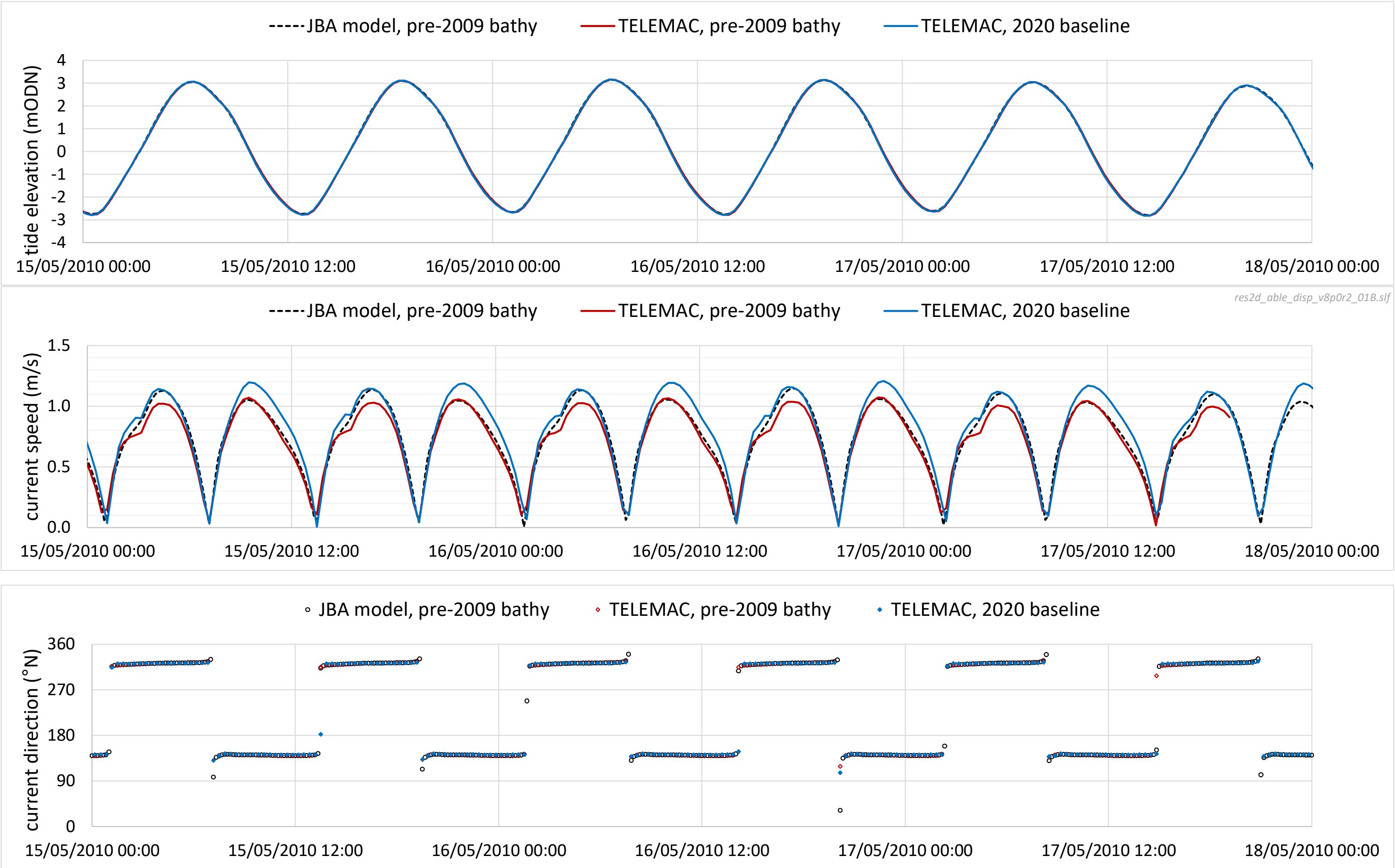
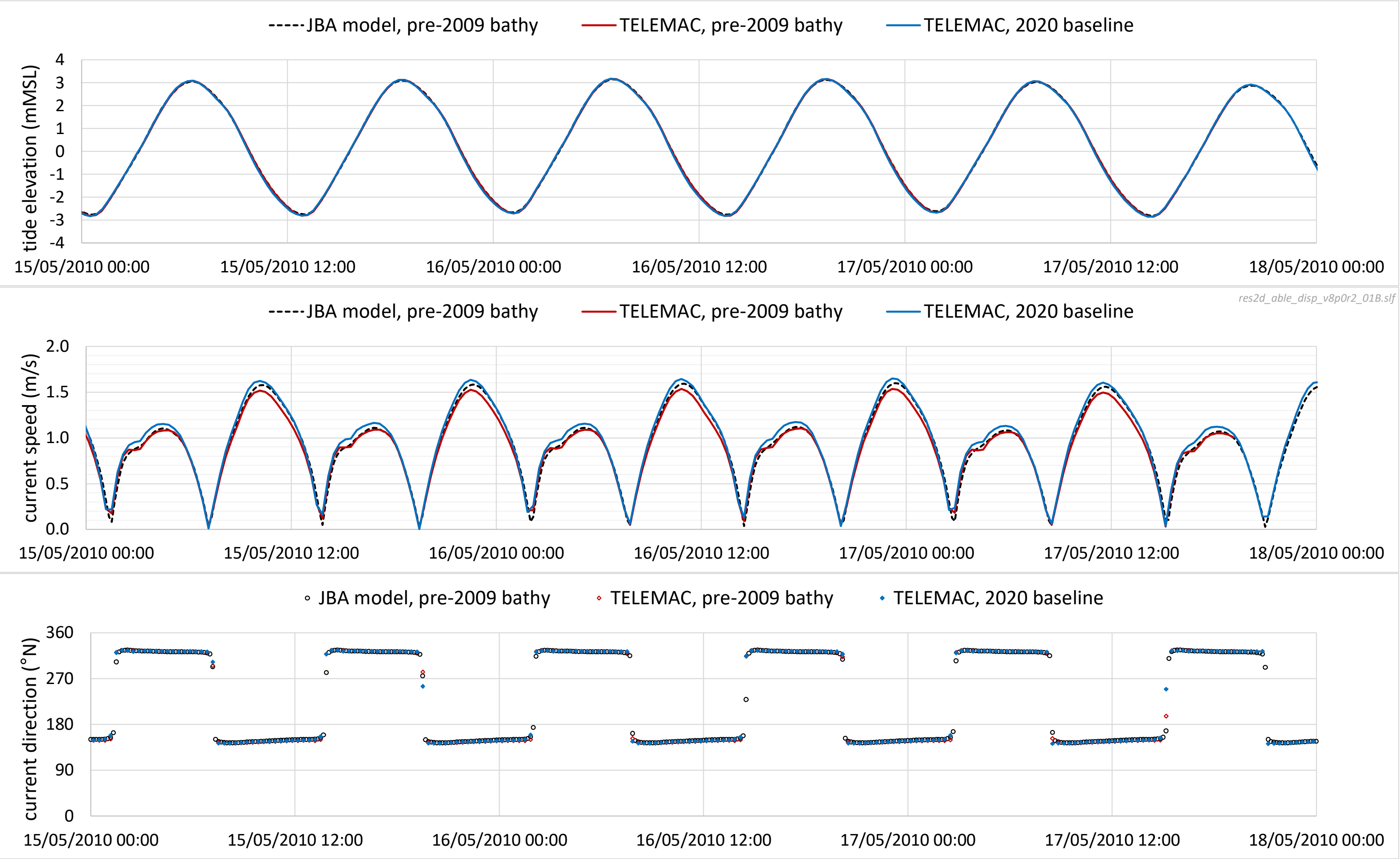


Figure 8-5: Predicted water levels and depth-averaged current speeds and directions at ADCP2 location



Waves

8.3.23 The Environment Agency's February 2021 guidance (Humber Extreme Water Levels (2020)) on relative sea level rise at AMEP was used for updated overtopping calculations for the Flood Risk Assessment (both for Higher Central and Upper End scenarios).

8.3.24 Note that for the updated overtopping analysis for the AMEP Amended Quay (Ch 13), the EA's 2021 Higher Central and Upper End scenarios have now adopted and for a date 100 years into the future. Assumed future sea level rise for these scenarios were 0.9m and 1.14m respectively. In terms of sea level rise after 20 years of AMEP operation (previously for consented scheme this was 2033, now considered to be 2045), the closest epoch provided as output by the EA is for 2046. The EA's "2021 Tide Levels Map and Tables" document suggests a sea level rise of 0.17m is adopted for both North Killingholme and South Killingholme points, when comparing the 200 year extreme level in 2021 against the 200 year extreme level quoted for 2046.

Changes in Baseline

8.3.25 The baseline bathymetry used for the hydrodynamics and sediment modelling was updated, compared to the DCO modelling. The differences in bathymetry are shown in Figure 8-40. The dynamic nature of the estuary morphology is clear from the differences. There has been ongoing accretion along the shoreline south of the proposed AMEP. This natural accretion will have consequences for the maintenance dredging at nearby berths.

8.3.26 The allowances for sea-level rise in the wave modelling have also been updated to follow the latest EA guidance.

8.4.0 Assessment of Effects

Construction Phase Effects

Plume dispersion from dredging and disposal

8.4.1 Capital dredging is required to construct the berth pockets and turning area at the proposed AMEP. The sediments to be dredged consists of alluviums, clays, sand and gravels and glacial till. These are likely to require a combination of hydraulic dredging methods (cutter suction dredgers (CSD) or trailing suction hopper dredgers (TSHD)) and mechanical, backhoe (BHD) dredging to remove the stiffer glacial till. Table presents the maximum volumes of sediment to be removed by each method.

Table 8-4: Maximum Quantities of Dredge Material and Proposed Dredging Methods[7]

Material Type	Volume (m^3)	Dredge Method
Alluvium, Clays, Sands and Gravels	1,440,000	Hydraulic (CSD or TSHD)
Glacial Till	590,000	BHD or CSD

8.4.2 Figure A7.5 of the dredging strategy (Appendix UES4-2) shows around 150,000 m^3 of sand and gravel deposits to be dredged by hydraulic methods whilst the remainder of the hydraulically dredged material will be alluvium / clay.

8.4.3 During dredging and subsequent disposal fine sediment will be released into the water column. This will form a plume of increased suspended sediment concentrations that may be transported some distance before it is deposited on the seabed. The dispersion of fine sediment released by dredging has been modelled using SEDPLUME-RW and is reported in Appendix UES8-1. The modelling has considered a TSHD dredging in alluvium; a TSHD dredging in sand and gravel; a CSD dredging in all material types including glacial till; and a BHD dredging in glacial till. CSD and BHD dredging will involve filling of barges at AMEP and the dredged material is to be placed by barge at disposal sites HU081 and HU082. TSHD would dispose of dredged material at HU080.

8.4.4 A plan showing the locations of the licensed disposal sites HU080, HU081 and HU082 is provided on drawing AME-036-10014 within Appendix UES4-1.

Backhoe dredging

8.4.5 For backhoe dredging of the glacial till peak increases in suspended sediment concentration exceeding 10 mg/l are predicted to extend up to 17 km from the dredger. No increases greater than 50 mg/l are predicted.

8.4.6 Compared with the consented scheme, the footprint of the plume for the amended scheme, as characterised by an increase of 10 mg/l, extends slightly further upstream and peak concentrations of more than 20 mg/l are more prevalent than for the consented scheme. For both scenarios, however, the predicted changes in suspended sediment concentration arising from the backhoe plume are negligible compared to the variation in background concentrations.

8.4.7 At the Uniper intake, the peak increase in near bed suspended sediment concentration was

[7] Source: Appendix UES4.2, Table 3.1

predicted to be 71 mg/l; depth-averaged was 35 mg/l. Typical suspended sediment concentrations at the intakes are slightly higher with the amended scheme than with the consented but remain very low compared to background concentrations in the Humber Estuary.

8.4.8 Mud deposition at the Uniper intake was less than 1 mm and was resuspended on subsequent tides. The CGEN infrastructure further to the north, which currently has no operational Permit, received slightly lower concentrations and deposition.

8.4.9 Predicted increases in siltation at nearby berths, relating to the backhoe dredging, is shown in Table 8-6. The quantity dredged over a spring neap cycle is presented and then scaled up to represent the siltation arising from the full quantity that could be dredged by backhoe to provide the total siltation. Slight increases in siltation are predicted at Humber International Terminal and Immingham Bulk Terminal compared to the consented scheme. These remain insignificant compared to the annual maintenance dredging requirements.

Table 8-5: Predicted infill arising from backhoe operations

Local berth	Predicted infill (m^3) (amended)		Predicted infill (m^3) (consented)	
	spring-neap cycle	Total	spring-neap cycle	Total
Humber Sea Terminal	0	0	0	0
South Killingholme Oil Jetty	3	15	140	760
Immingham Gas Terminal	2	11	-	-
Humber International Terminal	88	516	18	105
Immingham Bulk Terminal	736	4,330	325	1,750
Western Jetty	3	19	-	-
Eastern Jetty	1	6	-	-
Immingham Oil Terminal	-	-	-	-

TSHD dredging

8.4.10 Trailing suction hopper dredger (TSHD) could be used to dredge both alluvium and sand/gravel, with sand and gravel accounting for approximately 150,000 m^3 of the total 1,440,000 m^3 to be dredged by hydraulic methods. When dredging alluvium, the sediment release is smaller, 20 kg/s from the drag head only. For sand and gravel, there is an additional release from hopper overflow that has been assessed to be of 483 kg/s.

8.4.11 For dredging of the alluvium peak increases in (depth-average) concentration exceed 100 mg/l in the vicinity of the dredging and are less than 50 mg/l further away. The plume disperses a maximum of 16 km to the north on a flood tide and a maximum of 15 km to the south on an ebb tide, though concentration increases at this distance are generally below 20 mg/l. The footprint of the plume for the amended scheme extends slightly further upstream and offshore of the coast than for the consented scheme. To the south of the site, the footprint is very similar. For both scenarios, however, the predicted changes in suspended sediment concentration, except for the location of the dredging itself, are negligible compared to the variation in background concentrations.

8.4.12 For dredging of alluvium, peak increases in suspended sediment concentration above background are in the region of 10-15 mg/l (depth-averaged) and a maximum of 45 mg/l (near bed) at the Uniper intake. The CGEN infrastructure further to the north, which currently has no operational Permit, received slightly lower concentrations. The predicted increase in suspended sediment concentrations at the intakes for the amended scheme are lower than for the consented scheme.

8.4.13 Siltation at the nearby berths is given in Table 8-7. Over a spring-neap cycle the predicted siltation is similar to or less than the consented scheme for South Killingholme Oil Jetty, Immingham Gas Terminal and Humber International Terminal. The quantity dredged over a spring neap cycle is then scaled up to represent the siltation arising from the full quantity that could be dredged by TSHD to provide the total siltation. Increased siltation is predicted at Immingham Bulk Terminal, Western Jetty and Eastern Jetty for the amended scheme. Total volumes are predicted to be larger. For the Immingham Riverside Berths the predicted increase in siltation (about 18,000m^3) represents an additional tonnage of about 23,000 wet tonnes. This is insignificant (~1%) compared to the average total mass reported to be dredged and placed at disposal site HU060 from these berths over the period 2016 to 2019.

Table 8-6: Predicted infill arising from TSHD dredging alluvium

Local berth	Predicted infill (m^3) Amended		Predicted infill (m^3) Consented	
	spring-neap cycle	Total	spring-neap cycle	Total
Humber Sea Terminal	0	0	0	0
South Killingholme Oil Jetty	162	400	640	960
Immingham Gas Terminal	59	170	210	315
Humber International Terminal	611	1,750	630	945
Immingham Bulk Terminal	530	1,510	-	-
Western Jetty	2,991	8,550	-	-
Eastern Jetty	1,955	5,590	-	-
Immingham Oil Terminal	0	0	-	-

8.4.14 When dredging sand and gravel with the TSHD, peak increases in (depth-average) concentration rise to 1,000 mg/l within about a 100m of the dredging with near bed concentrations of several thousand mg/l. The plume was predicted to disperse as far as the Humber Bridge on the flood tide at its peak, and as far as Spurn Head on the ebb tide, though concentration increases at this distance are generally below 20mg/l.

8.4.15 The footprint of the plume for the amended scheme, as characterised by an increase of 10 mg/l, extends slightly further upstream and offshore of the coast than for the consented scheme. To the south of the site, the footprint is very similar. For both scenarios, however, the predicted changes in suspended sediment concentration, except for the location of the dredging itself, are negligible compared to the variation in background concentrations.

8.4.16 The Uniper and CGEN intakes are located on the edge of the dredging plume. Increases in near bed SSC are generally less than 300 mg/l although peak concentrations are predicted to reach up to 450 mg/l and averaged 31 mg/l. Depth averaged suspended sediment concentrations are predicted to be smaller, averaging 14 mg/l. These values are slightly reduced compared to those predicted for the consented scheme.

8.4.17 Mud deposition over the spring-neap cycle modelled was predicted to be approximately 10 mm (note this simulation is longer than required to dredge the full quantity of the sand and gravel). This is a reduction in deposition compared to the consented scheme, where 40 mm to 80 mm of deposition was predicted at the Uniper intake and 10 mm to 20 mm at the GCEN intake location.

8.4.18 Table 8-8 shows the total predicted siltation arising from TSHD of sand/gravel for the amended and consented schemes. In general, predicted siltation reduces to the north of the site for the amended scheme. The infill at the nearby berths resulting from this operation is insignificant when compared to the total annual maintenance dredge requirements across all the berths and the natural variation in those quantities.

Table 8-7: Predicted infill arising from TSHD dredging sand and gravel

Local berth	Predicted infill (m^3) (amended)	Predicted infill (m^3) (consented)
Humber Sea Terminal	530	80
South Killingholme Oil Jetty	700	1,960
Immingham Gas Terminal	300	1,160
Humber International Terminal	2,330	3,850
Immingham Bulk Terminal	1,500	2,370
Western Jetty	650	-
Eastern Jetty	560	-
Immingham Oil Terminal	110	-

Cutter Suction Dredging

8.4.19 A CSD may be used to dredge some of the material, including glacial till. For CSD dredging, including releases from the cutter head and barge overflow, peak increases in (depth-average) concentration will exceed 200 mg/l only directly adjacent to the dredging activity. Peak concentrations of up to 100 mg/l extend 15 km upstream and 20 km downstream of the dredging location. Overall, peak concentrations are lower than for the TSHD dredging of sand/gravel although the plume footprint was larger and would likely extend for longer periods because of the increased duration of the dredging.

8.4.20 The predicted peak increase in depth averaged suspended sediment concentration at the Uniper and CGEN intakes was 150 mg/l with a mean increase of 24 mg/l. Near bed concentrations at the intakes are predicted to be slightly higher, averaging 28 mg/l with a peak value of 200 mg/l. These values are lower than for the TSHD dredging of sand/gravel. Increased mud deposition was predicted to be less than 1 mm at the intakes over a spring neap cycle.

8.4.21 Table 8-9 shows the predicted siltation at nearby berths from the CSD dredging and barge overflow. The quantity dredged over a spring neap cycle is then scaled up to represent dredging a total of about 1.4 Mm^3 by CSD to provide an indicator of the total siltation that could arise. Whilst these are an increase compared to previous predictions, the infill at the nearby berths remains insignificant when compared to annual maintenance dredge requirements and the natural variation in those quantities. For the Immingham Riverside Berths the predicted increase in siltation (about 17,000m^3) represents an additional wet tonnage of about 21,000 wet tonnes this is insignificant (~1%) of the average total mass reported to be dredged and placed at disposal site HU060 from these berths over the period 2016 to 2019.

Table 8-8: Predicted infill arising from CSD dredging

Local berth	Predicted infill (m^3)	
	Spring-neap cycle	Total
Humber Sea Terminal	0	0
South Killingholme Oil Jetty	304	1,427
Immingham Gas Terminal	206	966
Humber International Terminal	1,724	8,103
Immingham Bulk Terminal	1,389	6,526
Western Jetty	4	18
Eastern Jetty	0	1
Immingham Oil Terminal	0	0

Disposal

8.4.22 Disposal of sediment by barges arising from dredging with the CSD was modelled as an intermittent discharge of fine sediment alternating between 12 locations within disposal sites HU081 and HU082. Peak increases in (depth-average) concentration will be greater than 500 mg/l extending up to 4 km upstream and downstream from the release site. High concentrations are restricted to the streamlines away from the disposal site and concentrations reduce across the estuary. Peak concentrations are higher than predicted for disposal activities for the consented scheme. However, the disposal modelling for the consented scheme was at disposal site HU080 and the hydrodynamics and release assumptions differed.

8.4.23 Disposal activities are not predicted to have any impact at the intake locations north of the proposed

AMEP.

8.4.24 Infilling at the berths near AMEP was negligible for the disposal, less than 2 m^3 after a spring-neap cycle. Accretion (of silt) in Sunk Dredged Channel was predicted to be 13,000 m^3 over a spring-neap cycle and 60,000 m^3, equivalent to about 75,000 wet tonnes, over the entire disposal activity associated with disposal of about 1.4 Mm^3. This infill is spread thinly along 10 km of these channels and so of itself does not materially cause a change in bed level within these channels. The increased infill of order 75,000 wet tonnes is about 6% of the average wet tonnage of sandy material reported as being dredged annually from Sunk Dredged Channel over the period 2016 to 2019.

8.4.25 The disposal of material arising from CSD operations by barge at disposal sites HU081 and HU082 would result in the release of greater quantities of fines than the disposal by barge of glacial till that was mechanically dredged by BHD. This is because the CSD dredging will produce greater quantities of fines in the barge which would be available for initial dispersion. The disposal scenario assessed is therefore a worse-case scenario in terms of the potential for dispersion of fines and siltation in the Sunk Dredged Channel for material placed resulting from BHD.

Impact of capital dredge disposal

8.4.26 The construction of the AMEP requires dredging and disposal of approximately 4.3M wet tonnes of materials including a proportion of firm/stiff clay. Schedule 8[8] of the extant DCO provides for up to 1M tonnes of clay to be deposited at HU082, a consented disposal site within the Humber Estuary and for 1.1M tonnes of clay to be deposited on land to be used as fill within the terrestrial areas of the AMEP site.

8.4.27 As the proposed beneficial use of the clay as fill may no longer be an option, it is proposed that all the firm/stiff clay to be dredged by BHD will now be disposed of at disposal sites HU081 and HU082 within the Humber Estuary. At the disposal sites bed levels will be raised locally to a maximum level of -5.3 m CD. This is equivalent to placement of about 1.1Mm^3 of material into HU081 and about 1.6Mm^3 of material into HU082. In reality it would not be possible to place this full amount of material into the site because individual placements will form mounds and overall the placement, particularly of glacial till, will create an undulating surface of mounds and troughs across the site. The capacity of the sites where the existing bed level is at least -7m CD (i.e. a placement depth of 1.7m is available) is about 70% of the volume available. The impact of the bed changes associated with a scenario of complete filling of the sites to a level of -5.3m CD has been examined using the TELEMAC 3D flow model to predict the changes in peak flows and shear stresses resulting from this disposal.

8.4.28 The difference in flow speed predicted as a result of the bed changes caused by disposal of material to a level of -5.3m CD at HU081 and HU082 are shown in Figure 8-6 **Error! Reference source not found.** and Figure 8-7**Error! Reference source not found.**. This represents a total disposal of about 2.7 Mm^3 which is well in excess of the quantities proposed for placement at the sites and is therefore a worse case assumption. The contours in the figures are in ODN so the -5m contour is at about -1m CD. Over the disposal site, where the water depth is shallower following the deposition, flow velocities increase on both ebb and flood tides. For ebb flows, the maximum increase was predicted to be 0.2 m/s at the western edge of HU081 and 0.1 m/s at the western edge of HU082. Increases of up to 0.15 m/s are predicted north of HU081. Smaller increases in flow velocity (less than 0.1 m/s) are predicted north and south of the HU082 disposal site. Decreases are predicted immediately

[8] https://www.gov.uk/government/publications/amep-marine-energy-park-variation-2

up and down stream of both HU081 and HU082.

8.4.29 A similar pattern was predicted for peak flood tides (Figure 8-7), however overall the differences are smaller. The blue line represents the water's edge at the time in the simulation for which the results are extracted. The sinusoidal image in the top left of the figure shows the tide curve through the simulation and the time at which the results from the model have been output. The changes in current speeds are not predicted to impact the flows over the intertidal area.

8.4.30 Changes to bed shear stress are shown in Figure 8-8 and Figure 8-9**Error! Reference source not found.** for ebb and flood flows respectively. For ebb flows increases in shear stress of up to 1.2 N/m^2 are predicted at the western edge of HU081 and up to 0.8 N/m^2 at the western edge of the HU082. As with flow speeds, smaller changes are predicted for flood tides.

Figure 8-6: Changes to predicted peak ebb flow velocity with disposal of clay at HU082

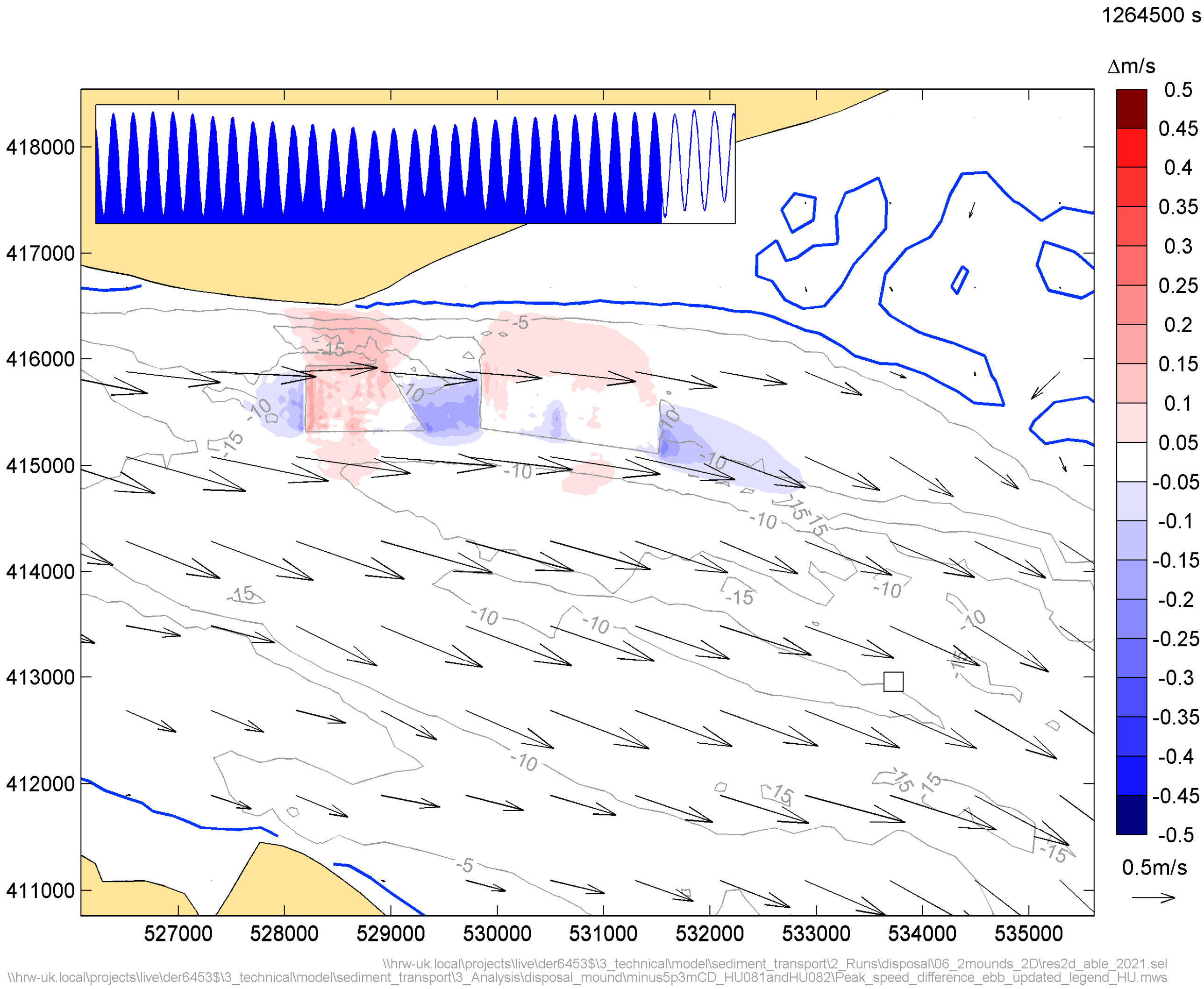
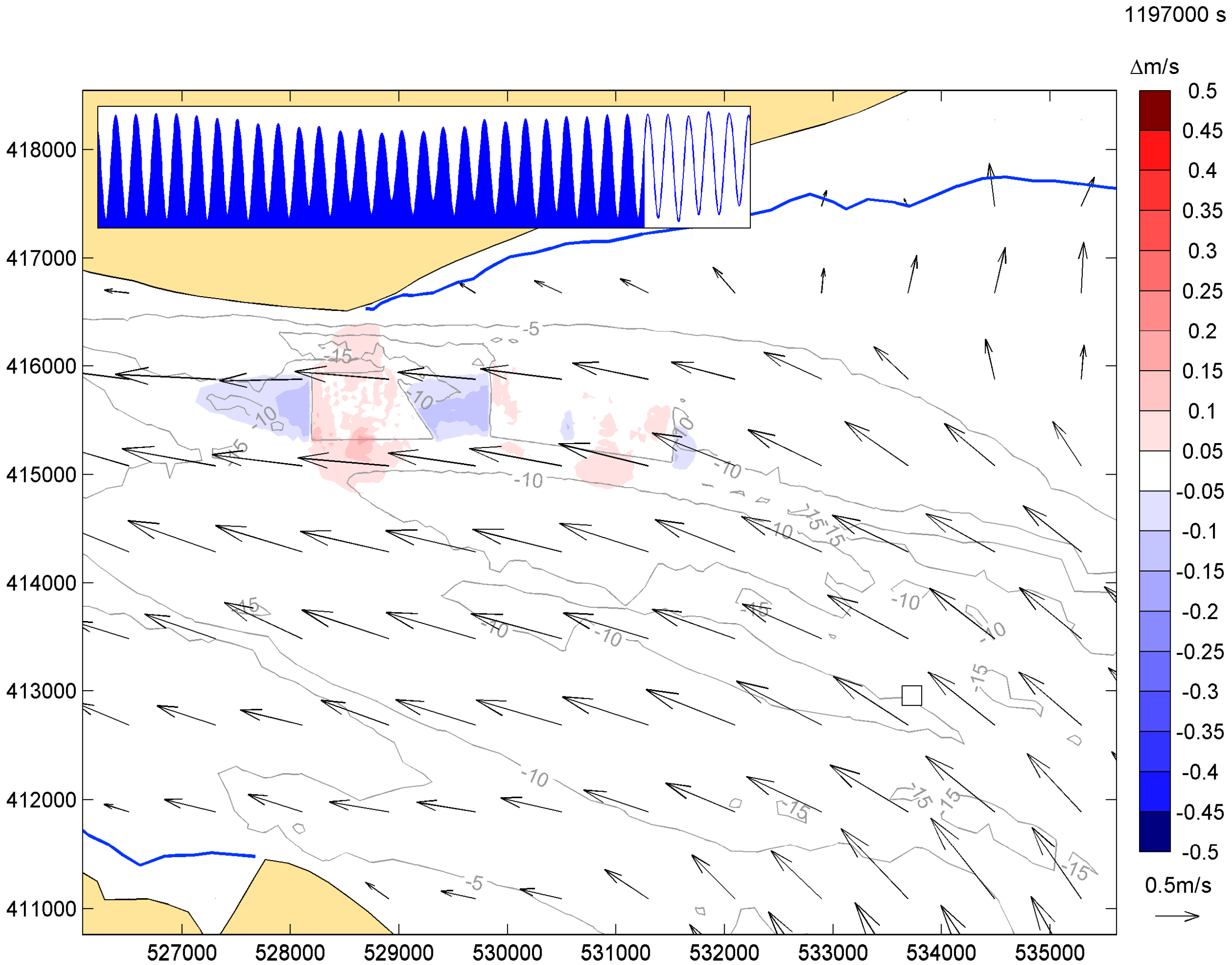


Figure 8-7: Changes to predicted peak flood flow velocity with disposal of clay at HU082



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\\hrw-uk.local\projects\live\der6453$\3_technical\model\sediment_transport\3_Analysis\disposal_mound\minus5p3mCD_HU081andHU082\Peak_speed_difference_flood_updated_legend_HU.mws

Figure 8-8: Changes to predicted peak ebb bed shear stress with disposal of clay at HU082

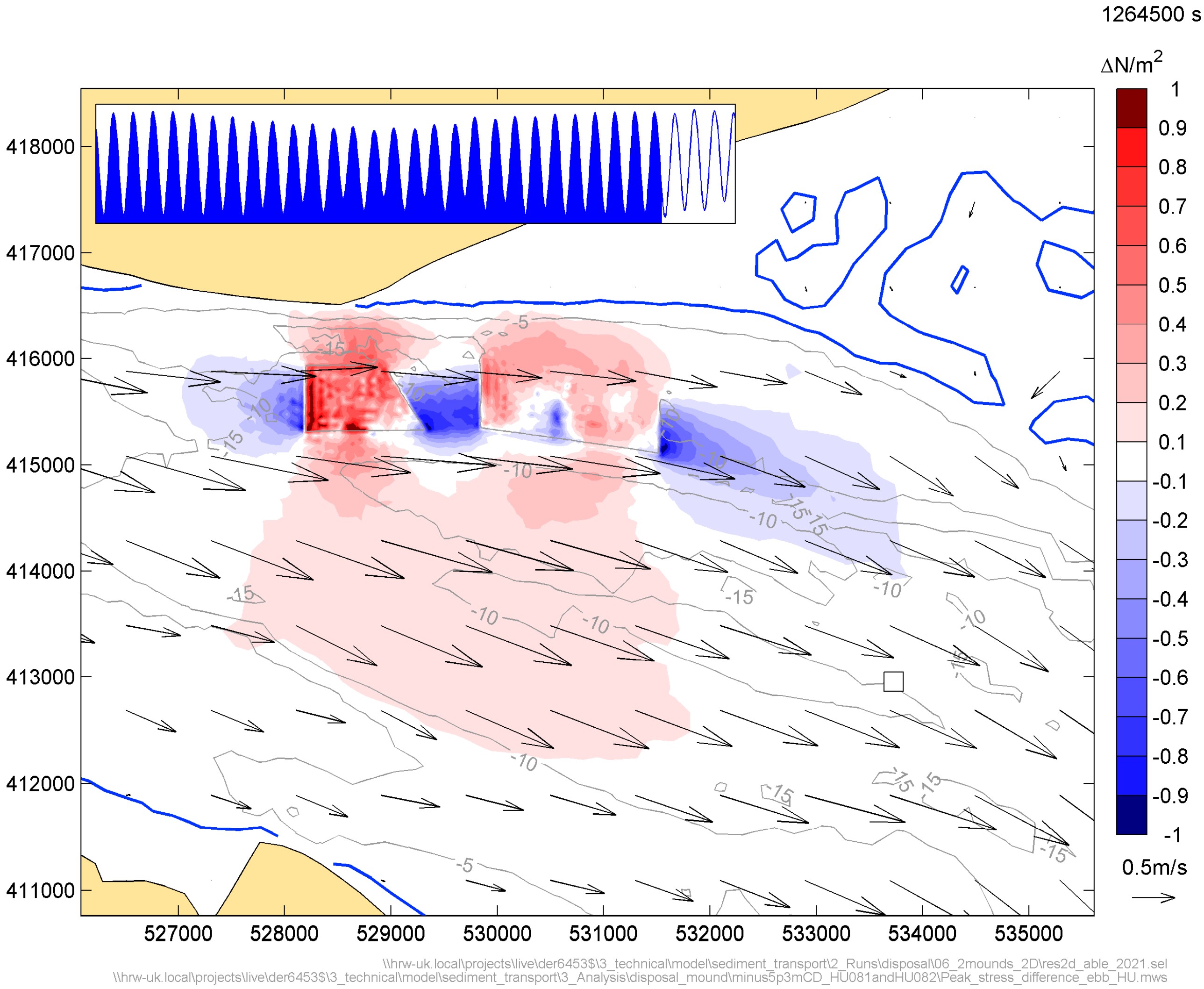
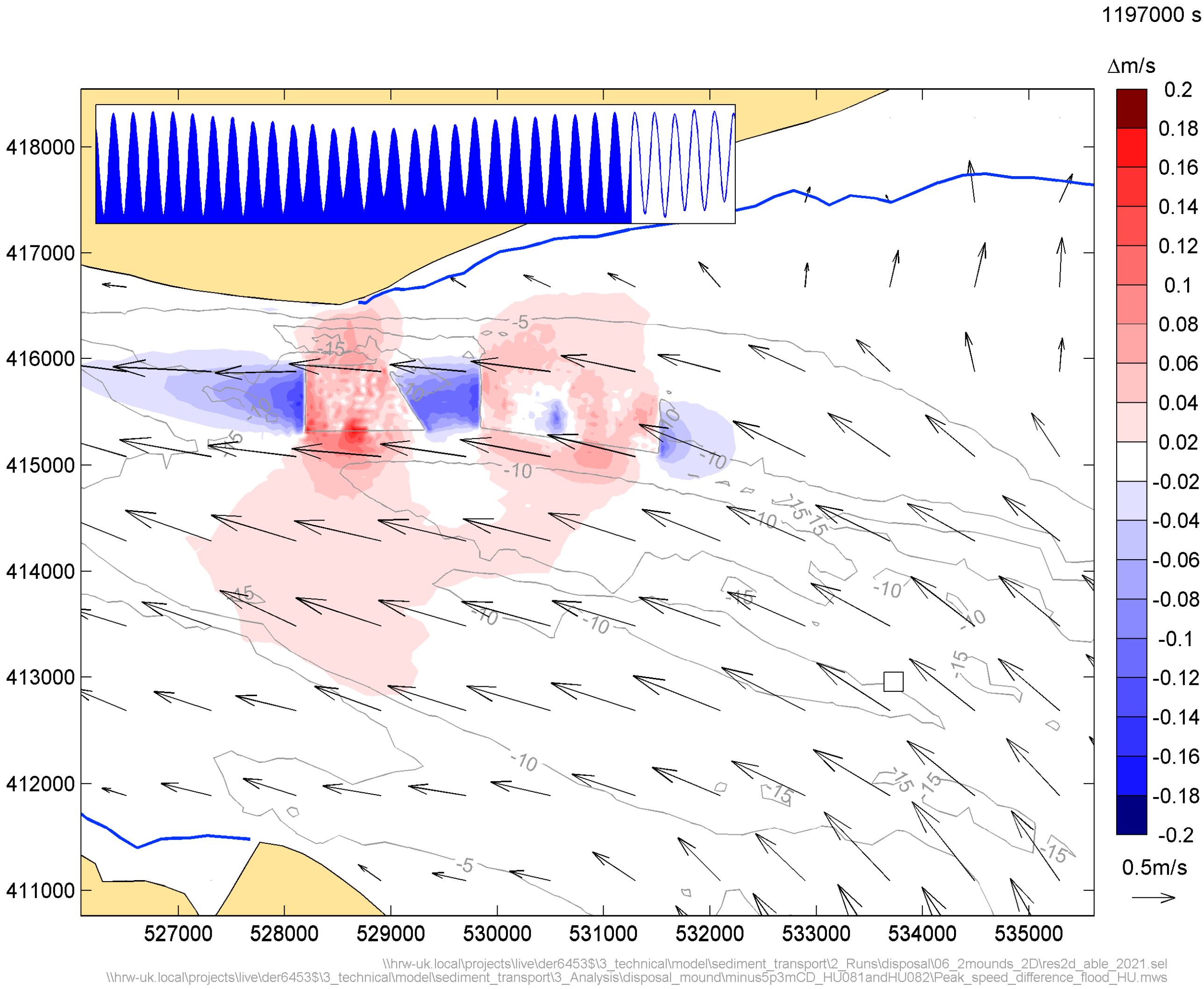


Figure 8-9: Changes to predicted peak flood bed shear stress with disposal of clay at HU082



8.4.31 The volume of material proposed to be deposited to HU081 and HU082 by barges loaded by either CSD or BHD will be less than the 2.7Mm^3 represented in the scenario modelled.

8.4.32 An assessment of the likely behaviour and erosion rate of mechanically dredged glacial till placed at HU081 and HU082 has been made (see Technical Appendix UES8-2). This shows that stiff glacial till placed at the site will gradually breakdown and disperse from the sites. Sands and gravels arising from this break down of the till will be temporarily retained in the low points between the individual mounds arising from the placement of till at the site. The dispersion of this coarser material will act to slow the overall abrasion and dispersion of the till by tidal currents and wave action. Erosion of the material placed at HU081 and HU082 will occur more quickly in the southern parts of the sites where the currents are higher.

Impact on waves from placement of inerodible material at HU081 and HU082

8.4.33 As waves propagate into the estuary, they will be modified by the processes of depth refraction and shoaling as they travel through increasingly shallow waters. Wave models that simulate the nearshore wave transformation processes are well established and for the present assessment, the

SWAN (Simulating WAves Nearshore) model has been used. SWAN is a third generation spectral wave model which simulates the transformation of random directional waves considering wave shoaling, wave refraction, depth-induced breaking, bottom friction and whitecapping, wave growth due to the wind and far-field wave diffraction around headlands. The SWAN model has been extensively validated and is ideally suited to the transformation of wave energy spectra in relatively large coastal areas.

8.4.34 The local SWAN model was set up to adequately represent wave propagation into the estuary. The seaward boundary of the model coincides with the boundary of the flow model. For the assessment, one representative wave condition was used to determine the effects of the disposal of the material at disposal sites HU081 and HU082 on the waves at Hawkins Point. The offshore condition was selected such that it corresponds to the condition used in the wave assessment in EX8.7A, i.e. with a wave direction from 135°N (SE sector), and such that the predicted significant wave height at Hawkins Point is 1m at MHWS, with a mean wave period (T_{m-10}) of approximately 4s. The SWAN model was run applying the selected wave along the seaward model boundary and a spatially uniform wind of 11m/s from 135°N applied across the whole model domain. The selected condition was then simulated in the SWAN model at MLWS (-2.8 mODN), MSL and MHWS (+3.2 mODN) for the existing (present-day) bathymetry and the existing (present-day) bathymetry including the disposal sites HU081 and HU082 filled to a level of -5.3m CD.

8.4.35 Figure 8-10 shows the predicted significant wave height for the selected wave condition for the existing (present-day) bathymetry at MHWS. Figure 8-11 to Figure 8-13 show the modelled changes to the predicted significant wave height at MLWS, MSL and MHWS. Changes of approximately +/-5% (0.05m) are predicted at MLWS, and approximately +/-2% (0.02m) at MSL. The effect on waves at MHWS is less than +/- 0.02m and is considered insignificant. Changes are observed locally around the disposal sites, and are more pronounced at the lower water levels due to the refraction around the placement in the disposal sites. At higher water levels, when waves can reach the coastline and sea defences, there is insignificant change to the waves because the change in bathymetry in the disposal areas is a lower proportion of the overall depth.

Figure 8-10: Predicted significant wave height for the selected offshore condition, MHWS, existing present-day bathymetry (GoogleEarth imagery)

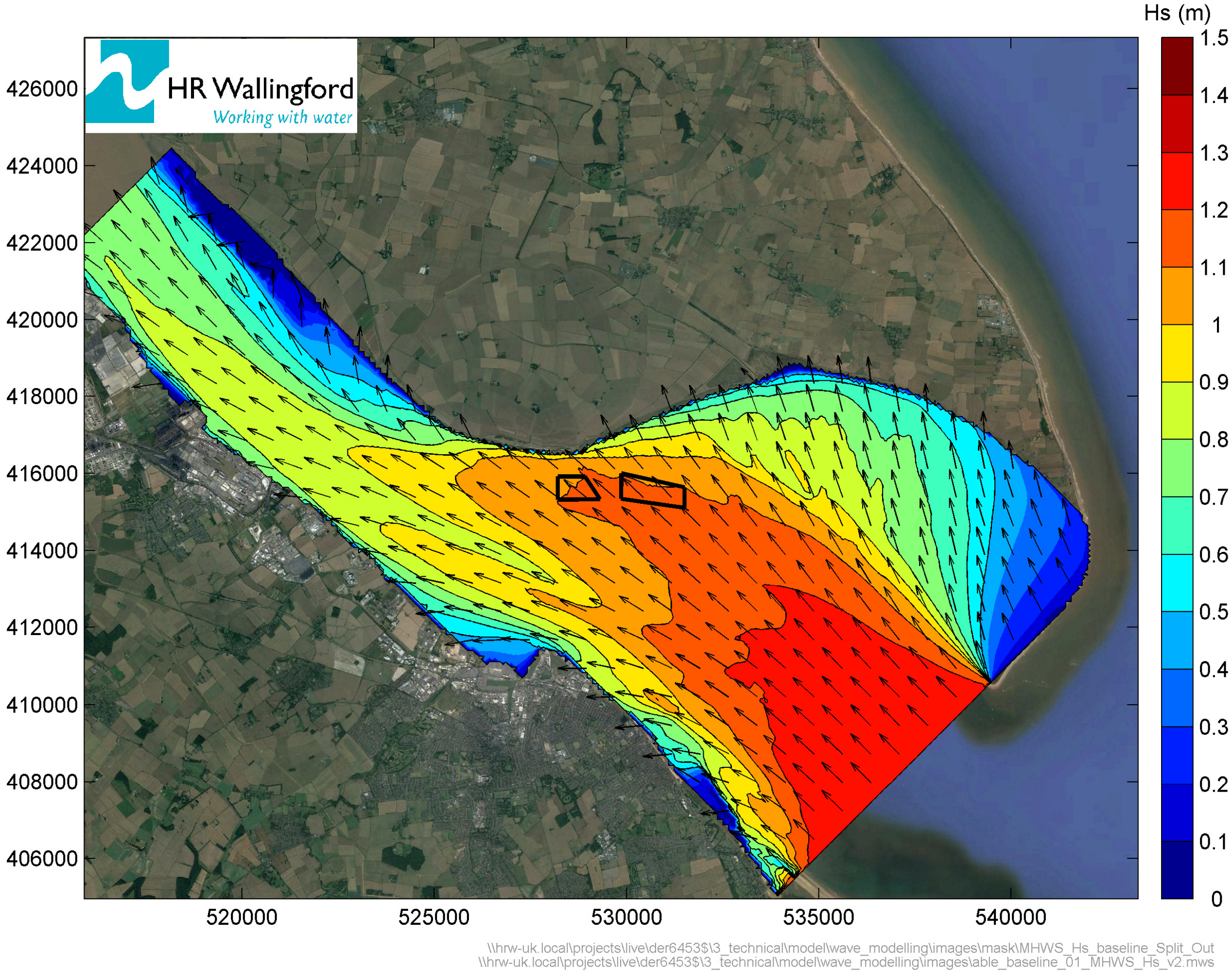
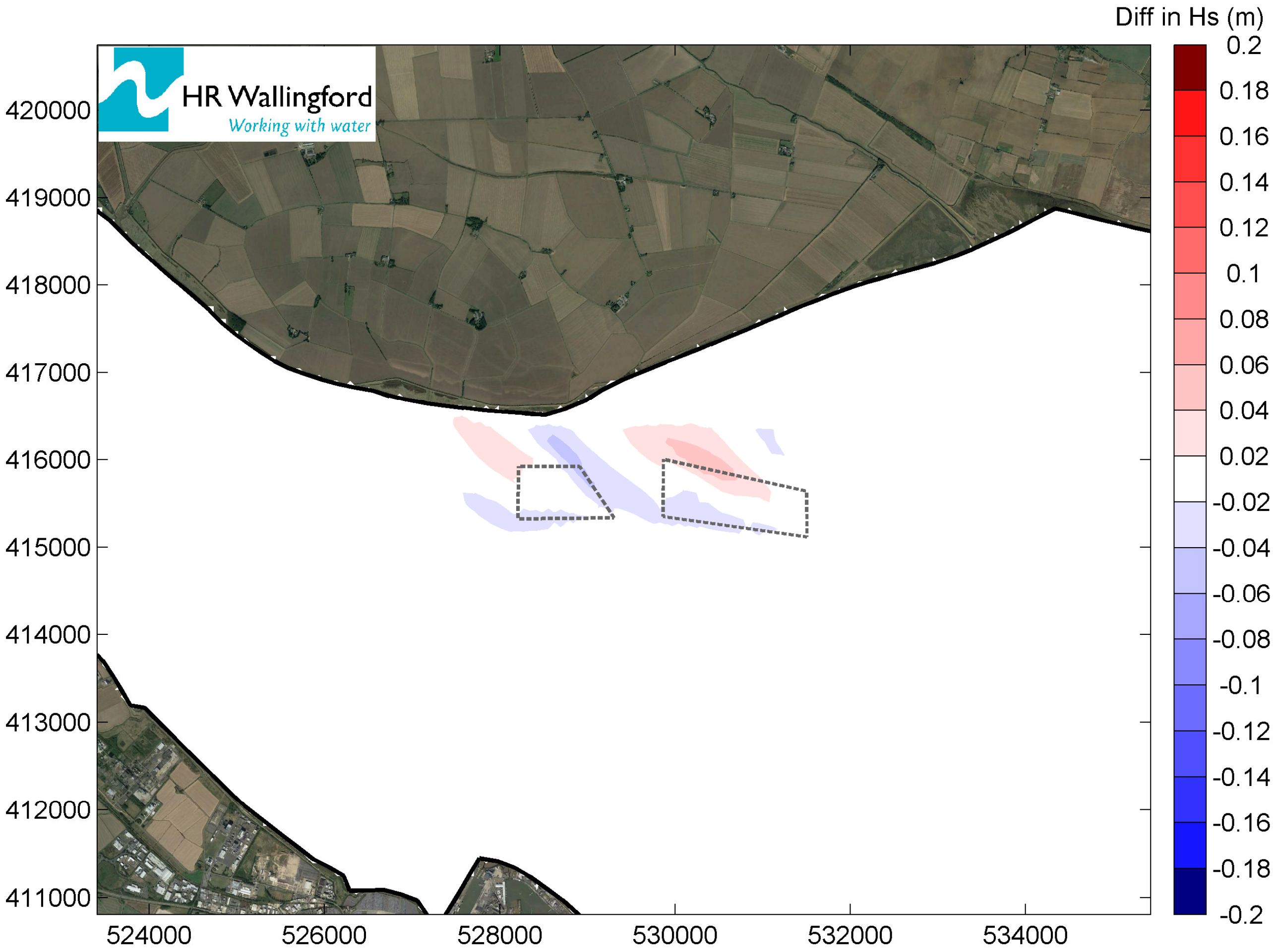


Figure 8-11: Changes in predicted significant wave height with diposal sites HU081 and HU082, MLWS. (Contours in blue indicate a decrease; contours in red an increase)



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\\hrw-uk.local\projects\live\der6453$\3_technical\model\wave_modelling\images\Diff_Hs_01_MLWS_GE_v2.mws

Figure 8-12: Changes in predicted significant wave height with diposal sites HU081 and HU082, MSL (Contours in blue indicate a decrease; contours in red an increase)

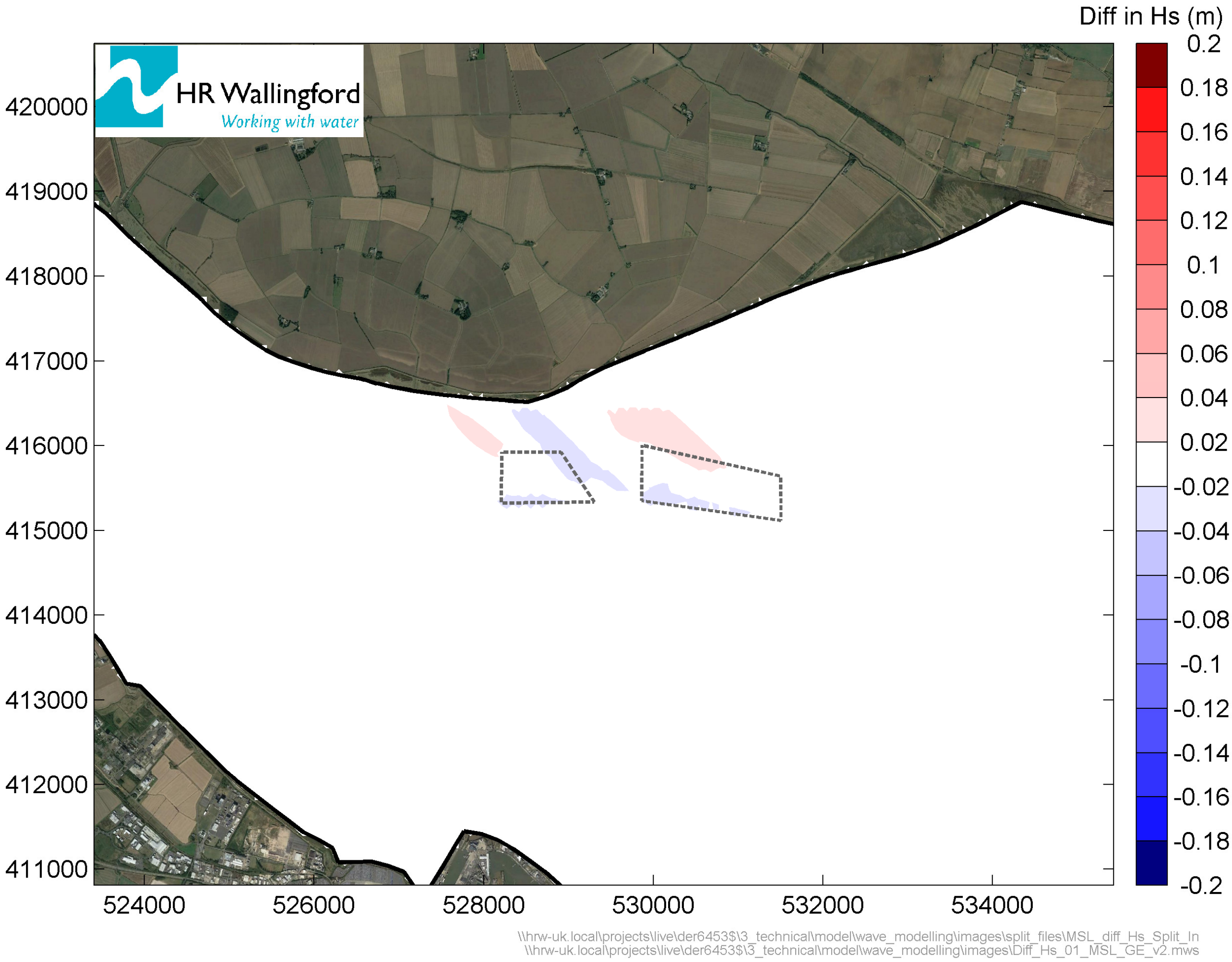
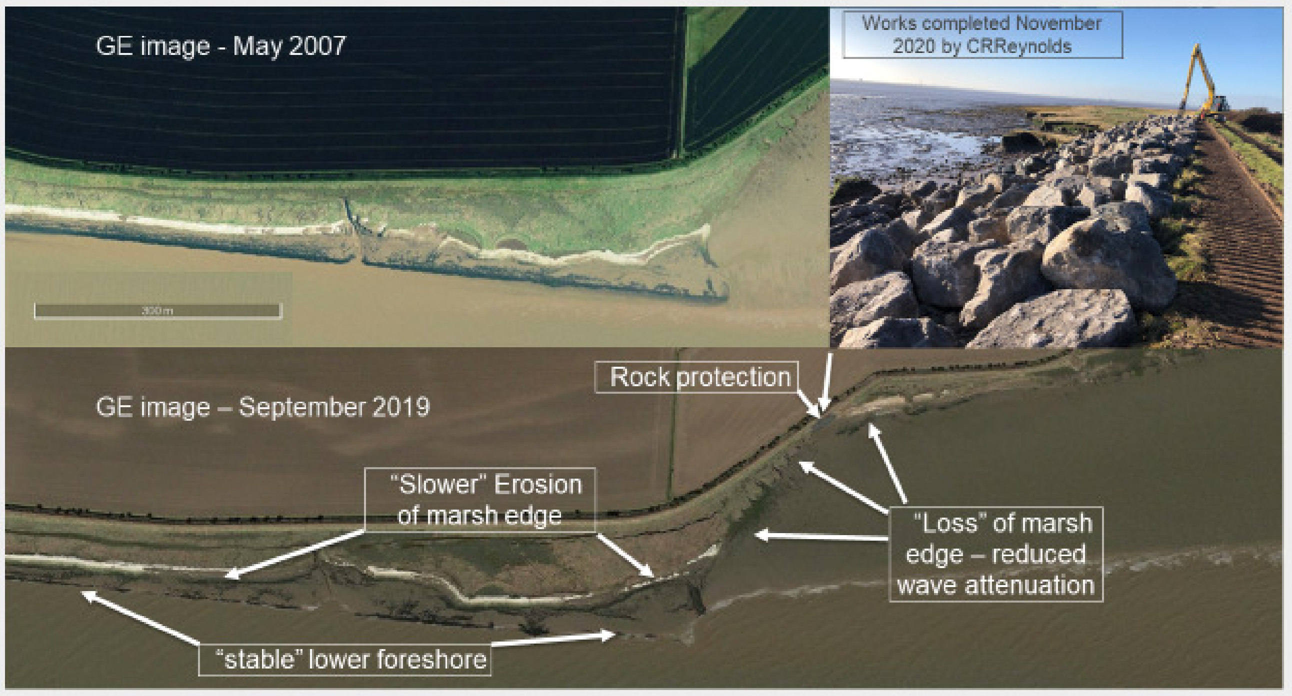


Figure 8-13: Changes in predicted significant wave height with diposal sites HU081 and HU082, MHWS. (Contours in blue indicate a decrease; contours in red an increase)

Impact of changes to hydrodynamics on Hawkins Point

8.4.36 The shoreline to the north and east of Hawkins Point has been subject to ongoing erosion and protection, in the form of rock placement, has been undertaken on behalf of the Crown Estate and the Environment Agency. Figure 8-14 shows Google earth images of Hawkins Point from 2007 and 2019 and an inset of the recent protection works undertaken in 2020 on behalf of the Crown Estate. The 2019 image has been overlain with text and arrows indicating the location of most concern where the rock protection has been placed.

Figure 8-14: Google earth Imagery of Hawkins Point (2007 and 2019)

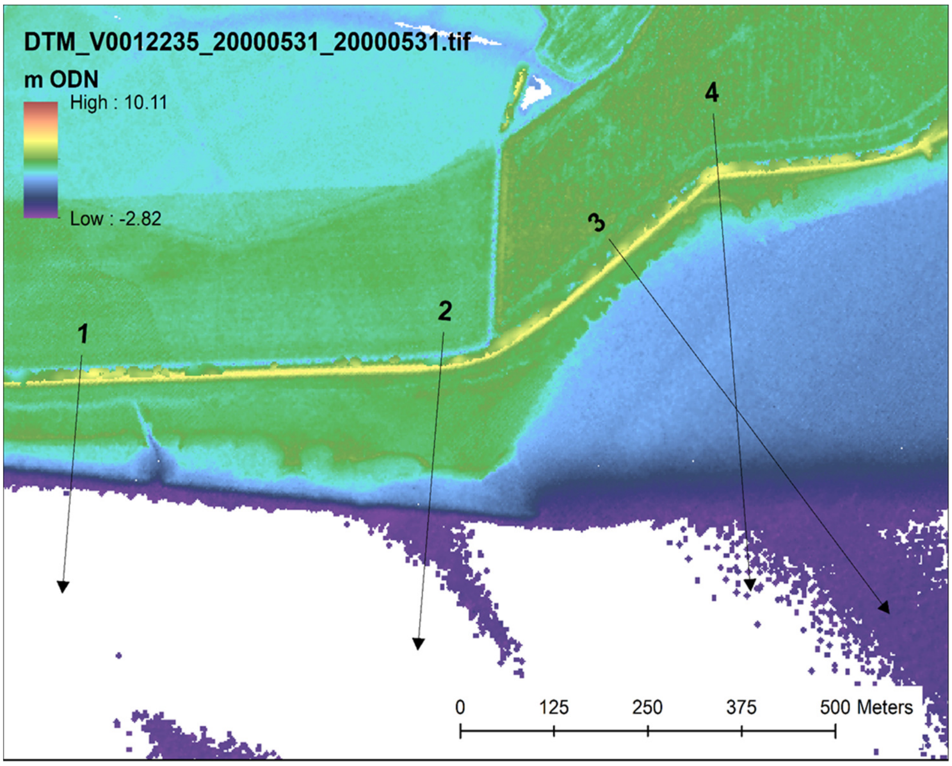


8.4.37 The area has been covered by LiDAR surveys in recent decades. Figure 8-15 shows data from 2000 and 2019. The positions of four transects where data has been extracted from these two surveys are also shown in Figure 8-15. The four transects, working from west to east are shown in Figure 8-16. The blue line shows the elevations along the transect from 2000 and the red lines the elevations in 2019. It can be seen that all transects demonstrate some erosion (the redline being lower than the blue line at the same distance from the origin of the transect). On transects 1 and 2, which are to the west of Hawkins Point, the erosion occurs mainly above MSL (0 m ODN). This is largely erosion of the vegetated marsh. On transects 3 and 4 there is erosion below about +1.0m ODN extending down to below -1.5m ODN. This is largely erosion of the intertidal flat fronting the marsh. On transect 3, which is adjacent to where the rock protection has previously been placed it can be seen that there is also loss of the 25m width of marsh that had fronted the seawall at this location in 2000.

8.4.38 The hydrodynamic factors that drive the erosion of the marsh are storm waves over high tides and surge tides. The hydrodynamic factors that drive the erosion of the lower intertidal flat fronting the marsh can be a combination of waves and tidal currents. Figure 8-13 shows that placement of dredged material into disposal sites HU081 and HU082 has no significant effect on waves at the level of MHWS. Therefore it is concluded that placement of dredged material at HU081 and HU082 will not have an impact on the ongoing marsh erosion to the east and west of Hawkins Point. Figure 8-6 to Figure 8-10 show that the predicted changes to flows inshore of HU082 do not extend so far as to affect the ongoing intertidal erosion on the transects fronting the sea wall to the east of Hawkins Point. The same figures do indicate that the tidal flows are predicted to increase slightly inshore of HU081 and therefore might possibly affect the relatively stable intertidal areas fronting the seawall to the west of Hawkins Point.

8.4.39 This assessment indicates that the placement of material to HU081 and HU082 will not adversely affect the ongoing erosion of the intertidal and salt marsh fronting the seawall to the east of Hawkins Point. The assessment also indicates that there could be an increasing driver for intertidal erosion as a result of slightly increased tidal currents to the west of Hawkins Point. However, in this location the morphology is relatively stable.

Figure 8-15: LiDAR images of Hawkins Point from 2000 (top) and 2019 (bottom) showing extracted cross-sections



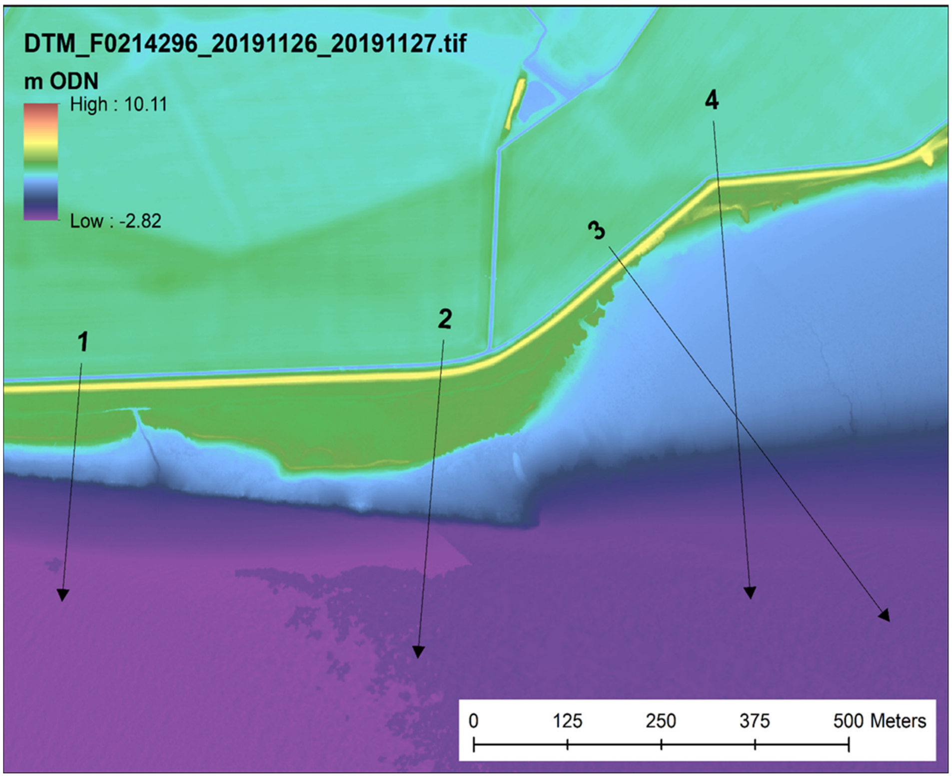
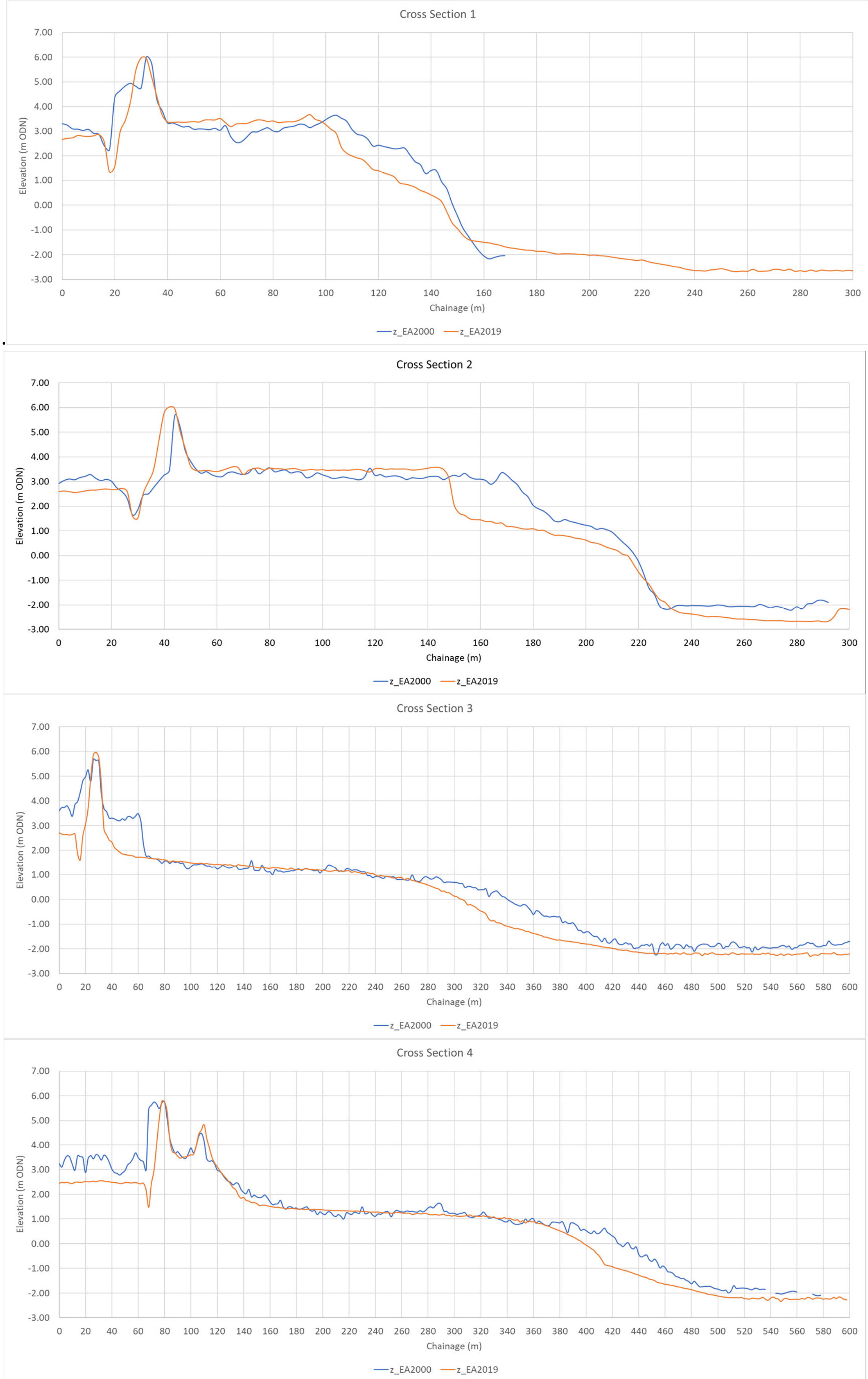


Figure 8-16: Cross section profiles from 2000 and 2019 LiDAR



Operational Phase Effects

Hydrodynamic Impacts – Impacts on tidal levels

8.4.40 Figure 8-17 and Figure 8-19 show the modelled impacts on high water levels arising from the AMEP Amended Quay layout when compared with the updated baseline. The effect of the AMEP Amended Quay is slightly reduced compared with the changes predicted for the consented scheme (Figure 8-18 and Figure 8-20). The already small changes to High Water levels are made smaller by the change in design at the upstream end of the AMEP Amended Quay, in particular the set-back nature of the upstream end of the AMEP Quay. Changes are less than 4 mm everywhere except for immediately north of AMEP where a reduction of up to 10 mm is predicted. Further away from AMEP no change is predicted.

8.4.41 A small change (mainly decreases, and all <5 mm) is predicted to low water levels in the AMEP berthing / turning area with no significant changes further away from the development.

Figure 8-17: Modelled changes to High Water levels (AMEP Amended Quay minus updated Baseline – negative shows a predicted reduction in High Water level)

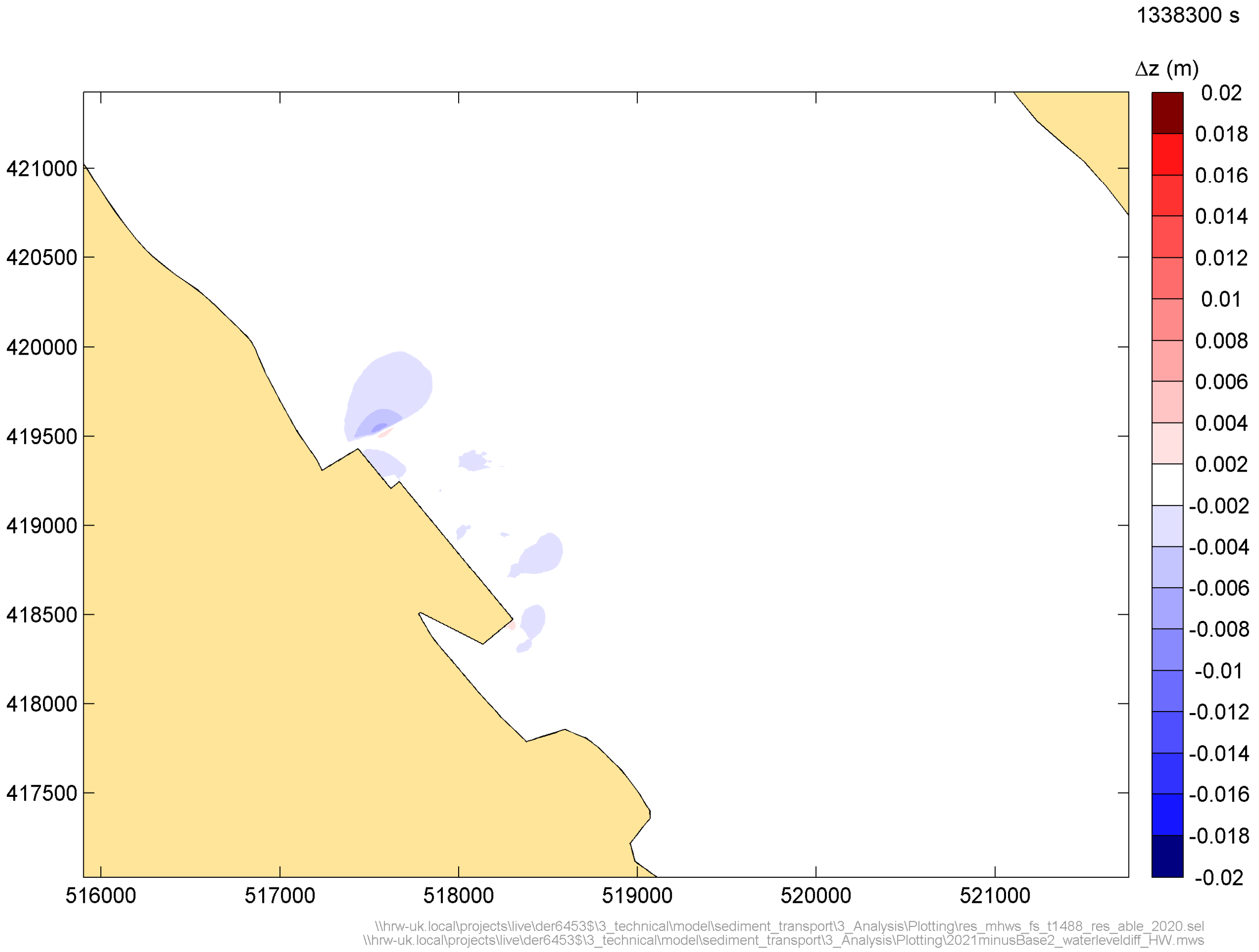


Figure 8-18: Modelled changes to High Water levels for consented layout (AMEP layout minus baseline – negative shows a predicted reduction in water High Water level). From EX 8.7A (JBA, 2012).

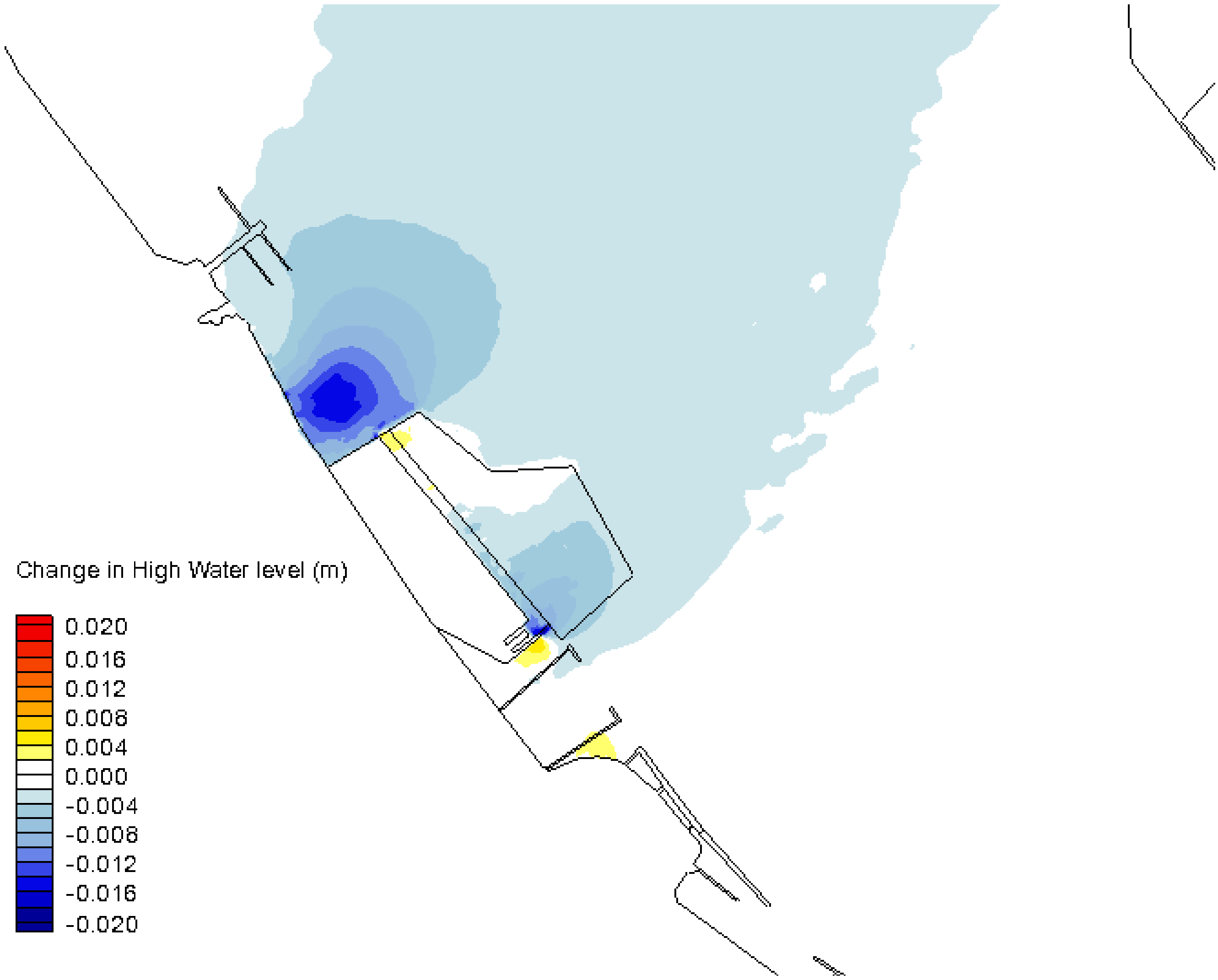


Figure 8-19: Modelled changes to High Water levels (AMEP Amended Quay minus updated Baseline – negative shows a reduction in water High Water level).

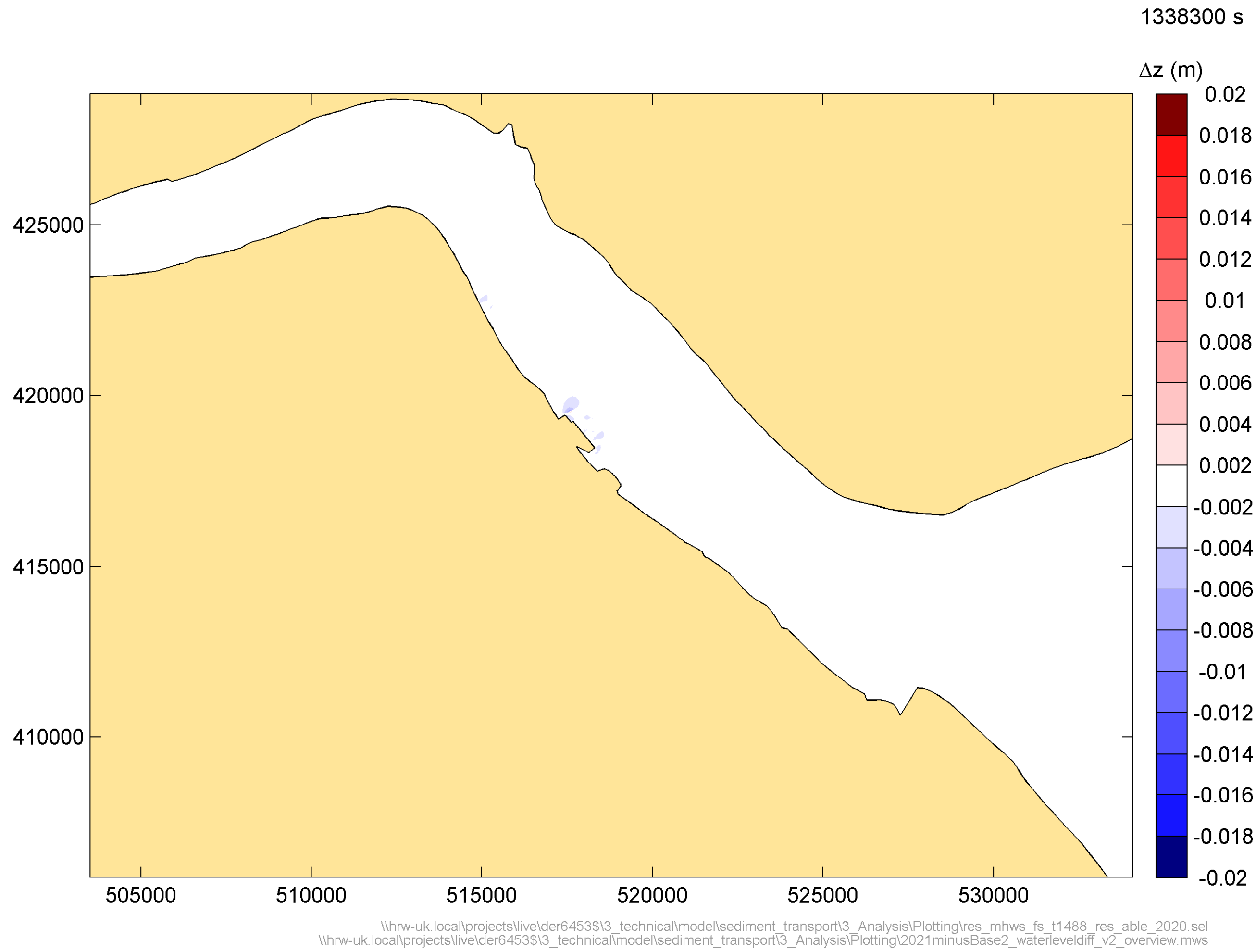
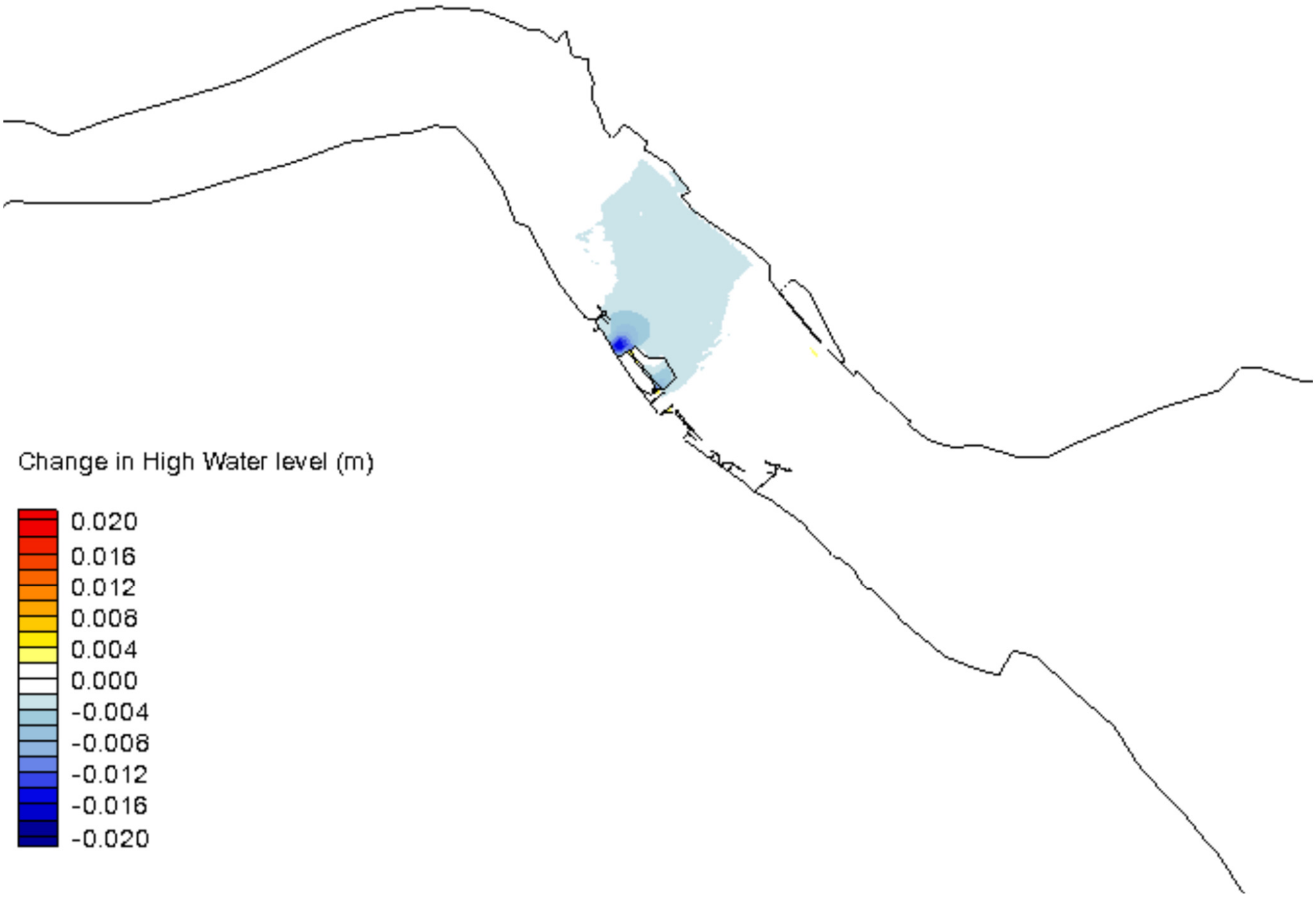


Figure 8-20: Modelled changes to High Water levels for the consented layout (AMEP minus baseline – negative shows a reduction in water High Water level). From EX8.7A (JBA, 2012).



8.4.42 Figure 8-21 and Figure 8-23 show modelled changes to peak flood and ebb flows respectively for a mean spring tide, comparing the AMEP Amended Quay layout against the updated baseline.

8.4.43 During flood flows (Figure 8-21), as before, reductions in flow speeds are predicted upstream and downstream of AMEP, although the amended quay leads to a smaller footprint of flow speed reduction upstream of AMEP when compared with the consented AMEP layout (Figure 8-22). Reductions of less than 0.1 m/s extend approximately 0.5 km in an upstream and downstream direction, with greater reductions in and near to the AMEP berth pockets.

8.4.44 During ebb flows (Figure 8-23), the footprint of flow speed changes immediately upstream and downstream is reduced compared with the consented layout (Figure 8-24). A reduction of less than 0.1 m/s extends for less than 0.5 km upstream. There is no noticeable (<0.05 m/s) reduction in peak ebb flow speed downstream This is partly due to the updated bathymetry (Figure 8-40 showing that significant intertidal accretion has continued in this location (in the lee of the HIT reclamation) since 2012, as well as development of the 'natural' channel in front of AMEP, but it is also as a result of the AMEP Amended Quay layout. With the consented layout (Figure 8-24) there is a zone of speed reduction inshore of the South Killingholme Oil Jetty extending downstream to the Immingham Gas Jetty. A zone of increased currents speeds extends off the berths. With the amended scheme the area of speed reduction on the ebb tide is not noticeable and the area of speed increase is smaller and moved inshore where flow speeds immediately downstream and offshore of AMEP are predicted to increase, with an increase in peak ebb flow speed of up to 0.3 m/s extending approximately 300 m downstream of the AMEP Quay, and an increase of 0.1 m/s extending less than 0.5 km downstream.

8.4.45 The Amended Quay leads to a further change: peak flow speeds in the AMEP turning area are predicted to reduce by up to 0.15 m/s, and more in close proximity to the recessed quay at the northern end of AMEP.

Figure 8-21: Modelled changes to peak mean spring tide flood flows (AMEP Amended Quay layout minus updated baseline)

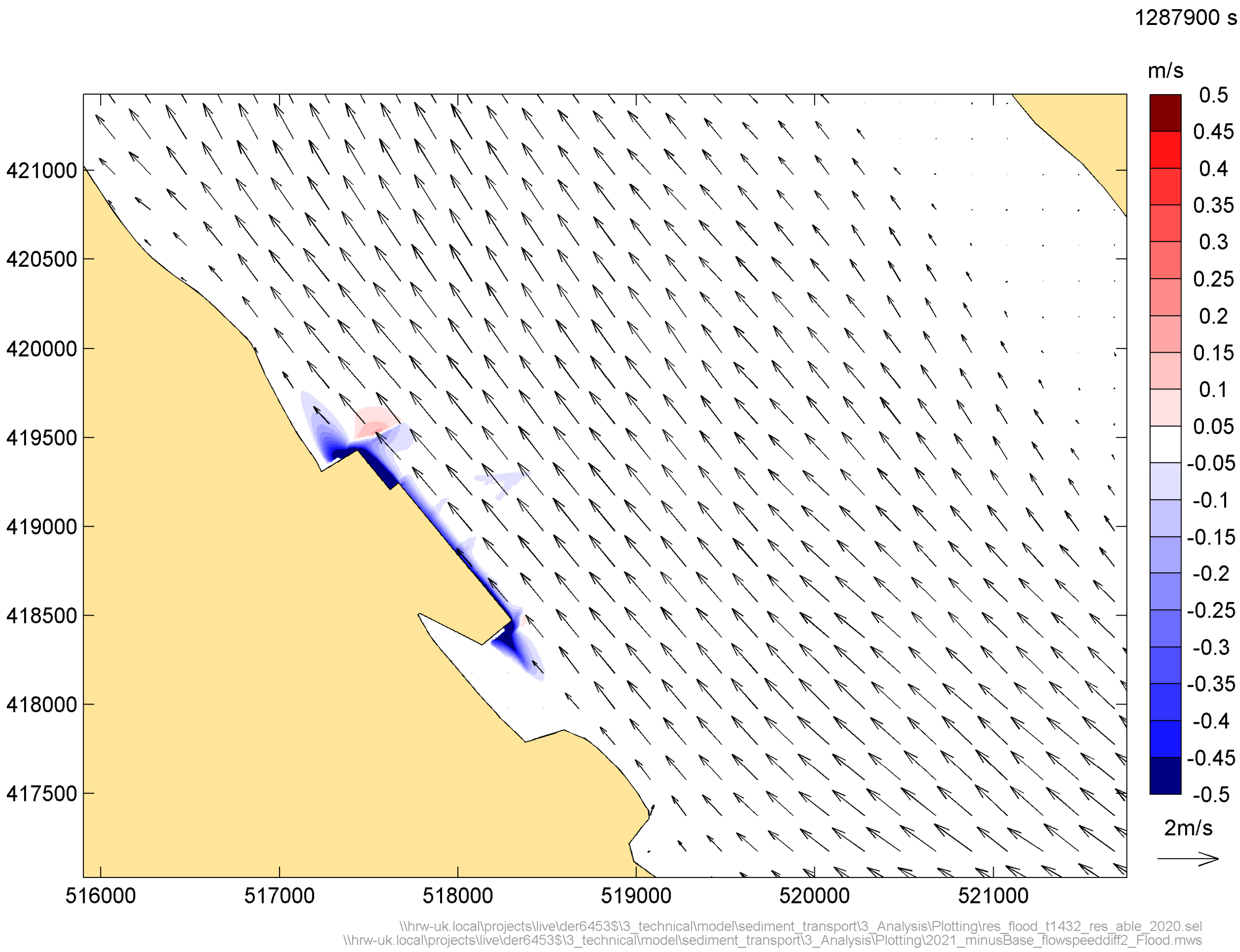


Figure 8-22: Modelled changes to peak mean spring tide flood flows for consented layout (AMEP minus baseline). From EX 8.7A (JBA, 2012)

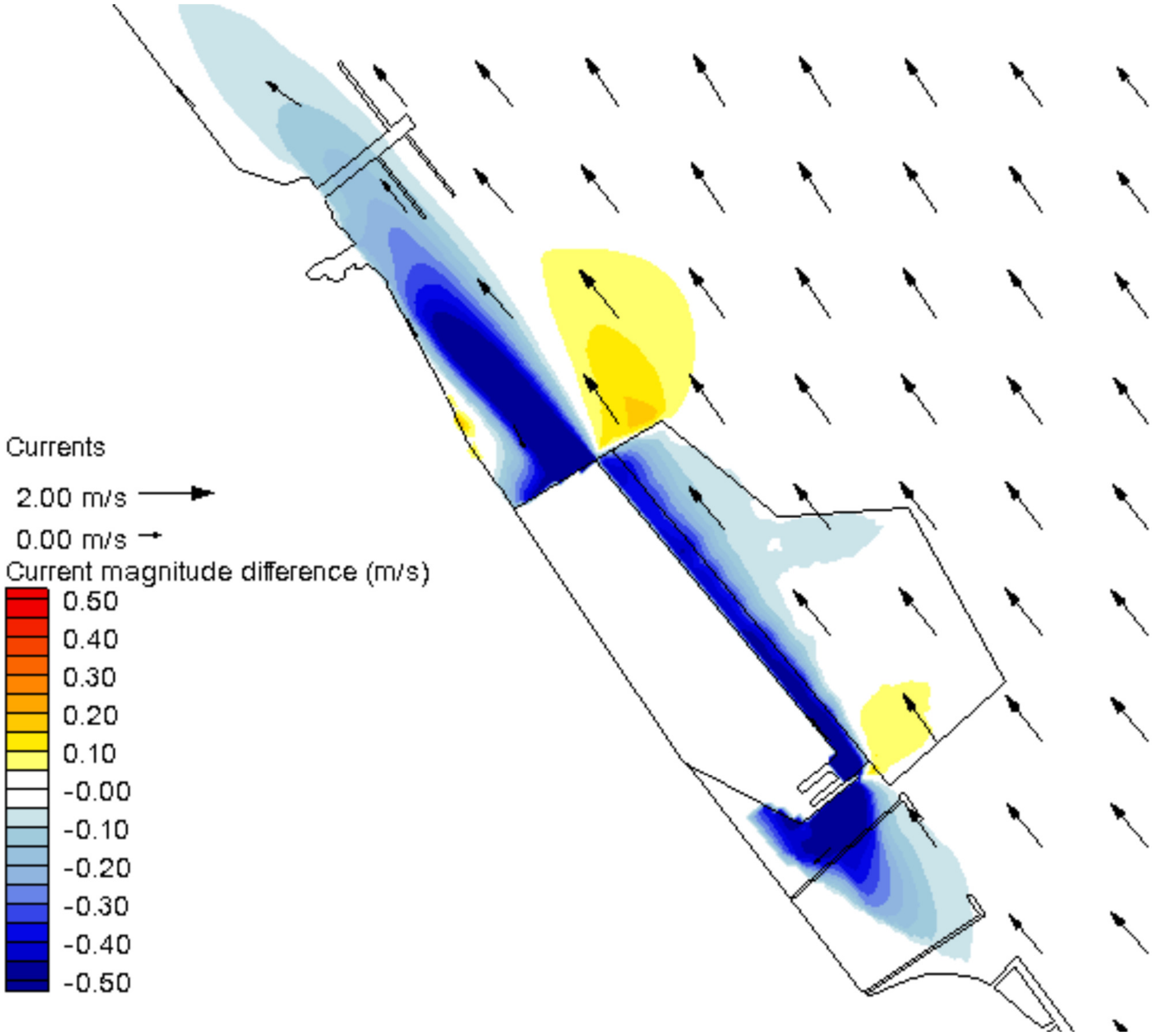


Figure 8-23: Modelled changes to peak mean spring tide ebb flows (AMEP Amended Quay layout minus updated baseline).

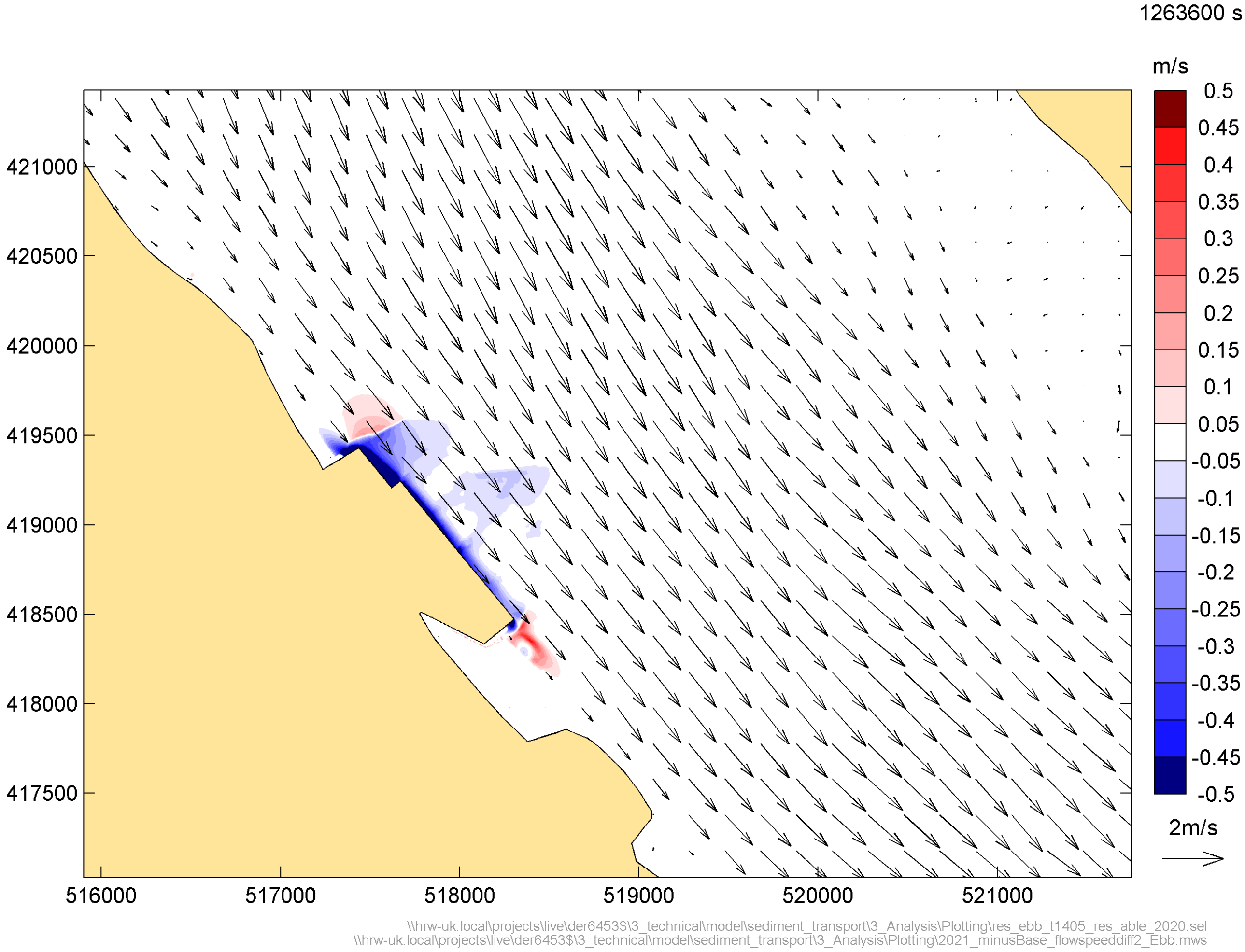
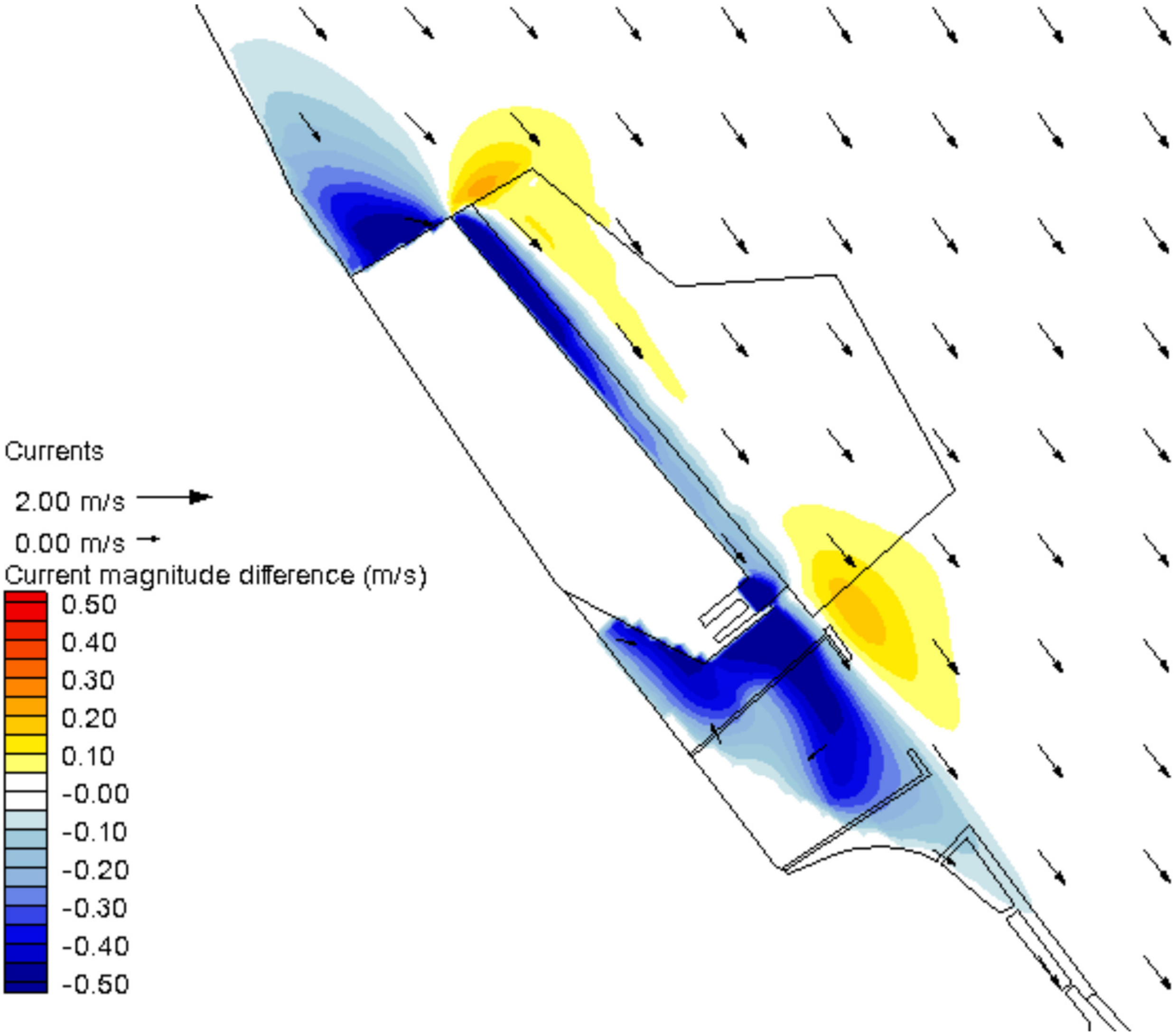


Figure 8-24: Modelled changes to peak mean spring tide ebb flows (AMEP minus baseline). From EX8.7A (JBA, 2012). Impacts on Bed Shear Stress (due to changes in tidal flows)



8.4.46 Figure 8-25 and Figure 8-29 show predicted changes to bed shear stress (flood and ebb) in response to the AMEP Amended Quay layout. These are compared against Figures for the previously consented scheme (Figure 8-26 and Figure 8-30 respectively). Figure 8-27 and Figure 8-31 show predicted changes over the wider estuary (compared with Figure 8-28 and Figure 8-32 respectively for the previously consented scheme).

8.4.47 The AMEP Amended Quay layout when compared against the updated baseline shows a similar but reduced footprint of reductions to peak bed shear stress immediately upstream and downstream of AMEP when compared with the consented layout. Predicted increases in peak bed shear stress are similar in footprint. The AMEP Amended Quay is predicted to result in a decrease in peak bed shear stress in the AMEP turning area compared with the updated baseline, which is due both to the updated bathymetry and the Amended Quay. The wider area figures show that, as for the consented layout, no significant changes to peak bed shear stress are shown in the Estuary further away from AMEP.

Figure 8-25: Modelled changes to peak mean spring tide bed shear stress, flood tide (AMEP Amended Quay minus updated baseline).

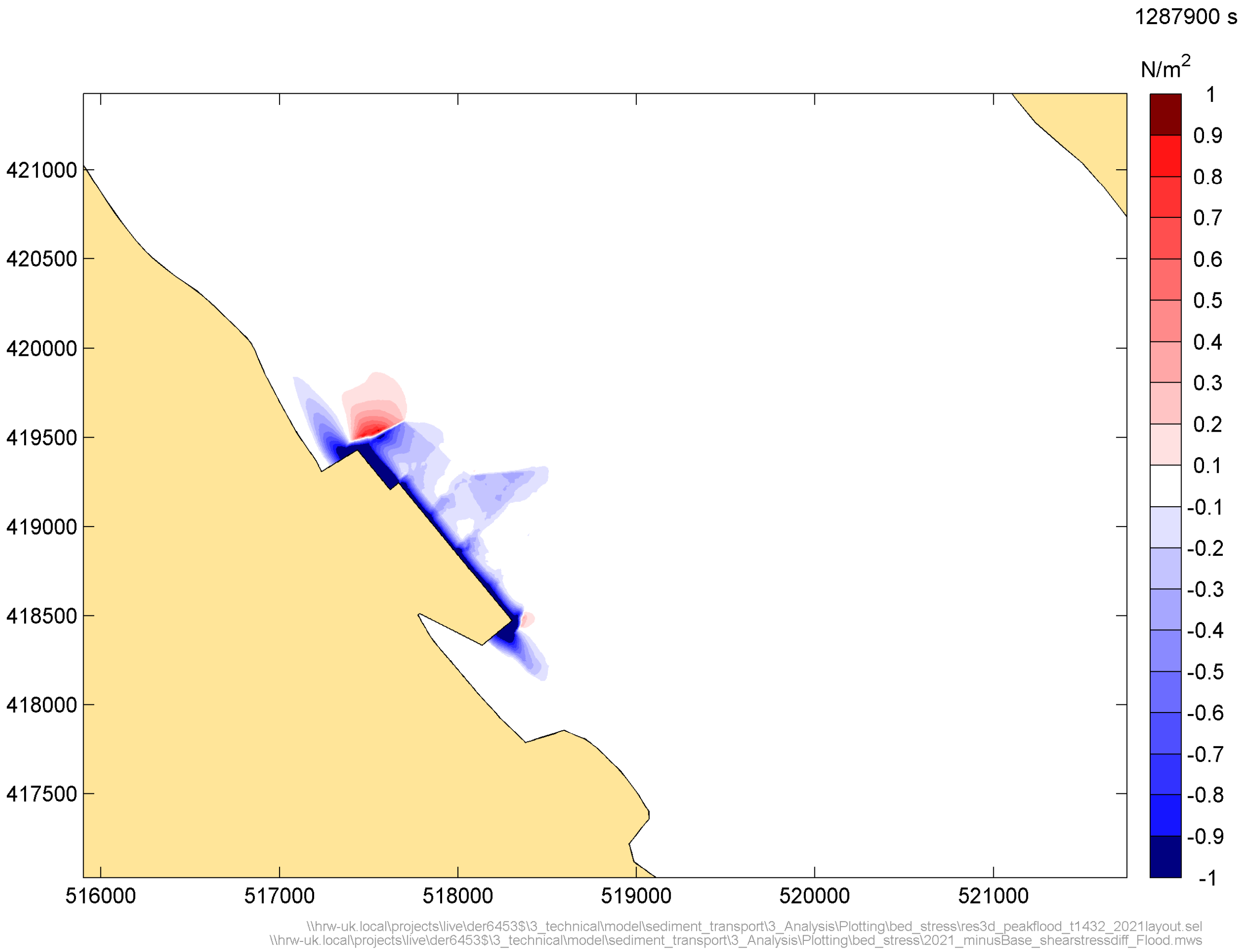


Figure 8-26: Updated modelled changes to peak mean spring tide bed shear stress, flood tide (AMEP minus baseline). From EX8.7A (JBA, 2012).

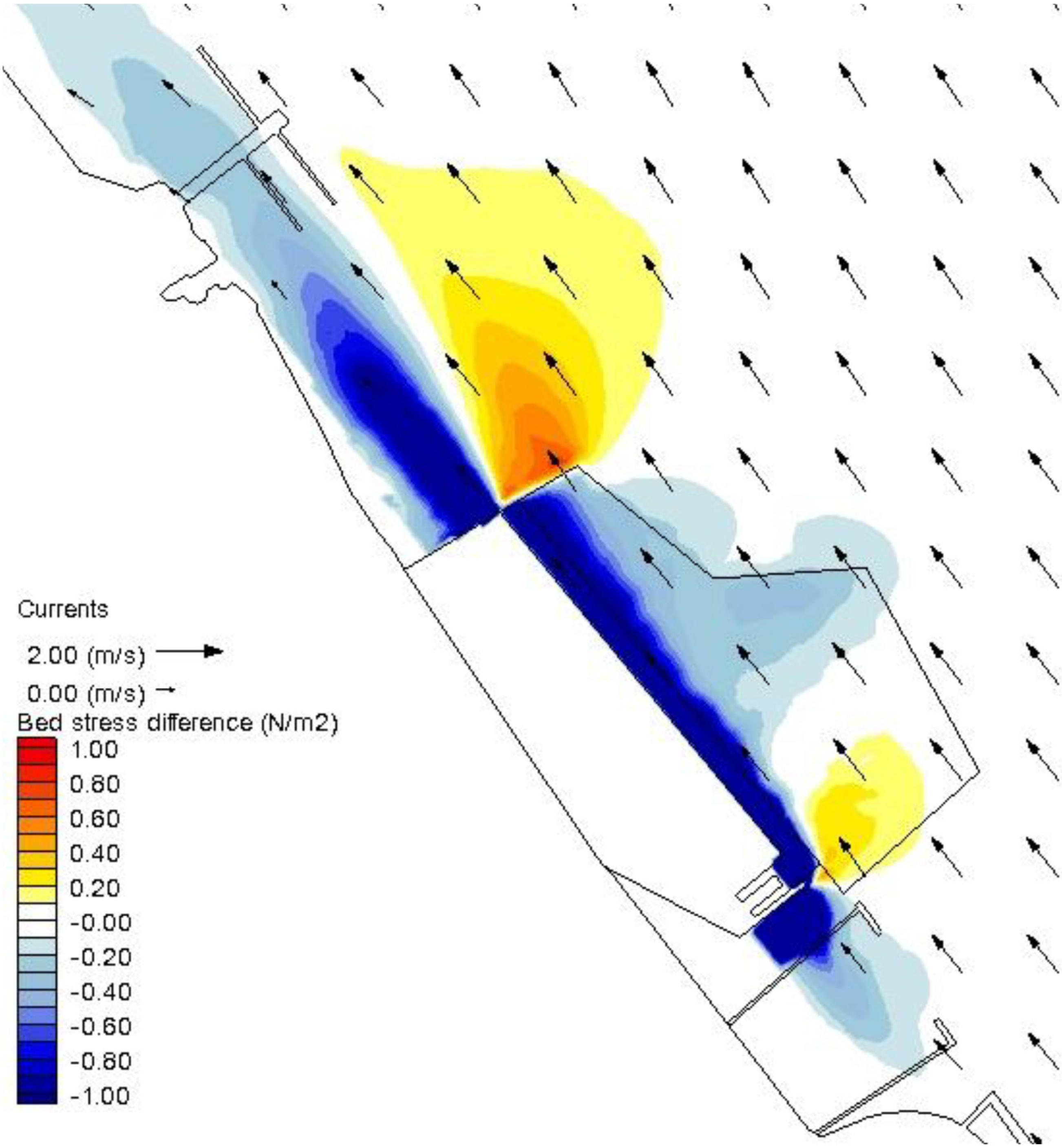


Figure 8-27: Wider Estuary modelled changes to peak mean spring tide bed shear stress, flood tide (AMEP Amended Quay minus updated baseline).

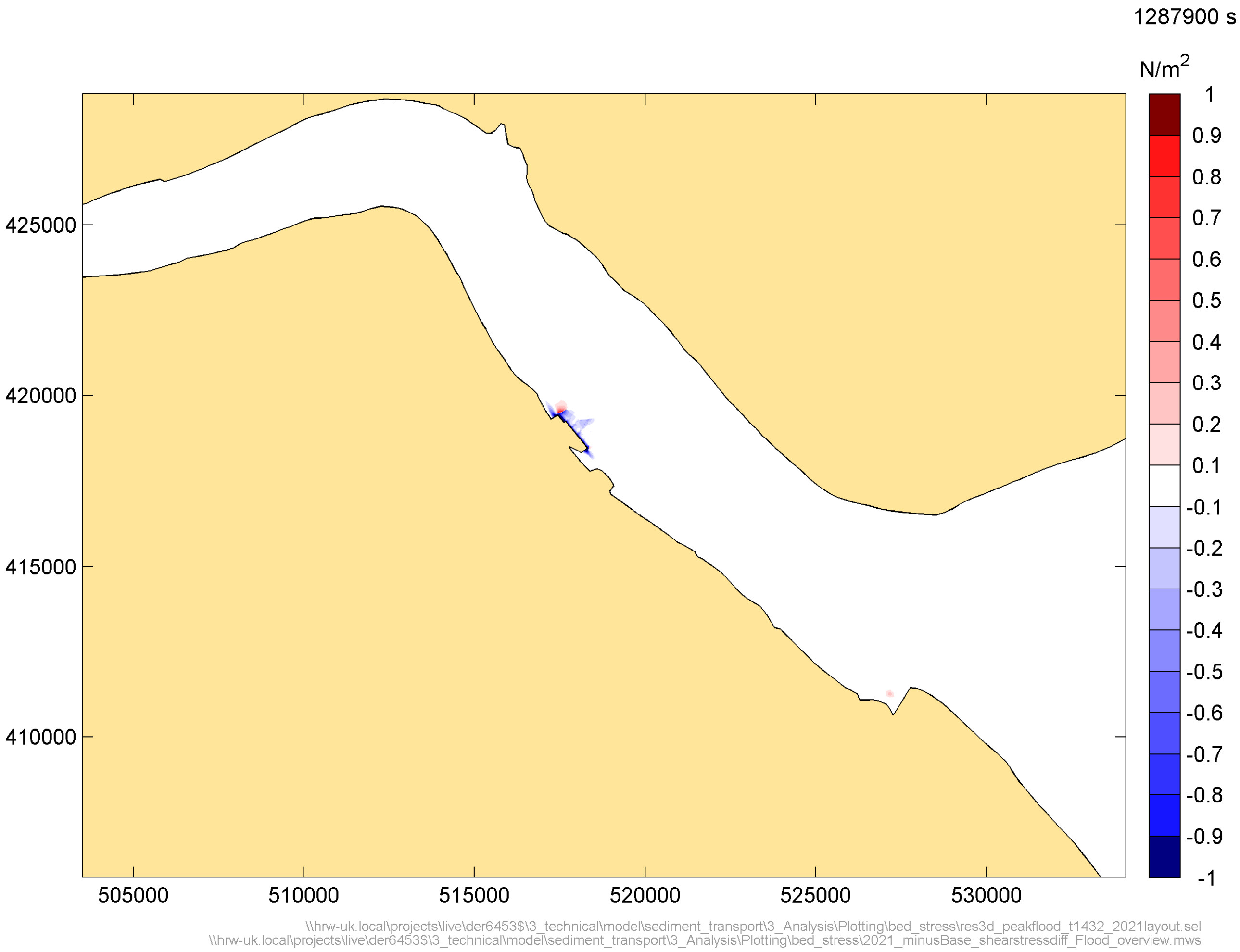


Figure 8-28: Wider Estuary modelled changes to peak mean spring tide bed shear stress, flood tide (AMEP minus baseline). From EX8.7A (JBA, 2012).

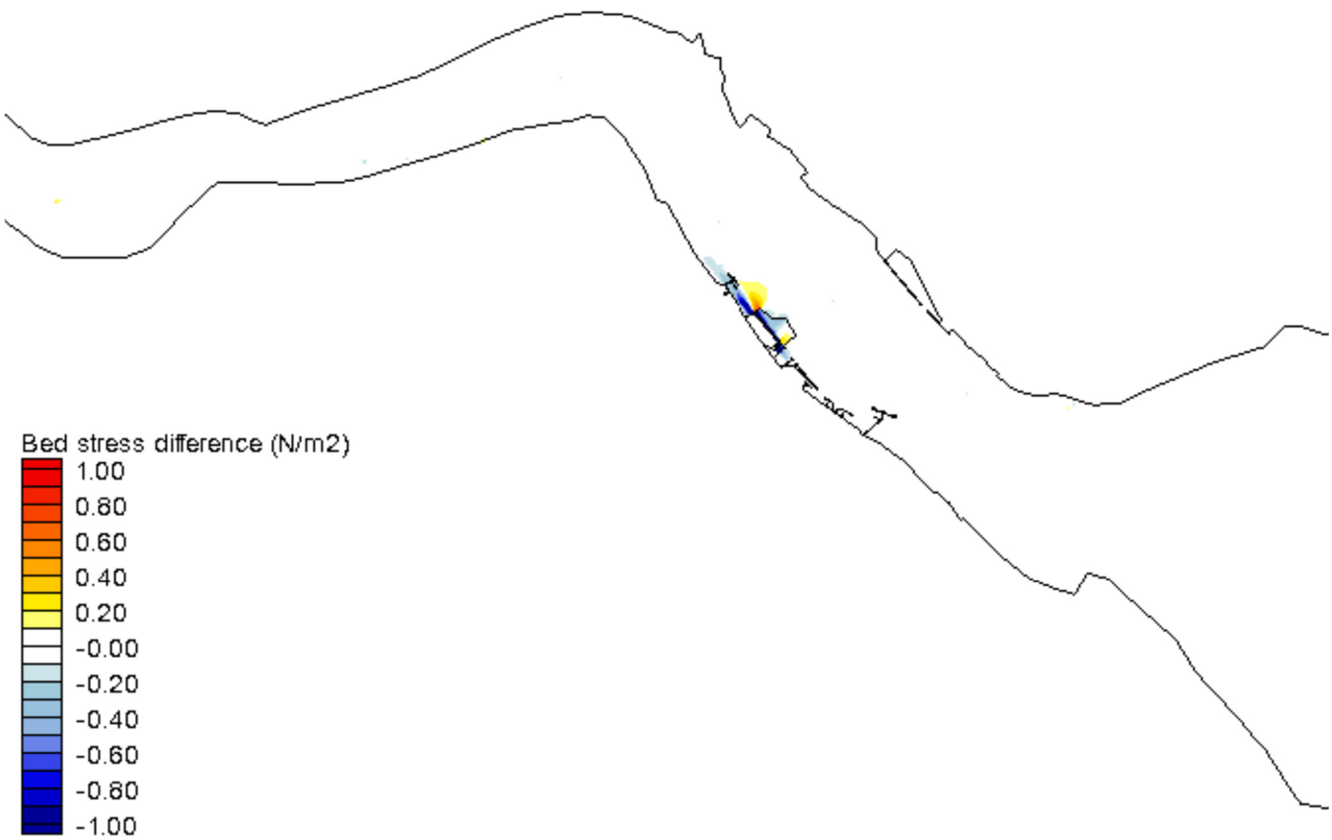


Figure 8-29: Modelled changes to peak mean spring tide bed shear stress, ebb tide (AMEP Amended Quay layout minus updated baseline)

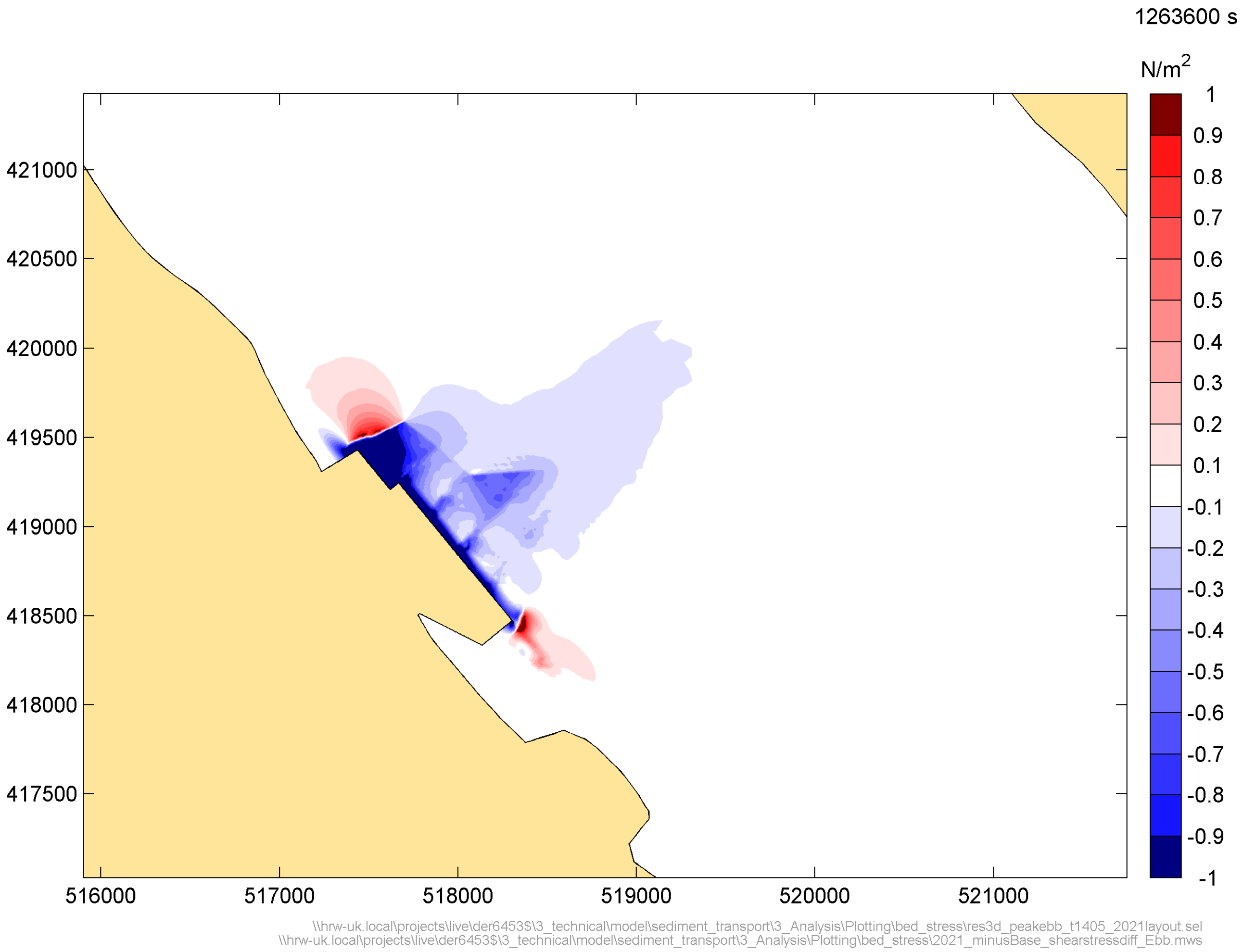


Figure 8-30: Updated modelled changes to peak mean spring tide bed shear stress, ebb tide (AMEP minus baseline). From EX8.7A (JBA, 2012)

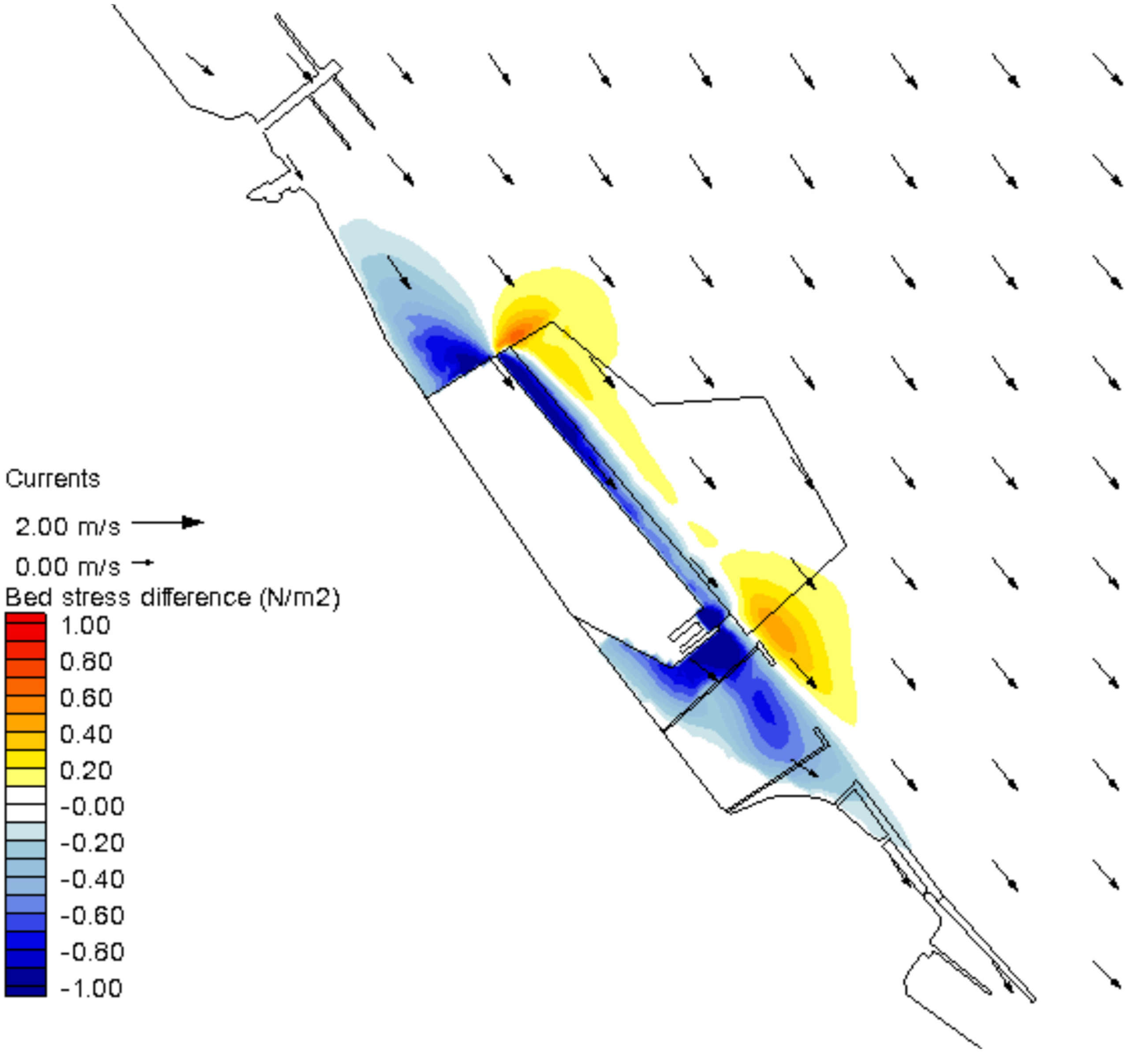


Figure 8-31: Wider estuary modelled changes to peak mean spring tide bed shear stress, ebb tide (AMEP Amended Quay layout minus updated baseline).

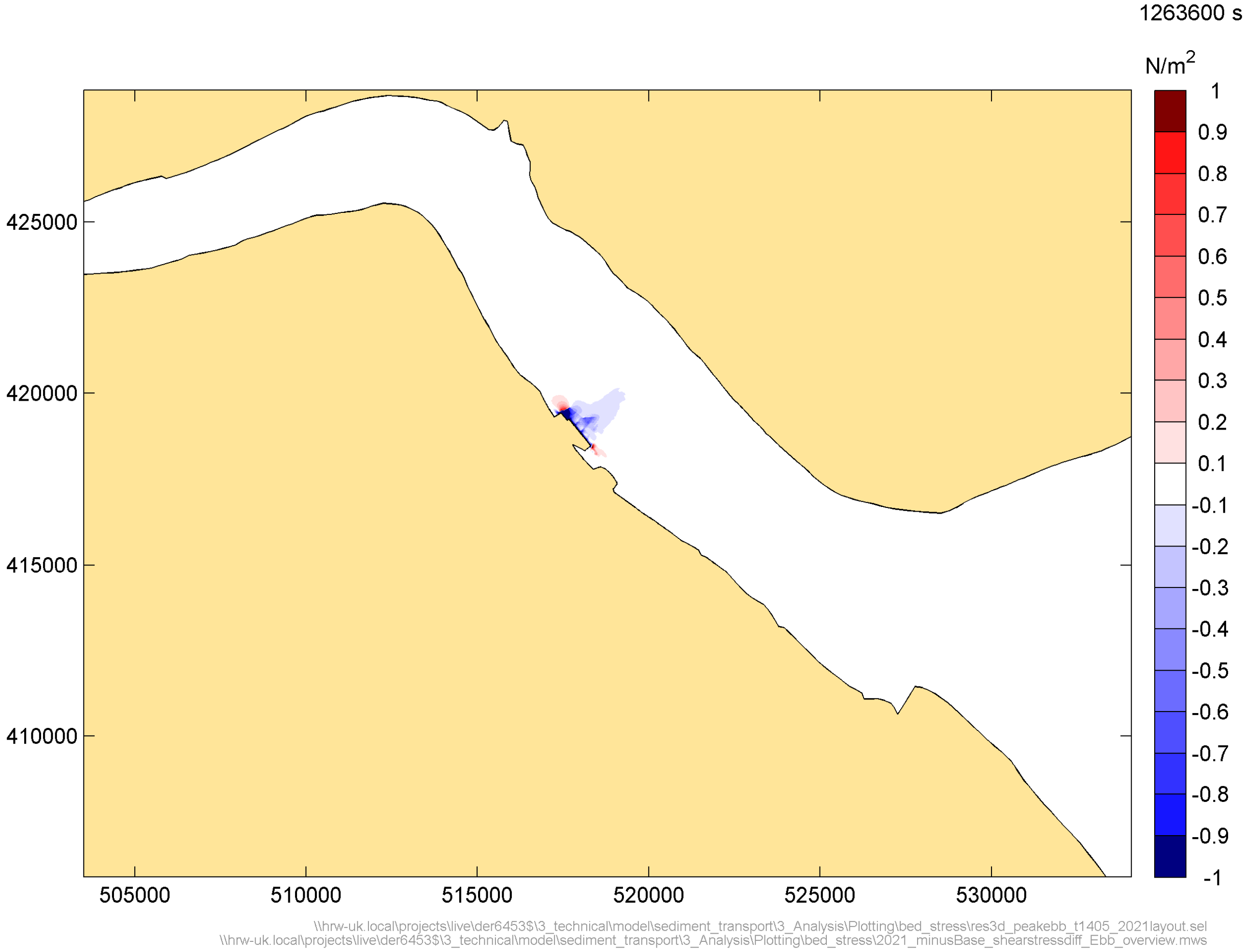
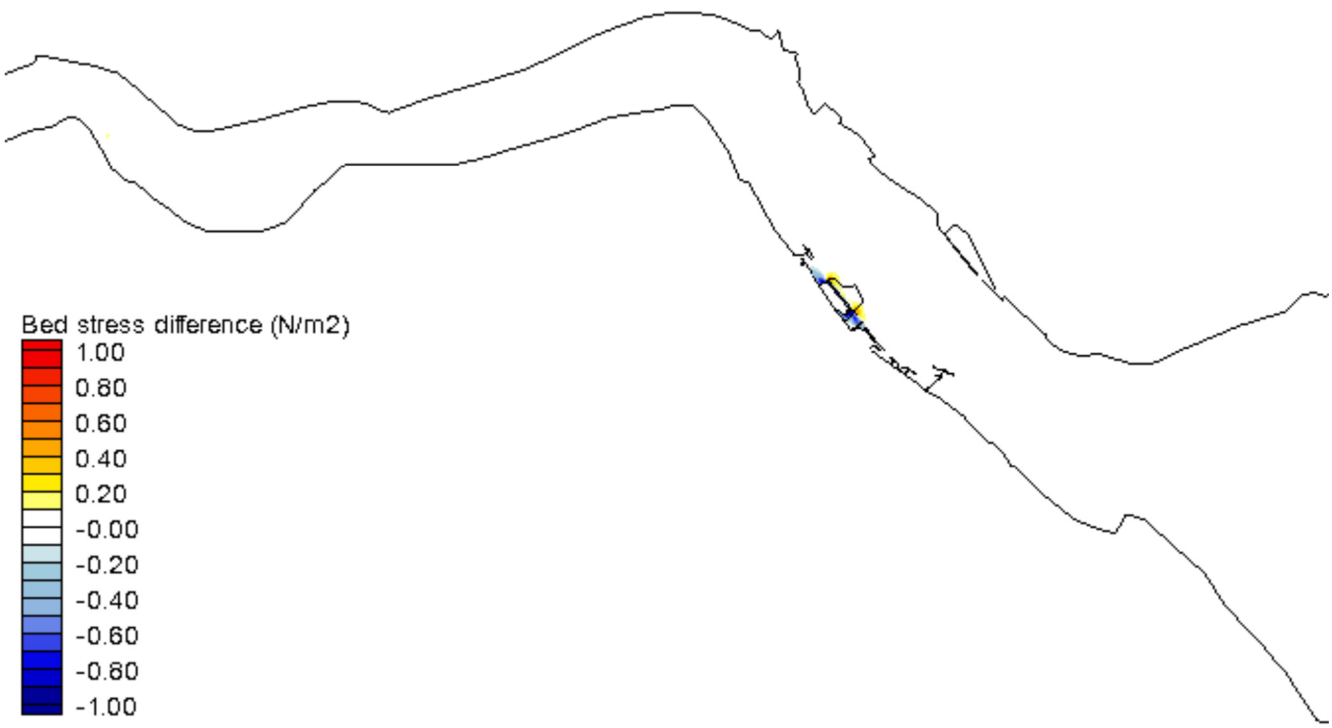


Figure 8-32: Wider estuary modelled changes to peak mean spring tide bed shear stress, ebb tide (AMEP minus baseline). From EX8.7A (JBA, 2012).



Impacts on Waves and Overtopping

8.4.48 Because of the minor changes associated with the proposed Amended Quay compared with the consented scheme, impact on waves has been assessed by expert opinion rather than by application of further wave modelling.

8.4.49 Figure 8-1 shows the AMEP Amended Quay layout compared with the consented AMEP Quay. The differences between the layouts that may affect waves are as follows:

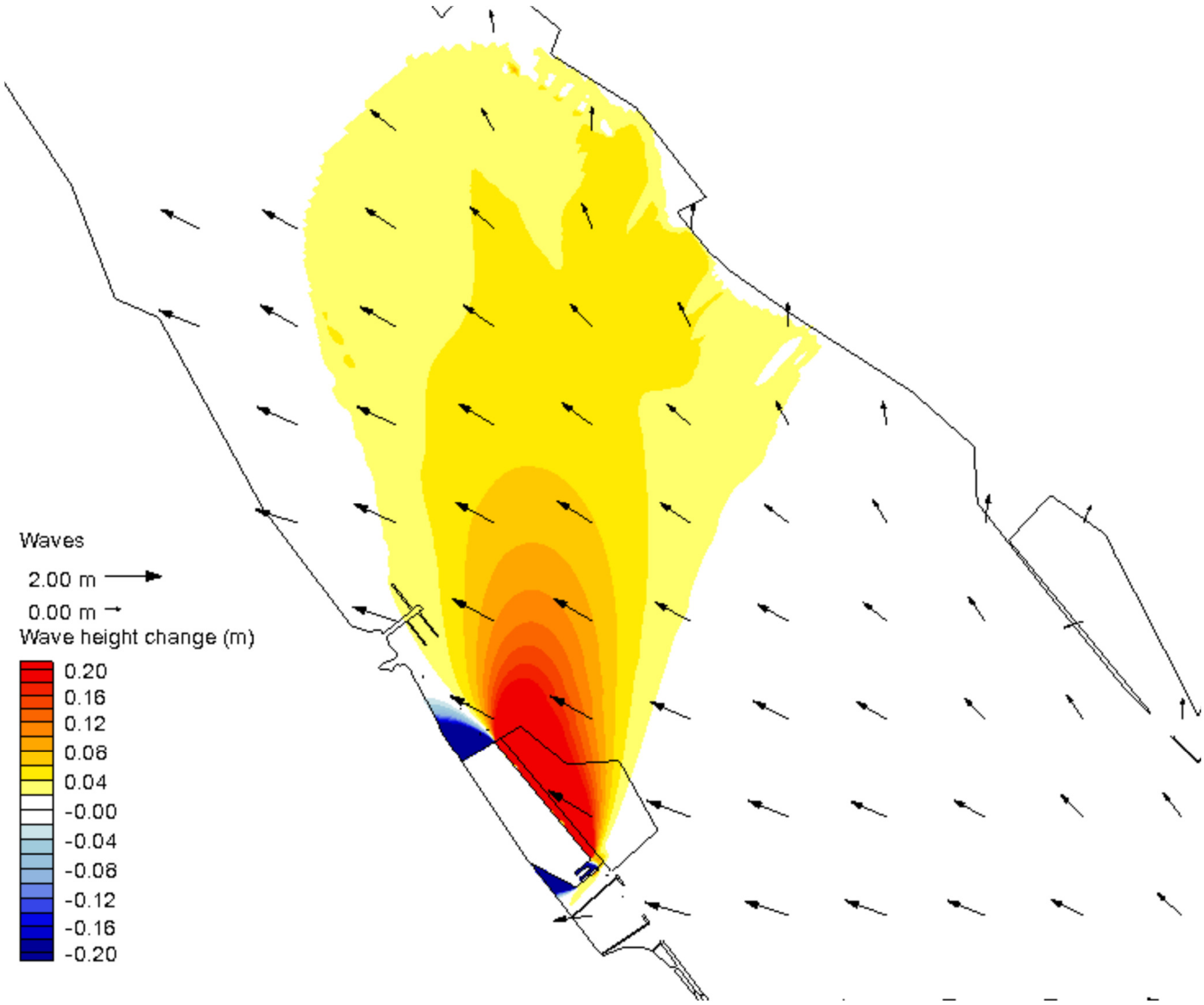
- The berth at Quay 7 (upstream end) has been inset from the line of the other berths;
- The specialist dock at Quay 1 (downstream end) has been filled in to a straight quay aligned with the main quay face and the caisson breakwater at the south eastern end removed; and
- The local baseline intertidal bathymetry has further accreted since the DCO assessment.

8.4.50 Differences to predicted wave impacts arising from the AMEP Amended Quay layout are described below.

Changes to wave reflections from the main quay

8.4.51 For the consented layout, wave reflections from the main quay face are predicted to cause local increases in waves in front of the quay and reflections across the estuary (Figure 8-33).

Figure 8-33: Modelled increase in wave heights for a 1:200-year water level/wave height event in 2033 for waves from the east (Final AMEP Layout minus future 2033 'baseline'). From EX8.7A (JBA, 2011)



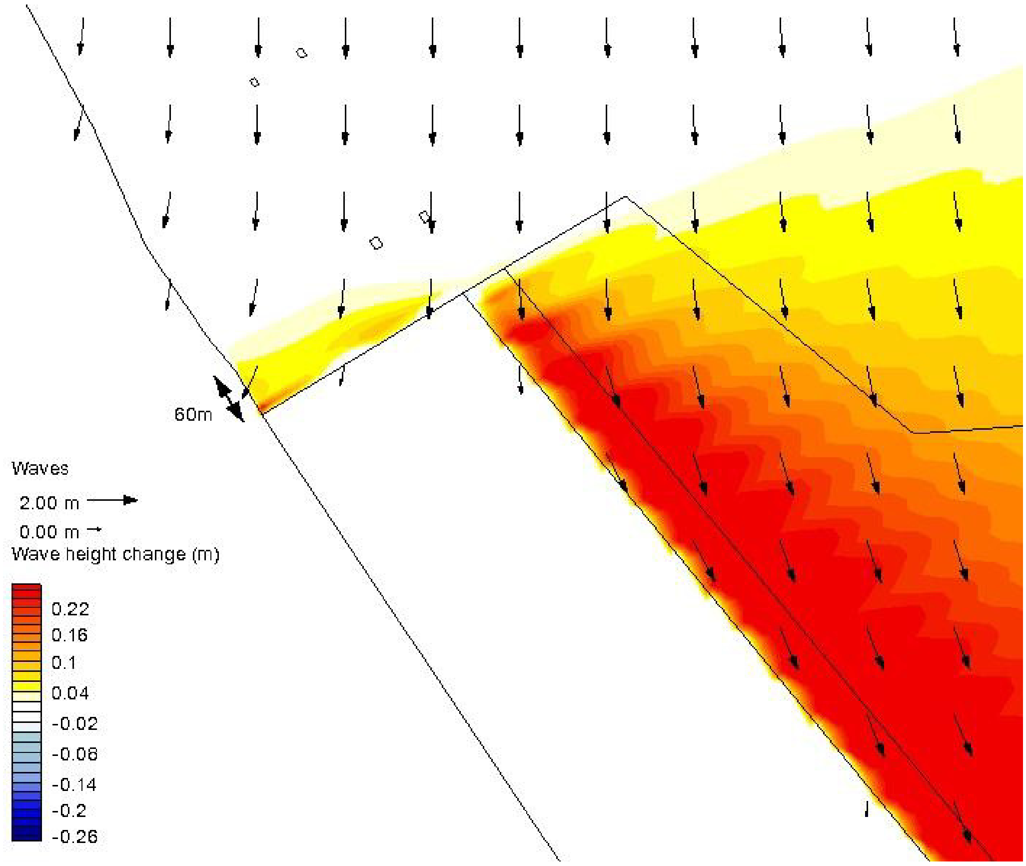
8.4.52 For the AMEP Amended Quay, the line of the quay is less continuous since the Quay 7 berth is set back. The waves are relatively short period. As the reflected wave travels back out of the berth pocket the refraction effect will be reversed so any change in direction of the reflected waves is likely to be minimal. The fact that the face of the quay wall includes a setback to Quay 7 is likely to induce slightly more spreading of the reflected wave as the wave front is not being reflected from a single plane face. It is therefore concluded that the wave reflected to the north shore will be no greater and likely slightly smaller than for the consented scheme.

8.4.53 Waves from the Northwest also reflect from the quay wall but do not significantly affect the north shore of the estuary. The difference for these waves in the proposed new layout is that there is a corner in the new Quay 7 berth. There will be a concentration of wave energy in this corner as waves reflect from both Quay 6 and Quay 7 on either side of the corner. This is a local effect that may increase the chance of wave overtopping locally onto the quay in this corner. This will need to be considered in the design of the quay and its drainage arrangements.

Changes to wave reflections from the Northwestern face

8.4.54 For the consented AMEP quay, reflections of Northwesterly waves from the Northwestern face of the reclamation are predicted to cause local increases in wave heights in the corner just upstream of the development (Figure 8-34). The scheme therefore includes a mitigation measure of rock armour extending 60m upriver in front of the EA sea defences.

Figure 8-34: Modelled increase in wave heights for a 1:200-year water level/wave height event in 2033 for waves from the north (Final AMEP Layout minus future 2033 'baseline'). From EX8.7A (JBA, 2012)



8.4.55 In the proposed amended quay layout, the fact that Quay 7 is inset means that the vertical wall along the Northwestern face of the reclamation extends for a shorter distance. This will mean that reflections from this face onto the upriver shore will be slightly reduced causing less of an impact. It should also be noted that there has been, and is likely to continue to be, accretion of the intertidal area at this location which will provide protection to the sea defences.

Changes to wave reflections from the Southeastern face

8.4.56 Waves from the Southeast also reflect from the Southeastern face of the development. However, as explained in the JBA (2012) report, in this area the depths in front of the sea defences are very shallow so that any additional reflected wave energy will break before it reached the sea defences. Further accretion has continued in this location since 2012 with effects correspondingly further reduced.

8.4.57 For the AMEP Amended Quay, rock armour extending along the same part of this face of the development is proposed as for the consented scheme. The only difference is that the outer (seaward) section will be the vertical face of the reclamation rather than a caisson breakwater. Both the caisson breakwater modelled previously and a vertical wall would have a similar reflection coefficient of close to 1.0 so would locally reflect a similar amount of wave energy. Therefore, the proposed layout is likely to have a similar effect on waves to the southeast of the development than the consented scheme.

Impacts on Sediments

8.4.58 The sediment on the bed in the vicinity of the proposed quay varies between mud, sandy mud, and muddy sand. For this reason impacts on sediment transport are assessed through the use of 2D sand transport and 3D mud transport models. The 3D model was used to investigate the likely effects of the scheme on suspended sediments and morphology along the intake/outfall lines and sedimentation onto designated intertidal areas and into the existing adjacent downstream berths.

8.4.59 Figure 8-35 shows predicted deposition into the proposed amended quay berth pockets. A similar pattern of deposition to that in Figure 8-36 (consented layout) is seen downstream of the development. Upstream it is seen that the Amended Quay leads to a change (reduction) in the predicted increase in deposition towards the former HST (now C.Ro Port) berths.

Figure 8-35: Predicted increases to deposition or erosion of muddy sediments after a spring-neap cycle (AMEP Amended Quay layout minus updated baseline)

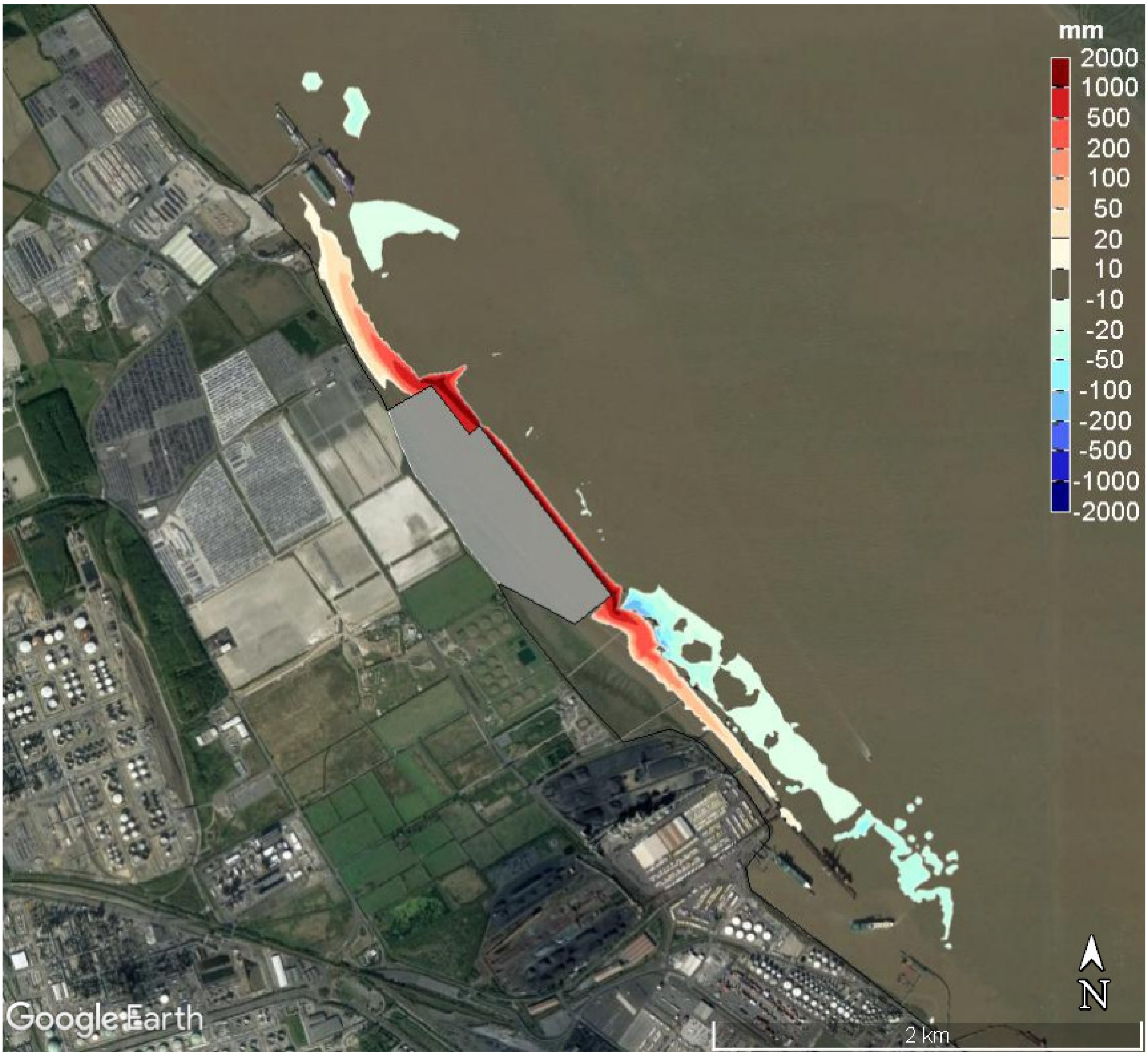


Figure 8-36: Predicted increases **to deposition or erosion of muddy sediments after a spring-neap cycle (AMEP minus baseline (consented)). From Annex 8.3 (HR Wallingford, 2011)**

Figure 8-37: Predicted increases to potential deposition or potential erosion of sandy sediments after a spring-neap cycle (AMEP Amended Quay layout minus updated baseline).

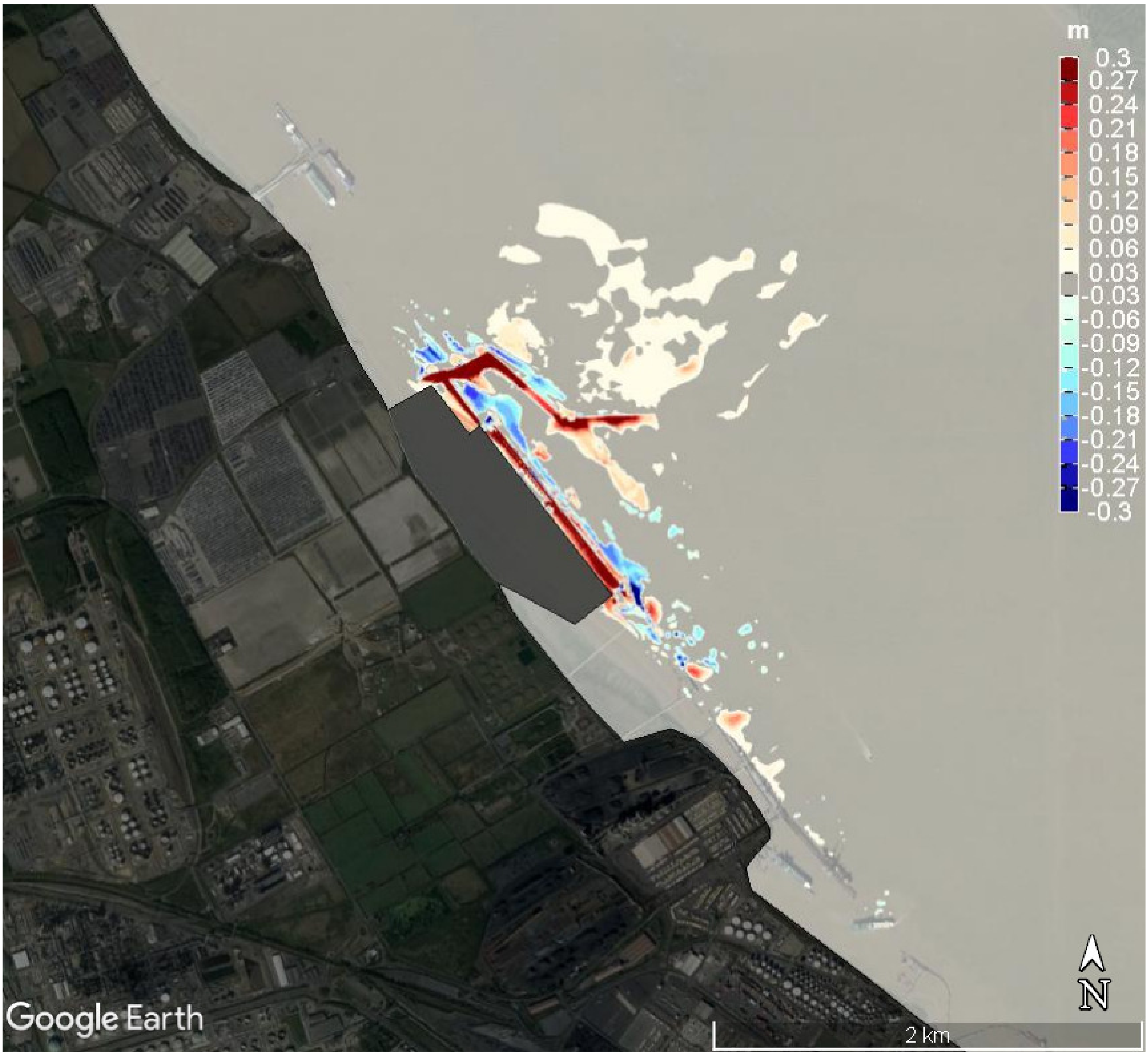
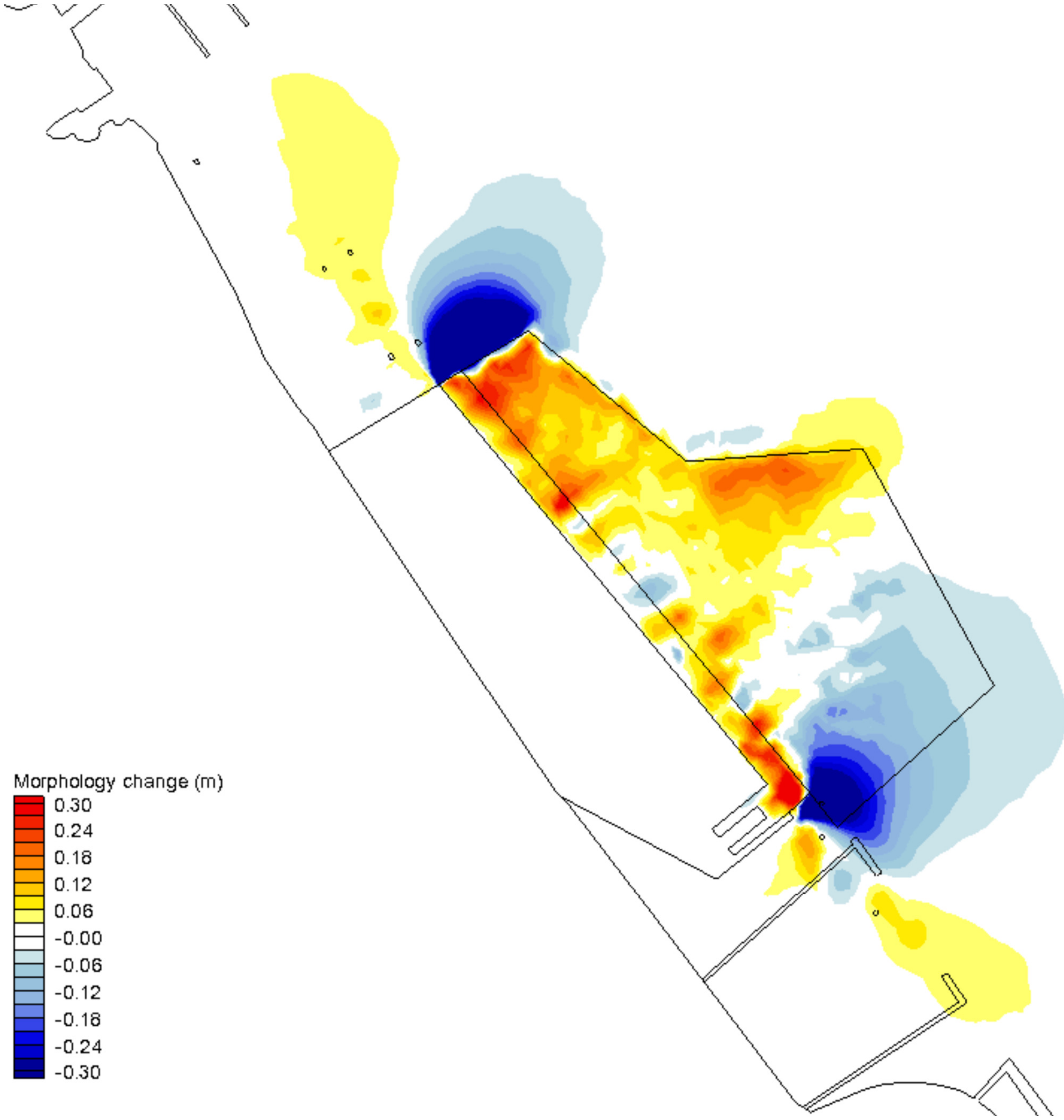


Figure 8-38: Predicted increases to potential deposition or potential erosion of sandy sediments after a spring-neap cycle (AMEP minus baseline (consented)). From (EX8.7A, JBA, 2012)



Impacts on Future Maintenance Dredging Requirements

8.4.60 Annualised sedimentation values are presented in Table 8-10 below. To convert from masses in the 3D model to volumes, a dry density of 500 kg/m^3 was assumed.

8.4.61 Table 8-10 shows the predicted annualised sedimentation into the AMEP Amended Quay layout berths and turning area, as well as the predicted changes to sedimentation rates into adjacent berths, for both mud and sand (AMEP Amended Quay minus updated baseline).

Table 8-9: Annualised changes to deposition and erosion for AMEP Amended Quay compared with updated baseline derived from the 3D mud and 2D sand transport modelling

Area	Predicted Annual Increase in Deposition (m^3/Year)	Predicted Annual Increase in Deposition (m^3/Year)
	AMEP Amended Quay	AMEP Amended Quay
	3D mud transport model	2D sand transport model*
Humber Sea Terminal	-9,000 to -22,000	13,000 to 18,000
South Killingholme Oil Jetty	35,000 to 88,000	-100,000 to -204,000
Immingham Gas Terminal	3,000 to 7,000	-29,000 to 18,000
Humber International Terminal	-11,000 to -27,000	50,000 to 102,000
Immingham Bulk Terminal	-19,000 to -47,000	8,000 to 13,000
AMEP	418,000 to 1,044,000	474,000 to 697,000
Inshore of E.ON and Centrica Intakes	131,000 to 327,000	0
Immingham Outer Harbour	-53,000 to -132,000	2,000 to 3,000

** The lower figure assumes a 0.3 mm median grain size and the higher figure a 0.1 mm median grain size for the estuary bed as a whole as the boundary condition for the sand transport modelling. Sand transport volumes reflect potential transport subject to sand availability.*

8.4.62 The updated baseline bathymetry leads to changes in the overall infill rates predicted for both muddy and sandy sediments. It is worth noting that the operational depth in the turning area was -9m CD for these simulations and that the polygon defining the outer turning area for the amended layout is slightly different to that used for earlier predictions in 2012.

8.4.63 By comparing the AMEP Amended Quay layout simulation against an updated simulation of the consented layout (both using the latest bathymetry), the following changes presented in Table 8-11 are predicted solely as a result of the amendments shown in Figure 8-1.

Table 8-10: Annualised changes to deposition and erosion for AMEP Amended Quay layout compared with updated consented Quay, from the 3D mud and 2D sand transport modelling

Area	Predicted increase in sedimentation (m^3/Year) arising solely from changes to AMEP	Predicted increase in sedimentation (m^3/Year) arising solely from changes to AMEP
	3D mud transport model	2D sand transport model**
Humber Sea Terminal	-23,000	5,000 to 10,000
South Killingholme Oil Jetty	-4,000	2,000 to 11,000
Immingham Gas Terminal	-17,000	-22,000 to 1,000
Humber International Terminal	0	10,000 to 12,000
Immingham Bulk Terminal	0	3,000
AMEP Berth Pockets	60,000	-16,000 to -50,000
AMEP ***	60,000	163,000 to 287,000
Inshore of E.ON and Centrica Intakes	-165,000	0 to 31,000
Immingham Outer Harbour	0*	1,000

**As seen in Table 8-10, a reduction in baseline sedimentation of muddy sediments into Immingham Outer Harbour continues to be predicted for the* proposed AMEP Amended Quay layout.
***Predicted potential sand transport will be limited by availability of sand. Examination of recent maintenance reports (volumes/ composition) at adjacent berths, if available, would indicate the degree to which modelled potential sand transport is limited by availability of supply.*
**** For mud, the deposition within the AMEP is all within the Berth Pockets, so total additional mud deposition within AMEP is predicted to be 60,000m^3*

AMEP berth pockets, turning area and approach channel:

8.4.64 Supplementary report EX8.6 was produced in 2012 in response to a request from the MMO/EA to consider an upper estimate maintenance dredging quantity (annual and three-yearly) for AMEP. The study (Maintenance Dredging Variability) took as inputs: the 3D mud modelling results for the latest scheme; OSPAR reported dredge disposal figures, and; ABP published maintenance dredging quantities in 2010 and 2011 for different Humber berths. By relating the modelled sedimentation quantities to the published maintenance dredging quantities and by adding a component of uncertainty based upon variability from year to year in the published returns, the study gave a refined upper estimate for maintenance dredging for AMEP.

8.4.65 Using the same methodology described above, the assessment of the AMEP Amended Quay, when compared against the remodelled consented layout with present-day (2017-19) bathymetry, provides an upper estimate of ((60,000 / 1.9) x 1.3) = 41,000 m^3/year additional infill of muddy sediments into the AMEP Amended Quay layout berthing pockets. This net increase reflects the sum of a decrease of sedimentation into the specialist quay dock (because it has been removed) plus the relocation of 288 m of berth pocket 61 m landward (in a location where the natural depths are somewhat shallower), together with the shape of the inset quay meaning that there will be locations within the quay that are likely to be more prone to deposition than the remaining 1 km of quay line.

8.4.66 With respect to sandy sediments, it is predicted that any sand volume accumulating in the berth pockets annually will be decreased compared with the consented scheme. The predicted potential increase of sandy sediment infill to the turning area is up to 196,000m^3/year. The predictions of sand infill are considered conservative because the existing Immingham berths are not presently subject to significant sandy infill, the accumulations being silty, the seabed surficial deposits contain significant proportions of muddy material which will reduce the mobility of the sand fraction.

Morphological assessment

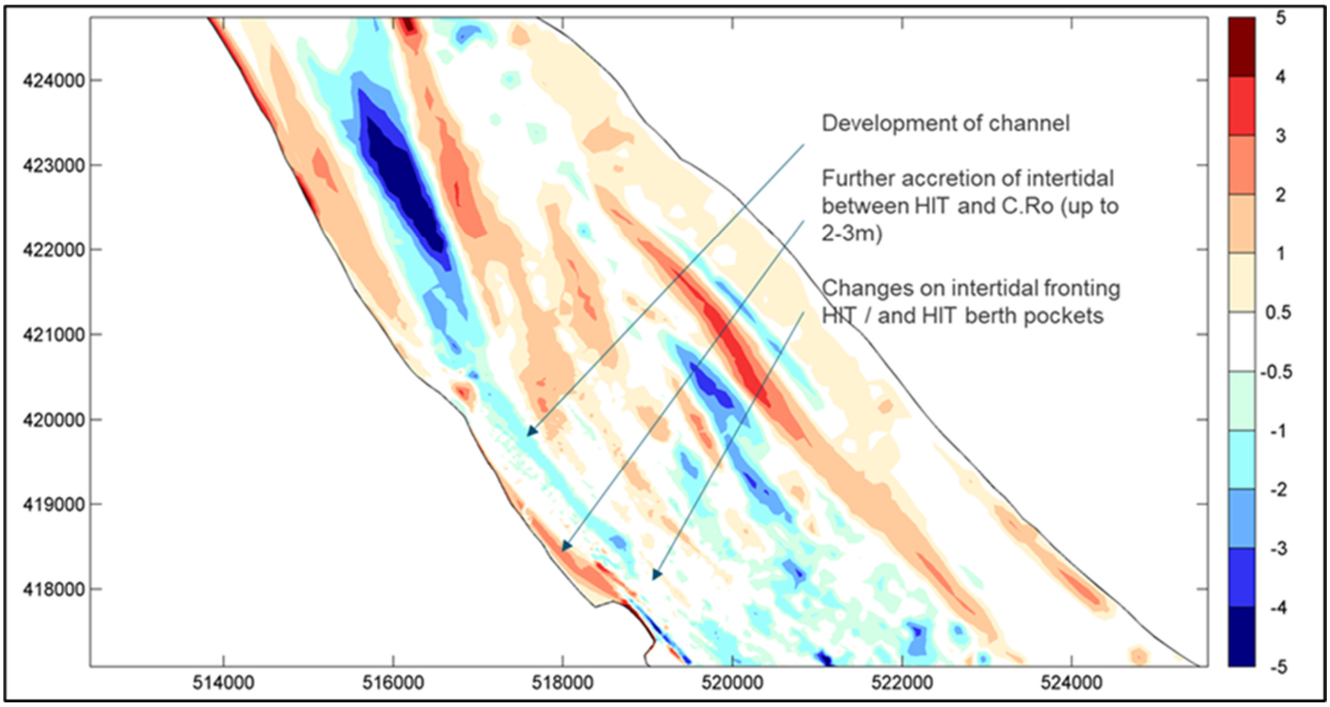
8.4.67 In terms of muddy sediments for the AMEP Amended Quay layout compared against the updated simulation (present-day bathymetry) of the consented layout, the Amended Quay results in 41,000 m^3/year more predicted accretion into the AMEP berth pockets. A beneficial effect of the amended quay design is to reduce the previously predicted impacts on the region inshore of the Uniper and CGEN intake and outfall locations. The predicted impact at SKOJ is found to be a requirement for increased maintenance dredging as a result of the updated bathymetry. The Amended Quay makes little difference to this situation (a smaller reduction compared to the consented AMEP). A similar picture is seen at IGT, although the overall impact is small. At HIT, IBT and IOH there is no predicted increase in maintenance dredging requirements arising from the AMEP Amended Quay layout. In summary, the Amended Quay layout is predicted to slightly reduce (a reduction of about 29,000 wet tonnes per year, or <6%) the average annual disposal quantity of 503,000 wet tonnes from HST/C.Ro for the period 2016 to 2019. For the Immingham Riverside berths, the Amended Quay is predicted to slightly reduce (a reduction of about 26,000 wet tonnes per year, or ~1%) the average annual disposal quantity of 3,447,000 wet tonnes for the period 2016 to 2019.

8.4.68 In terms of sandy sediments, impacts of the AMEP Amended Quay layout are a small increase in potential deposition of sands into SKOJ (depending on current actual composition of dredged sediments). At IGT either a little less or more deposition is predicted subject to actual grain sizes, at HST/C.Ro there is a small increase in potential sand transport into the area, less than the reduction in fine sediments; at HIT there is predicted to be more deposition of sandy sediments in the updated scenario, and with a little more (5-10%) predicted to arise solely due to the AMEP Amended Quay layout. Changes at IBT and IOH are minimal. The region behind the Uniper and CGEN intakes sees no increase in sandy sediment deposition. The berth pockets of the AMEP Amended Quay are predicted to receive 34,000 m^3 less sandy sediment per year when compared with the consented scheme. The prediction conservatively assumes there is an abundance of mobile sand in proximity to the manoeuvring area. In reality the material dredged and disposed in proximity to AMEP is described as silt and likely has a low sand content.

Bathymetry changes

8.4.69 It is noted that intertidal accretion upstream of HIT has continued between 2012 and present day, with a further increase in intertidal level of 2-3 m as can be seen in Figure 8-40 which shows the difference between bathymetry and LiDAR available at the time of the assessment in 2012, and the updated bathymetry and LiDAR data now available.

Figure 8-39: Recent changes to local bathymetry and intertidal levels (difference shown in metres with positive or red showing accretion)



Summary of Effects

8.4.70 Disposal of dredged material to sites HU081 and HU082 by barge will result in localised changes to the tidal currents and wave action in proximity to the site. These changes to the hydrodynamics will have no effect on the ongoing coastal erosion to the north east of Hawkins Point or to the proposed site for managed realignment further to the east.

8.4.71 The material placed at sites HU081 and HU082 will be eroded by the action of the tidal currents and waves and the silt and clay sized material arising will disperse rapidly from the sites. Sands and gravel sized material arising from the placement will tend to accumulate in undulations on the seabed at the disposal site. Any glacial till dredged by BHD and placed by barge at HU081 or HU082 will slowly be eroded by the action of tidal currents and waves. Sands and gravel sized material at the disposal sites and arising from the erosion of the glacial till will reduce the overall rate of erosion of the placed till. It is expected that the majority of the glacial till placed at either site will erode within a few years of placement.

8.4.72 The proposed AMEP Amended Quay leads to no significant change in assessed impacts on water levels compared to the consented layout.

8.4.73 The proposed AMEP Amended Quay leads to no significant change in assessed impacts to flood tide flows compared to the consented layout. During the ebb tide, a localised region of flow acceleration is predicted off the downstream end of the quay. This initial change may diminish with time but should be noted.

8.4.74 Similar patterns of bed shear stress are presented for the AMEP Amended Quay as for the consented layout.

8.4.75 The proposed AMEP Amended Quay leads to no significant change in assessed impacts on waves compared to the consented layout.

8.4.76 The AMEP Amended Quay layout is predicted to slightly reduce by 29,000 wet tonnes per year (or <6% of the average annual disposal quantity of 503,000 wet tonnes for the period 2016 to 2019) of the HST/C.Ro berths and approaches. For the downstream Immingham Riverside berths, the AMEP Amended Quay is predicted to slightly reduce the annual siltation by about 26,000 wet tonnes per year (or ~1% of the average annual disposal quantity of 3,447,000 wet tonnes for the period 2016 to 2019).

8.4.77 The predicted annual maintenance requirement arising from operations will be in the range 210,000 to 520,000 dry tonnes (previously consented scheme 250,000-630,000 dry tonnes) from the dredging of the AMEP berthing pocket and dock. This is likely to require dredging by TSHD and disposal at the Sunk Deep Channel disposal site HU080 as currently consented.

8.4.78 Re-applying the same methodology adopted in EX8.6 to the infill volumes for the amended quay presented in Table 8-10 leads to an upper estimate based on present-day bathymetry modelling of 357,000 dry tonnes which is consistent with the value for the consented scheme (429,000 dry tonnes). It is noted however that an additional 21,000 dry tonnes per year is predicted to be deposited into the berth pockets, with 288 m of berth pocket now set 61 m further towards the shore in a slightly shallower location.

8.4.79 Significant localised sand deposition onto the dredged slopes of the proposed turning area / approach channel is predicted, again subject to sand availability. The overall potential deposition of sandy sediments into the turning area is significantly increased compared to the previous modelling. This is likely due to the change in sand transport model applied, the changed sea bed morphology and not substantially as a result of the AMEP Amended Quay layout. In practice any sandy infill will be limited by availability and supply and it is noted that since consent this area has already significantly deepened. The prediction conservatively assumes there is an abundance of mobile sand in proximity to the manoeuvring area.

8.4.80 To the north of AMEP larger scale sea bed level rising of the estuary, particularly on the intertidal is likely to be at a slightly lower rate with the proposed AMEP Amended Quay layout. To the south there is likely to be no significant change from that predicted, other than to note that significant accretion has taken place since the original assessment (as a result of HIT) which leads to less further accretionary effect possible by AMEP (AMEP Amended Quay or Consented).

8.4.81 There are no in-combination projects to be considered relevant to this topic. The placement of dredged material to HU081 and HU082 has been shown to have no effect on the ongoing coastal erosion at Hawkins Point and will also have no interaction with the proposed managed realignment further to the east.

8.5.0 Requirement for Additional Mitigation

DCO Mitigation

8.5.1 The extant DCO provides for monitoring and managing the impacts of the scheme on the hydrodynamic and sedimentary regime as follows:

- Schedule 8 contains multiple conditions to control activities in order to mitigate the impacts of construction and dredging. In particular Condition 31 requires detailed method statements for all works below MHWS to be approved by the MMO.
- Schedule 9 contains Protective Provisions for the Harbour Master and neighbouring port operators.
- Schedule 11 Requirement 19 requires the Marine Environmental Management and Monitoring Plan to be agreed with the MMO.
- Schedule 11 Requirement 36 requires a Monitoring and Management Plan for the '*Centrica and E.ON cooling intakes and outfalls*' to be approved by the MMO.
- Schedule 11 Requirement 38 requires a scheme for the monitoring of the foreshore levels around the quay to be agreed with the MMO.

Alternate or Additional Mitigation

8.5.2 Taking into account the mitigation already secured through the extant DCO and the relatively low level of change pursuant to the proposed material change, the following additional monitoring and mitigation is proposed and would need to be accommodated within any Amendment Order:

- Placement by barge of material dredged by CSD into sites HU081 and HU082 to spread impact during the placement period.
- Depending upon overall volumes of material to be placed at HU081 and HU082 consider greater quantity of material being placed into HU082 than HU081 to reduce potential for increased tidal currents around HU081.
- Target placement of any glacial till dredged by BHD to HU082 so that changes caused by placement at HU081 occur for a shorter period.
- Programme of bathymetric survey over HU081 and HU082 and in their vicinity during and after placement
- Use ongoing LiDAR monitoring as a source for surveillance of foreshore around Hawkins Point
- Current measurements pre- and post- construction of AMEP at the South Killingholme Oil Jetty to establish the significance of any changes to ebb tidal currents after construction of AMEP.

8.6.0 Residual Effects

Operational Phase

8.6.1 Given that the effects are permanent, even with mitigation, the residual impacts remain as per the impacts described in the Assessment of Effects section of this chapter (Section 8.4.0).

8.6.2 The predicted annual maintenance requirement arising from operations will be in the range 210,000 to 520,000 dry tonnes (previously consented scheme 250,000-630,000 dry tonnes) from the dredging of the AMEP Berthing Pocket and Dock. This is likely to require dredging by TSHD and disposal at the Sunk Deep Channel disposal site HU080.

8.6.3 Re-applying the same methodology adopted in EX8.6 to the infill volumes for the AMEP Amended Quay presented in Table 8-10 leads to an upper estimate based on present-day bathymetry modelling of 357,000 dry tonnes which is consistent with the value for the consented scheme (429,000 dry tonnes). It is noted however that an additional 21,000 dry tonnes per year is predicted to be deposited into the berth pockets, with 288 m of berth pocket now set 61 m further towards the shore in a slightly shallower location. Additionally, a potential reduction of 16,000 m^3 in sand infill is predicted to occur in the AMEP Amended Quay berthing pockets compared with the consented Quay.

Consideration of DCO

8.6.4 There is an increase in maintenance dredging requirement at the AMEP for the proposed AMEP Amended Quay layout compared with the consented layout, this arises from the potential for sand infill in the manoeuvring area and approaches.

8.7.0 Other Environmental Issues

8.7.1 This Section seeks to detail any considerations and environmental effects which have been identified with regard to the range of topics which have been introduced into EIA requirements through the EIA Regulations 2017. Where there are no such considerations or environmental effects, this is also specified below for clarity.

8.7.2 Refer to Chapter 25 for a summary of the 'Other Environmental Issues' identified across all of the technical assessments undertaken and the Chapters prepared as part of the UES.

Other Environmental Issues of Relevance

Infrastructure

8.7.3 Whilst the purpose of the project is to provide the infrastructure necessary to enable offshore renewable electricity generating infrastructure to be built, the impacts of the scheme on the hydrodynamic and sedimentary regime has no consequential impacts on existing infrastructure.

Waste

8.7.4 The impacts of the scheme on the hydrodynamic and sedimentary regime will result in changes to maintenance dredging and this could result in more waste being generated. Maintenance dredging within the Humber Estuary varies significantly from year to year and the additional volume of maintenance dredging at AMEP (357,000 dry tonnes/year) is about 30% of the dry mass disposed from the adjacent berths and approaches over the period 2016 to 2019 at HST/C.Ro (average 255,000 dry tonnes/year) and the Immingham Riverside berths and approaches (average 945,000 dry tonnes/year). The disposal of maintenance dredged material is controlled by the Marine Management Organisation to ensure it is disposed of appropriately.

Population and Human Health

8.7.5 The impacts of the scheme on the hydrodynamic and sedimentary regime has no consequential effects on population or human health.

Climate and Carbon Balance

8.7.6 The impacts of the scheme on the hydrodynamic and sedimentary regime has no consequential effect on the climate or carbon balance.

Risks of Major Accidents and/or Disasters

8.7.7 The impacts of the scheme on the hydrodynamic and sedimentary regime will not give rise to consequential increase in the risk of major accidents or disasters. The indirect effect of dredging in relation to navigation risk is assessed in Chapter 14 of this document.

8.8.0 Summary of Effects

8.8.1 Disposal of dredged material to sites HU081 and HU082 by barge will result in localised changes to the tidal currents and wave action in proximity to the site. These changes to the hydrodynamics will have no effect on the ongoing coastal erosion to the north east of Hawkins Point or to the proposed site for managed realignment further to the east.

8.8.2 The material placed at sites HU081 and HU082 will be eroded by the action of the tidal currents and waves and the silt and clay sized material arising will disperse rapidly from the sites. Sands and gravel sized material arising from the placement will tend to accumulate in undulations on the seabed at the disposal site. Any glacial till dredged by BHD or CSD and placed by barge at HU081 or HU082 will slowly be eroded by the action of tidal currents and waves. Sands and gravel sized material at the disposal sites and arising from the erosion of the glacial till will reduce the overall rate of erosion of the placed till. It is expected that the majority of the glacial till placed at either site will erode within a few years of placement.

8.8.3 The proposed AMEP Amended Quay layout leads to no significant change in assessed impacts on water levels.

8.8.4 The proposed AMEP Amended Quay layout leads to no significant change in assessed impacts to flood tide flows compared to the consented layout. During the ebb tide, a localised region of flow acceleration is predicted off the downstream end of the quay. This initial change may diminish with time but should be noted.

8.8.5 Similar patterns of bed shear stress are presented for the proposed AMEP Amended Quay layout as for the consented layout.

8.8.6 The proposed AMEP Amended Quay layout leads to no significant change in assessed impacts on waves compared to the consented layout.

8.8.7 The Amended Quay layout is predicted to slightly reduce by 29,000 wet tonnes per year (or <6% of the average annual disposal quantity of 503,000 wet tonnes for the period 2016 to 2019) of the HST/C.Ro berths and approaches. For the downstream Immingham Riverside berths, the Amended Quay is predicted to slightly reduce the annual siltation by about 26,000 wet tonnes per year (or ~1% of the average annual disposal quantity of 3,447,000 wet tonnes for the period 2016 to 2019).

8.8.8 The change to maintenance dredging requirements at the proposed AMEP Amended Quay layout when compared to the consented scheme is predicted to be an increase of up to 41,000 m^3/year muddy sediments and a decrease of 34,000 m^3/year for sandy sediments into the AMEP Berth Pockets. Significant localised sand deposition onto the dredged slopes of the proposed turning area / approach channel is predicted but the degree to which sandy infill occurs will be influenced by the availability of sand on the seabed. Presently material dredged from the area is described as silt.

8.8.9 To the northwest of AMEP, bed level rising is likely to be at a slightly lower rate with the proposed AMEP Amended Quay layout. To the southeast there is likely to be no significant change from that predicted, other than to note that significant accretion has taken place since the original assessment (as a result of HIT) which leads to less further accretionary effect possible by AMEP.

8.9.0 Conclusions

Changes in water levels, bed shear stresses and waves are similar for the AMEP Amended Quay layout and the consented. There are small differences in the peak flow patterns on the ebb tide. Changes to dredging requirements at the AMEP and surrounding facilities are detailed in Table 8-10.

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