6 HYDRODYNAMIC AND SEDIMENTARY REGIME

6.1 Introduction

This section presents the baseline conditions with regard to the hydrodynamic and sedimentary regime of the Tees estuary and describes the predicted effects of the proposed scheme on the estuarine system. It incorporates previous work (outlined in **Section 6.3.2**) as well as recent data from a metocean survey undertaken in July 2020 (**Section 6.3.3**) to characterise the baseline understanding and draws upon numerical modelling and expert geomorphological assessment for the assessment of potential effects.

While the proposed scheme has the potential to alter hydrodynamic and sedimentary processes, the significance of such changes or effects have not been defined in this section as 'impacts'. This is because coastal processes themselves are not considered to be receptors sensitive to change. Hence, while a change to a physical process can be predicted and described with respect to the known baseline in terms of its magnitude, it is not appropriate to predict the significance of an impact on the physical process. The significance of this change is nevertheless assessed with respect to those environmental receptors that could be influenced, such as water quality, marine ecological interests, navigation and marine waterbird populations, within the other relevant sections of this EIA Report.

6.2 Policy and consultation

6.2.1 National Policy Statement for Ports

The assessment of potential effects on the hydrodynamic and sedimentary regime has been made with reference to the NPS for Ports (Department for Transport, 2012). The particular assessment requirements that are relevant to the hydrodynamic and sedimentary regimes, as presented within the NPS for Ports, are summarised in **Table 6.1**.

Table 6 Summary of NPS for Ports requirements with specific regard to coastal processes

NPS requirement	**NPS reference**	**Section where requirement has been addressed**
Where relevant, applicants should undertake coastal geomorphological and sediment transfer modelling to predict and understand impacts and help identify relevant mitigating or compensatory measures	Section 5.3.4	**Section 6.5** and **6.6.**
The ES should include an assessment of the effects on the coast. In particular, applicants should assess: • the impact of the proposed project on coastal processes and geomorphology, including by taking account of potential impacts from climate change. If the development will have an impact on coastal processes, the applicant must demonstrate how the impacts will be managed to minimise adverse impacts on other parts of the coast; and • the implications of the proposed project on strategies for managing the coast, as set out in Shoreline Management Plans, any relevant marine plans, River Basin Management Plans and capital programmes for maintaining flood and coastal defences.	Section 5.3.5	**Section 6.5** and **6.6** and the Planning Statement which supports the planning application**.**
The decision-maker should not normally consent new development in areas of dynamic shorelines where the proposal could inhibit sediment flow or have an impact on coastal processes at other locations. Impacts on coastal processes must be managed to minimise adverse impacts on other parts of the coast. Where such proposals are brought forward, consent should only be granted where the decision-maker is satisfied that the benefits (including need) of the development outweigh the adverse impacts.	Section 5.3.9	**Section 6.5**

6.2.2 Marine Policy Statement

The UK Marine Policy Statement (MPS) (HM Government, 2011) provides the framework for preparing Marine Plans and taking decisions affecting the marine environment. The MPS sets out high level objectives for marine planning, which have directed development of the Plan at a local level. Marine Plans must be in accordance with other relevant national policy and are intended to contribute to the achievement of sustainable development in the UK marine area. The Marine and Coastal Access Act 2009 requires all public authorities taking authorisation or enforcement decisions that affect, or might affect, the UK marine area to do so in accordance with the MPS unless relevant considerations indicate otherwise. Regarding the topics covered by this section, the key references from the MPS are summarised in **Table 6.2**.

Table 6.2 MPS requirements relevant to hydrodynamic and sedimentary regime

Policy Description	MPS Reference	Section where requirement has been addressed
Marine plan authorities should not consider development which may affect areas at high risk and probability of coastal change unless the impacts upon it can be managed. 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.	Section 2.6.8.6	**Section 6.5**

6.2.3 North East Marine Plan

Public consultation on the draft North East Marine Plan (MMO, 2020) concluded on 20th April 2020 and the MMO is currently finalising plans for submission to the Secretary of State for Environment, Food and Rural Affairs for adoption. **Table 6.3** summarises the policies of the North East Marine Plan that are relevant to hydrodynamics and the sedimentary regime.

Table 6.3 North East Marine Plan policies relevant to hydrodynamic and sedimentary regime

Policy Code	Policy text	Section where requirement addressed
NE-DD-2	Proposals that cause significant adverse impacts on licensed disposal areas should not be supported. Proposals that cannot avoid such impacts must, in order of preference: a) minimise b) mitigate c) if it is not possible to mitigate the significant adverse impacts, proposals must state the case for proceeding.	**Section 6.5.2** and **6.6.4**.
NE-DD-3	Proposals for the disposal of dredged material must demonstrate that they have been assessed against the waste hierarchy. Where there is the need to identify new dredge disposal sites, proposals should be supported which are subject to best practice and guidance.	**Section 3.14**.

6.2.4 Consultation

A summary of consultation responses relevant to the assessment of hydrodynamics and sedimentary regime, and how these are addressed within this section, is presented in **Table 6.4**.

Table 6.4 A summary of relevant consultation responses

Consultation	Summary of Response	Section where response addressed
MMO Scoping Opinion (previously proposed scheme from 2019)	The ES needs to be based on the physical characteristics of the site, which should include a description of the proposed works; geography of the site; seabed properties, and; tidal/estuarine dynamics (tidal range and currents). The type of data used and detail required will depend on the sensitivity of each receptor (identified by the applicant) to these physical factors and the evidence the applicant requires to present their case. The use of in-situ and/or modelled data may be necessary to demonstrate a point. The MMO is unable to provide further comment on what should and should not be included in the assessment without further information. The applicant should conduct their own scoping assessment based on the physical characteristics of the site as described above.	**Section 6.4** describes the existing environment. **Sections 6.5.2** and **6.6.3** presents the findings of modelling undertaken for the proposed scheme.
Environment Agency (general)	The Environment Agency advised that updates to two guidance documents on climate change became available in July 2020, • Flood and coastal risk projects: https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances • Flood risk assessments: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances The 'flood risk assessment guidance' is coarser, providing allowances for different epochs for whole river catchment basins, whereas the 'flood and coastal risk projects guidance' is more specific to individual sites, encouraging the use of the UKCP18 User Interface.	**Section 6.4.3.**
Environment Agency (letter dated 14th August 2020)	The Environment Agency's response to RCBC during scoping consultation listed three aspects of relevance to hydrodynamics and sedimentary processes, namely: • Impacts of dredging on the tidal prism of the estuary, and therefore the extent and condition of existing intertidal habitats and the resultant impact on WFD ecological classification elements should also be included within the WFD assessment. • In addition to the initial capital dredge, consideration of the impacts associated with the continued maintenance of the dredged area in future years should be assessed too, in terms of the continued impact to fish, as well as water quality. • it is likely that dredging activity will need to take into account the protection of vulnerable fish species such as European Eel, Atlantic Salmon and Lamprey during critical migration periods. This would entail limiting dredging activity to certain times of the year and/or providing suitable monitoring and mitigation such as stop start thresholds for parameters such as suspended sediment and dissolved oxygen levels.	Impacts of dredging on the tidal prism of the estuary are addressed in **Section 6.6.3**. Consideration of impacts associated with maintenance dredging is made in **Section 6.6.4.** Impacts to fish and water quality are addressed in **Section 13** and **Section 7** respectively.

6.3 Methodology

6.3.1 Study area

For hydrodynamics and sedimentary processes, the study area needs to cover all areas of river, adjacent coastline and offshore seabed that potentially could be affected by the proposed scheme, including the dredging and offshore disposal activities. For this reason, the study area shown in **Figure 6.1** has been applied. Key locations referred to in this section are shown in **Figure 6.2**.

Figure 6.1 Study area for assessing potential effects on hydrodynamics and sedimentary processes

6.3.2 Review of existing information

There has been much previous work to characterise the baseline hydrodynamic and sedimentary regime of the River Tees estuary, undertaken over many decades. This work is summarised below in **Table 6.5**, together with an overview of how it has been developed and incorporated into subsequent studies.

Table 6.5 Review of existing information on the baseline hydrodynamic and sedimentary regime

Date	Study	Reference	Comments
1989	Tees Barrage - Effect of the barrage on marine mud siltation.	HR Wallingford, 1989	Incorporated within NGCT ES 2006.
1989	Tees Weir Feasibility Study - Correlation between waves, tides and suspended mud concentrations in Tees Bay.	HR Wallingford, 1989	
2002	Teesmouth Sediment Study.	HR Wallingford, 1989	
2002	Conceptual model of estuary processes.	ABPmer, 2002	
2005	Maintenance dredging baseline document.	ABPmer, 2005	
2006	NGCT Environmental Statement.	Royal Haskoning, 2006	Baseline characterisation and assessment of construction and operation effects, based upon numerical modelling. Informed NGCT ES 2020.
2007	NGCT Environmental Statement Supplement.	Royal Haskoning, 2007a	Further information relating to sediment contamination and potential impact on water quality, and further information on changes in tidal prism at north Tees mudflats. Reviewed for consideration within NGCT ES 2020.
2007	Tees maintenance dredging baseline document.	Royal Haskoning, 2007b (updated by Royal	Documents the maintenance dredging material regularly removed from the Tees

Date	Study	Reference	Comments
		HaskoningDHV in 2017a, 2018, 2019a and 2020a)	estuary, and the potential implications of maintenance dredging and disposal for European and Ramsar sites. Informed NGCT ES 2020.
2009	QEII Berth Development – Environmental Statement.	Royal Haskoning, 2009	Baseline description largely based on NGCT 2006 ES, but updated with further information about maintenance dredging regimes and materials arising from above and informed by modelling for scheme-related effects. Informed NGCT ES 2020.
2011	Tees Dock No.1 Quay – Technical Note.	Royal Haskoning, 2011	Agreed with regulators that existing modelling results from the NGCT and QEII schemes could be used to provide suitable evidence upon which to base predictions of possible effects from the proposed dredging operations required for this scheme. Informed NGCT ES 2020.
2014	Anglo American Harbour Facilities – Environmental Statement.	Royal HaskoningDHV, 2014	Modelling of scheme-related effects included tidal flow modelling, wave modelling, sediment transport, bed change modelling and modelling of sediment plume released from construction activities. Informed NGCT ES 2020.
2017	Northern Gateway No. 1 Container Operation - Vessel navigation assessment using numerical modelling of current flows.	Royal HaskoningDHV, 2017b	3-D numerical modelling of the tidal current streams within the Tees (particularly in the vicinity of the turning circle and Tees Dock) to provide input data to a vessel simulator for PDT. Informed NGCT ES 2020.
2019	Tidal Stream Atlas.	Royal HaskoningDHV, 2019b	Atlas of tidal current streams within the Tees (particularly in the vicinity of the turning circle and Tees Dock) derived from 3-D numerical modelling of the tidal current streams to inform vessel pilots for PDT. Informed NGCT ES 2020.
2020	NGCT - Environmental Statement.	Royal HaskoningDHV, 2020b	Baseline description largely based on NGCT 2006 ES and corroborated through review of all above further information. Supplemented with further analysis of climate change projections using UKCP18 outputs and Environment Agency (EA) guidance December 2019.

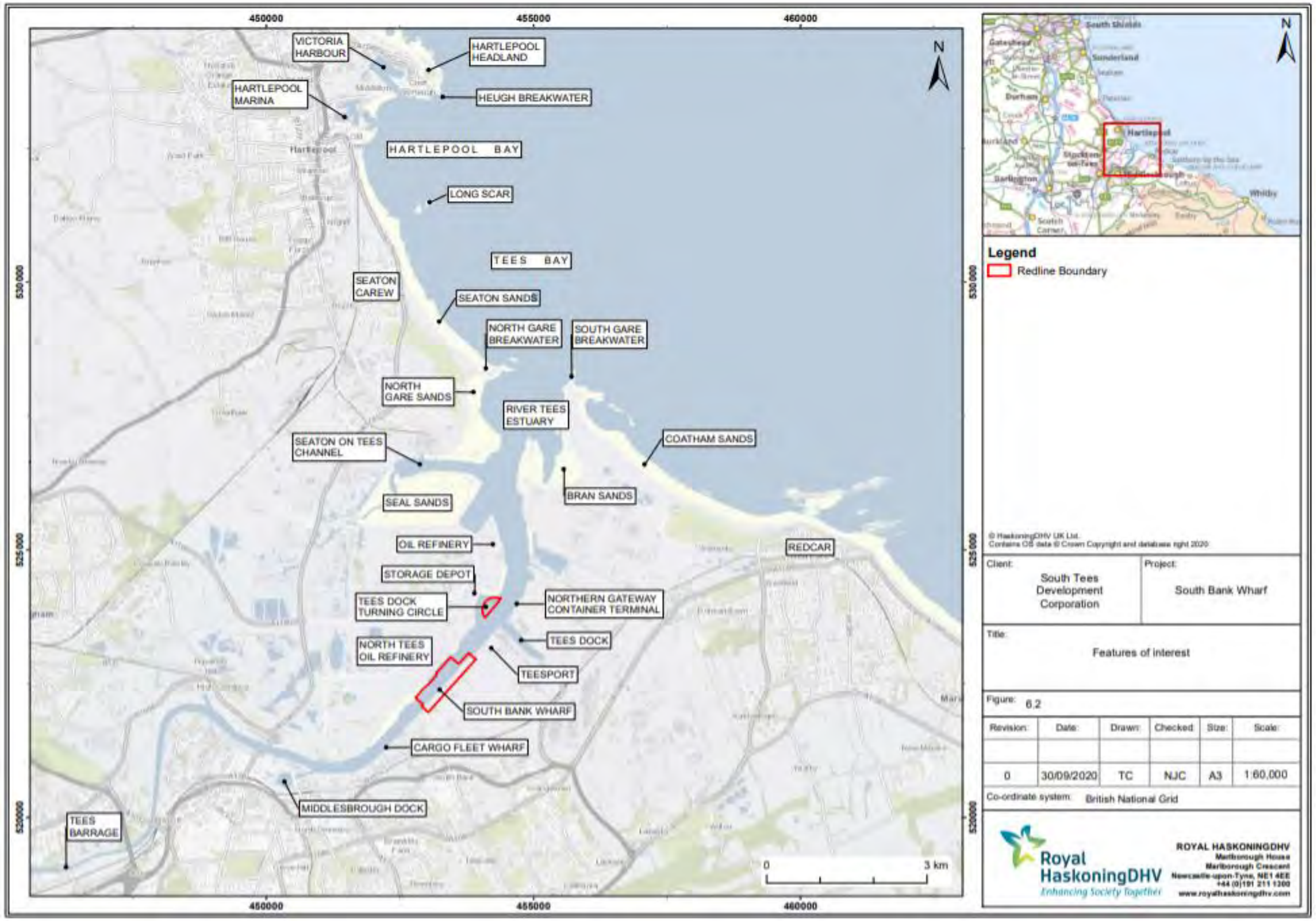


Figure 6.2 Features of interest

6.3.3 Review of existing information

There has been much previous work undertaken to characterise the baseline hydrodynamic and sedimentary regime of the Tees estuary, carried out over many decades. This work is summarised below in **Table 6.6**, together with an overview of how it has been developed and incorporated into subsequent studies.

Table 6.6 Review of existing information on the baseline hydrodynamic and sedimentary regime

Date	Study	Reference	Comments
1989	Tees Barrage - Effect of the barrage on marine mud siltation.	HR Wallingford, 1989	Incorporated within NGCT ES 2006.
1989	Tees Weir Feasibility Study - Correlation between waves, tides and suspended mud concentrations in Tees Bay.	HR Wallingford, 1989	
2002	Teesmouth Sediment Study.	HR Wallingford, 1989	
2002	Conceptual model of estuary processes.	ABPmer, 2002	
2005	Maintenance dredging baseline document.	ABPmer, 2005	
2006	NGCT Environmental Statement.	Royal Haskoning, 2006	Baseline characterisation and assessment of construction and operation effects, based upon numerical modelling. Informed NGCT ES 2020.
2007	NGCT Environmental Statement Supplement.	Royal Haskoning, 2007a	Further information relating to sediment contamination and potential impact on water quality, and further information on changes in tidal prism at north Tees mudflats. Reviewed for consideration within NGCT ES 2020.
2007	Tees maintenance dredging baseline document.	Royal Haskoning, 2007b (updated by Royal HaskoningDHV in 2017a, 2018, 2019a and 2020a)	Documents the maintenance dredging material regularly removed from the Tees estuary, and the potential implications of maintenance dredging and disposal for European and Ramsar sites. Informed NGCT ES 2020.
2009	QEII Berth Development – Environmental Statement.	Royal Haskoning, 2009	Baseline description largely based on NGCT 2006 ES, but updated with further information about maintenance dredging regimes and materials arising from above and informed by modelling for scheme-related effects. Informed NGCT ES 2020.
2011	Tees Dock No.1 Quay – Technical Note.	Royal Haskoning, 2011	Agreed with regulators that existing modelling results from the NGCT and QEII schemes could be used to provide suitable evidence upon which to base predictions of possible effects from the proposed dredging operations required for this scheme. Informed NGCT ES 2020.
2014	Anglo American Harbour Facilities – Environmental Statement.	Royal HaskoningDHV, 2014	Modelling of scheme-related effects included tidal flow modelling, wave modelling, sediment transport, bed change modelling and modelling of sediment plume released from construction activities. Informed NGCT ES 2020.
2017	Northern Gateway No. 1 Container Operation - Vessel navigation assessment using numerical modelling of current flows.	Royal HaskoningDHV, 2017b	3-D numerical modelling of the tidal current streams within the Tees (particularly in the vicinity of the turning circle and Tees Dock) to provide input data to a vessel simulator for PDT. Informed NGCT ES 2020.
2019	Tidal Stream Atlas.	Royal HaskoningDHV, 2019b	Atlas of tidal current streams within the Tees (particularly in the vicinity of the turning circle and Tees Dock) derived

Date	Study	Reference	Comments
			from 3-D numerical modelling of the tidal current streams to inform vessel pilots for PDT. Informed NGCT ES 2020.
2020	NGCT - Environmental Statement.	Royal HaskoningDHV, 2020b	Baseline description largely based on NGCT 2006 ES and corroborated through review of all above further information. Supplemented with further analysis of climate change projections using UKCP18 outputs and Environment Agency (EA) guidance December 2019.

This section makes best use of existing information from the sources listed in **Table 6.6** and combines it with newly collected project-specific data from bespoke metocean surveys to characterise the baseline environment.

In addition, an analysis of historical data, including dredge and disposal volumes and land reclamation from the Tees Estuary, was used to identify past and predict future trends in morphology through an Historical Trend Analysis (HTA) (Pye and van der Wal, 2000a).

6.3.4 Metocean survey

A metocean survey was undertaken within the Tees estuary by Partrac in July 2020 to provide relevant information to inform the baseline understanding and input to the numerical modelling and design of the proposed scheme. This involved the collection of: (i) tidal levels; (ii) tidal current velocities; (iii) conductivity, temperature and depth (CTD) casts; (iv) water samples for assessment of turbidity; and (v) wind speed.

Vessel-based surveys were undertaken along three transects crossing the river channel in the vicinity of the proposed scheme to characterise the channel bathymetry using single-beam echo sounder and record tidal currents using vessel mounted Acoustic Doppler Current Profiler (ADCP). The start and end coordinates of these transects is shown in **Table 6.7** and the transects are plotted in **Figure 6.3**. CTD casts and water sampling for turbidity were undertaken at the central point of the middle transect (Transect 8). Surveys were undertaken on 24th July 2020 to characterise a spring tide event (with a predicted tidal range of 3.9m) and on 30th July 2020 to characterise a spring tide event (with a predicted tidal range of 2.7m). During both the spring and neap survey dates, each of the three transects was surveyed, in sequence, on a total of 26 occasions, thus providing a record of the tidal cycle over 13 hours on each day. In addition, 26 CTD casts and water samples were collected from each of the spring and neap surveys.

Table 6.7 Metocean survey transect locations

Transect	Start of Line (OSGB36)		End of Line (OSGB36)		Length (m)
8	453255.98	522407.69	453066.33	522573.64	252
9	452799.73	521863.71	452590.08	522029.66	252
11	453629.00	522878.99	453439.35	523044.94	252

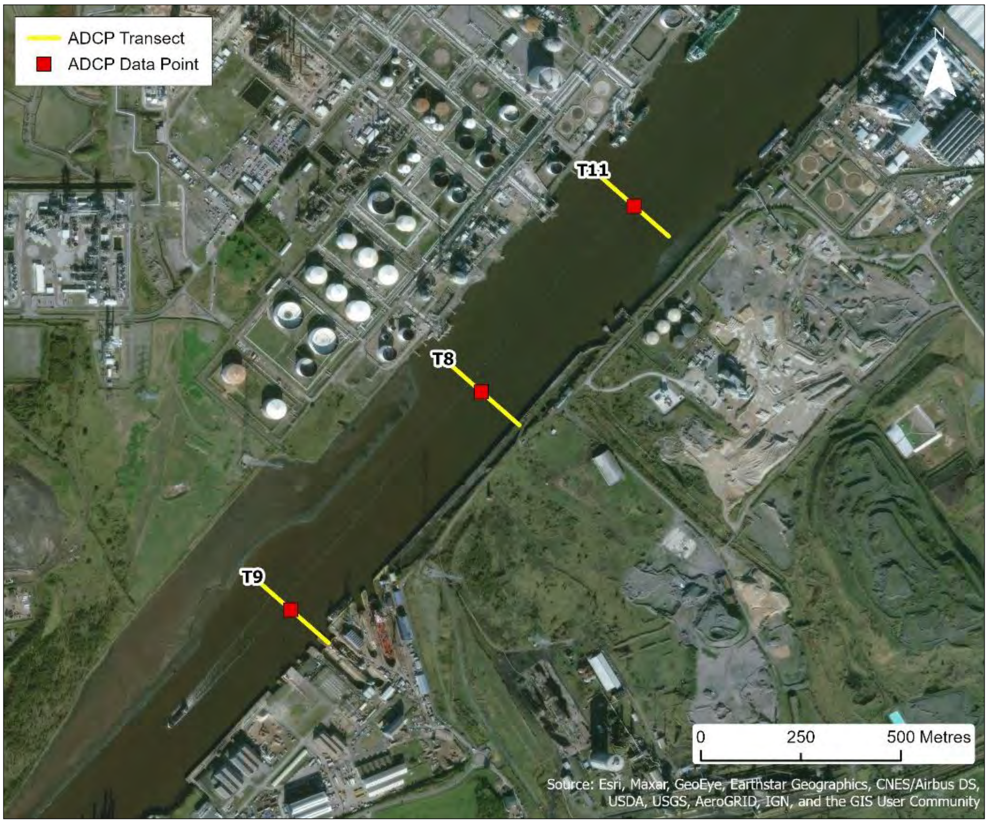


Figure 6.3 Metocean survey transect locations

Measured tidal levels from Tees riverside and wind velocities from South Gare were obtained from PDT for a period coincident with the vessel-based surveys to aid in the analysis.

Full details of the surveys, including operations, equipment, calibrations and verifications, configuration, mounting, software configuration, data quality control, data processing, survey vessel and health, safety and environmental performance, is provided in the survey report (Partrac, 2020 - see **Appendix 4**).

6.3.5 Numerical modelling

The baseline understanding and assessment of potential effects of the proposed scheme draws from results of numerical modelling which has adopted the following approaches:

- **Wave and wind conditions**: Since the site is well sheltered from North Sea swell waves, it is locally-generated wind waves that are of more significance at the proposed scheme. To demonstrate this understanding of the baseline wave conditions, an established North East Coast Wave Model built in MIKE-SW was used to transform extreme offshore waves (1 in 1 year and 1 in 100 year) to the site. In addition, extreme value analysis was undertaken for extreme wind conditions in the Tees Estuary. Locally-generated waves caused by extreme winds were then hindcast using a Tees Estuary Wave Model, also built in MIKE-SW.

- **Hydrodynamic modelling**: An existing 2D North East Regional Tidal Model built in MIKE-2D was used to provide boundary conditions for an existing 3D Tees Estuary Tidal Model built in MIKE-3. The latter model was updated with new bathymetry data and its mesh was refined around the site of the proposed scheme. The model was re-calibrated and then further verified using the acoustic doppler current profiler (ADCP) data newly-collected as part of the metocean survey. The updated and verified 3D model was then used to characterise baseline conditions and predict potential local and estuary-wide changes in hydrodynamics caused by the proposed scheme. The model was run for three different fluvial flow conditions (e.g. mean daily flow, Q_{med} and 1 in 100 year flow).

- **Sediment plume modelling**: The updated and verified 3D Tees Estuary Tidal Model was used to predict movement of suspended sediment from the proposed dredging and disposal activities by coupling with a sediment plume model built in MIKE21-MT software. The sediment plume model was run for the entire dredging and disposal period under astronomic tidal and daily mean fluvial flow conditions.

6.3.6 Impact assessment

Results from the review of existing information, HTA, metocean survey and numerical modelling were synthesised and used in combination with knowledge of other factors, such geological constraints, sediment supply, physical processes and anthropogenic activities, to describe the effects of the proposed scheme on the baseline hydrodynamic and sedimentary regime through an Expert Geomorphological Assessment (EGA) (Pye and van der Wal, 2000b).

6.4 Existing environment

6.4.1 General overview

Tees Bay is largely dictated at a macro-scale by the Permian Magnesium Limestone outcrop at Hartlepool Headland (the physical effect of which is exacerbated by the presence of the Heugh breakwater) and a sandstone outcrop at Redcar. Between these constraints, the coastline within Tees Bay has few rock exposures and mostly consists of boulder clay and alluvial deposits up to 30m thick overlying Sandstone and topped by marine-derived sand. Within this context, the mouth of the Tees estuary exerts a significant influence, effectively dissecting the frontage into two.

In the north, Hartlepool Headland (and, by way of an accentuation of its effect, The Heugh breakwater) causes a wave sheltering effect (**Figure 6.4**) and induces a tidal current gyre in its lee (**Figure 6.5**) at the northern end of Hartlepool Bay. As a consequence, there is a deposition of some sand in the navigation approach channel to Victoria Harbour. Due to their sheltered locations, there is also deposition of sand in the harbour and marina berths. All of these locations require dredging to maintain a safe navigable depth of water.

South of Hartlepool Old Town, there is generally a southerly drift of sand within the littoral zone, but this is interrupted initially by the Long Scar rock outcrop, which acts to pull the shoreline forward by creating shelter in its lee, and then by the North Gare Breakwater at the mouth of the Tees estuary.

The effect of the North Gare Breakwater in retaining beach sand on its updrift side is well demonstrated by the increasing beach widths to the south along Seaton Carew. At this location, there was historically sand extraction from the dunes and foreshore. This activity continues, on a small scale, inside the mouth of the estuary on North Gare Sands, but this is in an area where there is considerable sand deposition because the outer estuary acts as a major sink for marine sand and the North Gare Breakwater provides shelter against waves and induces a tidal current gyre, in a similar manner to that previously described at Hartlepool Headland.

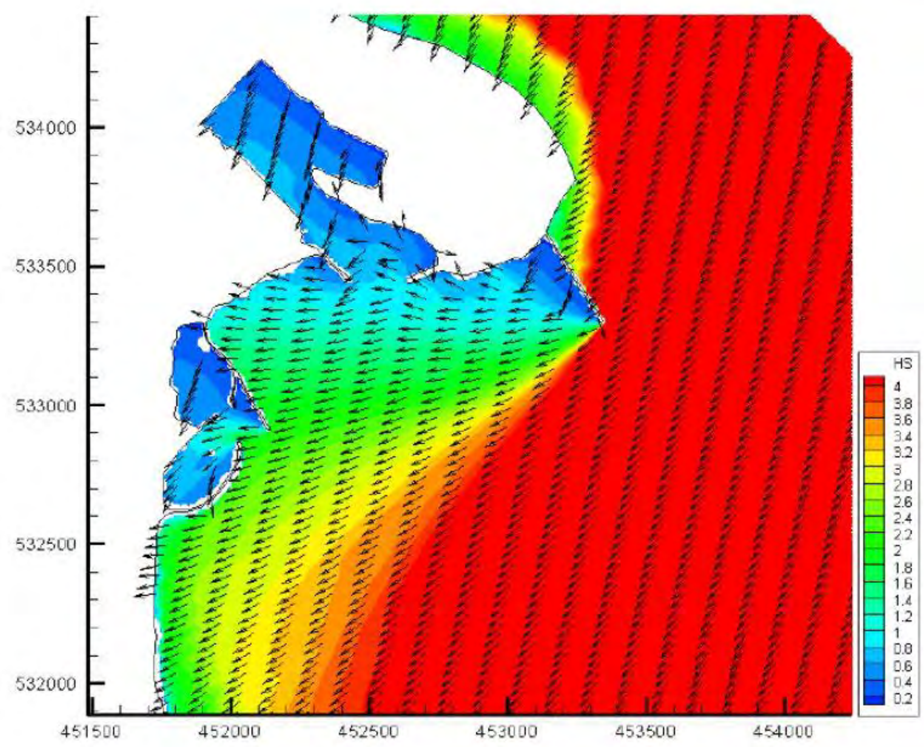


Figure6.4 **Wave shelter in the lee of Hartlepool Headland (Royal HaskoningDHV, 2013)**

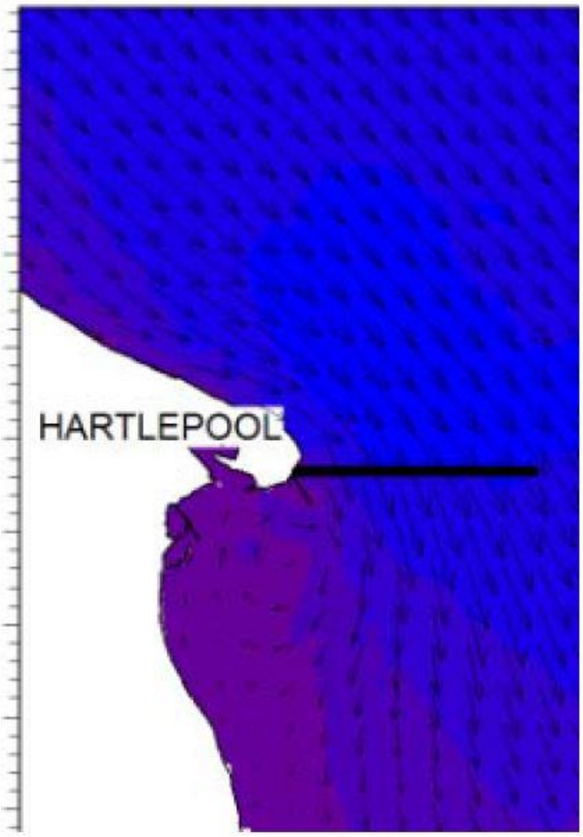


Figure 6.5 **Tidal gyre in the lee of Hartlepool Headland (Royal HaskoningDHV, 2013)**

Further upstream of the mouth, the Tees estuary also acts as a major sink for river-born silts and a number of reaches require maintenance dredging to remove both sands and silts. The volume of sediments dredged annually from the Tees estuary and Hartlepool's Victoria Harbour and approaches varies depending on the rates of accumulation that have been experienced, but over the long term is of the order of 1.1Mm^3 cumulatively (Royal HaskoningDHV, 2013). A notable proportion of this sediment is marine sand that is dredged from the river mouth and navigation approach channels within Tees Bay, with river silts mainly dredged from within the berths and river channel further upstream in the Tees estuary.

Prior to the mid-19th century, the Tees estuary was a wide, shallow estuary bordered by extensive wetlands and had tidal ingress for about 44km inland from the mouth (see **Figure 6.6**). Since this time, the estuary has undergone substantial anthropogenic changes as the channel was trained, land was reclaimed and the channel deepened to its present depth. The role of the River Tees in supplying fine sediment to the coastal zone has been reduced considerably by the construction of the Tees Barrage. The barrage was designed to allow bypassing of sediment, but observed accumulations upstream, and a 24% reduction in the dredging requirement of the harbour, indicates that much of the river sediment is trapped by the structure (Royal Haskoning, 2014).

Figure 6.6 Tees Estuary OS One Inch, 1885-1900 map series (reproduced with the permission of the National Library of Scotland, 2020)

Anthropogenic activities over the last 150 years have therefore resulted in an estuary that now is, essentially, a narrow 'canalised' channel bordered near the estuary mouth by sandy/muddy intertidal areas with a channel that is partly trained by various historic training works. The level and form of much of the intertidal area is controlled by the presence of these training works. Within this area, a remnant of the originally larger Seal Sands is divided from the other intertidal areas by Seaton on Tees Channel.

6.4.2 Bathymetry

Historical charts suggest that the natural channel level at the mouth of the Tees estuary is around -10m OD (Newlyn) (7.15m below CD). As a result of training works and deepening by dredging, the current depth at the mouth is about double this natural level. Dredging and training works have occurred since the establishment of the first dredged channel of 4.3m from Middlesbrough Docks to the sea after 1853.

No significant changes in estuary bathymetry have occurred since the NGCT ES was written in 2006. The only notable project undertaken since that time has been the dredging and re-strengthening of No.1 Quay in Tees Dock; all works associated with this project were contained within Tees Dock, and therefore it is considered that this removes the potential for any significant impacts to have arisen to the bathymetry of the estuary.

Generally, there has been net infilling of the estuary (the estuary and the wider Tees Bay act a sink for sediments) which is offset by maintenance dredging and disposal at offshore licenced disposal site Tees Bay A (see **Section 6.4.4**).

PDT is required by the Tees and Hartlepool Port Authority Act 1966 to publish dredge depths; the published Admiralty Charts show the maximum licensed depths for the channel and berths. A summary of the dredge depths is provided below.

The present main channel in the Tees has a declared depth of 15.4m bCD in the approach channel (i.e. in Tees Bay), 14.1m bCD to upstream of Redcar Ore Terminal, 10.4m below CD up to Teesport and then progressively less depth up to 4.5m below CD in Billingham Reach. Parts of the channel now declared at 14.1m below CD were originally dredged to a deeper depth.

The declared depth of berths and docks varies depending on the location and the vessels which require access. The berth pocket within Tees Dock has been dredged to a depth of 14.5m below CD, with the general dock area dredged to 10.9m below CD.

Single beam echo sounder data recorded during the July 2020 metocean survey (Partrac, 2020) reveal the channel bathymetry to be broadly similar and largely featureless along the three surveyed transects (T8, T9 and T11). Directly adjacent to the proposed scheme at T8, the bed depth is around -10mODN with a shallow bank towards the southern edge. Upstream at T11 the channel is deeper, at around -12 to -14mODN but the shallower bank on the southern edge is also present. Downstream at T9, the channel is slightly shallower than at T8, at around -9.5 to -10.0mODN, with a bank on the northern edge.

6.4.3 Hydrodynamic regime

Water levels

Tidal water levels are predominantly governed by astronomical effects but can also be significantly influenced (elevated or depressed) by meteorological influences and surge effects.

Astronomical tidal levels

The tidal curve at the mouth of the Tees estuary is observed to be very close to sinusoidal in shape with ranges of 4.6m and 2.3m for mean spring and neap tides, respectively (UKHO, 2020). The other astronomical tidal parameters of the estuary mouth are presented in **Table 6.8**.

Table 6.8 Tidal levels for the Tees estuary

Description	Level (m CD)	Level (m ODN)
Highest astronomical tide	6.10	3.25
Mean high water spring tide	5.50	2.65
Mean high water neap tide	4.30	1.45
Mean sea level	3.20	0.35
Mean low water neap tide	2.00	-0.85
Mean low water spring tide	0.90	-1.95
Lowest astronomical tide	0.00	-2.85

Extreme water levels

The regular, predictable astronomical tidal levels can strongly be influenced by meteorological effects, such as wind set-up and surge. This can clearly be seen from a timeseries of measured water level data at Tees Dock tide gauge from 2005 (**Figure 6.7**) where around the 29/30th April a 'spike' in the measured data occurs compared with modelled data covering the same period. This correlates with the occurrence of a real-time surge which was captured by the measured data.

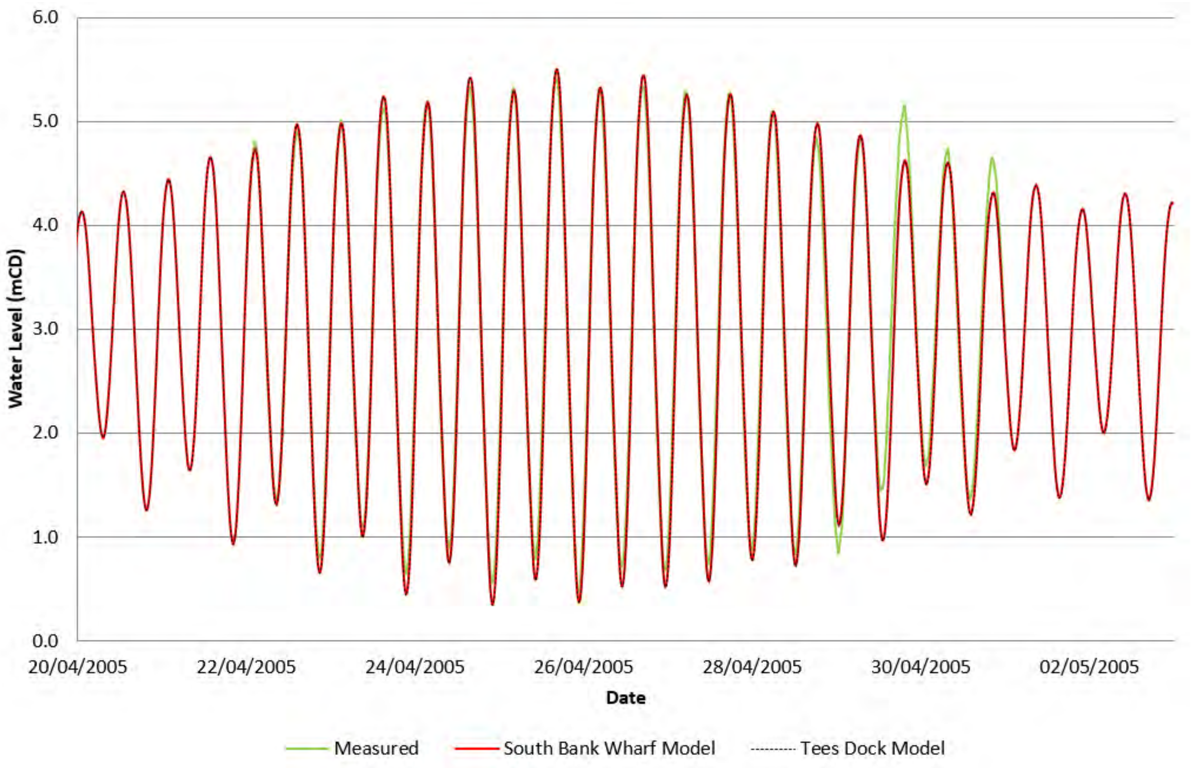


Figure 6.7 Comparison of Measured and Modelled Tidal Elevation at Tees Dock Tide Gauge

The most recent published sources of information on extreme water levels are the Environment Agency's Coastal Flood Boundaries (CFB) outputs for Tees Bay (Environment Agency, 2018) and the Environment Agency's Tees Estuary modelled outputs that are used to inform published flood risk maps. Extreme water level values from these sources for various return period events, together with associated confidence levels where published, are presented in **Table 6.9**. Note that the Tees Estuary model was run by the Environment Agency for only the 1 in 200 year and 1 in 1,000 year events and has a base date of 2011, whereas the CFB outputs cover a wider range of return periods (with confidence levels) and have a base date of 2017.

Table 6.9 ***Extreme water levels for Tees Bay and Tees Estuary (2017 baseline)***

Return Period	Tees Bay (2017 base date)		Tees Estuary (2011 base date)
	Level (m ODN)	Confidence limits (m)	Level (m ODN)
1 in 1 year	3.36	± 0.1	-
1 in 5 years	3.56	± 0.1	-
1 in 10 years	3.65	± 0.1	-
1 in 25 years	3.77	± 0.1	-
1 in 50 years	3.86	± 0.1	-
1 in 100 years	3.96	± 0.2	-
1 in 200 years	4.07	± 0.2	4.13
1 in 1000 years	4.32	± 0.4	4.39

Measured water levels

During the metocean surveys in July 2020, water levels were measured over both a spring and neap tidal cycle using vessel-based Real Time Kinematics (RTK) and compared against measured data from the permanent tide gauge installed and operated along the riverbank by PDT. There was excellent correlation between the two datasets. **Figures 6.8** and **6.9** show the tidal curves for the spring tide survey and neap tide survey, respectively.

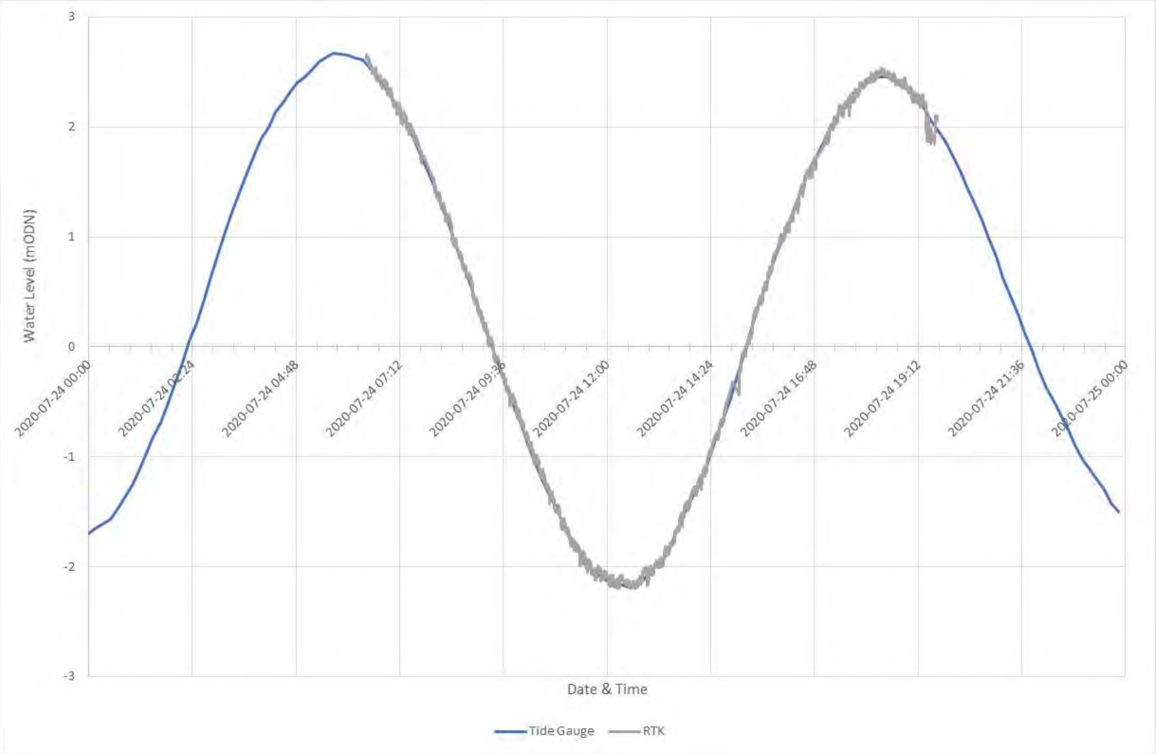


Figure 6.8 ***Measured tidal data during spring tide metocean survey***

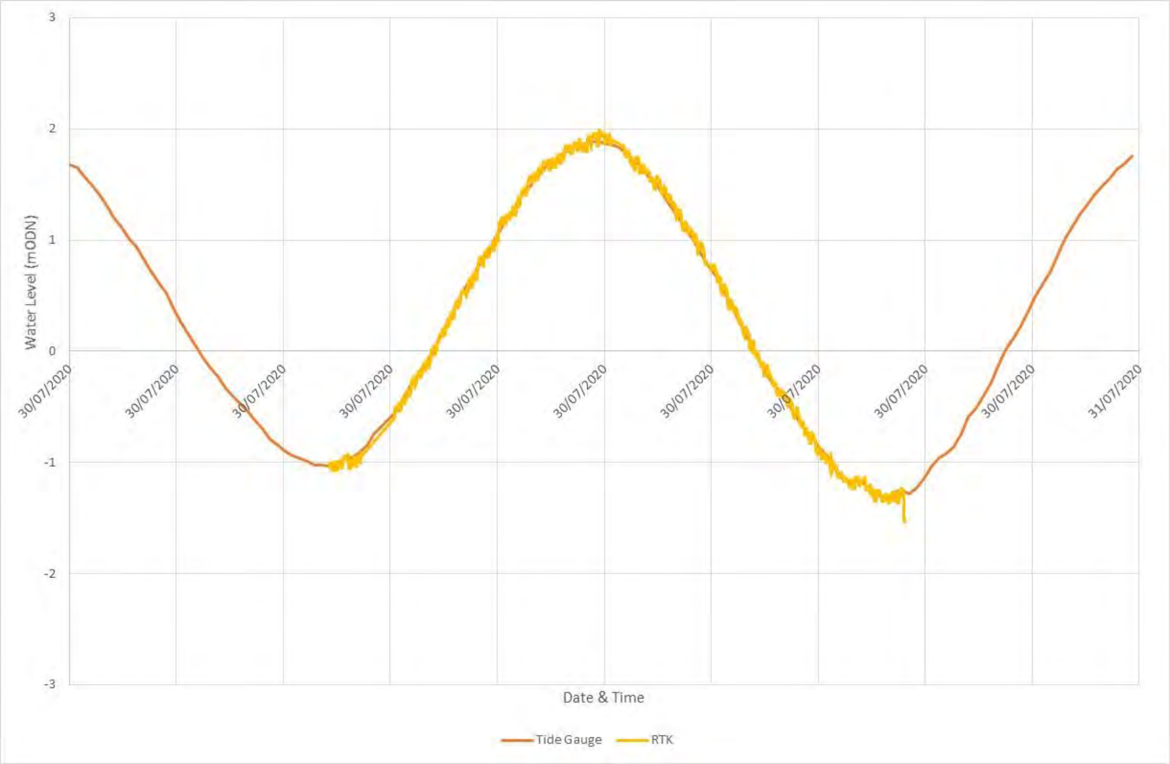


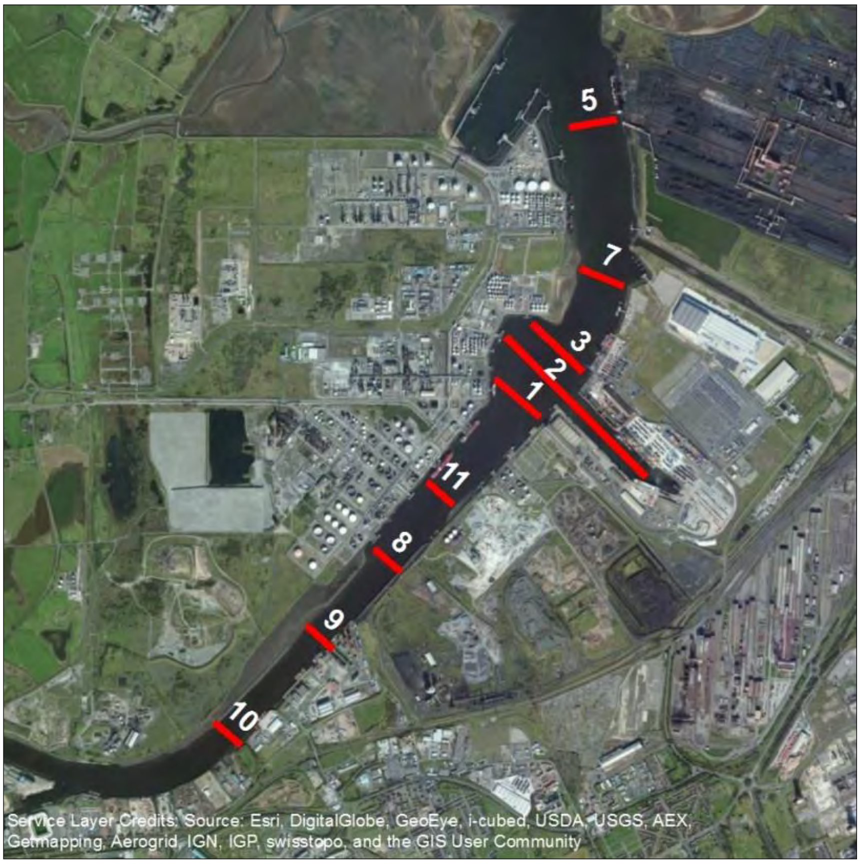
Figure 6.9 Measured tidal data during neap tide metocean survey

Tidal currents

Tees Bay and the Tees estuary attract sediment because the tidal current flows are generally quite low compared to many other coastal areas. This is due to Tees Bay forming a shallow embayment within the general alignment of the north east coastline. The low tidal current flows mean that sands brought into Tees Bay from the North Sea tend to settle on the sea or riverbed below the water surface, gradually building up over time.

The tidal current flow patterns within Tees Bay generally run parallel to the shore, flowing towards the south on the flooding tide and towards the north on the ebbing tide. Generally, these tidal flow patterns determine the transport of sediment within Tees Bay, with an overall tendency for southerly directed transport because the flood tides are stronger than the ebb tides. The larger waves that occur during storm events will stir sediment from the seabed enabling more to become transported by the tidal currents during these storms. However, there are also more complex patterns in the vicinity of features which interrupt the general flow patterns, as previously discussed for the Hartlepool Headland and the North Gare Breakwater, and these subtleties locally influence sediment transport in these locations.

Within the River Tees estuary, tidal current measures were recorded along a series of cross-channel transects from 22nd to 30th April 2005 (covering both a spring tide and a neap tide) using vessel-mounted ADCP. The location of these transects is shown in **Figure 6.10**. These data have previously been used to characterise baseline conditions and calibrate a MIKE-21/ MIKE-3 flexible mesh hydrodynamic (HD) model of the Tees for use in many previous studies.



Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 6.1 Location of ADCP transects in the River Tees (2005 survey)

Due to the length of time that has passed since these data were collected, vessel-mounted ADCP data were newly collected from transects 11, 8 and 9 in July 2020 to inform the present study. These transects represent river channel sections downstream (#11), at (#8) and upstream (#9) of the proposed scheme. Current velocities recorded during this most recent survey are presented in **Table 6.10**, indicating relatively low current speeds within the estuary, even during spring tides. It is also notable that peak current speeds during neap tides occurred on the ebb phase of the tide, whereas the reverse was observed during the spring tides. This indicates that the river flows have a relatively lesser effect on overall currents during spring tides.

Table 6.10 Tidal current velocities for the Tees estuary

Transect	Tide Condition	Recorded current during July 2020 ADCP Survey			
		Minimum Speed (m/s)	Average Speed (m/s)	Maximum Speed (m/s)	Direction at Maximum Speed (°N)
T8 (at site)	Neap	0.00	0.11	0.23	215 (i.e. ebb tide)
	Spring	0.01	0.18	0.40	42 (i.e. flood tide)
T9 (upstream)	Neap	0.00	0.12	0.25	221 (i.e. ebb tide)
	Spring	0.01	0.18	0.35	40 (i.e. flood tide)
T11 (downstream)	Neap	0.00	0.08	0.18	228 (i.e. ebb tide)
	Spring	0.01	0.14	0.31	41 (i.e. flood tide)

Numerical modelling of hydrodynamic currents during both neap and spring tides was undertaken, each with a mean daily river flow through the Tees Barrage (20 cumecs), to further characterise the baseline conditions. **Figures 6.11** and **6.12** show the peak current speeds during the flood and ebb phases of a neap tide with a mean daily river flow, whilst peak current speeds during corresponding phases of a spring tide with a mean daily river flow are shown in **Figures 6.13** and **6.14**. These plots confirm the findings of the measured data, showing maximum current speeds greater on the spring tides than the neap tides and a tendency for ebb dominance during neap tides and flood dominance during spring tides. Note that the layout of the proposed scheme is shown on these figures for context only (these model runs represent the baseline conditions without the scheme in place).

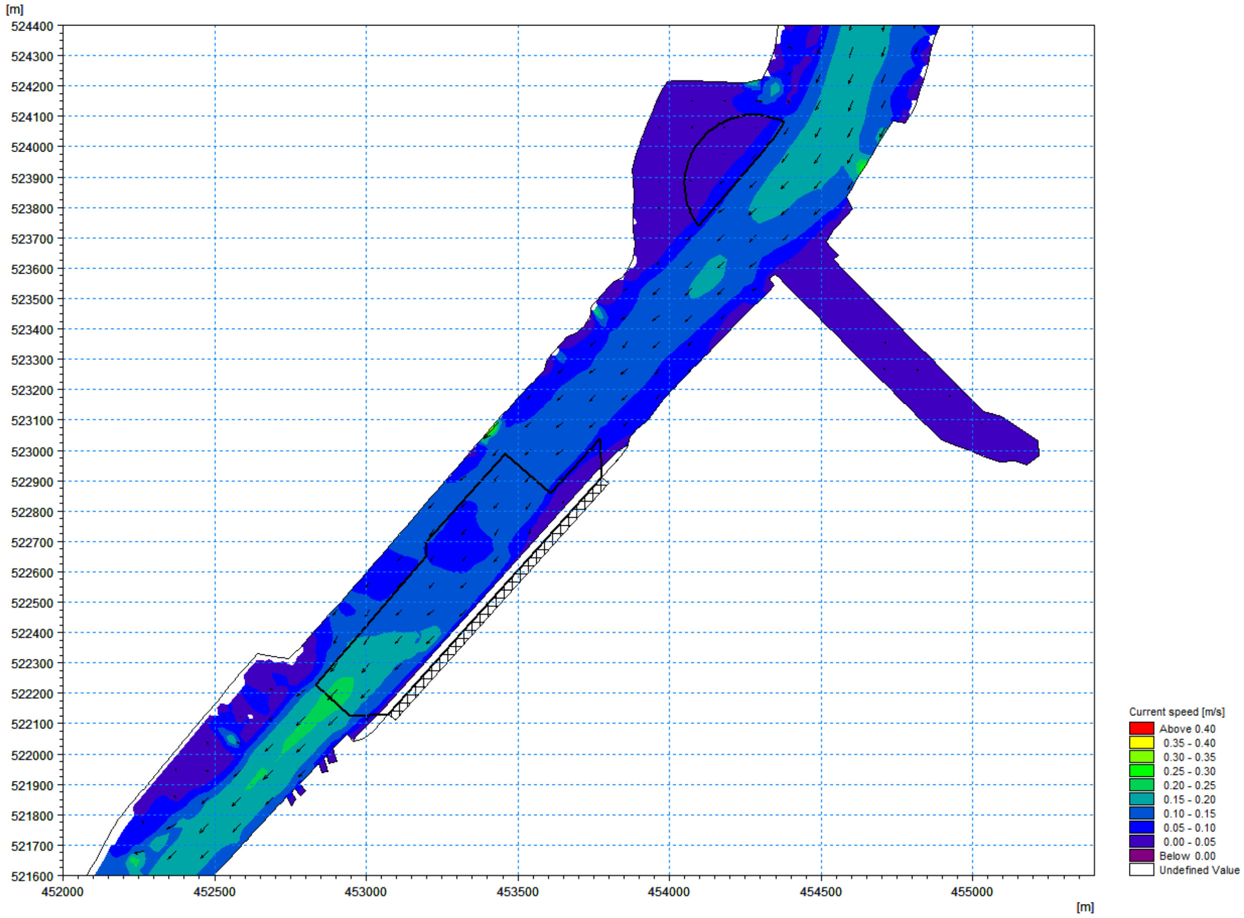


Figure 6.11 Peak current velocities during the flood phase of a neap tide with mean daily river flow - baseline

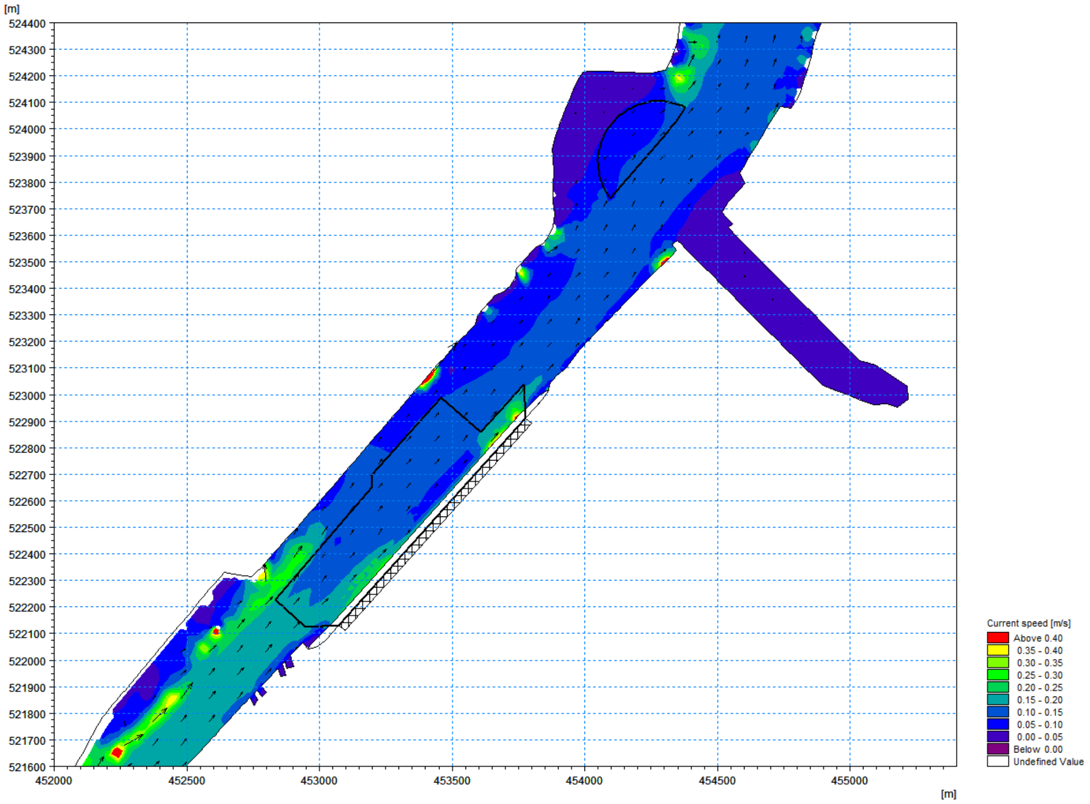


Figure 6.12 *Peak current velocities during the ebb phase of a neap tide with mean daily river flow - baseline*

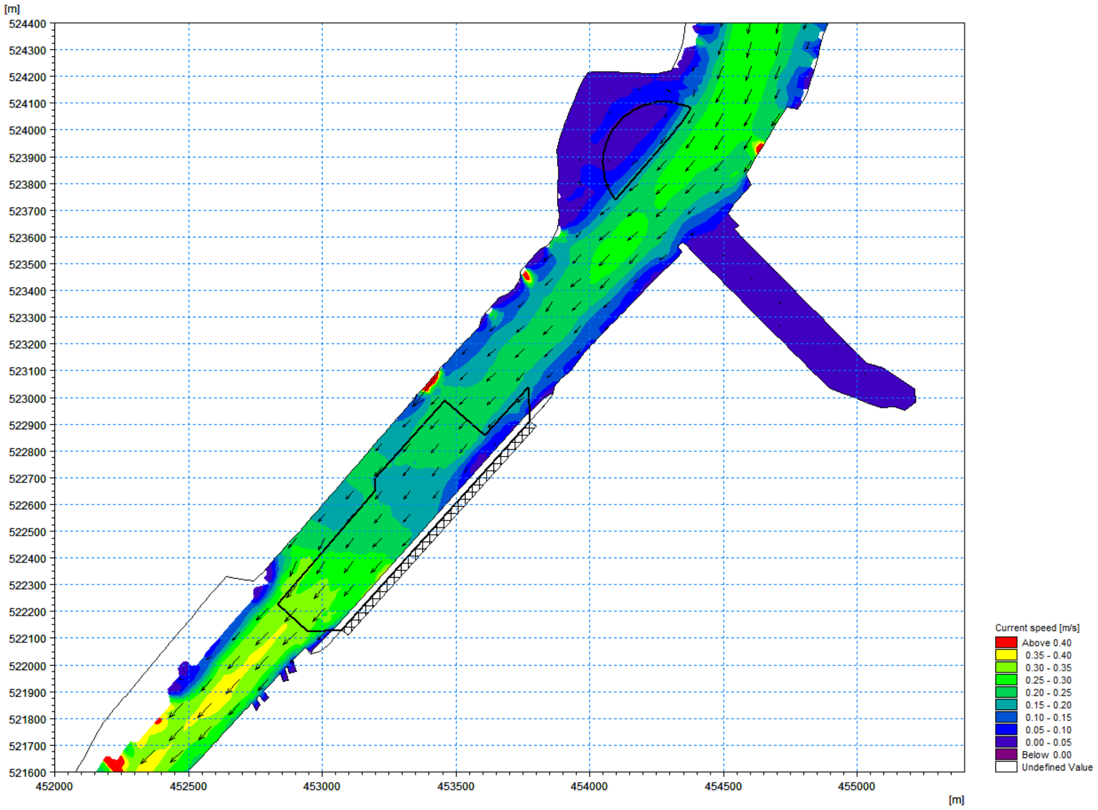


Figure 6.13 *Peak current velocities during the flood phase of a spring tide with mean daily river flow - baseline*

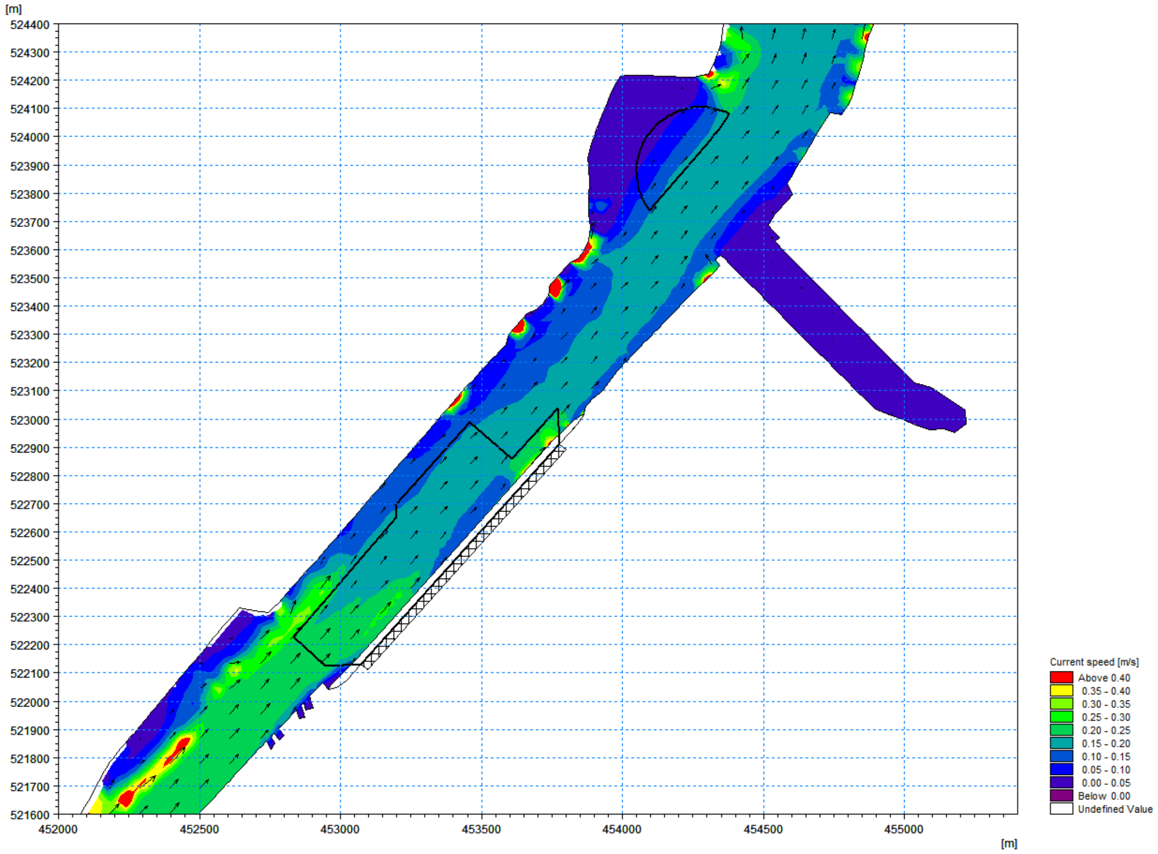


Figure6.14 Peak current velocities during the ebb phase of a spring tide with mean daily river flow - baseline

Flow discharges and mixing

The River Tees has its source about 160km from the sea on Cross Fell in the Pennines and drains a catchment of 1932km^2. The main freshwater input to the estuary is measured at Low Moor. HR Wallingford (1992) calculated the long term monthly mean flows for the period 1981-88 as shown in **Table 6.11**.

Table 6.11 Monthly mean flow at Low Moor

Month	Mean daily flow (m^3/s)	Month	Mean daily flow (m^3/s)
Jan	36.7	Jul	8.6
Feb	21.2	Aug	11.2
Mar	26.6	Sep	12.5
Apr	19.6	Oct	22.0
May	12.5	Nov	26.1
Jun	9.3	Dec	30.0

Lewis *et al.* (1998), also looked at the flows at Low Moor and presented a long-term average flow of 20m^3/s, a maximum recorded flow of 563m^3/s, a minimum of less than 3m^3/s and a 10% exceedance flow of about 47m^3/s.

Before reaching the proposed scheme, the Tees' fluvial flow is regulated by the Tees Barrage, which is operated to maintain upstream water levels and prevent the upstream penetration of saline water. The regulated flow through the barrage is, therefore, very unlike the natural flow that would otherwise occur, especially as the flows are no longer continuous. **Figure 6.15** shows the time history of recorded discharge through the barrage during June – July 2020.

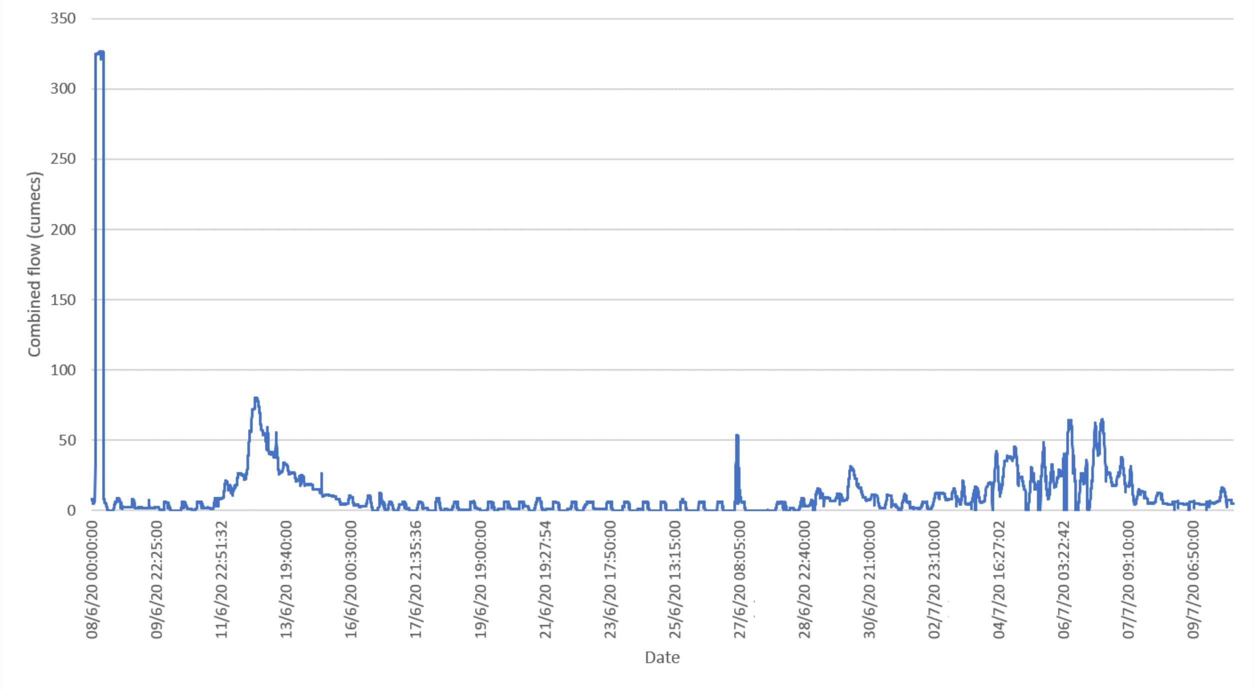


Figure 6.15 Flow measured through the Tees Barrage June – July 2020 (Canal and Rivers Trust, 2020)

The regulated freshwater flow enters the estuary and partially mixes with saline water entering through the estuary mouth. This partial mixing and the longitudinal salinity gradient both contribute to a density driven gravitational circulation. This effect is a result of the density changing the vertical profile of the flow such that the ebb flows are strong at the surface whereas the flood flows are more evenly spread through depth. The tidally averaged currents tend, therefore, to be seawards in the surface waters and landwards in the waters closer to the bed.

In the Tees estuary, under many circumstances this effect becomes dominant such that continuous near-bed upstream (flooding) flows are observed. These effects are important in supplying sediment to the estuary from offshore (the main sediment supply).

During the metocean surveys in July 2020, CTD measurements were taken at the centre point of transect T8 on 26 occasions during each of the neap tide and spring tide surveys, and results show evidence of formation of both a halocline (**Figure 6.16**) and a thermocline (**Figure 6.17**).

The halocline was observed to occur over 2m to 4 m depth within the water column. Within this zone the waters are fresher than those at greater depths, and the halocline shows a variation in structure throughout the surveys. The homogenous layer beneath the halocline shows very little structural change throughout the surveys.

During the spring survey a tidal signature was observed in the halocline layer. Greatest stratification occurs at low water, whereas with progression towards high water the stratification reduces due to increasing tidal influence.

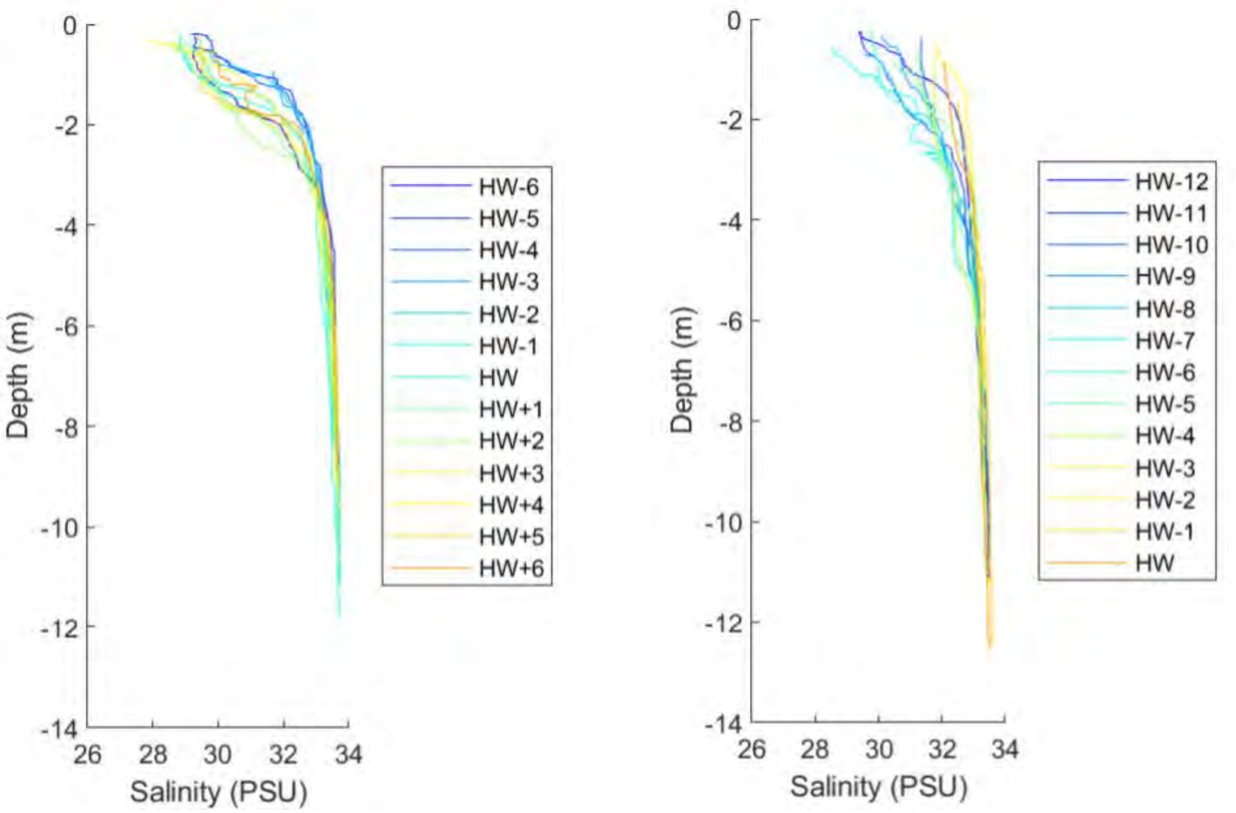


Figure 6.16 Measured hourly salinity profiles at the centre of transect T8 during neap (left) and spring (right) tides in July 2020

During both spring and neap surveys, it is evident that surface waters warm by around 1.5°C to reach temperatures close to 16°C.

During the neap survey, the thermocline between warmer near-surface waters and cooler deeper waters exists at 2m to 3 m depth. The bottom layer of the thermocline has a variation of ~1°C during the survey. This bottom water is warmest at low water before cooling as the tide floods and then warming again as the tide ebbs. The surface water continues to warm throughout the day until HW+4, with the HW+5 and HW+6 profiles showing some cooling occurring at the end of the day.

The spring survey profiles show a similar thermocline, although with greater variability in the depth and strength of the stratification throughout the survey.

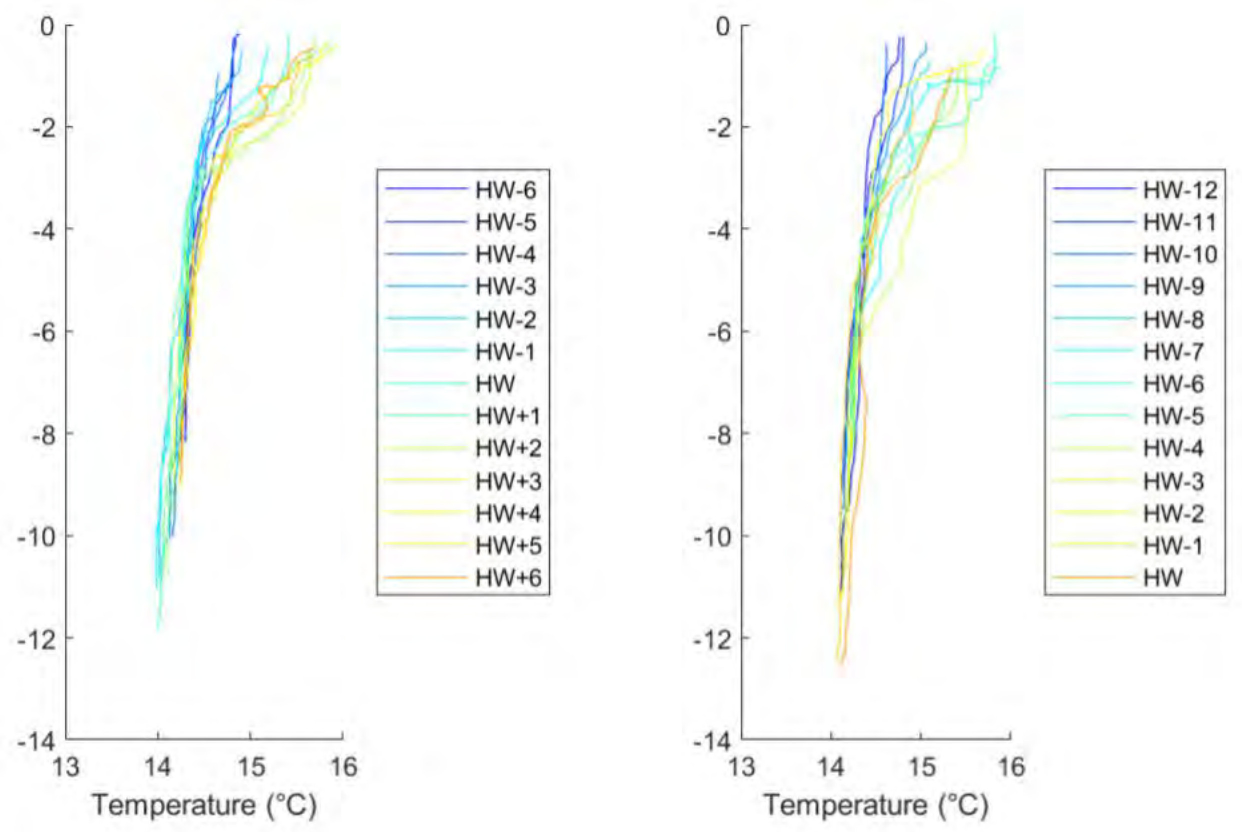


Figure 6.17 Measured hourly temperature profiles at the centre of transect T8 during neap (left) and spring (right) tides in July 2020

When river flows and tidal flows are combined and temperature and salinity effects are included, the modelled peak flow rates at the proposed scheme are around 728 m^3/s and 386 m^3/s for spring and neap tides respectively (**Figure 6.18**). At time of peak ebb flow the flows reduce to around 662 m^3/s and 368 m^3/s for spring and neap tides respectively. At the proposed scheme, the estuary reach is flood dominant (i.e. peak flood flow is stronger than peak ebb flow, but the duration of flood flow is shorter than that for ebb flow).

The modelled combined mean flood flow (over a tidal cycle) is about 410 m^3/s and 234 m^3/s and for spring and neap tides respectively and the modelled mean ebb flow (over a tidal cycle) is about 417 m^3/s and 252 m^3/s for spring and neap tides respectively. The mean ebb flow is larger than mean flood flow because of the effects of river flow from upstream, which is relatively more significant at times of mean tidal flow than at times of peak tidal flow.

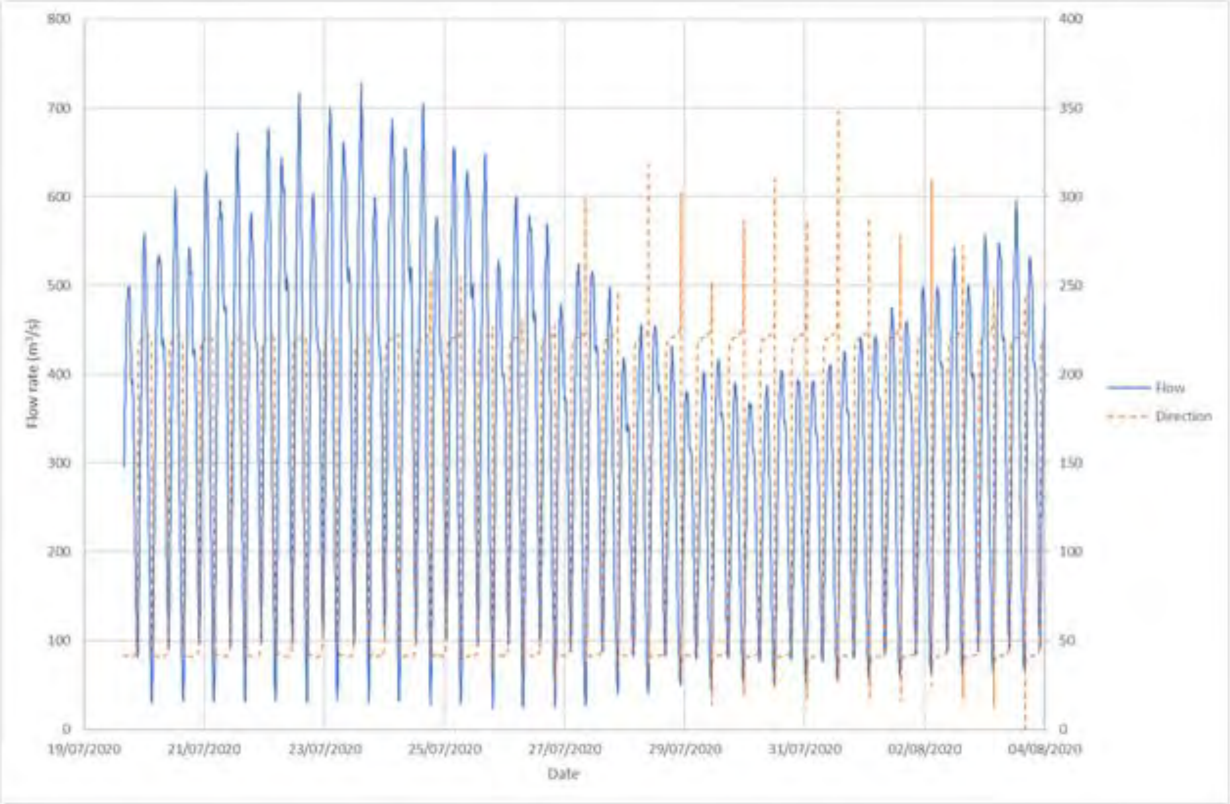


Figure 6.18 Modelled combined flow rates at the proposed scheme footprint

Wind

An analysis of wind speeds observed at South Gare between 1999 and 2005 was undertaken as part of the studies for the NGCT (HR Wallingford, 2006). This showed that the most frequent winds prevail from the south-west (210°N to 270°N), but the largest wind events (> 40 m/s) are from the north. This analysis was brought up to date with measured data from Tees Dock between October 2019 and July 2020, which confirmed the south-westerlies as the predominant winds (**Figure 6.19**).

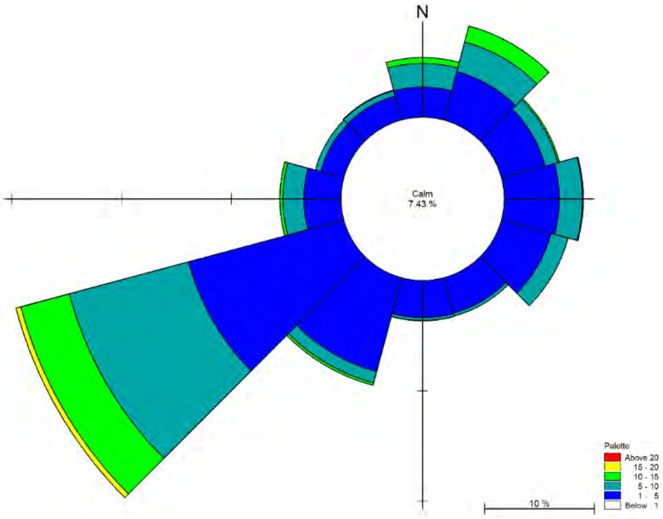


Figure 6.19 Wind rose based on recorded data at South Gare (October 2019 – July 2020)

This analysis further was brought up to date with long-term Met Office wind data from Loftus. From these data, extreme wind speeds from three separate directions were analysed, namely north (0 degrees), north-northeast (30 degrees) and south-southwest (210) (**Table 6.12**).

Table 6.12 Extreme wind speeds for the Tees estuary

Return Period (years)	Wind Speed (m/s)		
	0 degrees	**30 degrees**	**210 degrees**
1	20.12	18.88	20.08
100	31.68	30.69	30.25

During the metocean survey, recorded wind data were obtained from PDT for dates coinciding with the spring tide (24th July 2020) and neap tide (30th July 2020) surveys. As can be seen, relatively benign wind conditions were experienced over these two survey dates (**Table 6.13**).

Table 6.13 Wind speeds recorded at Tees Dock by PDT

Location	Tidal Condition	Wind Speed (m/s)		
		Minimum	Mean	Maximum
Tees Dock	Neap	0.05	1.28	3.29
	Spring	0.05	0.85	3.34

Waves

Wave conditions in outer parts of the Tees estuary are a combination of offshore swell and locally-generated wind waves, although only remnants of swell wave activity exist a short distance up-estuary from the mouth.

Offshore swell

The majority of offshore swell in the region has been found to come from a northerly direction (HR Wallingford, 2002), although the direction from which swell can enter the estuary is limited by the presence of the North Gare and South Gare Breakwaters.

The Tyne Tees WaveNet buoy, deployed by Cefas in 2006, is located 35km offshore from Tees Bay in around 65m water depth and provides a suitable baseline of offshore wave conditions. Wave heights recorded at the Tyne Tees buoy for 2019-20 are shown in **Figure 6.20**. The largest storms recorded during the period April 2019 to March 2020 were in December 2019 and March 2020, with significant wave heights (Hs) of 5.2m, however there were also notable storms in May and November 2019 (both Hs <5m) (Royal HaskoningDHV, 2020c).

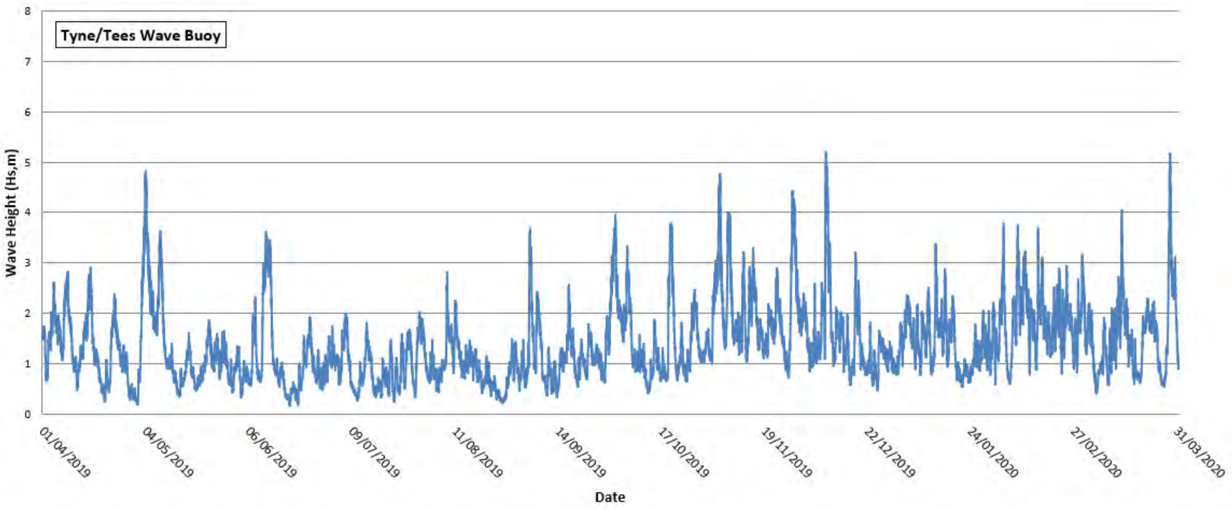


Figure 6.20 Offshore wave heights recorded at the Tyne/Tees wave buoy for 2019-2020

An offshore wave rose for the Tyne Tees buoy (**Figure 6.21**; Royal HaskoningDHV, 2020c) shows that the majority of the waves approach from the north to north-northeast sector (0-30 degrees). There is a small secondary peak in approach direction for waves from the south east sector (120-150 degrees). Other waves approach from easterly directions (30-120 degrees) located between the primary and secondary peaks. Due to the offshore location of this buoy there are also small peaks from the southwest and northwest that would represent calm periods along most of the inshore sections of the north-east coast.

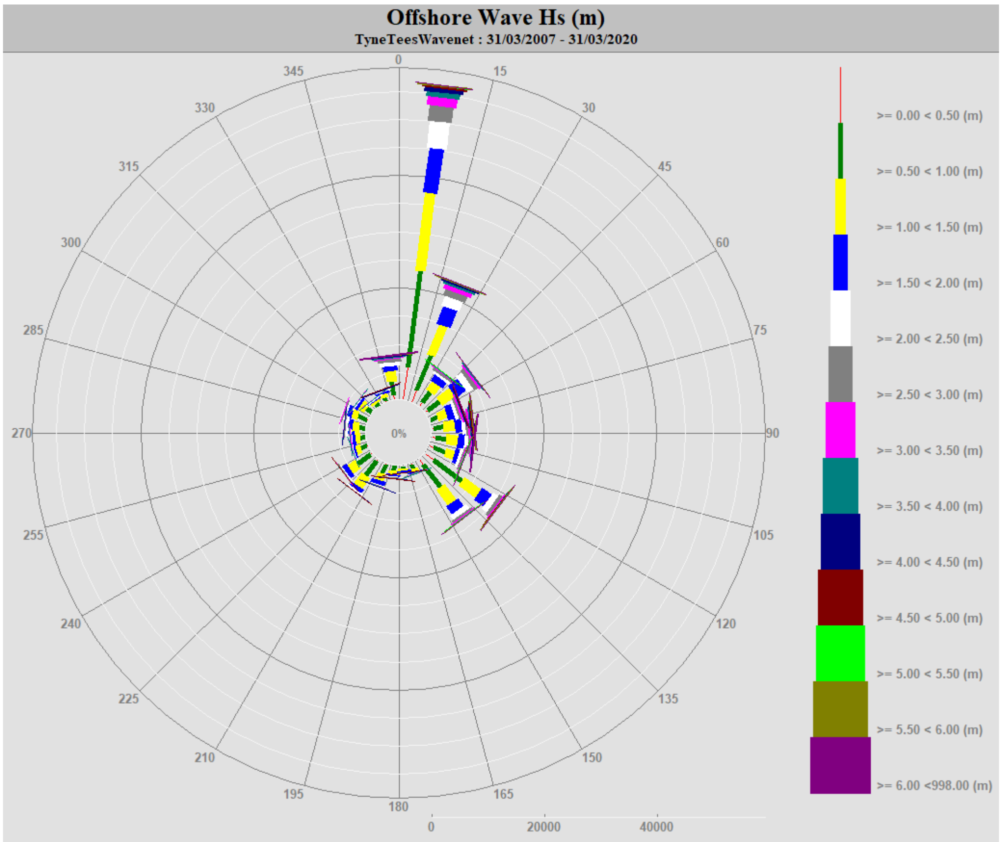


Figure 6.21 Offshore Wave Rose at Tyne Tees wave buoy site (WMO ID 62293)

Further inshore, the Environment Agency has a modelled swell wave data point in Tees Bay as part of its Coastal Flood Boundary Conditions (CFB) project, the location of which is shown in **Figure 6.22**. The 1 in 100 year extreme significant wave height at this nearshore location is 4.13m, with a corresponding period of 12 seconds and direction from north (0 degrees).

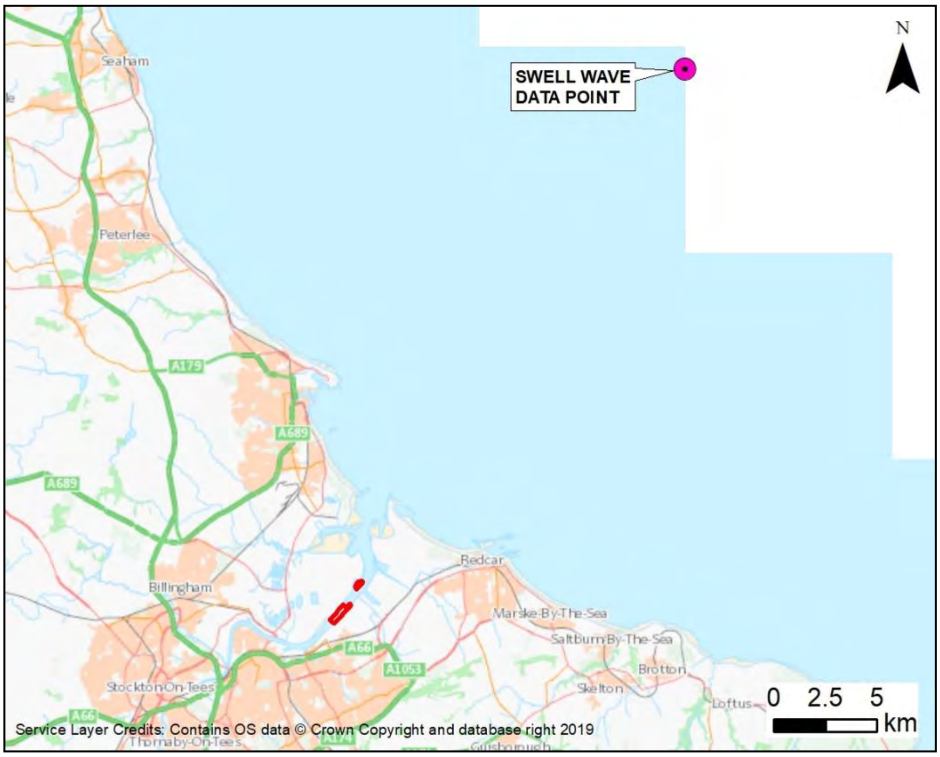


Figure 6.22 Location of Environment Agency's CFB swell wave data point

Numerical modelling of waves was undertaken using MIKE-SW to transform the offshore swell conditions from the Environment Agency CFB swell wave data point inshore and into the Tees estuary (**Figure 6.23**). Even under a scenario with a 1 in 100 year return period wave height coinciding with a Highest Astronomical Tide, swell waves would not propagate sufficiently far up-estuary to reach the proposed scheme (**Figure 6.24**). Even when the nearshore wave heights are increased by +0.2m as a sensitivity test, the swell waves would not propagate to the proposed scheme.

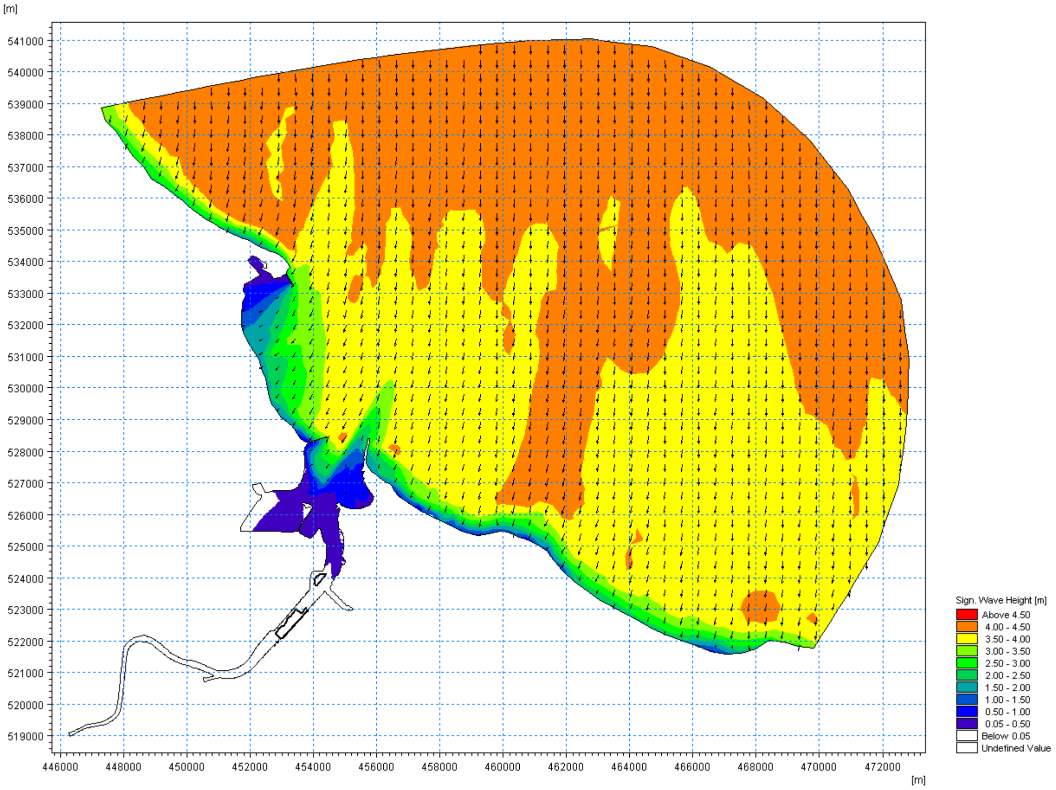


Figure 6.23 Swell Waves for 1 in 100 year return period coming from North (Tees Bay)

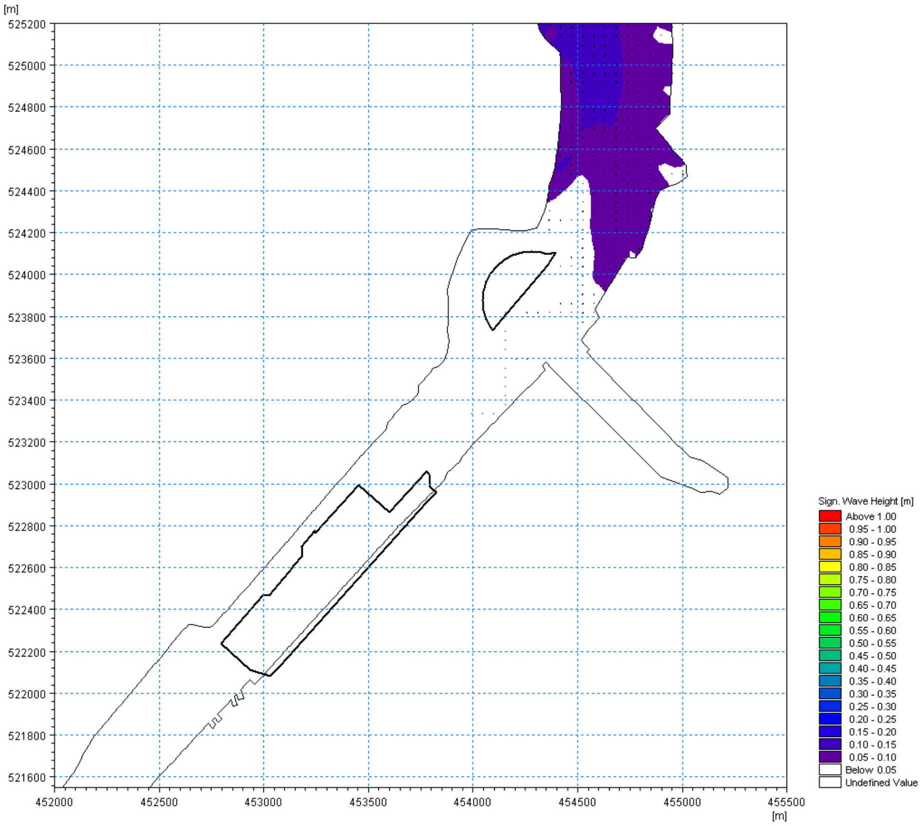


Figure 6.24 Swell Waves for 1 in 100 year return period coming from North (proposed scheme)

Local wind-generated waves
The local wind-generated waves for 1 in 1 year and 1 in 100 year return period events, with waves coming from north (0 degrees), north-northeast (30 degrees) and south-southwest (210 degrees), were modelled using MIKE-21 for the River Tees (**Figure 6.25**). These conditions were run coincident with a Highest Astronomical Tide for a worst case effect.

The wave model results show that at the proposed scheme the local wind-generated waves can reach a height of 0.3m to 0.4m for a 1 in 1 year return period wind event and 0.5m to 0.7m for a 1 in 100 year return period wind event.

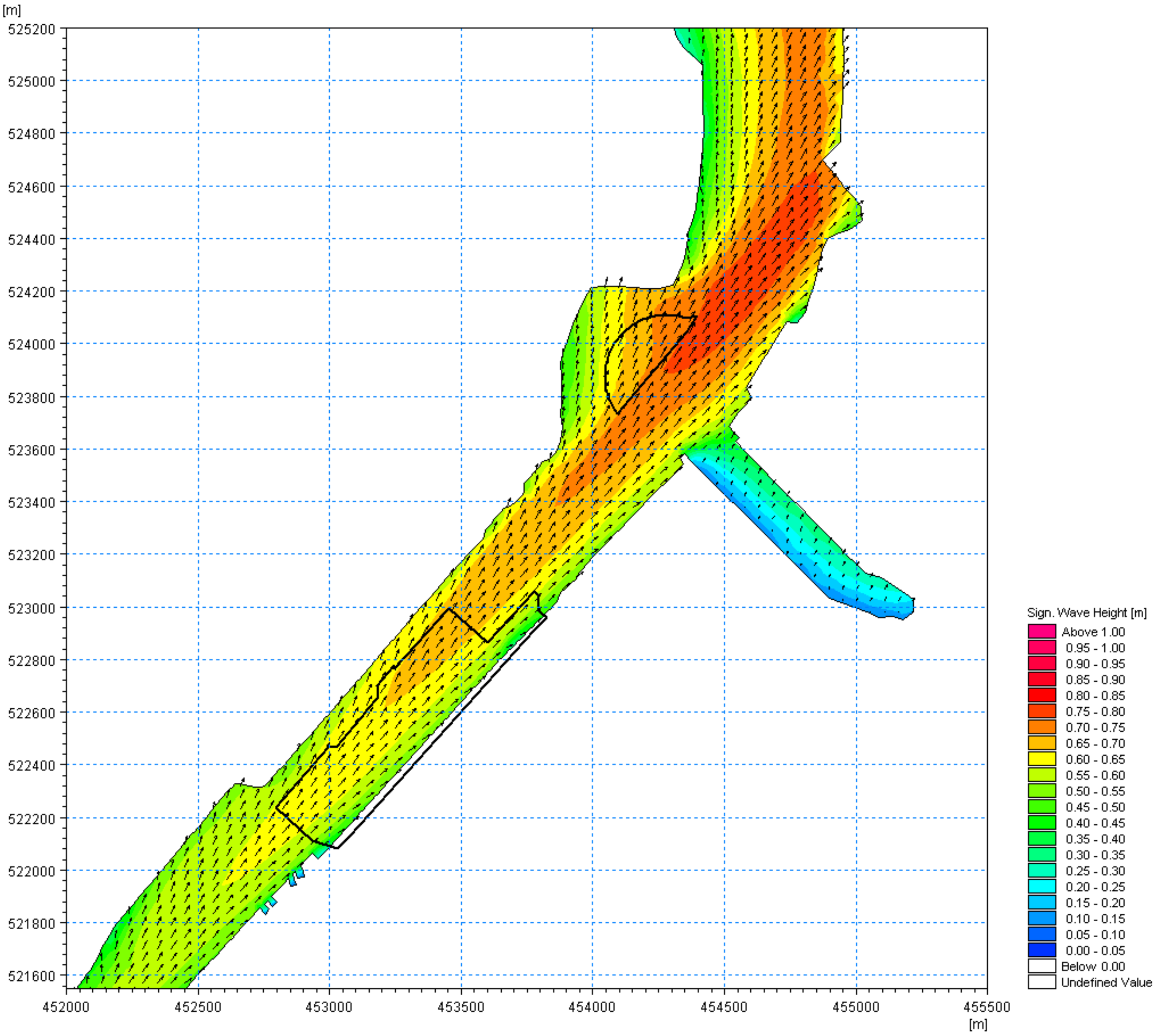


Figure 6.25 Local wind-generated saves for 1 in 100 year return period coming from south-southwest (210 degrees) (proposed scheme)

Climate change

The Environment Agency produced updated guidance on climate change allowances in July 2020 within two documents, namely for:

- Flood and coastal risk projects, schemes and strategies:

https://www.gov.uk/guidance/flood-and-coastal-risk-projects-schemes-and-strategies-climate-change-allowances

- Flood risk assessments: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

These documents include revised sea level rise allowances based on the latest UK Climate Projections (UKCP18). The ‘Flood and coastal risk projects’ guidance now recommends that a range of sea level rise values should be considered in assessing the impacts of climate change, instead of a single value. The purpose of this is to provide a range of scenarios for risk management authorities in the consideration of projects, schemes and scenarios. This guidance encourages the use of the UKCP18 ‘User Interface’ to yield allowances that are specific to individual project sites. In contrast, the ‘Flood risk assessment’ guidance is coarser, providing allowances for different epochs across whole river catchment basins.

The extreme sea level values presented in the earlier **Table 6.8** from the Environment Agency (2018) are based upon a baseline date of 2017. Between this baseline and 2070, by way of example, the sea level rise allowances under the two guidance documents is as follows:

- ‘Flood and coastal risk projects’ guidance:
    - Design value for the Tees Estuary, based on the Representative Concentration Pathway (RCP) 8.5 at the 70th percentile value is 0.380m sea level rise.
    - Sensitivity test value for the Tees Estuary, based on RCP 8.5 at the 95th percentile value is 0.499m sea level rise.

- ‘Flood risk assessment’ guidance:
    - Higher central allowance for the Northumbria river basin district, based on RCP 8.5 at the 70th percentile value is 0.358m sea level rise.
    - Upper end allowance for the Northumbria river basin district, based on RCP 8.5 at the 95th percentile value is 0.476m sea level rise.
    - There is also suggestion that a ‘catastrophic’ scenario called H++ is considered. This involves a sea level rise of 1.9m by 2100 plus 2mm/year surge (from 2017). i.e. 1.900m + 0.166m = 2.066m.

The assessment of climate change, and in particular sea level rise, has been incorporated into the design of the quay wall crest level and adjacent land levels and also in **Section 20** of this report.

It is recognised that the baseline hydrodynamic and sedimentary regime, as characterised within this section, is dynamic; it changes over timescales of seconds, minutes and hours (during storms), through days, weeks and months (through tidal cycles) to years and decades (through sea level rise). However, the *relative* effect of the proposed scheme upon the baseline hydrodynamic and sedimentary regime will be constant throughout such changes.

Whilst it is acknowledged that the effect of climate change on physical processes may lead to increased risk of adverse impacts such submergence or erosion of intertidal habitats due to sea level rise, these changes are not due to the proposed scheme; they are natural ongoing processes that would occur with or without the proposed scheme in place. The proposed scheme itself will not exacerbate (or alleviate) these ongoing natural processes. It therefore remains valid to assess the potential impacts of the proposed scheme upon the baseline hydrodynamic and sedimentary regime in a relative manner, using the baseline understanding presented in this section.

6.4.4 Sedimentary regime

Suspended sediment concentrations

In general, suspended sediment concentrations (SSCs) are low within the estuary and within Tees Bay. The highest observed values tend to occur on spring tides. This relationship is not strong, but the extreme values are also attributed to either high rainfall or storm events. In general, the SSCs appear to be dominated by freshwater inputs in the reaches above Middlesbrough and marine influences in reaches located further downstream.

In the vicinity of the proposed scheme (i.e. in the Tees Dock area) SSCs are, for the most part, less than 20mg/l with short-term peaks from 40 to 80mg/l (Royal Haskoning, 2006). In terms of the tidal sequence, the highest suspended sediment levels occur close to high water. After storm periods, higher concentrations of suspended sediment have been noted around the Shell Jetty, but with little penetration further up the estuary. On other occasions the reverse has been true, thus the effect of storm events is not consistent within the estuary.

During the metocean survey in July 2020, 26 water samples were taken at regular time intervals from the centre point of transect T8 during both the spring tide (24th July 2020) and neap tide (30th July 2020) surveys. In total therefore, 52 samples were collected and subsequently analysed in the laboratory for SSCs. The minimum detection level of the laboratory is 3mg/l, so anything lower than this threshold has been given a zero reading for the purposes of analysis. Results are summarised in **Table 6.14** and indicate very low SSCs in the estuary channel. It should be noted that the weather conditions during the metocean survey were very dry and calm and therefore the results are considered to only be reflective of potential spring/summer conditions.

Table 6.14 SSCs recorded at Transect T8 in July 2020

Location	Tidal Condition	Suspended sediment concentrations (mg/l)		
		Minimum	Mean	Maximum
Transect T8	Neap	0.0	3.9	7.5
	Spring	0.0	2.5	8.5

Figures 6.26 and **6.27** plot a timeseries of SSCs from the water sampling for the neap tide and spring tide surveys, respectively, alongside the corresponding water levels, current speeds and wind speeds during each survey. There is no particularly strong correlation between SSC and forcing conditions, although there is clearly a peak in concentration when both wind speed and current speed are greatest.

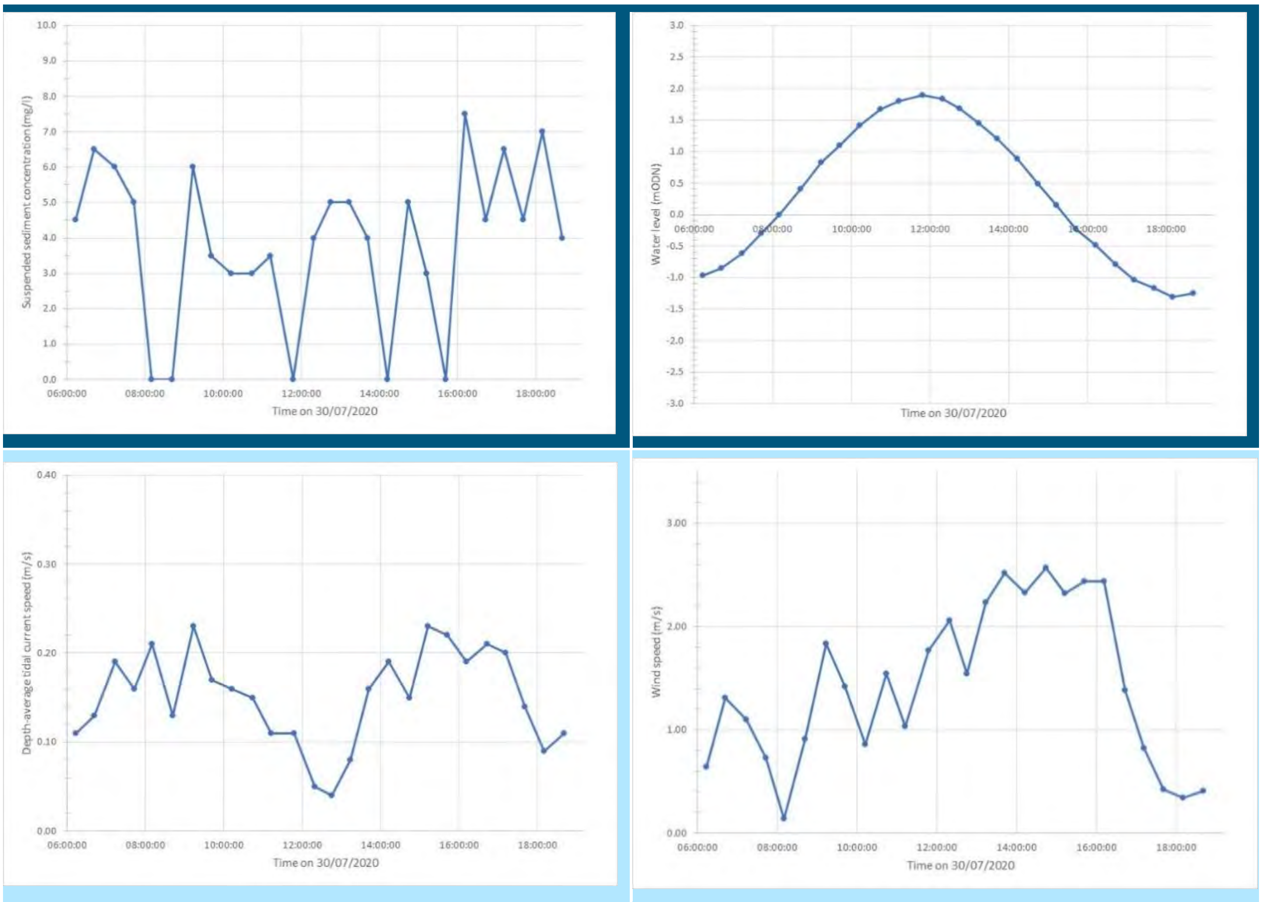


Figure 6.26 Timeseries of SSC (top left), water level (top right), current speed (bottom left) and wind speed (bottom right) during neap tide surveys on 30th July 2020

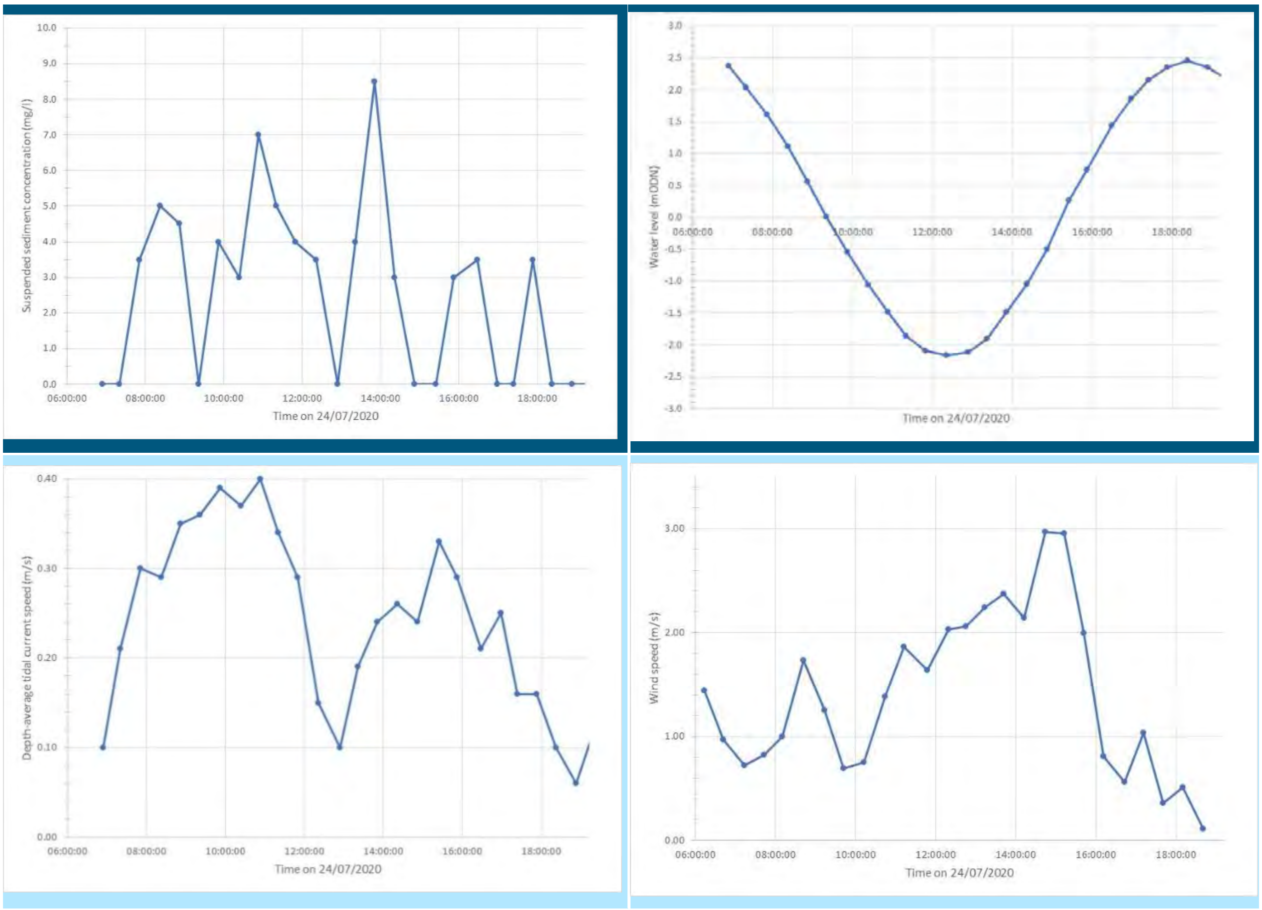


Figure 6.27 ***Timeseries of SSC (top left), water level (top right), current speed (bottom left) and wind speed (bottom right) during spring tide surveys on 24^{h} July 2020***

During the metocean surveys in July 2020, a turbidity sonde was deployed from the survey vessel. Two summary plots of measured turbidity through the depth of the water column at hourly time intervals are presented in **Figure 6.28**. A low turbidity water column was present during both surveys. The lowest turbidity values of <5 Formazin Turbidity Units (FTU) were found at the water surface, with increasing turbidity nearer to the bed (5 to 10 FTU).

Following analysis of the collected water samples and the low turbidity environment found during the surveys, it was decided that a conversion of FTUs into units of milligrams per litre would not have sufficient accuracy to be beneficial and was therefore not undertaken. The FTU measurements do, however, give a good indication of the turbidity in the water column throughout the duration of the surveys and it is noted that some variation between spring and neap tides is evident in the collected data. During the neap survey, less variation is found in the turbidity values (all data <6 FTU), when compared to the spring survey (all data <10 FTU).

During the spring cycle the surface 4 m layer shows very little variation, within 1-4 FTU, whilst the deeper sections of the water column show clear temporal variation. The highest turbidity values are found over low water, whereas over high water the water column has the lowest turbidity and shows very little change in turbidity with depth.

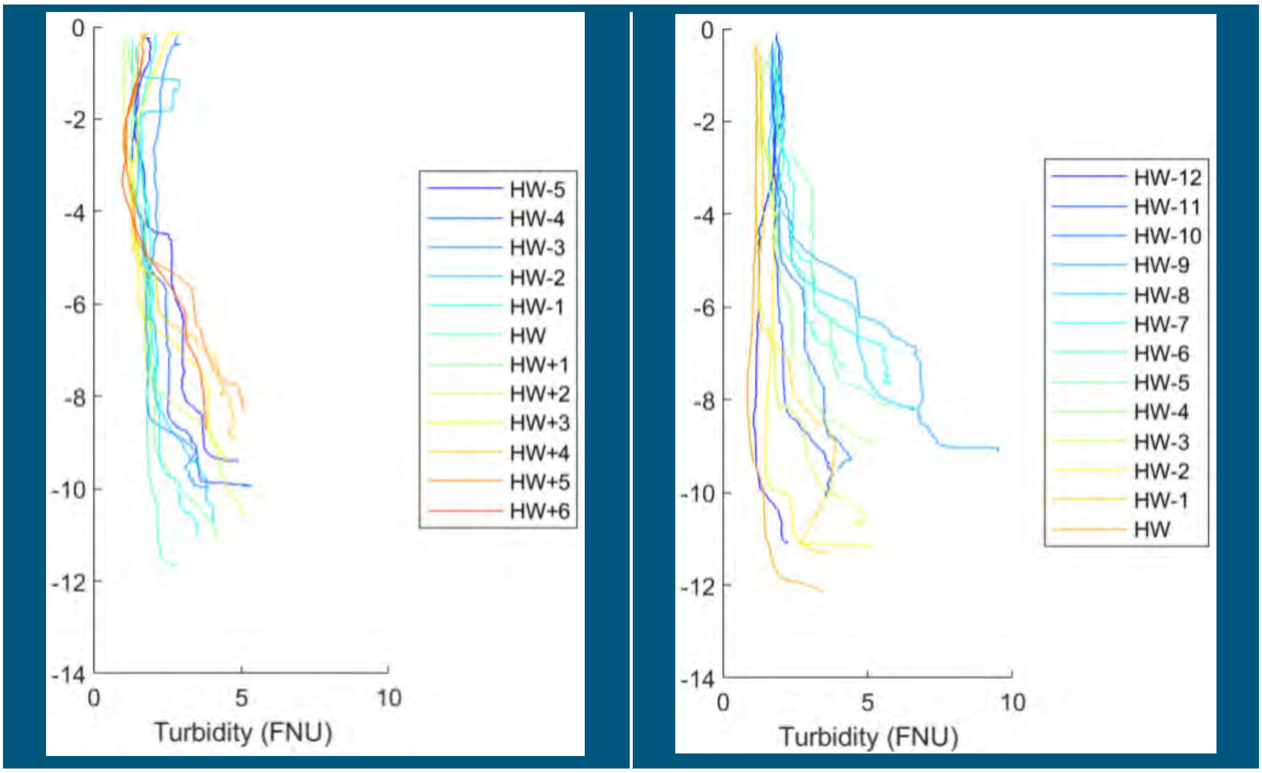


Figure 6.28 Measured hourly turbidity profiles at the centre of transect T8 during neap (left) and spring (right) tides in July 2020

Sediment sources and transport

Historic bed sampling results in the vicinity of the proposed scheme show bed sediments in the area to comprise predominantly (65% to 70%) silt, with some (20%) clay and the remainder sand and gravel (Halcrow, 1991). These observations match the particle size distribution results from bed grabs undertaken in this vicinity for previous studies (Royal Haskoning, 2009).

The sources of material into the Tees estuary system are fluvial inputs coming through the Tees Barrage, material entering from Tees Bay and any industrial inputs. These inputs are in addition to material eroded from the estuary bed. Of these sources, the main source of material is the marine component entering the estuary from Tees Bay. This material comes in on the flood tide, particularly during times when concentrations in Tees Bay are raised by the re-suspension of material from the seabed during storm events. The coarser material, mostly sand, is then able to settle out in the lower estuary, whereas the finer material is drawn further up the estuary by the gravitational circulation.

Within the system the driving forces for sediment transport are the tidal flows, density driven currents, wave induced currents, vessel induced forces and re-suspension by dredging operations. These last two were postulated by HR Wallingford (1989a) as a means by which material entering the system from offshore can be re-suspended and moved further upstream into the estuary. Inputs to the system can be summarised as follows (from HR Wallingford in Royal Haskoning, 2006):

- **Fluvial input:** HR Wallingford (1989a) outlined the pre-barrage conditions for fluvial input with general very low concentrations (<10 mg/l) which rose to about 200 mg/l during occasional floods. The inputs were suggested to be closely linked to large fluvial events with about 8,000 dry tonnes entering the estuary during the 1:1 year flood (300 cumecs at Low Moor, 44km up estuary of South Gare). The average total inputs were estimated at 40,000 dry tonnes per year; however the close link to high fluvial events would suggest that this could vary considerably from year to year. Most of this material is assumed to be trapped in the estuary.

Since construction of the Tees Barrage, considerable siltation has occurred upstream of the barrage with the implication that fluvial sediment input to the estuary has reduced (ABPmer, 2005). However, even the pre-barrage fluvial input is small when compared to marine inputs (see below).

- **Industrial input:** Up to 22,000 dry tonnes per year has been discharged under license from ICI Wilton at Redcar (ABPmer, 2002). This industrial material is discharged in the Dabholm Gut (directly downstream of the proposed scheme). This is the remaining major industrial source of material to the Tees estuary.

- **Marine input:** Comparison of the above figures with the present knowledge of the dredging requirements in the area (presently approximately 0.9 million m^3 per year within the Tees estuary) shows that the remaining source of material, i.e. that from Tees Bay, is the predominant source of sediment into the estuary system. This material comes in on the flood tide, particularly during times when concentrations in Tees Bay are raised by the resuspension of material from the seabed during storm events. The coarser material, mostly sand, is then able to settle out in the lower estuary, whereas the finer material is drawn further up the estuary by the gravitational circulation.

Dredging activities

PDT has a statutory duty to maintain navigation within the Tees estuary (and also into the Hartlepool docks). As part of this responsibility, PDT must maintain the advertised dredge depths within the defined areas (hereafter referred to as “the maintained areas”). In order to achieve this, PDT carries out maintenance dredging in the thirteen reaches of the river shown in **Figure 6.29** (as well as in berths within the Tees and Hartlepool’s Victoria Harbour, in the Seaton Channel and occasionally in other areas within their jurisdiction within Tees Bay). Maintenance dredging practices have remained unchanged since 2005.

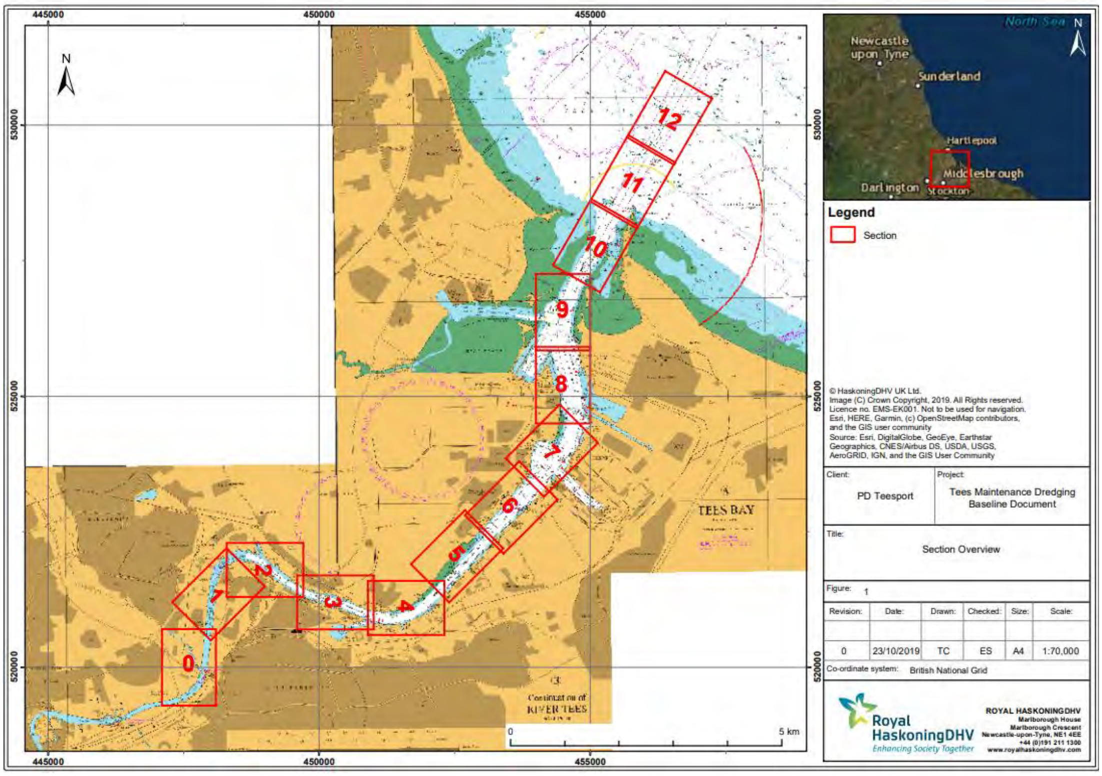


Figure 6.29 Maintenance dredging reaches within the River Tees

Most dredging within the Tees occurs in the approach channel and low-middle estuary in order to maintain access to berth pockets and impounded docks. TSHDs are currently used for the majority of the dredging and are supported by ploughing where required. PDT employs two TSHDs of 1,500m³ hopper volume to maintain depths within the navigable channel and berths within the Tees estuary and Hartlepool. Both dredgers have active bottom door offloading systems.

PDT also operates its own 11m plough to supplement ongoing suction dredging operations through the removal of isolated high spots on the riverbed, primarily in frontages or confined areas. Plough dredging has also been utilised to move recently deposited accumulations of sediment to adjacent scour spots within the river, thus maintaining sediment within the estuarine system and reducing the overall volumes of dredgings requiring disposal to sea.

A summary of the maintenance dredged volumes (m³) by each reach from 2001 to 2019 is provided in **Table 6.15** and shown in **Figure 6.30**. Data on dredging was obtained from PDT and extends the time series originally presented in Royal Haskoning (2008) from 2001 to 2019. No dredging has been required within Reach 0 during the reporting period. Note that these data also include maintenance dredging volumes from berths within the Tees and Hartlepool's Victoria Harbour, from within the Seaton Channel and from occasional other areas within Tees Bay as well as the thirteen reaches within the Tees estuary.

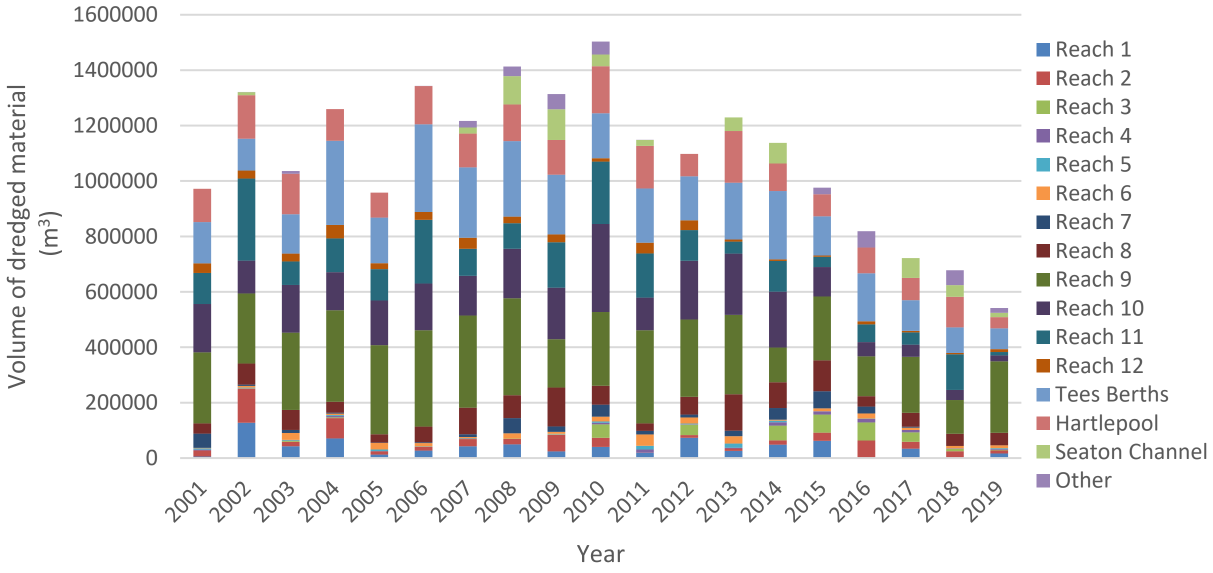


Figure 6.30 ***Summary of volumes (m^3) dredged and deposited offshore during the period 2001 to 2019***

The total volume of maintenance dredged material has decreased below the average annual volume for the period 2001 to 2019 in recent years. Contributing factors to this reduction are weather conditions and varied deposition rates within maintained areas.

Over the 19-year period, the average volume maintenance dredged from the Tees reaches is 740,266m^3, with an average of 183,980m^3 from the Tees berths making an average of 924,247m^3 for the Tees as a whole. When considering all 'other' areas outside of the Tees estuary but elsewhere within Tees Bay, the average over this period is 1.1Mm^3.

Table 6.15 *Summary of the total volumes of dredged material disposal (m^3) from 2001 to 2019*

Reach	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
1	5,911	127,827	42,384	70,856	12,361	27,075	42,701	49,701	24,159	40,237	19,066	73,544	25,674	48,268	62,094	1,500	33,972	2,165	16,509
2	21,768	122,381	16,470	73,210	11,649	12,982	26,028	19,805	60,118	32,817	371	9,814	8,863	15,894	29,830	61,722	25,133	22,508	11,379
3	0	1,366	4,176	3,205	412	412	1,925	735	1,772	48,532	0	37,429	0	52,857	64,998	65,468	33,698	8,501	1,693
4	3,131	1,666	127	4,468	676	282	1,514	0	274	6,056	11,386	1,500	2,996	12,504	11,770	12,884	8,771	1,879	2,605
5	4,621	1,634	2,751	3,815	5,997	1,339	764	0	1,336	4,745	13,496	2,541	15,018	5,370	471	951	0	0	3,270
6	1,625	5,282	24,645	4,859	23,640	12,092	3,088	18,906	7,037	17,009	41,303	21,755	26,210	3,630	10,534	18,383	8,242	8,624	10,618
7	51,303	4,804	10,765	3,297	1,243	2,642	9,841	55,084	19,322	43,157	12,502	10,160	19,746	42,200	61,866	25,041	3,339	0	0
8	37,075	76,297	72,261	39,251	30,172	56,926	96,160	82,531	140,839	68,357	27,102	64,468	131,948	93,188	111,145	37,485	50,317	44,138	44,965
9	256,158	252,715	279,054	330,835	321,316	347,365	332,679	349,982	174,009	266,187	336,050	278,883	286,441	124,821	230,316	143,677	202,051	121,796	258,315
10	174,248	118,613	171,950	137,022	161,349	168,733	143,089	178,819	186,336	317,961	117,635	211,799	221,176	201,953	106,326	51,239	44,053	36,072	21,132
11	112,437	296,471	85,385	121,807	113,304	230,099	97,682	92,427	163,910	225,143	159,529	110,787	43,032	110,777	36,893	64,146	44,546	129,283	12,204
12	34,747	28,437	28,156	48,707	21,307	28,262	39,441	23,548	27,937	12,133	38,877	35,415	7,662	5,954	4898	11,168	4,796	4,471	10,170
Sub-total Reaches	**703,024**	**1,037,493**	**738,124**	**841,332**	**703,426**	**888,209**	**794,912**	**871,538**	**807,049**	**1,082,334**	**777,317**	**858,095**	**788,766**	**717,416**	**731,141**	**493,664**	**458,918**	**379,437**	**392,860**
Tees berths	148,837	115,219	141,880	303,869	164,664	316,696	254,458	272,520	215,702	162,053	195,482	159,067	205,141	246,486	141,160	173,396	111,221	92,351	75,427
Sub-total Tees Reaches & Berths	**851,861**	**1,152,712**	**880,004**	**1,145,201**	**868,090**	**1,204,905**	**1,049,370**	**1,144,058**	**1,022,751**	**1,244,387**	**972,799**	**1,017,162**	**993,907**	**963,902**	**872,301**	**667,060**	**570,139**	**471,788**	**468,287**

Project related

Reach	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Hartlepool	119,847	157,329	146,457	114,104	89,811	137,606	121,605	132,041	125,032	170,170	154,025	80,410	186,229	99,068	79,818	92,781	79,936	110,448	39,943
Seaton Channel	0	10,900	0	0	0	0	22,279	102,463	111,424	42,110	21,060	0	49,598	74,652	0	0	71,803	41,712	15,951
Other	0	245	9,809	0	0	312	23,366	34,605	54,610	46,725	461	0	0	0	23,972	58,842	0	53,880	17,183
Total (x 10^6)	**0.972**	**1.321**	**1.036**	**1.259**	**0.958**	**1.343**	**1.217**	**1.413**	**1.314**	**1.503**	**1.148**	**1.098**	**1.230**	**1.138**	**0.976**	**0.819**	**0.722**	**0.678**	**0.541**

Maintenance dredge material (between 2001 and 2018) comprised around 180,000m^3 of mud, mostly found in the upstream reaches beyond the Transporter Bridge. Of the remainder, 80% typically is clean, fine sand (approximately 650,000m^3) and 20% typically is silty sand (approximately 170,000m^3) (Royal HaskoningDHV, 2020b).

A review of the dredged sediment quality data is presented in **Section 7.**

The active disposal sites present in Tees Bay are summarised in **Table 6.16** and shown in **Figure 6.31**. In general, Tees Bay A (TY160) is used for the disposal of maintenance dredge arisings while Tees Bay C (TY150) is used for capital dredge arisings. Tees Bay B (TY110) and Tees Bay Foreshore (TY170) are closed.

Table 6.16 Active disposal sites present in Tees Bay (Royal HaskoningDHV, 2018)

Disposal site	Status	Description	Comment
Tees Bay A (TY160) Within the area bounded by joining the points: 54 40.800 N 01 03.500 W 54 41.500 N 01 02.200 W 54 41.000 N 01 00.300 W 54 40.200 N 01 01.500 W 54 40.800 N 01 03.500 W	Active	Active site for soft non-cohesive maintenance material	DEFRA records show volume fluctuating from 0.3 million to 2.4 million wet tonnes over a 15 year period. Volumes drop off post 1996. Largest volume deposited since 1996 was 1.8 million wet tonnes.
Tees Bay C (TY150) Within the area bounded by joining the points: 54 42.600N 00 58.600W 54 41.900N 00 57.400W 54 41.400N 00 58.700W 54 42.300N 00 59.900W 54 42.600N 00 58.600W	Active	Predominantly used for capital dredged material. Some maintenance dredging has been disposed of at this site.	DEFRA records show small scale usage. Peak volume deposited was 1.9 million wet tonnes in 1999, associated with the construction of the downstream Ro-Ro berths. Typical annual volume is 0.1 million wet tonnes. Some years show no usage at all.

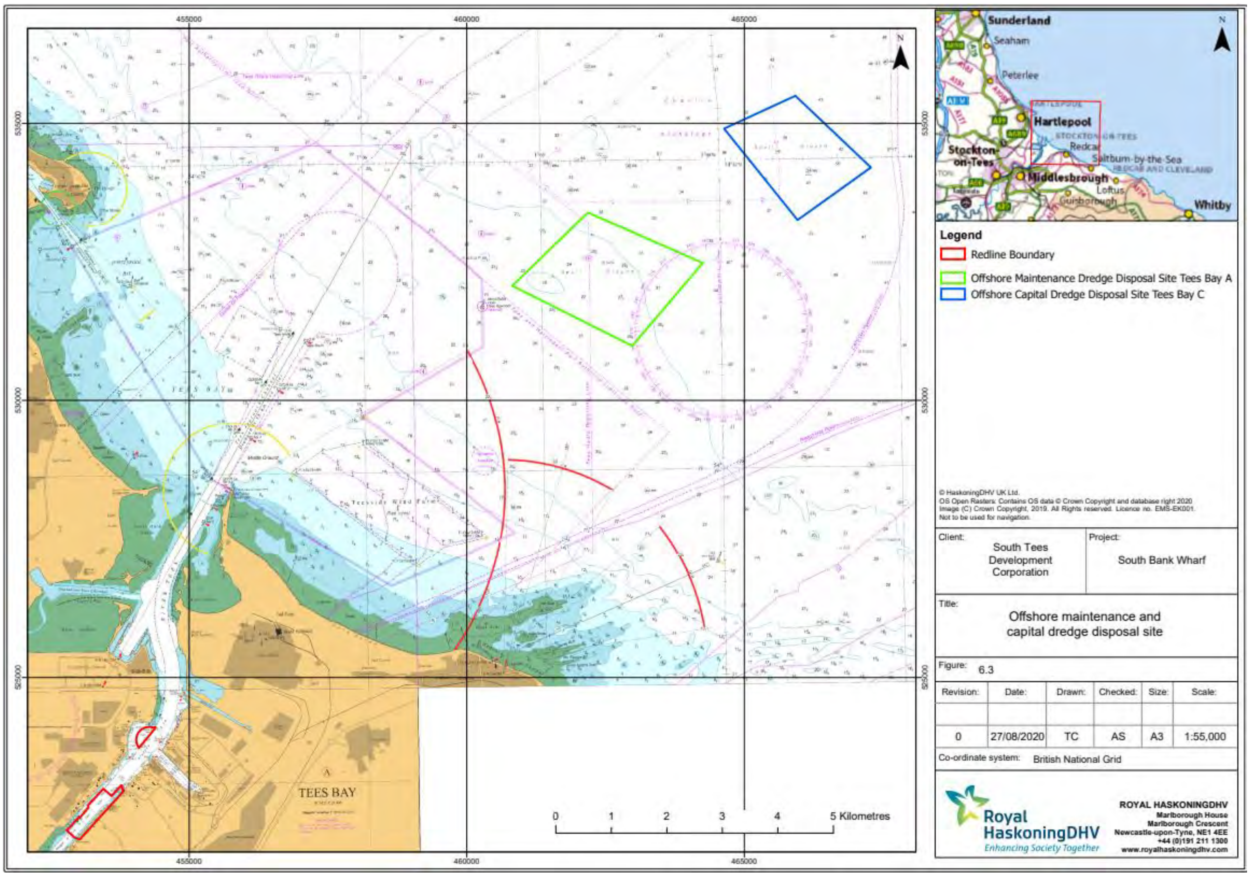


Figure 6.31 Location of offshore maintenance and capital dredge disposal sites

6.5 Potential impacts during the construction phase

6.5.1 Demolition of the existing wharf and jetties

A jack-up barge with a crawler crane, a slave barge and a safety vessel/workboat are likely to be used for the demolition of the existing wharf and jetties. It is envisaged that the demolition works will take approximately 12 months. Whilst the spud legs of the jack-up barge, anchors of the vessels and bow thrusters of the vessels as well as the pile removal activities themselves will result in some disturbance to the existing estuary bed, this will be minor and highly localised and thus is not of significant concern. The works also will be temporary in duration and the baseline conditions will be restored once the vessels have been demobilised from site. Given these findings, the magnitude of effect on baseline hydrodynamic and sedimentary regime arising from the demolition works is **very low**.

6.5.2 Capital dredging and offshore disposal of dredged sediments

Capital dredging is required to: (i) create a berth pocket adjacent to the new quay; (ii) deepen the river channel in the reach containing the new quay; and (iii) deepen part of Tees Dock turning circle.

Part of the Tees Dock turning circle will be deepened from 8.8m below CD to 11.0m below CD, yielding 170,000m^3 of material. Part of the existing navigation channel in the river will be deepened from between 5.7 – 8.5m below CD to 11.0m below CD and a new berthing pocket will be constructed adjacent to the new quay, deepening parts of the existing estuary from 2m below CD to 15.6m below CD and creating new areas of estuary to this depth from existing land areas. A 2m high rock blanket will be placed into the berthing pocket, creating a finished depth of 13.6m below CD. Dredging of the channel and berthing pocket will yield 1,620,000m^3 of material.

In total, approximately 1,800,000m^3 of material will be dredged from the areas described over an approximately four-month period. This material comprises Tidal Flat Deposits and Glacial Till (both classed as 'soft' material) and Mercia Mudstone (classed as 'hard' material). Dredging will be undertaken using a combination of TSHD (for some of the soft material below -5m CD) and BHD (for all of the soft material above -5m CD, some of the soft material below -5m CD, and all of the hard material). A safety vessel/workboat will be present throughout the operations.

Each year, between 25 – 30 million tonnes (wet weight) of dredged marine sediments from ports, harbours and marinas, and their approach channels, are disposed at sea within licensed disposal sites off the UK coast. This activity is highly regulated through international and regional-sea agreements between governments to control disposal at sea (e.g. the OSPAR and London Conventions). In England, the MMO is the regulator for the disposal of material to sea at licensed disposal sites, and these sites are routinely monitored as part of a national programme. In keeping with this principle, all non-contaminated material dredged from the proposed scheme will be taken to the Tees Bay C licensed offshore disposal site, some 18km from the proposed scheme footprint.

The capital dredging within the river, using TSHD and BHD, and the disposal activities at the licensed offshore site will both result in sediment plumes. These effects have been investigated using numerical modelling of the sediment dispersion associated with the dredging and disposal activities, as well as the changes in bed thickness when the suspended sediment falls from the plume to become deposited on the river or seabed.

A MIKE3-MT sediment dispersion model has been coupled with the 3D hydrodynamic model (MIKE3-HD) and run for the entire four month duration covering all proposed dredging and disposal activities. Wave disturbance effects have been included. The dredging methods, schedule and sediment release settings have been described in the Numerical Modelling Report (see **Appendix 5**). The simulations account for the movement of dredgers and transport barges (including dredging, sailing, disposal and downtime) such that sediment releases have been made near continuously throughout the dredging operations (except for allowed periods of downtime) from along the centre line of the dredged areas, running along the axis of the river channel, and also on a periodic basis from a single point in the centre of the offshore disposal site. The overall dredging and disposal operations may be considered as four stages in the following sequence:

- Stage 1: BHD working to dredge the upper soft material (above -5m CD) in the berthing pocket and river channel
- Stage 2: BHD and TSHD working in parallel to dredge the middle soft material (below -5m CD) in the berthing pocket and river channel
- Stage 3: BHD working to dredge the bottom hard material in the berthing pocket and river channel
- Stage 4: BHD and TSHD working in parallel to dredge the material in the Tees Dock turning circle

Results from the sediment dispersion modelling are discussed in turn for the dredging and disposal activities. Note that all the modelling plots in the following sections show the elevations in SSC or sediment deposition due to these activities above baseline levels.

For SSC, two types of plot are presented:

- SSC 'timestep' plots present values in units of kg/m^3, which can be translated into units of mg/l by multiplying the values by a factor of 1,000. It should be noted that the interpretation provided in the following sections is based on an animation of plots created at 5-minute timesteps (intervals) throughout the entire four-month period covered by the dredging and disposal simulations, but only representative examples from selected timesteps are presented in these plots to illustrate key points of discussion.

- Maximum 'zone of influence' plots present values in mg/l and show the maximum values and spatial extents of enhancement in SSC from any stage of the dredging or disposal operations during the relevant stage of the dredging programme. It is important to note that this type of figure does not represent a plume that would occur at any one point in time (such plumes are shown in the timestep plots). Rather, this type of figure shows the areas of the river channel or offshore area that will become affected by a plume at some point during the dredging or disposal activities (in some areas this will be on a single occasion, in other areas it will be on multiple occasions) and the maximum magnitude of change that will be experienced at that point.

Unless otherwise stated, all SSC plots show values within the near-bed layer of the 3D model. This is taken as the worst case in terms of SSC enhancement, but the effects described below generally exist throughout the water column but are of lesser magnitude with progression from the near-bed to the water surface.

Dredging

During Stage 1 of dredging (with the BHD working to dredge the upper soft material (above -5m CD) in the berthing pocket and river channel), the model simulates releases over time, moving from the south-western end of the dredging transect to the north-eastern end.

Peak concentrations from dredging are always local to the point of disturbance from dredging at the riverbed, typically reaching around 100 to 200mg/l, but sometimes up to 350mg/l for a very short duration (depending on timing of release with respect to the phase of the tide and location of dredging within the berthing pocket or river channel). To illustrate this, **Figures 6.32 – 6.35** shows the maximum extent of the plume during a release from the south-western corner of the dredging transect during the ebb phase (Plot A) and flood phase (Plot B) of the tide. Similar results are also shown for releases on the ebb phase (Plot C) and flood phase (Plot D) of the tide when the release is towards the north-eastern end of the dredging transect.

When the dredger is at the south-western end of the transect, the maximum spatial extent of the plume on the ebbing tide is as far north-east as Tees Dock and on the flooding tide is as far south-west as Middlesbrough Dock. When the dredger is at the north-eastern end of the transect, the extent of the plume correspondingly shifts towards the north-east such that during the ebbing tide it extends northwards beyond Tees Dock but during the flooding tide it extends only around 300m south-west of the upstream end of the new quay. However, in all cases considered, the lateral extent of the plume across the river channel is very narrow and the magnitude of the SSC within the plume beyond a few hundred metres from the point of release is of the order of 10 to 20mg/l and in the extremities of the plume reduces further to the same order as the background concentrations that were measured during the metocean survey.

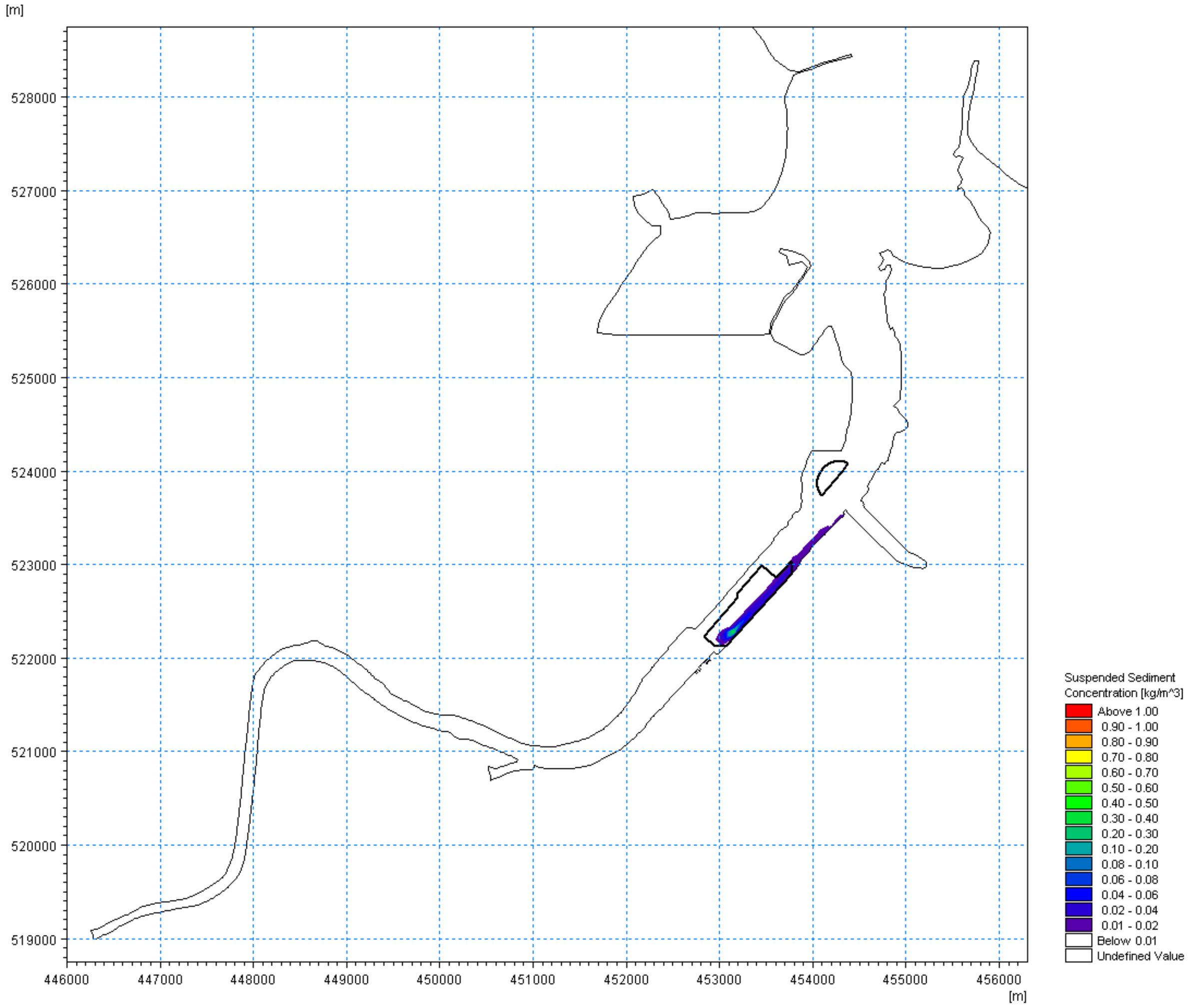


Figure 6.32 (Plot A) – Plume of enhanced SSCs arising from dredging activities during Stage 1 of the capital dredging programme

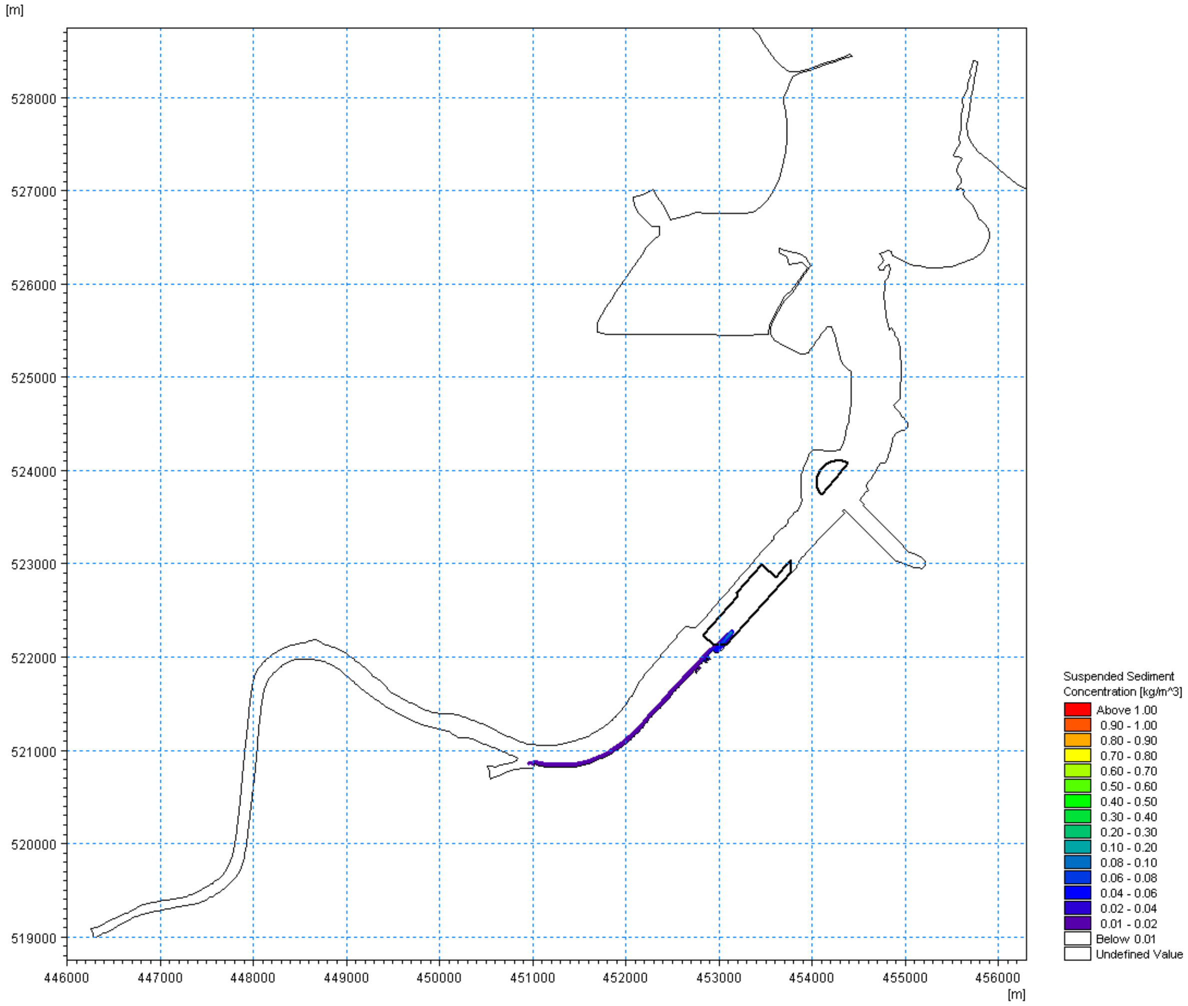


Figure 6.33 (Plot B) – Plume of enhanced SSCs arising from dredging activities during Stage 1 of the capital dredging programme

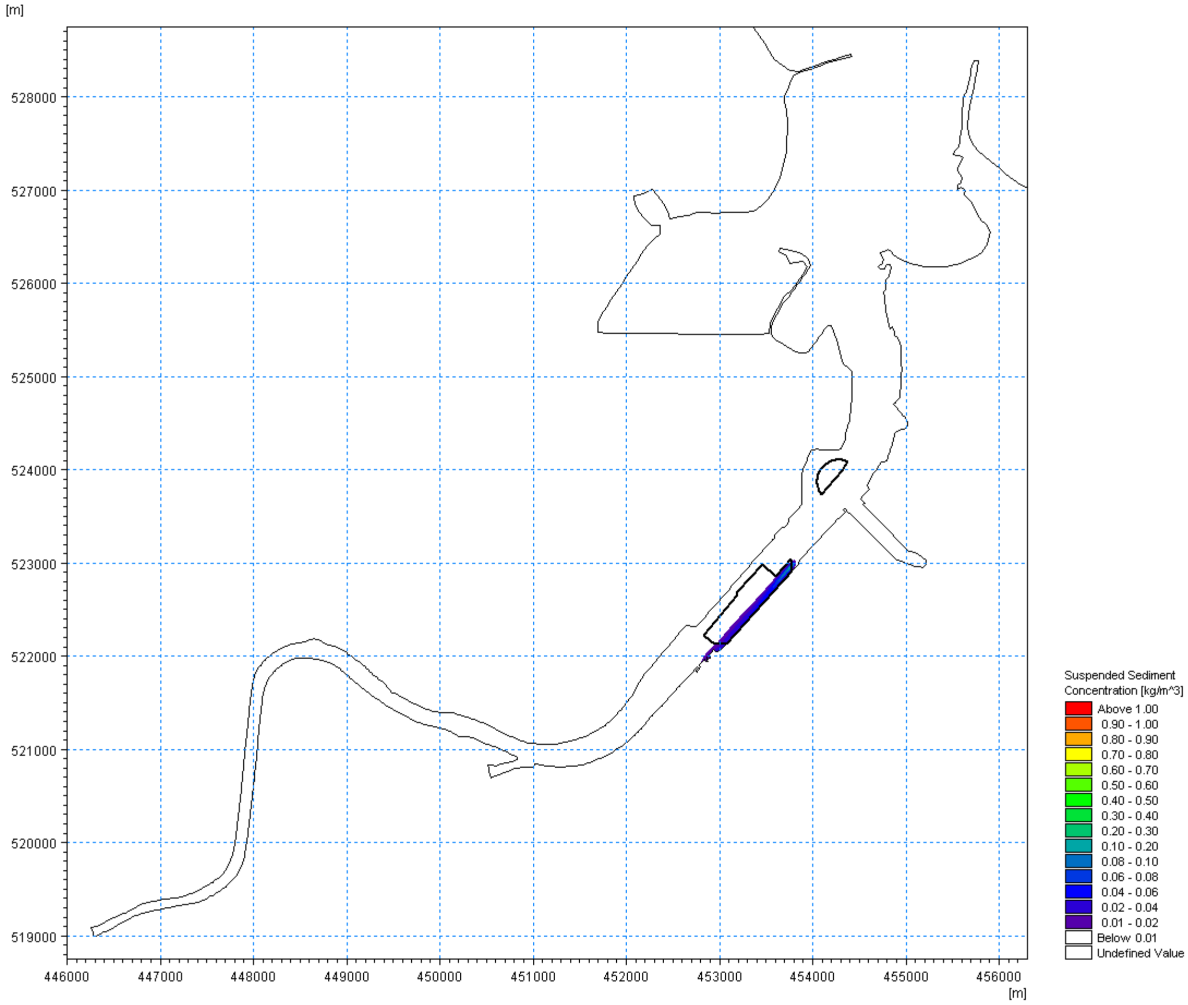


Figure 6.34 (Plot C) – Plume of enhanced SSCs arising from dredging activities during Stage 1 of the capital dredging programme

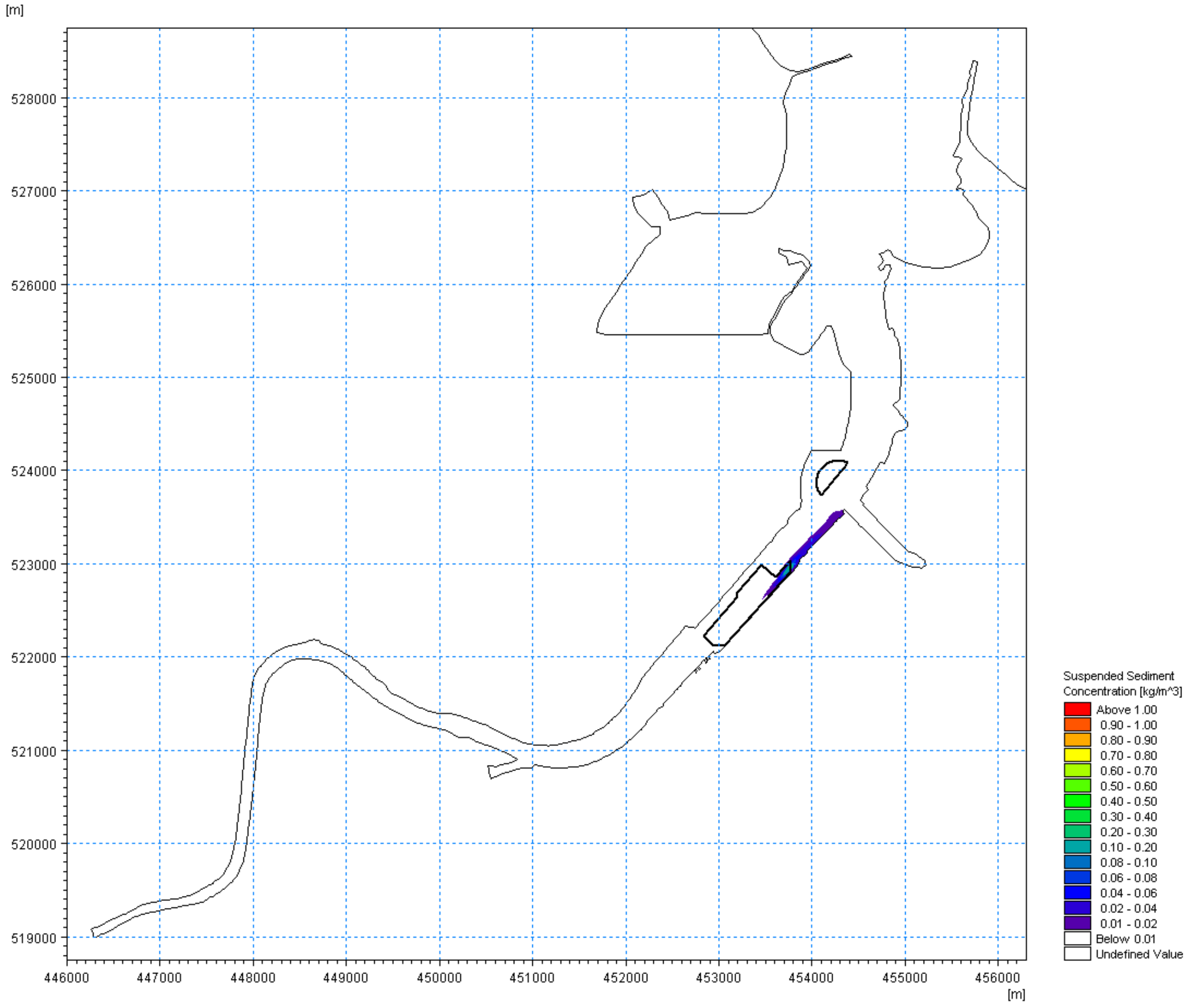


Figure 6.35 (Plot D) – Plume of enhanced SSCs arising from dredging activities during Stage 1 of the capital dredging programme

In order to determine a maximum ‘zone of influence’ from Stage 1 of the dredging activities, the maximum values of enhancement in SSC from any phase of the dredging operations during Stage 1 have been plotted in **Figure 6.36** (please note the earlier caution in interpreting this type of figure).

This figure shows that the maximum concentrations of SSC (up to a few hundred mg/l) are confined to the release points along the dredging transect at the proposed scheme site. Further upstream and downstream of the areas directly dredged, the SSC enhancement drops markedly (typically below 50mg/l a short distance from the point of dredging, and at the peripheries below 20mg/l) before merging with low background concentrations that characterise the baseline conditions.

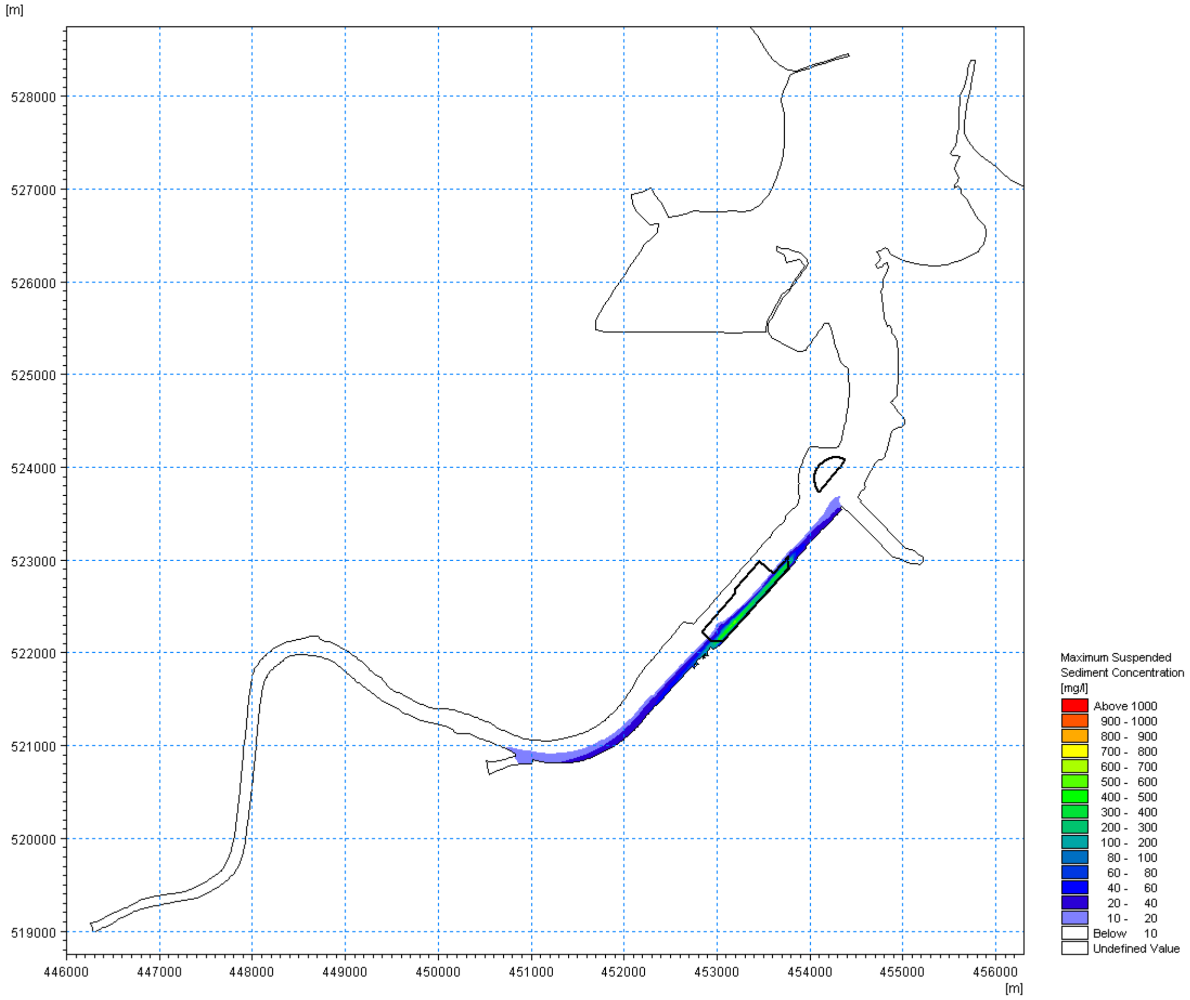


Figure 6.36 Maximum enhanced SSCs arising from dredging activities during Stage 1 of the capital dredging programme

During Stage 2 of the dredging activity (with the BHD and TSHD working in parallel to dredge the middle soft material (below -5m CD) in the berthing pocket and river channel), the model simulates releases over time, moving from the south-western end of each of two parallel dredging transects to the north-eastern end.

Results from this scenario are broadly similar to those from Stage 1, but now separate plumes are created from the two dredger types, as show in **Figures 6.37** and **6.38** (Plot A and Plot B show releases from the south-western and north-eastern ends of the two parallel dredging transects respectively). However, the principal difference to Stage 1 is that, at some points in the cycle, all or some parts of these initially separate plumes can coalesce and collectively occupy around half the width of the river channel as they move upstream and downstream according to the tidal phase, albeit at relatively low (typically <30mg/l and often <10 mg/l) SSC concentrations once a few hundred metres away from the point of initial release.

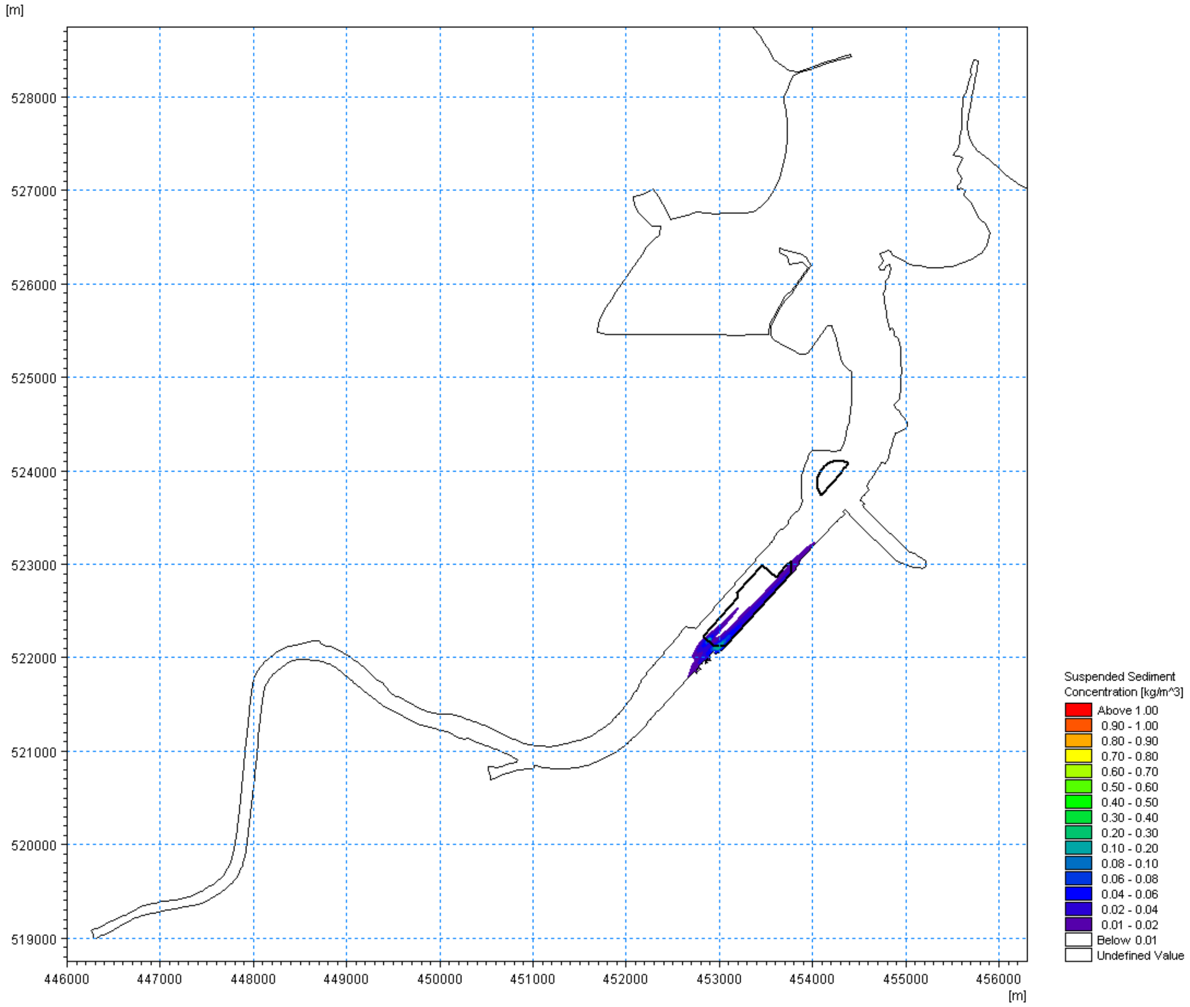


Figure 6.37 (Plot A) – Plume of enhanced SSCs arising from dredging activities during Stage 2 of the capital dredging programme

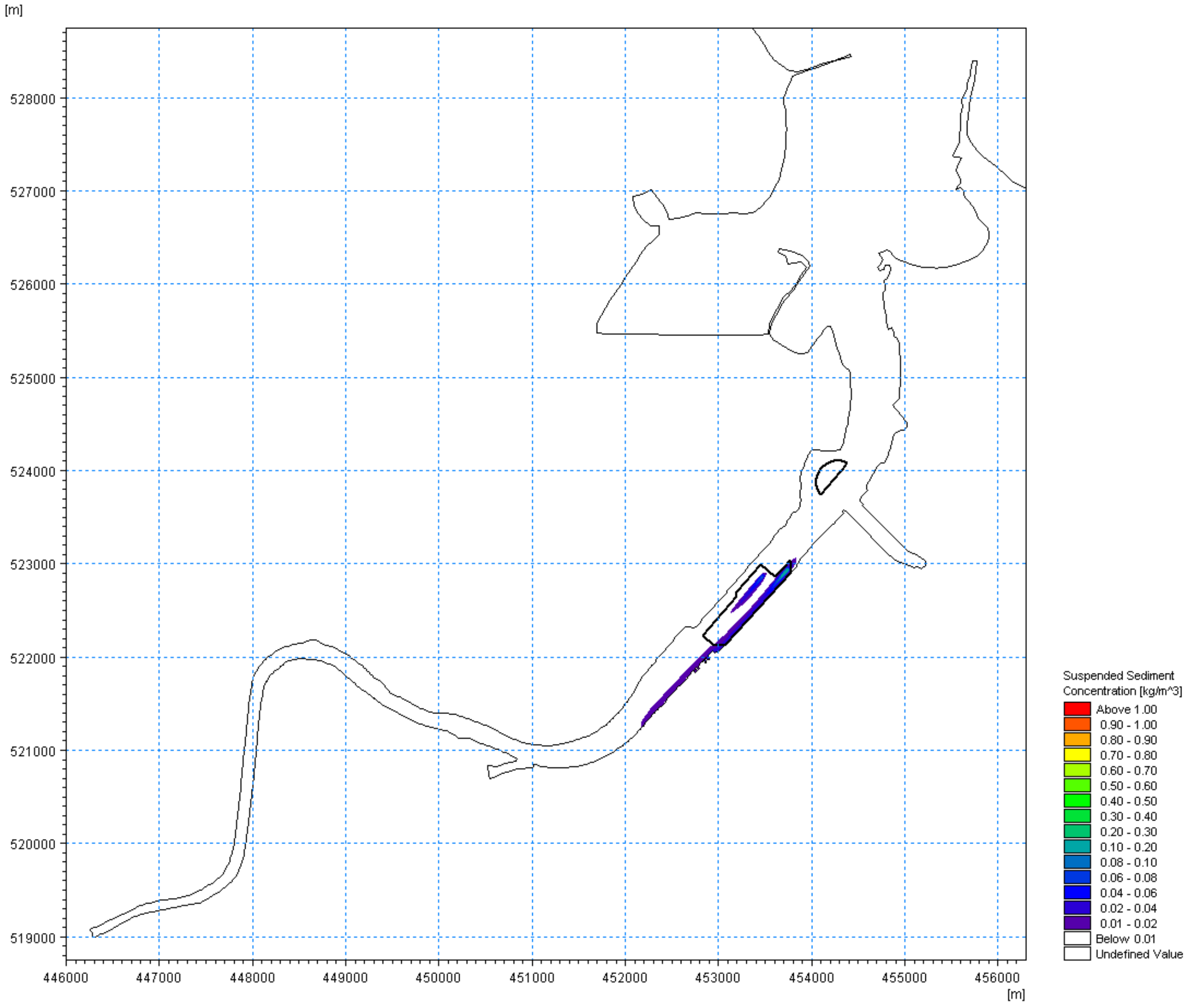


Figure 6.38 (Plot B) – Plume of enhanced SSCs arising from dredging activities during Stage 2 of the capital dredging programme

The maximum ‘zone of influence’ from Stage 2 of the dredging activities is shown in **Figure 6.39** (please note the earlier caution in interpreting this type of figure). This shows that during Stage 2 of the dredging, broadly similar patterns to those observed in Stage 1 are anticipated, although: (i) the lateral extent of the plume (at low concentrations) becomes slightly greater; (ii) the extent of the plume across the river channel becomes wider; and (iii) at times two plumes are created by the in-parallel dredging activities. Despite these subtle differences, maximum concentrations of SSC (up to a few hundred mg/l) remain confined to the release points along the dredging transects at the proposed scheme site. Further upstream and downstream of the areas directly dredged, the SSC enhancement drops markedly (typically below 50mg/l a short distance from the point of dredging, and at the peripheries below 20mg/l) before merging with low background concentrations that characterise the baseline conditions.

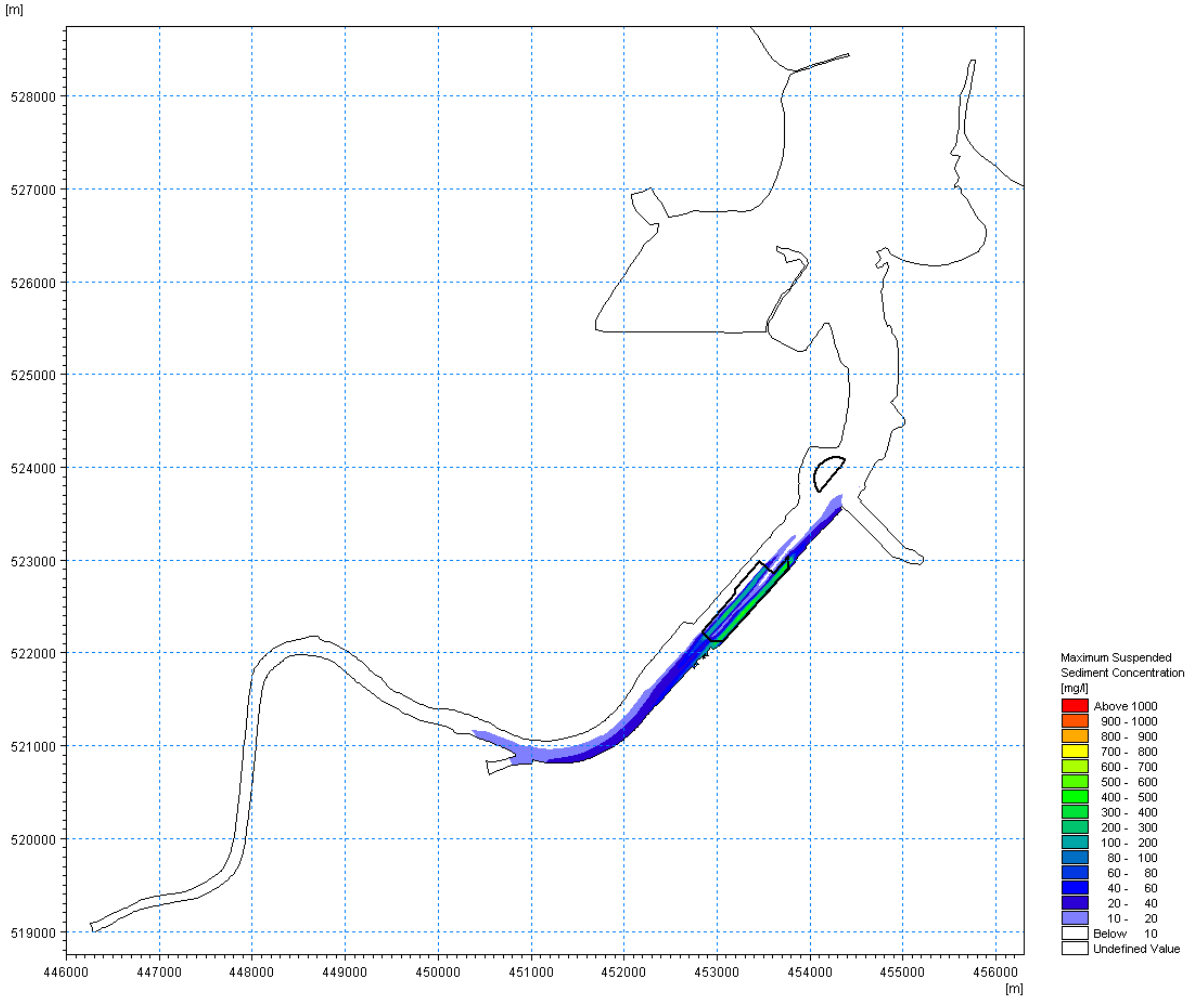


Figure 6.2 Maximum enhanced SSCs arising from dredging activities during Stage 2 of the capital dredging programme

During Stage 3 of the dredging activity (with the BHD working to dredge the bottom hard material in the berthing pocket and river channel), the model simulates releases over time, moving from the south-western end of the dredging transect to the north-eastern end.

Figures 6.40 – 6.43 shows the maximum extent of the plume during a release from the south-western corner of the dredging transect during the ebb phase (Plot A) and flood phase (Plot B) of the tide. Similar results are also shown for releases on the ebb phase (Plot C) and flood phase (Plot D) of the tide when the release is towards the north-eastern end of the dredging transect. It can be seen that the maximum SSC values and the spatial extents of the plume arising from Stage 3 of the dredging are much lower than those experienced during Stage 1, largely because the material being released is coarser and the production rate of dredging is notably lower.

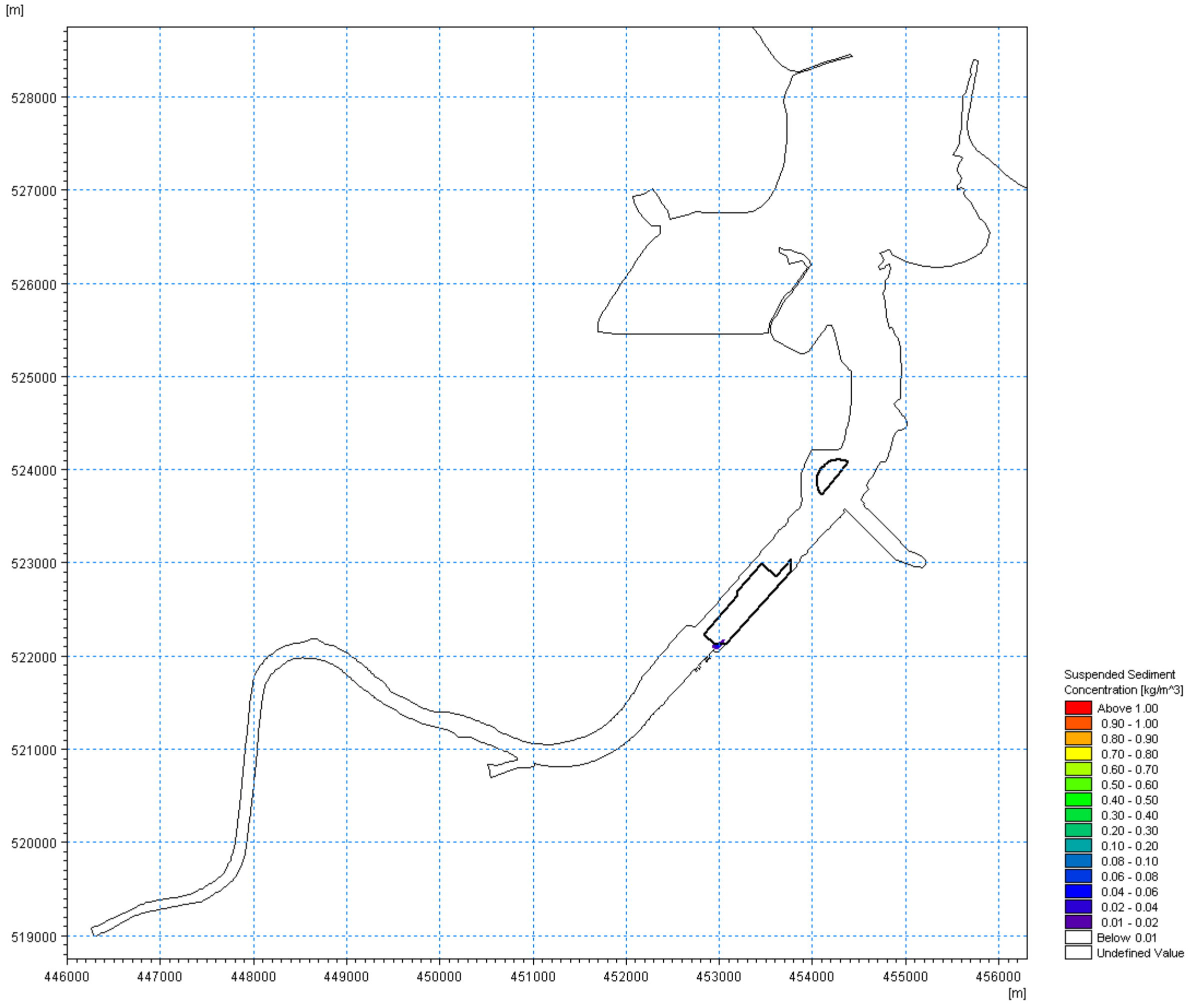


Figure 6.40 (Plot A) – Plume of enhanced SSCs arising from dredging activities during Stage 3 of the capital dredging programme

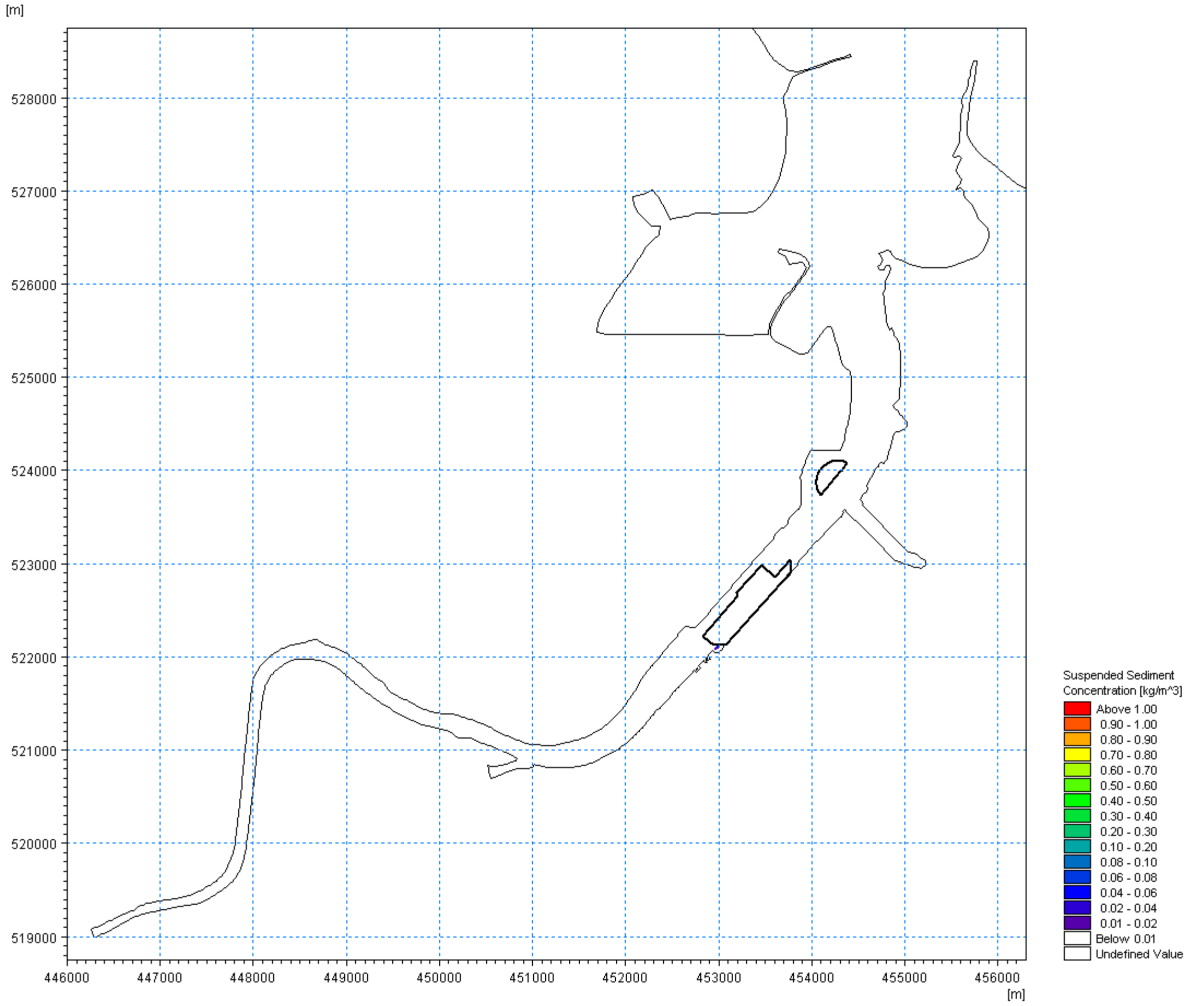


Figure 6.41 (Plot B) – Plume of enhanced SSCs arising from dredging activities during Stage 3 of the capital dredging programme

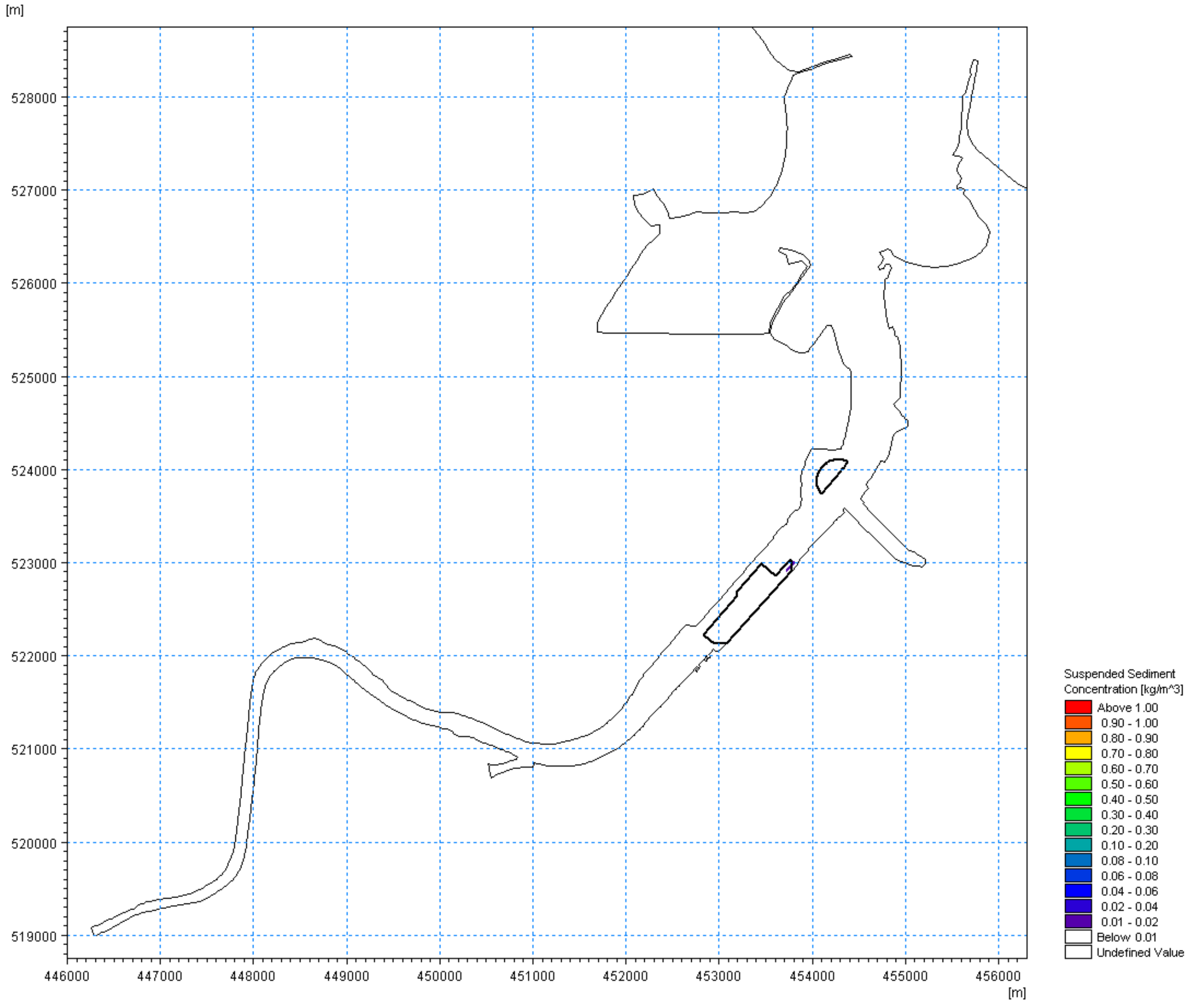


Figure 6.42 (Plot C) – Plume of enhanced SSCs arising from dredging activities during Stage 3 of the capital dredging programme

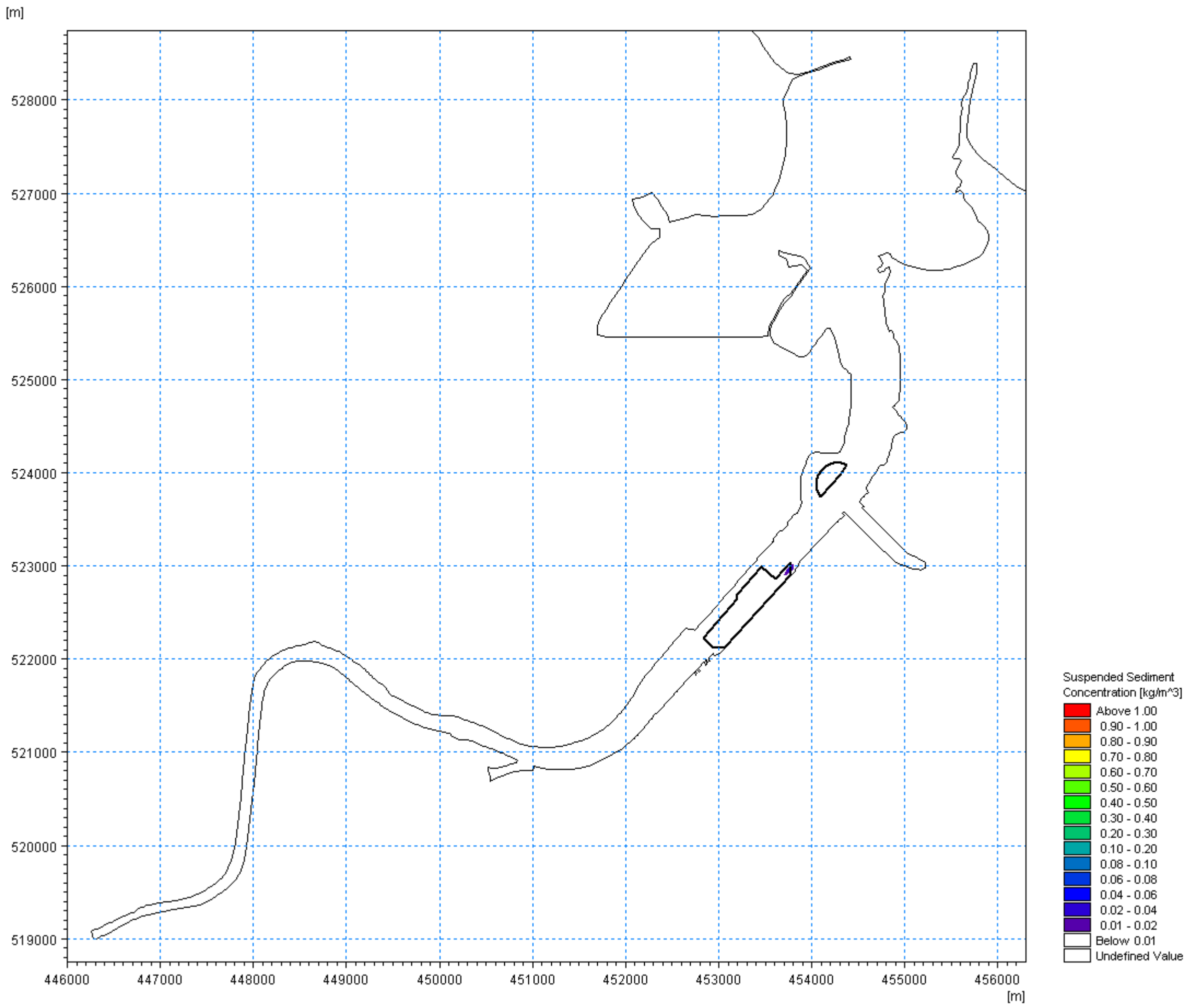


Figure 6.43 (Plot D) – Plume of enhanced SSCs arising from dredging activities during Stage 3 of the capital dredging programme

The maximum ‘zone of influence’ from Stage 3 of the dredging activities is shown in **Figure 6.44** (please note the earlier caution in interpreting this type of figure). This shows that during Stage 3 of the dredging, the maximum plume extent and maximum SSC values within the plume are much lower than experienced during both Stages 1 and 2 of the dredging (note the slight plume shown in the mid channel is a remnant of the Stage 2 dredging, which has not fully dissipated before Stage 3 commences). During Stage 3, the maximum extent of the plume is confined to within the length of the proposed quay and covers only a very narrow width of the channel, at very low peak concentrations.

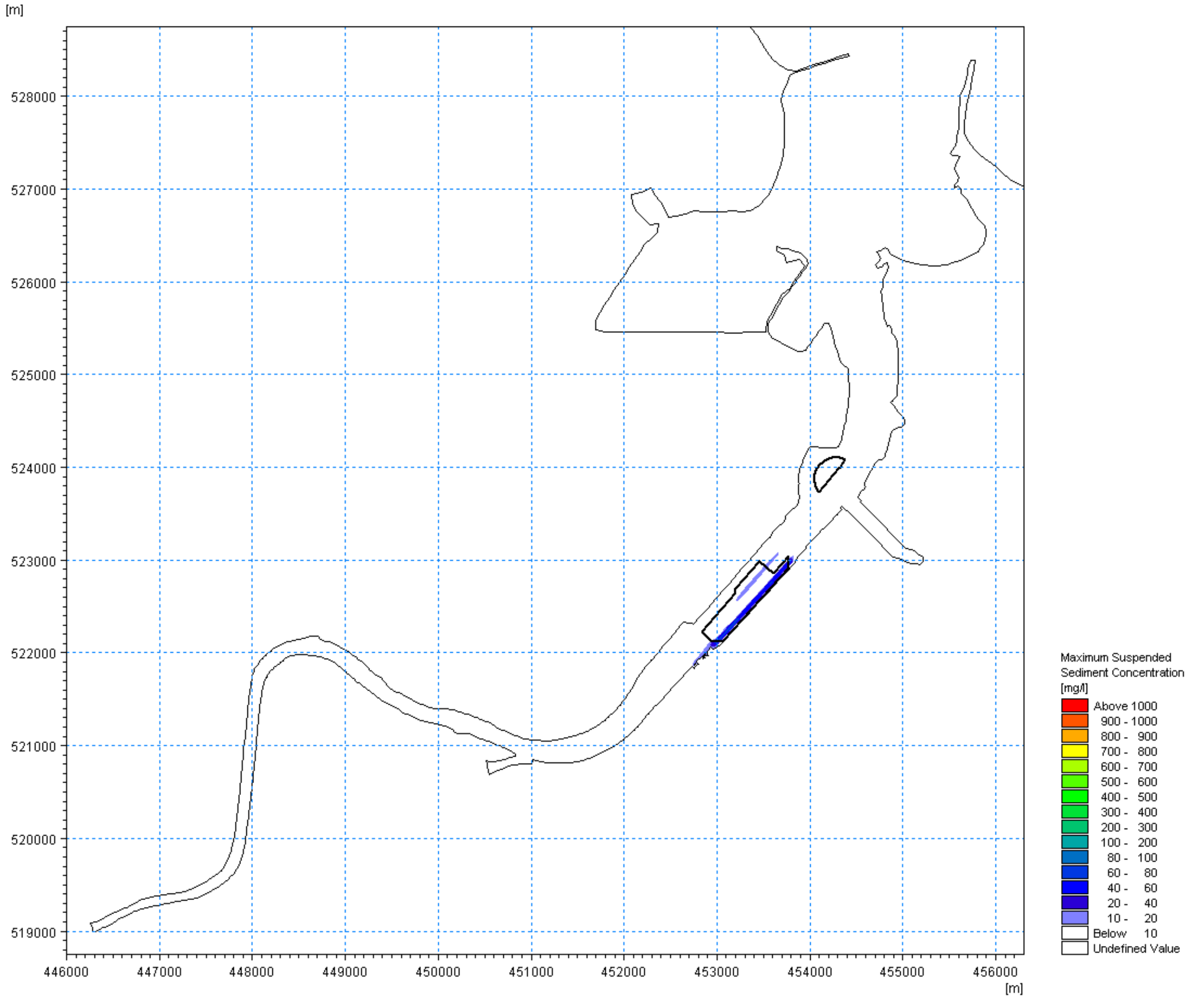


Figure 6.44 Maximum enhanced SSCs arising from dredging activities during Stage 3 of the capital dredging programme

During Stage 4 of the dredging activity (with the BHD and TSHD working in parallel to dredge the material in the Tees Dock turning circle), the model simulates releases over time, moving from the south-western end of each of two parallel dredging transects to the north-eastern end.

Peak concentrations from dredging are always local to the point of disturbance from dredging at the riverbed, typically less than 300mg/l for a very short duration (depending on timing of release with respect to the phase of the tide). **Figure 6.45** and **6.46** shows the maximum extent of the plume during a release from the turning circle during the ebb phase (Plot A) and flood phase (Plot B) of the tide.

On the ebb phase, the plume can extend at low (<30mg/l) concentrations along the jetties of the Oil Terminal towards (but not entering) the Conoco Phillips Inset Dock, whilst on the flood phase it tends to remain close to the northern bank over a narrow channel width extending along the North Tees Works jetties. At certain times in the dredging cycle, SSC values can become enhanced by typically 10 to 20mg/l between the point of release in the turning circle and the closest north bank within the embayment occupied by the Storage Depot. Under no conditions does the plume enter Tees Dock at any significant concentration.

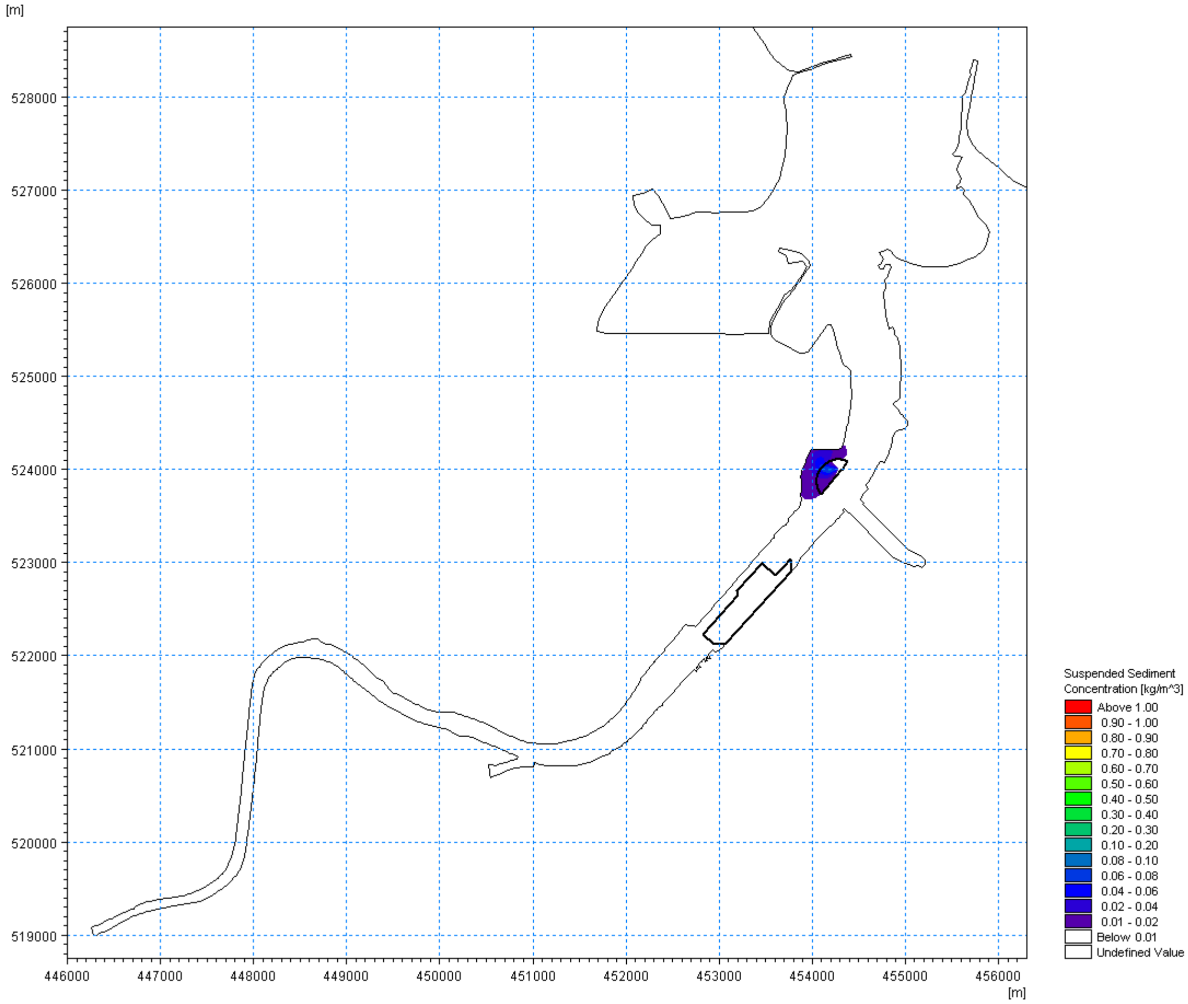


Figure 6.45 (Plot A) – Plume of enhanced SSCs arising from dredging activities during Stage 4 of the capital dredging programme

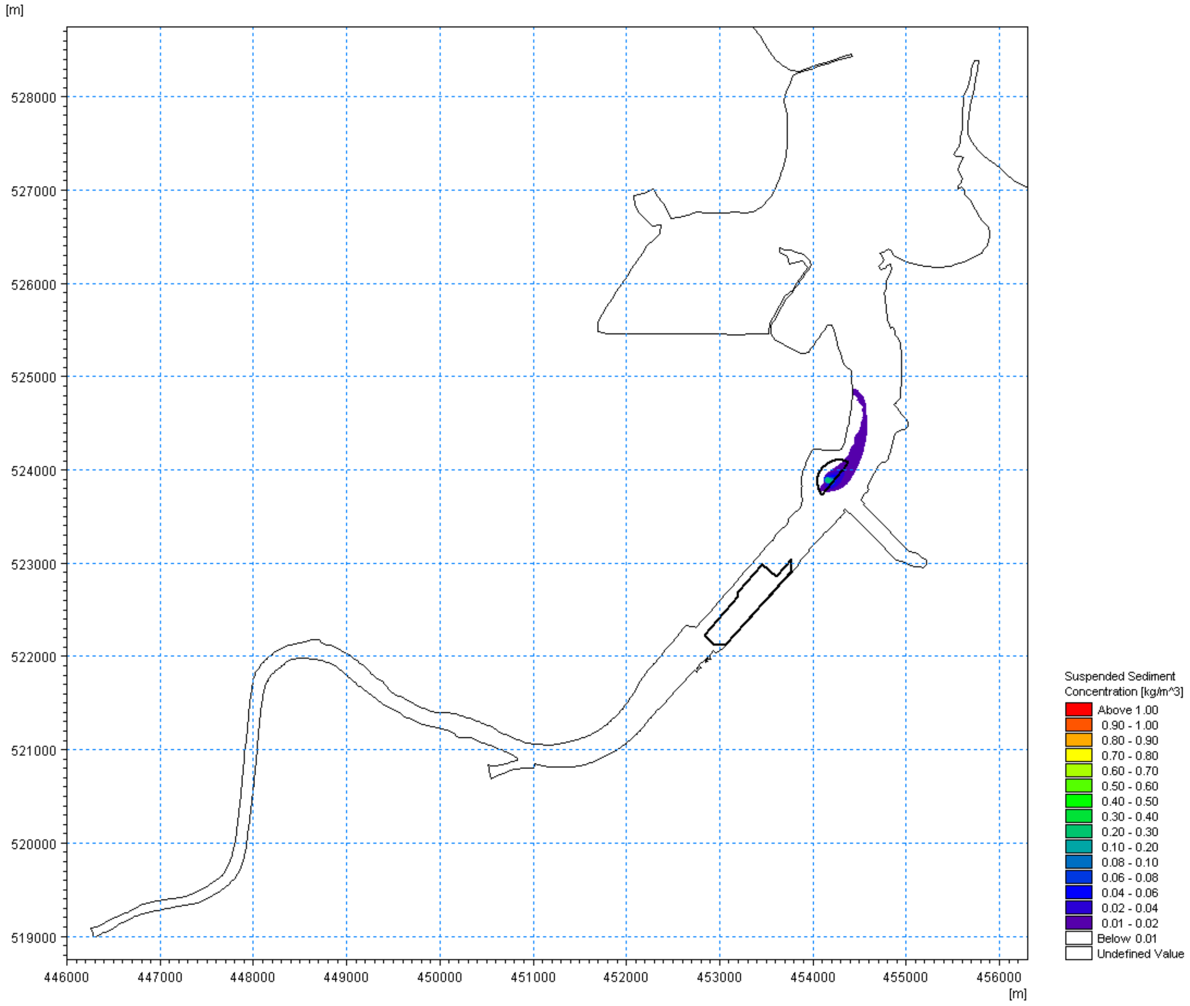


Figure 6.46 (Plot B) – Plume of enhanced SSCs arising from dredging activities during Stage 4 of the capital dredging programme

The maximum ‘zone of influence’ from Stage 4 of the dredging activities is shown in **Figure 6.47** (please note the earlier caution in interpreting this type of figure). This shows that during Stage 4 of the dredging, the plume is created at the turning circle and along parts of the north bank of the river. As with previous stages, the maximum SSC concentrations remain local to the point of dredging within the turning circle (up to a few hundred mg/l). Further upstream and downstream of the areas directly dredged, the SSC enhancement drops markedly (typically below 50mg/l a short distance from the point of dredging, and at the peripheries below 20mg/l) before merging with low background concentrations that characterise the baseline conditions.

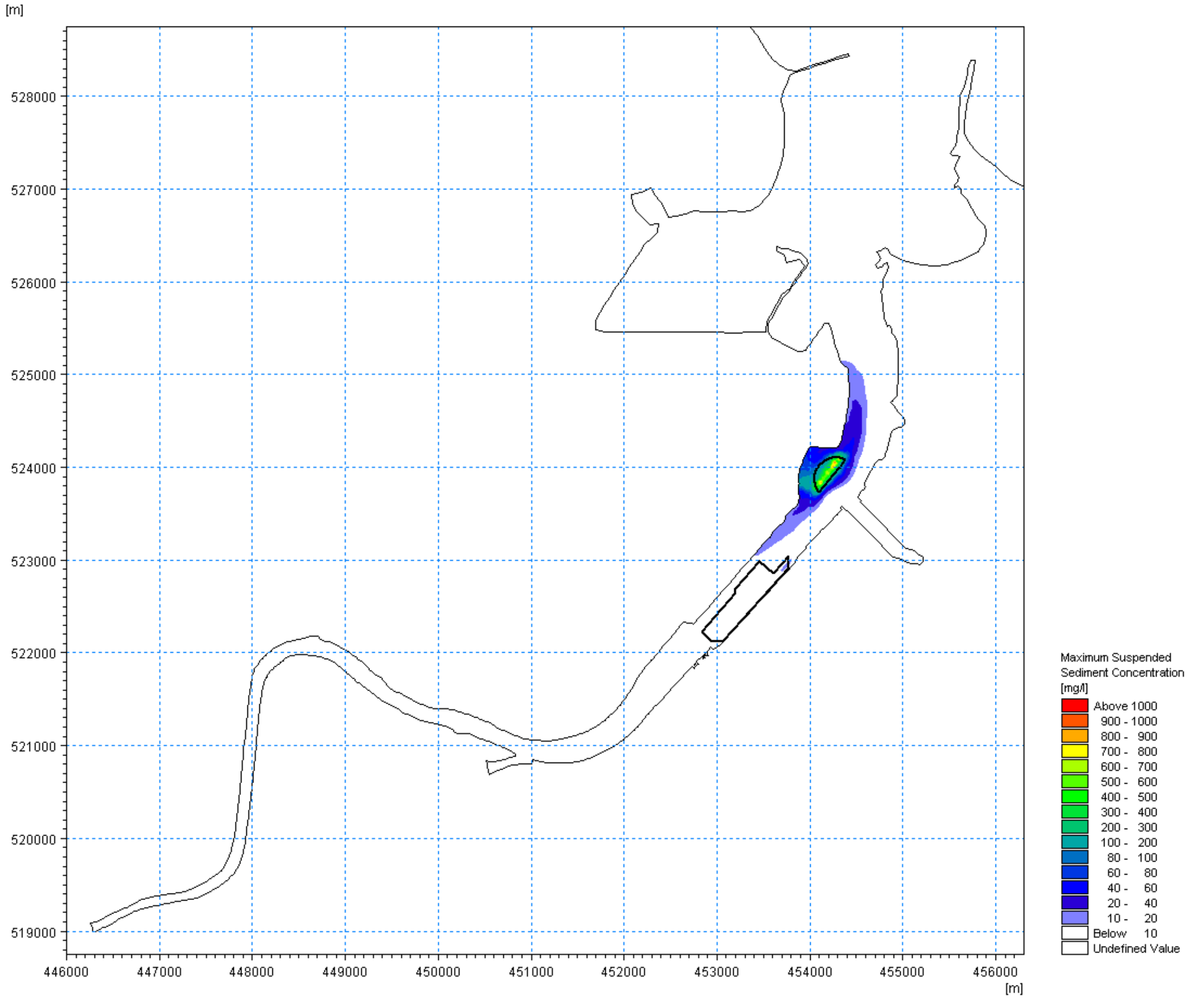


Figure 6.47 Maximum enhanced SSCs arising from dredging activities during Stage 4 of the capital dredging programme

The sediment plumes that arise from the four stages of the dredging could potentially affect areas of riverbed or seabed that are remote from the point of sediment release in terms of either increases in SSC or increases in sediment deposition. This could affect water quality (in terms of increased turbidity) or aquatic ecology (by ‘smothering’ of interest features) in the river. To further investigate this, the combined maximum ‘zone of influence’ from Stages 1 - 4 inclusive of the dredging activities has been plotted in **Figure 6.48** for the near-bed layer of the water column and in **Figure 6.49** for the near-surface layer (please note the earlier caution in interpreting this type of figure).

These figures demonstrate that near-surface effects are generally slightly lower than near-bed effects, and that during the predicted four months of dredging, all individual or coalesced plume effects are confined to within the river reaches that extend between Middleborough Dock/Transporter Bridge at the upstream end and the Oil Terminal on the north bank at the downstream end.

Furthermore, all plumes associated with dredging of the berthing pocket and river channel in the vicinity of the proposed new quay are confined to the right bank (south of centre line) portion of the channel’s width, whilst all plumes associated with dredging of the turning circle are confined to the left bank (north of centre line) portion of the channel’s width in the reaches that they respectively affect.

No plume effects (and by implication no deposition effects) of a significant level above background values will occur beyond these reaches (i.e. areas such as Tees Dock, Seal Sands, Bran Sands, North Gare Sands and the adjacent coastlines of Seaton Sands (west of the river mouth) and Coatham Sands (east of the river mouth) will not be affected).

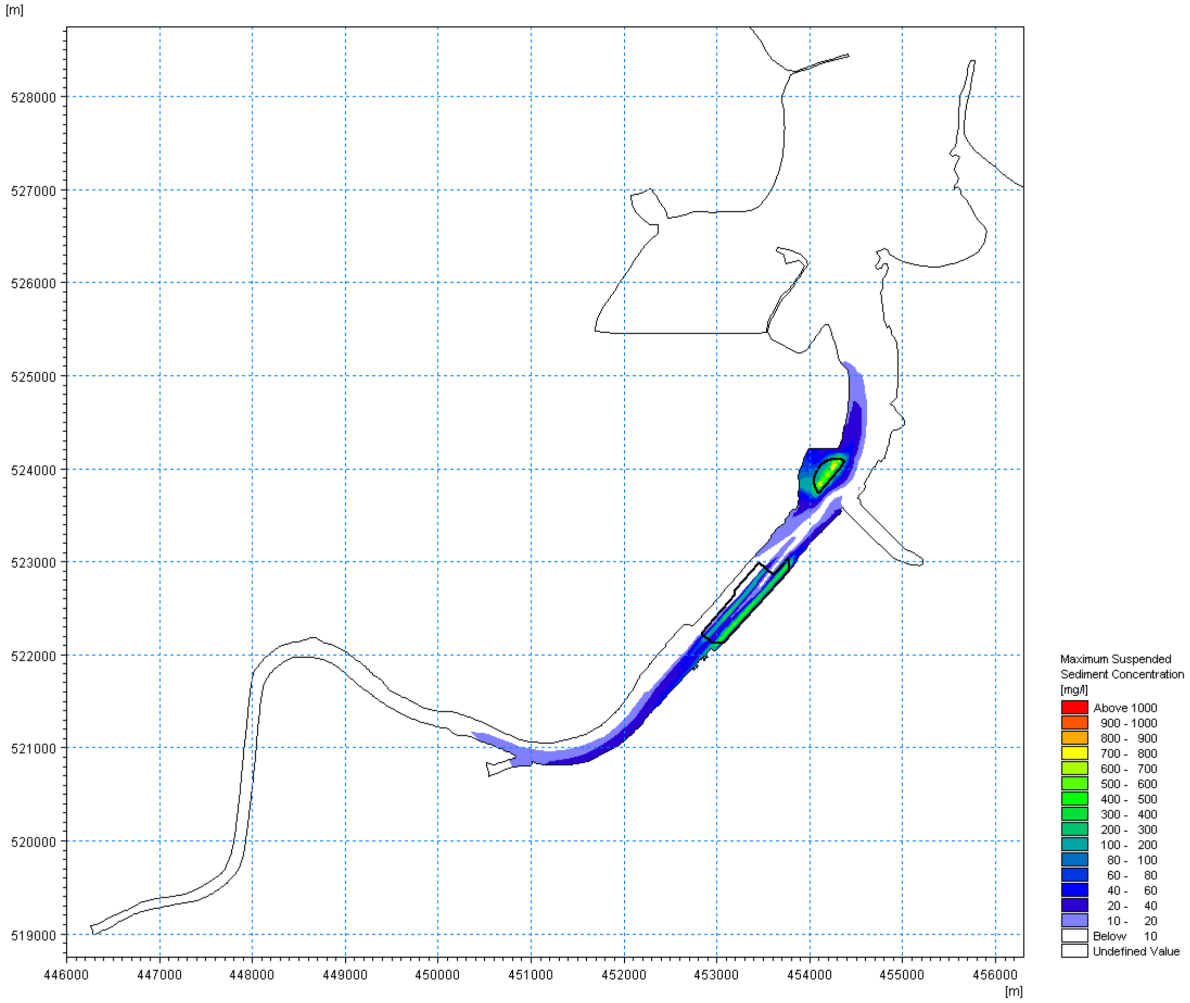


Figure 6.3 ***Maximum enhanced SSCs (near-bed layer) arising from dredging activities during Stages 1 - 4 inclusive of the capital dredging programme***

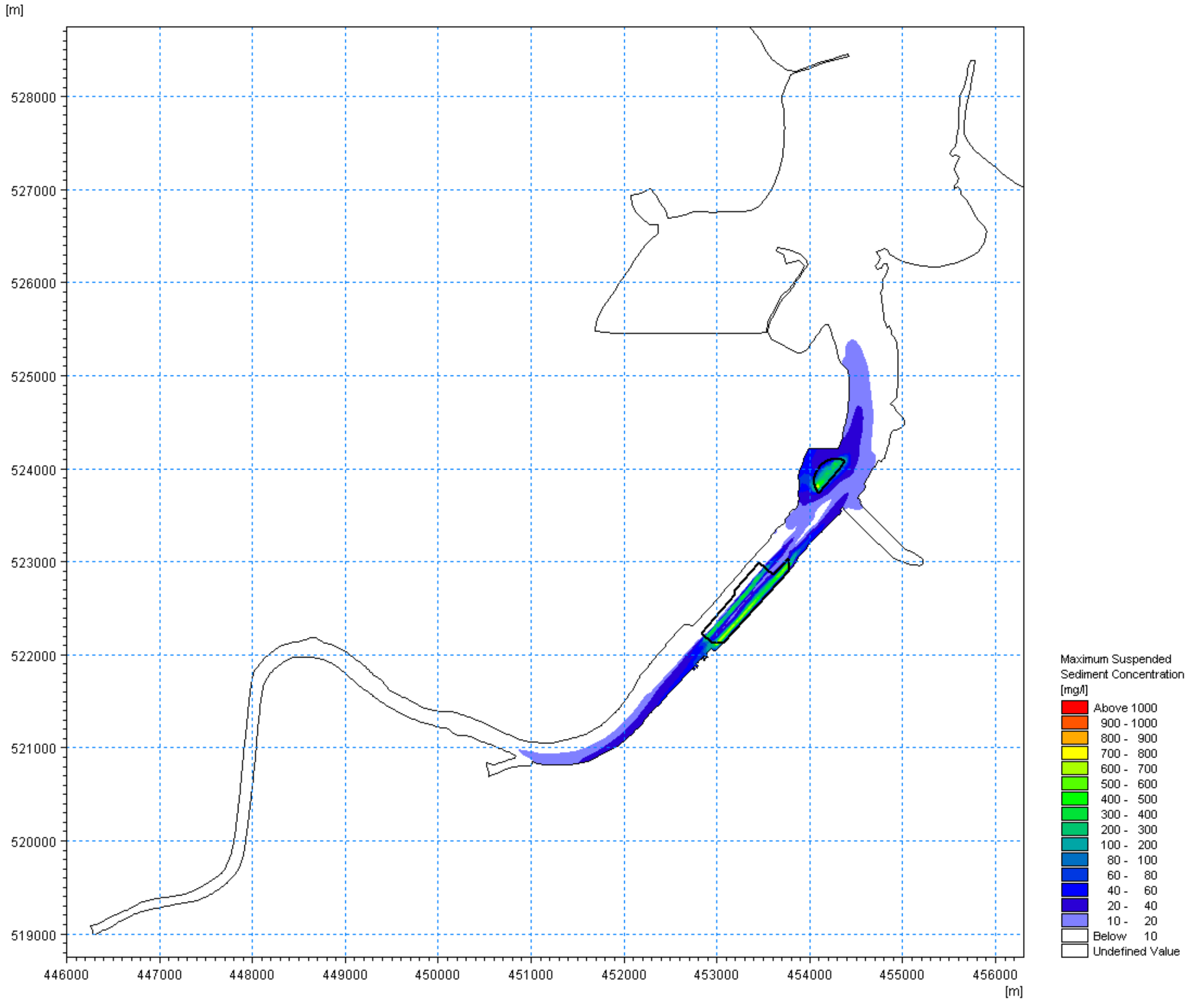


Figure 6.49 Maximum enhanced SSCs (near-surface layer) arising from dredging activities during Stages 1 - 4 inclusive of the capital dredging programme

Sediment suspended within the dredging plumes will fall to the riverbed, either soon after disturbance or spillage occurring during the dredging operation (for coarser-grained sediment fractions), or at a point in time within a few minutes to a few hours after this if it is carried in suspension by the prevailing currents (for finer-grained sediment fractions). **Figure 6.50** shows the maximum changes in riverbed thickness caused by this deposition. It can be seen that much of the sediment falls to the bed within the dredged areas (from where it will be re-dredged to achieve the necessary bed depths), whilst the deposition that occurs in other parts of the river is much lower, typically less than 5cm, within the same area of river that is affected by the zone of influence from the sediment plumes.

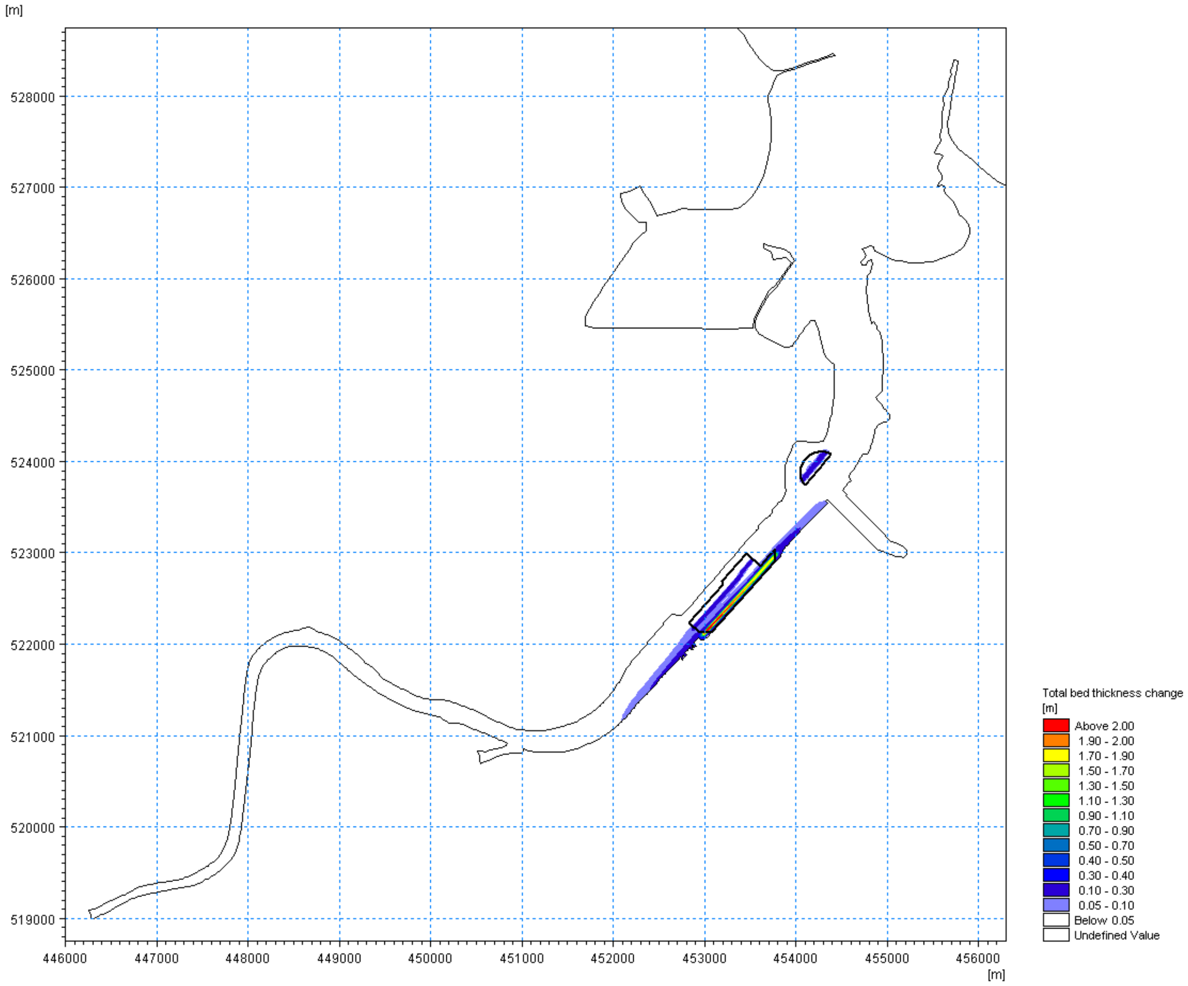


Figure 6.50 Maximum riverbed thickness change due to sediment deposition arising from dredging activities during Stages 1 - 4 inclusive of the capital dredging programme

Within this maximum zone of influence from sediment plumes and bed deposition, the following receptors could potentially be adversely affected by increases in SSC or increases in sediment deposition (or both factors occurring in combination):

- **Water quality** (the river reach, as represented by the water quality monitoring points located throughout the river - see **Section 28**).

- **Marine ecology** (the three areas of inter-tidal mudflat identified as Priority Habitats – see **Section 11**). [Note: None of the other significant areas of Priority Habitat in the river or adjacent coasts would be affected by the zone of influence of the dredging operations].

- **Navigation** (the main navigation channel of the river, parts of the Tees Dock turning circle, the jetties along North Tees Works Oil Refinery, the Storage Depot and the Oil Terminal on the north bank, the jetties along Cargo Fleet Wharf and Teesport on the south bank and parts of Middlesbrough Dock up to its lock gates).

To further investigate these effects, timeseries plots of changes in SSC and changes in riverbed thickness have been extracted from the model at a series of points within the affected river reaches (locations are shown in **Figure 6.51**). The points are:

- WQ1 – Water quality monitoring point (Tees at the Gares);
- WQ2 – Water quality monitoring point (Tees at Redcar Jetty);
- WQ3 – Water quality monitoring point (Tess at Smiths Dock);
- WQ4 – Water quality monitoring point (Tees at Haverton Hill Shipyard);
- WQ5 – Water quality monitoring point (Tees at the Barrage);

- M1 – Mudflat (north);
- M2 – Mudflat (centre);
- M3 – Mudflat (south);

- NV1 – Oil Terminal (north bank);
- NV2 – Storage Depot (north bank);
- NV3 – North Tees Works Oil Refinery (north bank);
- NV4 – Teesport (south bank);
- NV5 – Cargo Fleet Wharf (south bank); and
- NV6 – Middlesbrough Dock (south bank).

At the water quality monitoring points, it is only at point 3 (Smiths Dock) where SSC is elevated by any appreciable extent, with peak enhancements of between 15 and 85 mg/l during Stage 2 of the dredging programme (**Figure 6.52**). Whilst Stage 1 of the dredging also causes some enhancement in SSC at point 3, the values are so low (<5mg/l) as to be negligible compared with background levels and, in all cases, the elevations in SSC drop rapidly after each dredging plume has dispersed, and return to baseline levels at points of downtime or between successive dredging stages. There are no significant effects noted at the water quality sampling points during Stage 3 of the dredging and only negligible effects for a short duration during Stage 4. Similarly it is only point 3 where any appreciable sediment deposition occurs, and this is at a very low value (6mm) throughout the entire dredging programme (**Figure 6.53**) and in reality some of this material will become re-suspended by tidal currents or dredged during maintenance campaigns of the river channel.

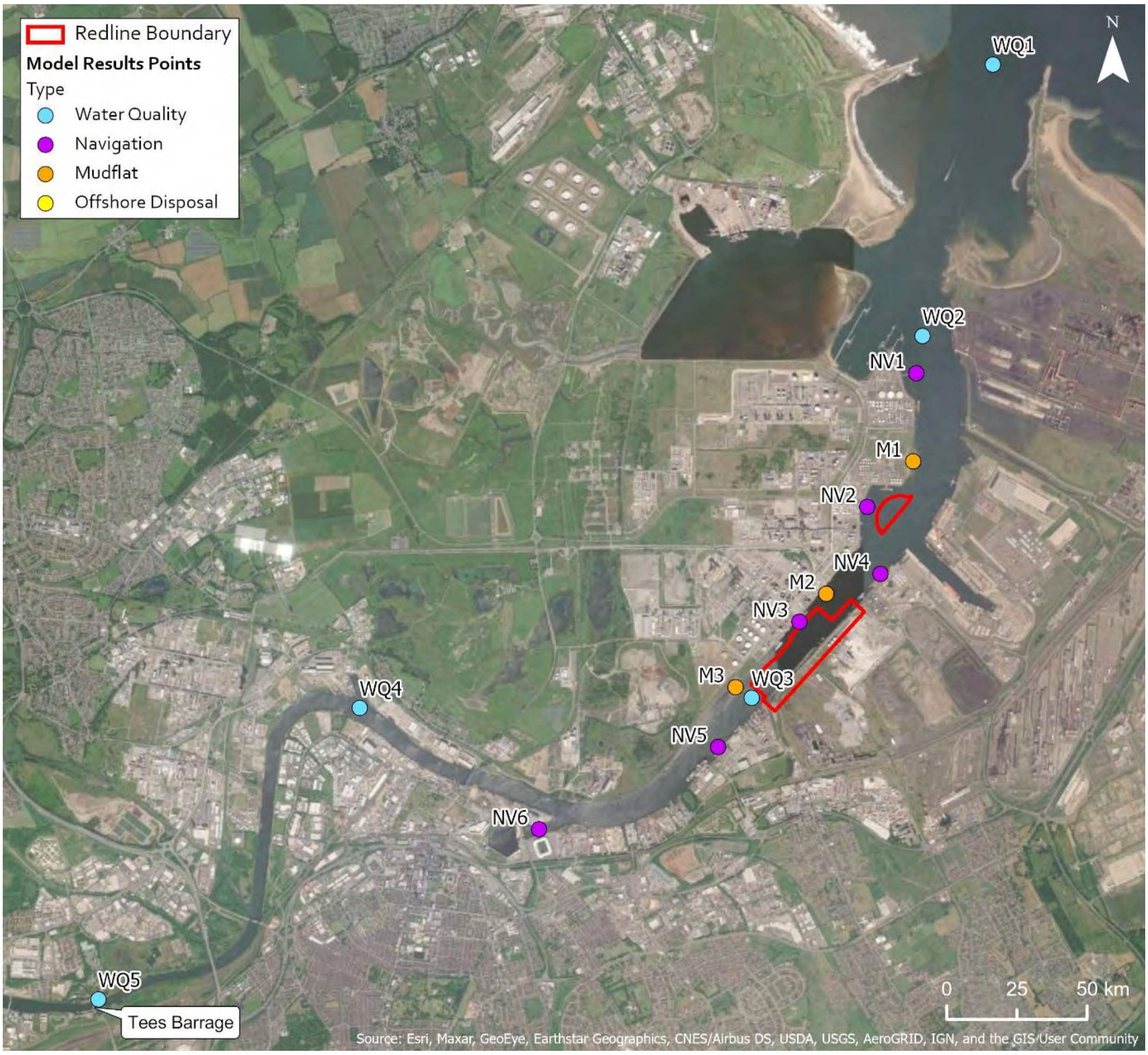
At the mudflat monitoring points, it is only during Stage 4 of the dredging that any discernible effects are noted, when at Mudflat 1 SSC increases by a peak of 22mg/l, at Mudflat 2 it increases by a peak of 10mg/l and at Mudflat 3 it increases by a peak of 8mg/l (**Figure 6.54**). Sediment deposition on the mudflats is predicted to be immeasurable (**Figure 6.55**).

At the navigation monitoring points on the north bank, it is only during Stage 4 of the dredging that any discernible effects are noted, when at Location 1 (Oil Terminal) SSC increases by a peak of 8mg/l, at Location 2 (Storage Depot) it increases by a single peak of 75mg/l (but with maximum values mostly being less than 50mg/l), and at Location 3 (North Tees Works Oil Refinery) it increases by a peak of 8mg/l (**Figure 6.56**). Sediment deposition at these locations is predicted to be immeasurable (**Figure 6.57**).

At the navigation monitoring points on the south bank, it is throughout Stages 1 and 2 of the dredging that discernible effects are most noted, when at Location 4 (Teesport) SSC increases by a peak of around 30mg/l, at Location 5 (Cargo Fleet Wharf) it increases by a peaks of between 15 and 48mg/l, and at Location 6 (Middlesbrough Dock) peaks occur on fewer occasions and reach a maximum value of 7mg/l. During Stages 3 and 4 of the dredging, only negligible effects are noted, equivalent to variations within the background levels of concentrations (**Figure 6.58**). Sediment deposition at Location 6 (Middlesbrough Dock) is predicted to be immeasurable, but up to 10mm of deposition is predicted at Location 5 (Cargo Fleet

Wharf) and up to 9mm at Location 4 (Teesport) (**Figure 6.59**). Some of this deposited material will become re-suspended by tidal currents or will be removed during maintenance dredging campaigns of the river channel and berths.

Overall changes of these magnitudes in SSC and sediment deposition are unlikely to cause significant effects on water quality, marine ecology or navigation in the river, but these matters are assessed more fully in **Sections 7**, **9** and **14**, respectively.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 6.51 Location of points used for of timeseries analysis of changes in SSC and sediment deposition

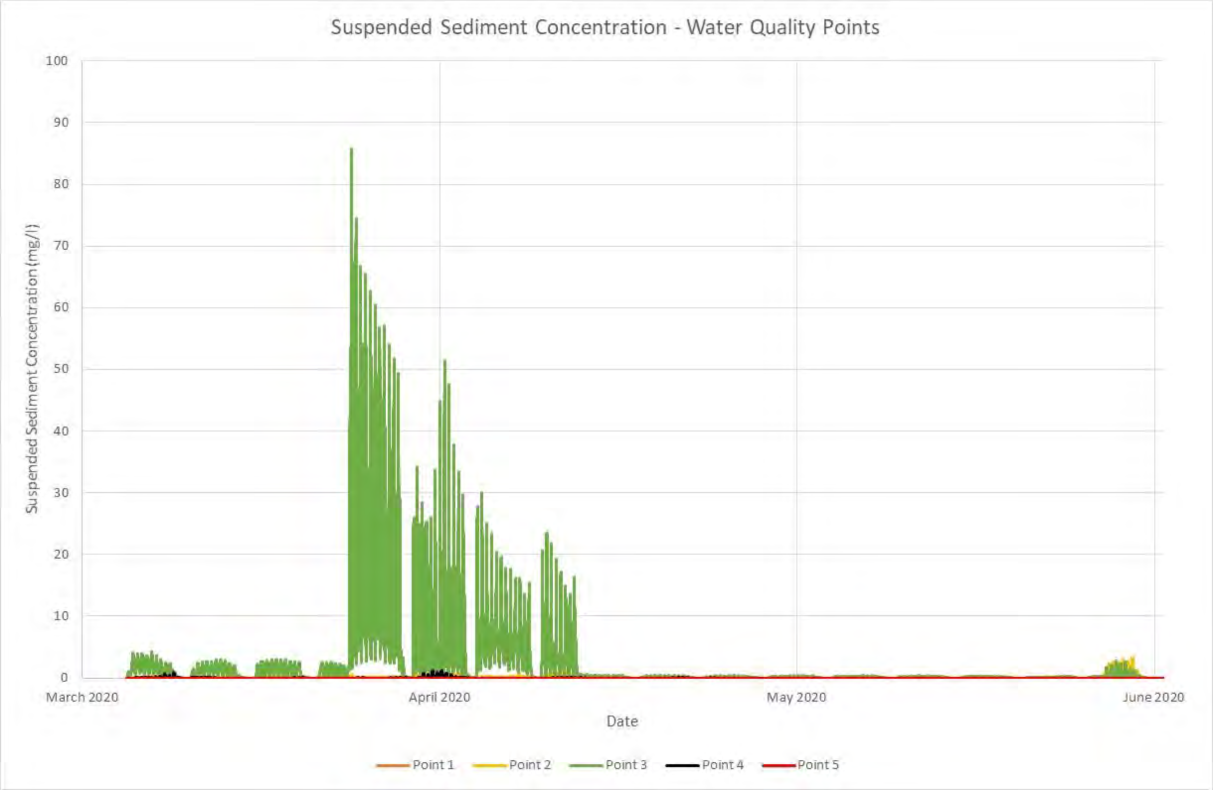


Figure 6.52 Timeseries of changes in SSC at the water quality monitoring points

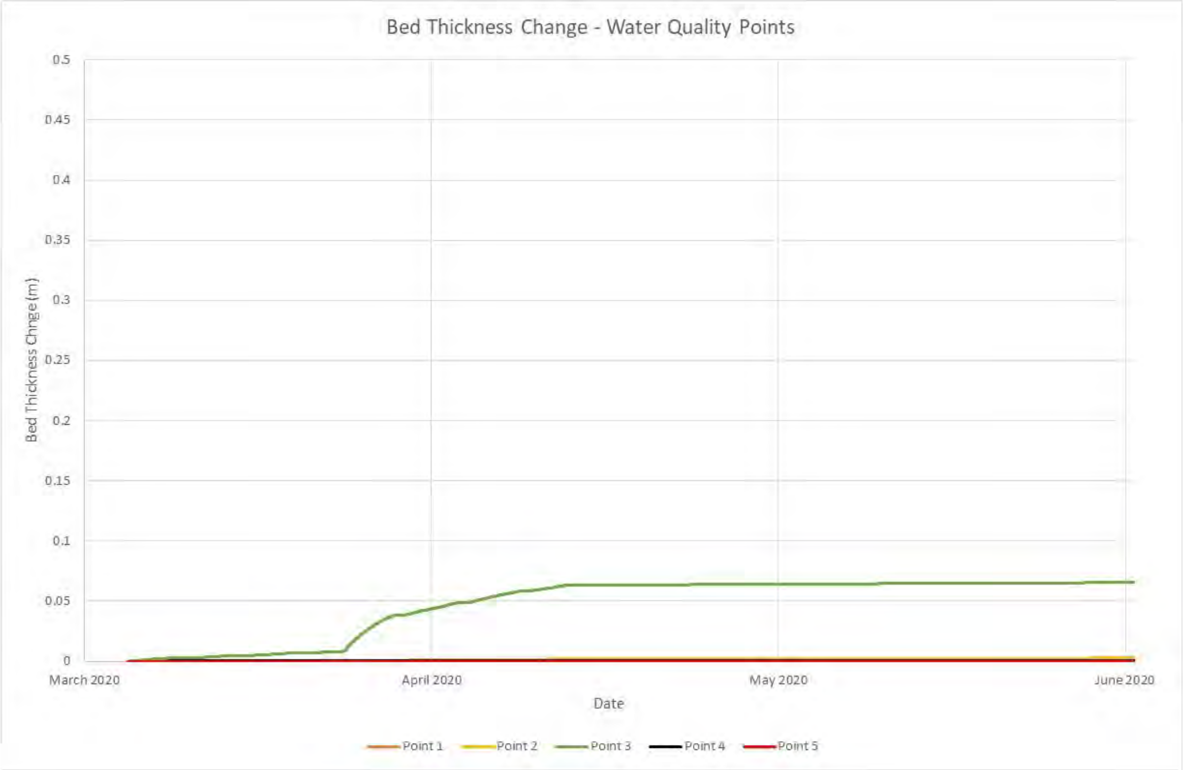


Figure 6.53 Timeseries of changes in sediment deposition at the water quality monitoring points

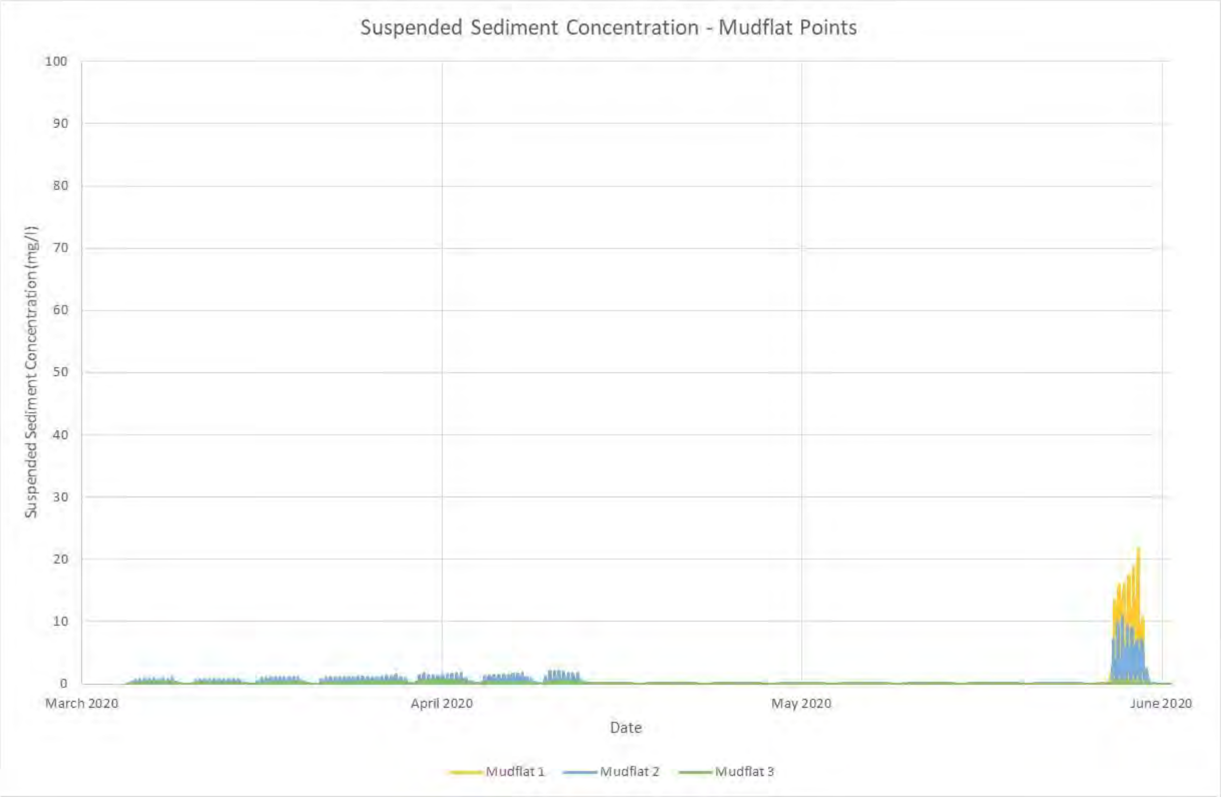


Figure 6.54 *Timeseries of changes in SSC at the mudflat monitoring points*

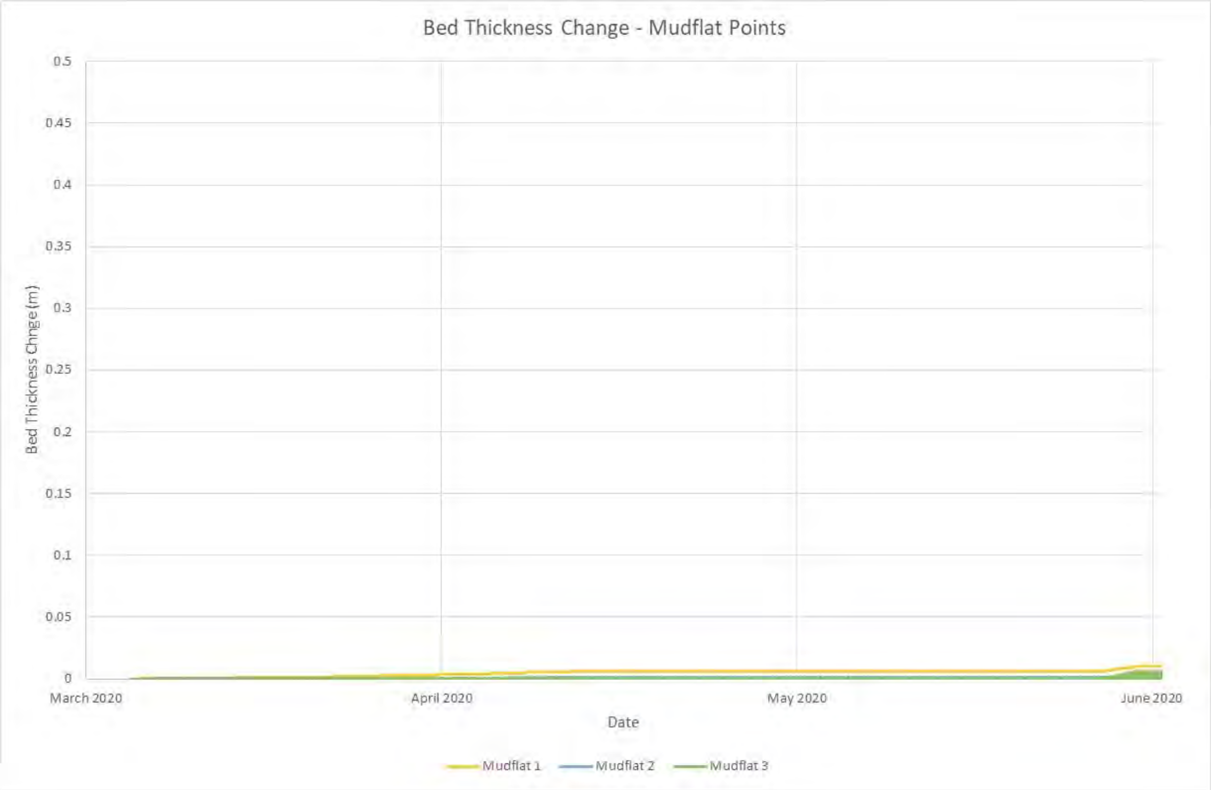


Figure 6.55 *Timeseries of changes in sediment deposition at the mudflat monitoring points*

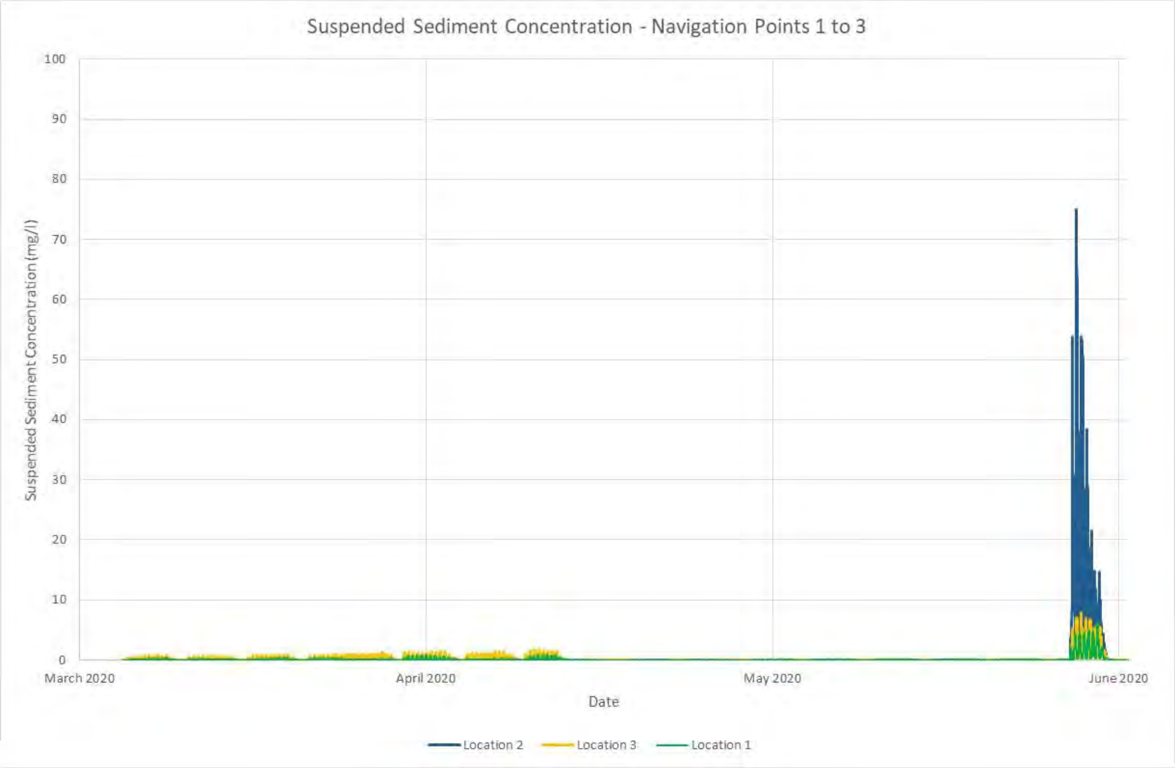


Figure 6.56 Timeseries of changes in SSC at the navigation (north bank) monitoring points

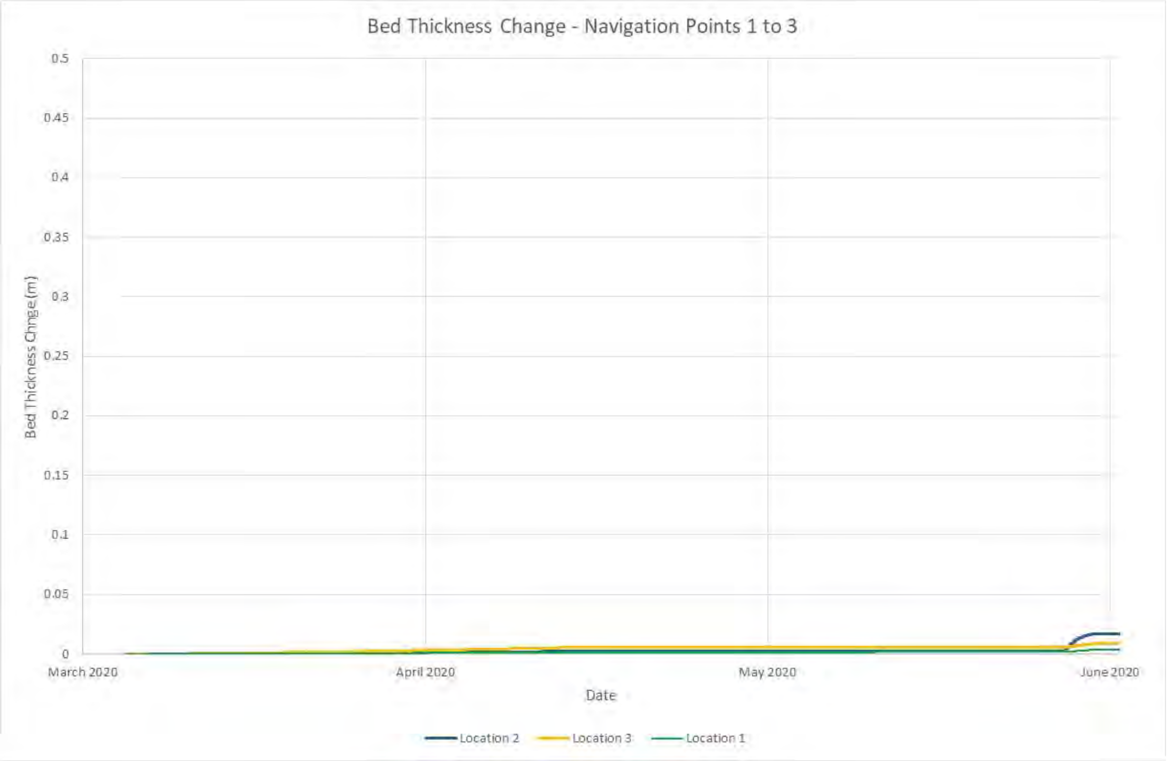


Figure 6.57 Timeseries of changes in sediment deposition at the navigation (north bank) monitoring points

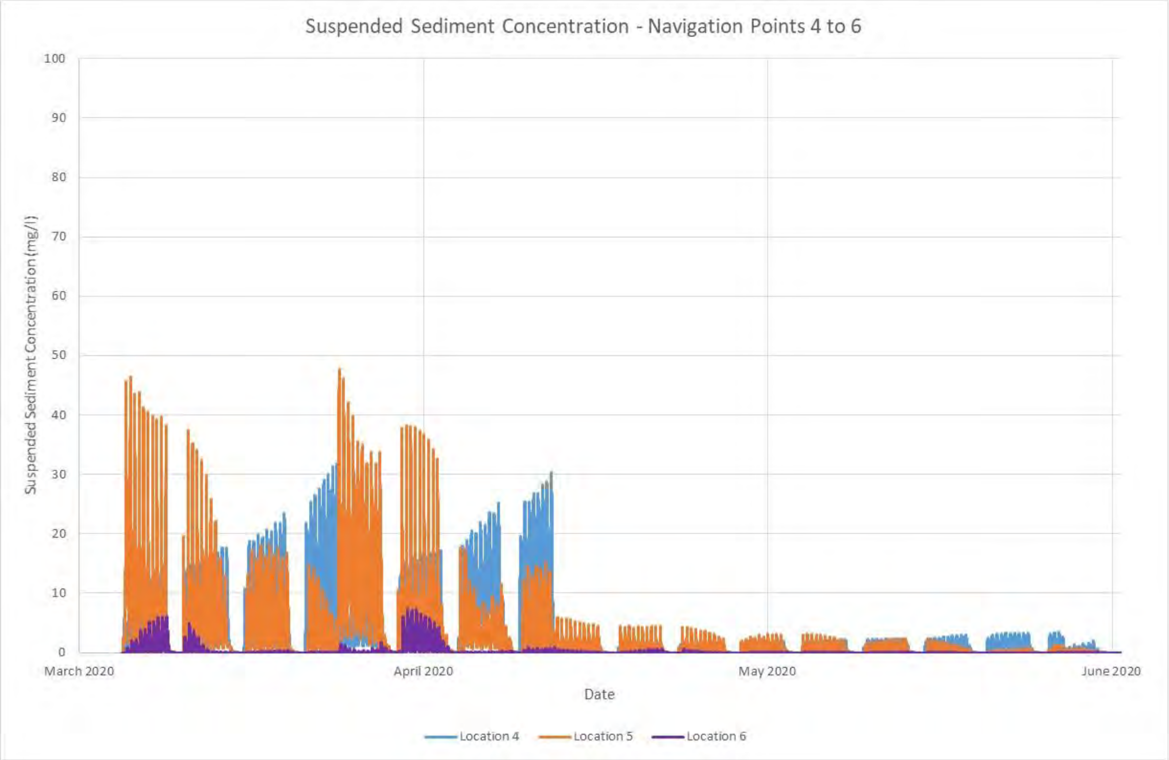


Figure 6.58 Timeseries of changes in SSC at the navigation (south bank) monitoring points

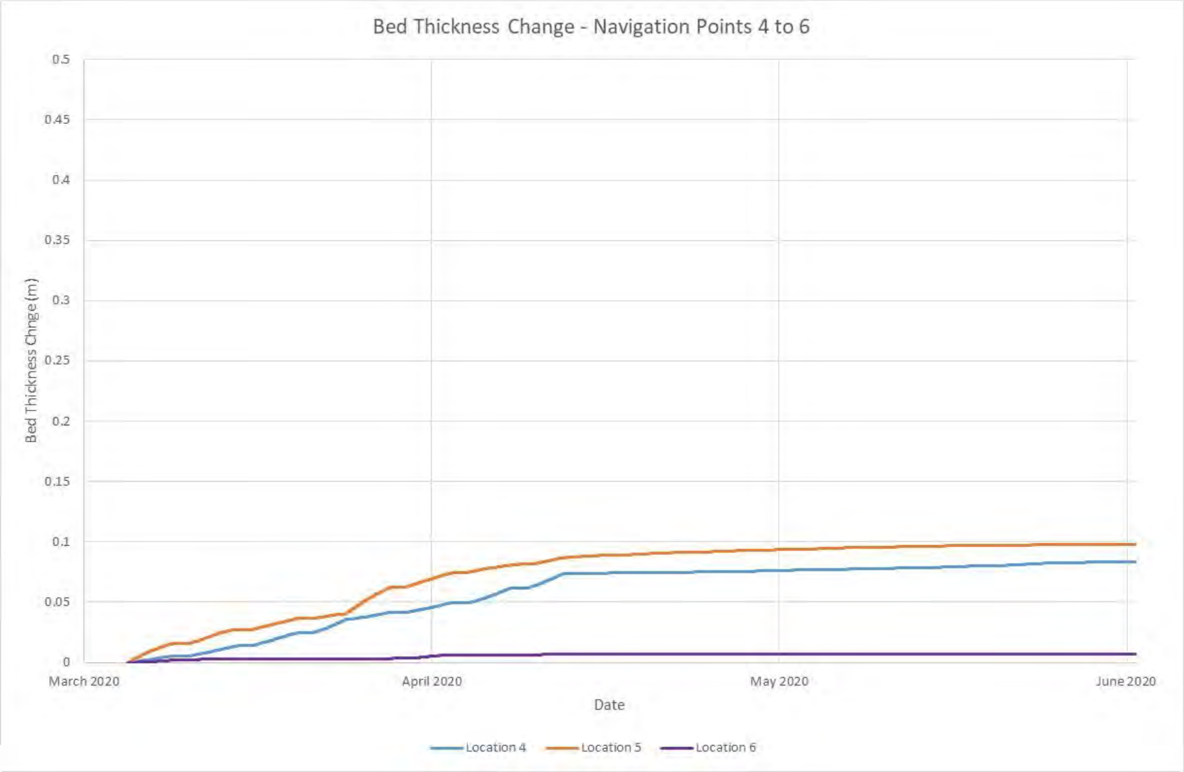


Figure 6.59 Timeseries of changes in sediment deposition at the navigation (south bank) monitoring points

Offshore disposal

The offshore disposal site is located within a water depth of approximately 43.5m, approximately 18km from the proposed scheme footprint and around 12km from the mouth of the river at its nearest point. The site is licensed for the disposal of dredged sediment and is routinely monitored as part of a national programme. Therefore, plumes arising from disposal activities and subsequent sediment deposition is unlikely to be of concern within the licensed area, or in immediately adjacent seabed areas.

During Stage 1 of dredging (with the BHD working to dredge the upper soft material (above -5m CD) in the berthing pocket and river channel), commencement of offshore disposal activities is repeated every 2 hours and 5 minutes. **Figure 6.60** shows one example disposal cycle, with material release shortly after high water on an ebbing tide. By way of illustration of key points in the following interpretation, plots are presented at the near-bed layer of the water column from: (i) immediately prior to disposal; (ii) at two stages through the 10-minute duration of disposal activity; and (iii) at selected intervals thereafter until the initial plume disappears.

Immediately prior to offshore disposal (Plot A) there is no enhancement to SSC in the offshore areas. As the offshore disposal commences (Plot B) a plume starts to be generated at the point of release. It can then be seen that the end of the discharge period coincides with the greatest enhancement in SSC at the offshore disposal site (Plot C), with values local to the point of material release exceeding 900mg/l (or 0.9 kg/m^3). This plume starts to increase in spatial extent shortly after cessation of discharge due to advection by tidal currents (Plot D), but then very rapidly reduces in concentration progressively over subsequent timesteps as some material falls relatively quickly to the sea bed whilst the material remaining in suspension starts to further disperse in spatial extent, moving in a north-westerly direction through advection by currents during the ebbing tide (Plot E).

At 30 minutes after cessation of discharge (Plot F), the plume is less than 250mg/l at its localised centre, reducing to less than 10mg/l at its peripheries and this trend of dispersion continues throughout the ebbing phase of the tide such that 1 hour after cessation of discharge (Plot G), the plume has a maximum SSC of less than 120mg/l at its centre reducing to less than 10mg/l towards its edges. By the time the next disposal activity commences and starts to form its own sediment plume (Plot H), the initial plume has moved sufficiently far from its point of release that it does not coalesce with the new plume and, by this time, is less than 40mg/l in SSC at its centre and mostly less than 20mg/l a short distance from the centre and thus is not visible in the plots at the magnitudes presented. The original plume continues to disperse such that after 4 hours and 25 minutes since cessation of discharge, there is absolutely no enhancement due to the initial event (and for a long period prior to this the enhancement is so small in magnitude and spatial extent as to be negligible in such a great depth of water in this deep water offshore area).

The above cycle is repeated throughout all disposal events associated with Stage 1 of the dredging, although when the discharge is made during the flooding tide, the plume moves in a south-easterly direction, along the axis of principal tidal flows. At times when the release is around slack water, the plume tends to reside closer to the point of release for longer, until the subsequent ebb or flood phase of the tide starts to transport it in suspension in the water column in the appropriate direction of dispersion (i.e. to the north-west or south-east, respectively). However, when this occurs the concentration in the plume reduces readily because more material falls to the seabed during the slack currents.

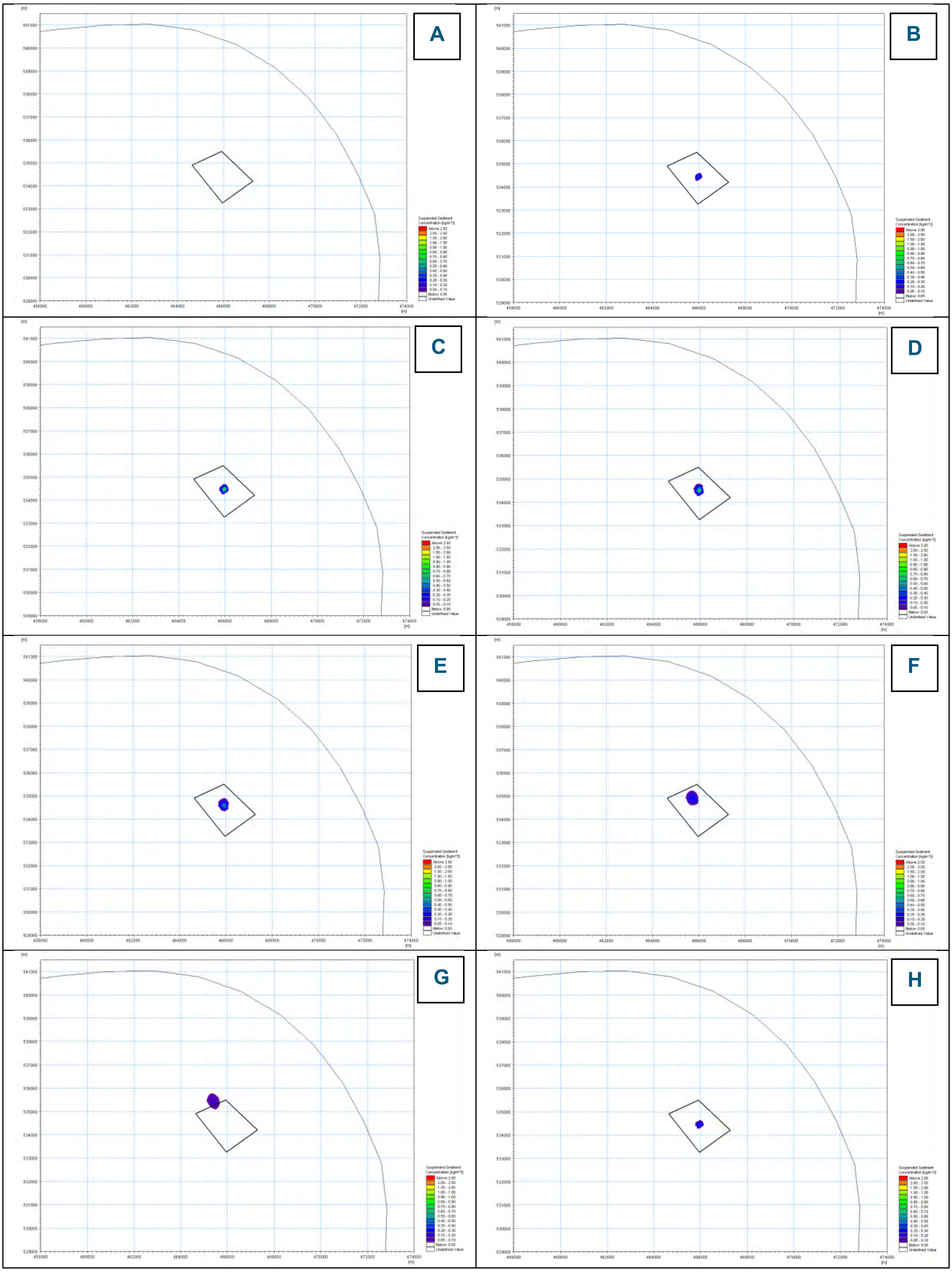


Figure 6.60 Plume of enhanced SSCs arising from disposal activities during Stage 1 of the capital dredging programme

Having described the pattern of dispersion thoroughly for disposal activities associated with Stage 1 of the dredging, the following descriptions focus on where particular aspects of subsequent stages differ from the general pattern described for Stage 1.

During Stage 2 of the dredging activity (with the BHD and TSHD working in parallel to dredge the middle soft material (below -5m CD in the berthing pocket and river channel), commencement of offshore disposal activities is repeated every 2 hours and 5 minutes for the BHD and every 3 hours and 10 minutes by the TSHD. The pattern of dispersion following discharge of the BHD-dredged material is as described for Stage 1, but this can now become further affected by coalescence with the TSHD discharges if, under a worst-case scenario, the subsequent discharges are all made at the same point in the centre of the disposal site. This coalescence does not occur on all discharges (from the same point) during Stage 2, but only when the timing of the respective discharges with respect to the phase of the tide allows or when the subsequent discharges are forced close to each other in time due to the different disposal intervals for each operation.

Figure 6.61 shows one example of where such coalescence occurs. Plot A shows the situation prior to the commencement of a TSHD disposal, which then occurs over the next two 5-minute timesteps (Plots B and C). Since the quantities of material being discharged from the TSHD are greater than those discharged from the BHD (although the time intervals are greater), the initial plume has greater SSC values at its centre, reaching close to 2,800mg/l. As the TSHD discharge occurred shortly before low water in this plot (a worst case for maximum SSC), the plume resides in spatial extent around the point of release during the slack phase of the tide, although the SSC values drop notably to a peak of around 1,200mg/l within 45 minutes of cessation of discharge (Plot D). After 1 hour and 30 minutes following cessation of discharge, the TSHD plume has started to move towards the south-east through advection by the flood tidal currents, and the peak concentration has reduced to around 350mg/l locally (Plot E). By 30 minutes later (some 2 hours after cessation of TSHD discharge) the subsequent BHD-dredged material disposal is commenced at a common release point (Plot F). At this point in time, the TSHD plume has further reduced in peak concentration to around 200mg/l. Some 30 minutes later, the TSHD plume and subsequent BHD plume have fully coalesced, with two peaks in concentration; the original TSHD plume has a peak now around 100mg/l locally at its centre whilst the more recently formed (but smaller) BHD plume has a peak SSC value at its centre of around 200mg/l (Plot G). Just before the next subsequent TSHD release, at 3 hours after cessation of the previous TSHD release, the now fully coalesced plume has a peak SSC of around 100mg/l very locally and this continues to disperse through the remainder of the flooding tide such that when the subsequent TSHD plume remains present a further 45 minutes later, the original coalesced plume is considerably smaller in magnitude and spatial extent (Plot H).

This shows that even if all discharges in the disposal site were made at exactly the same location on successive disposal events, any coalescence of subsequent plumes would continue to result in only temporary effects of a short duration, at relatively low magnitudes of SSC. In reality, successive disposal activities would not take place at the same location within the disposal site and so the likelihood of coalescence of successive plumes at significant concentrations or for long durations is very low even during this stage of the works, when disposal from both BHD and TSHD is being undertaken.

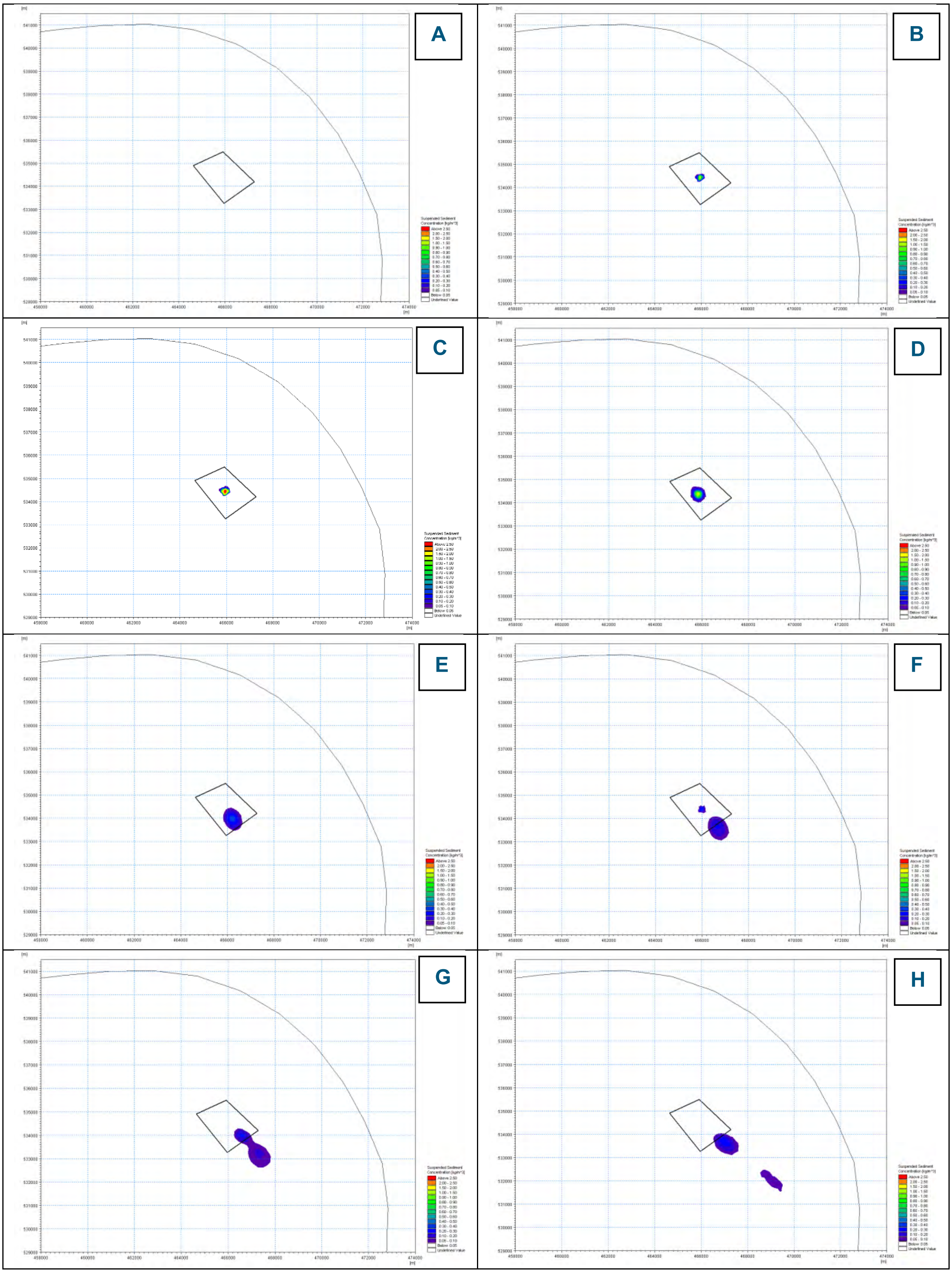


Figure 6.61 Plume of enhanced SSCs arising from disposal activities during Stage 2 of the capital dredging programme

During Stage 3 of the dredging activity (with the BHD working to dredge the bottom hard material in the berthing pocket and river channel), commencement of offshore disposal activities is repeated every 4 hours and 45 minutes. **Figure 6.62** shows one example disposal cycle, with material release shortly after high water on an ebbing tide. Results are very similar to those previously presented for Stage 1 but the frequency of disposals is lesser and the quantities involved in each disposal are greater and the material type is overall coarser.

Immediately prior to offshore disposal (Plot A) there is no enhancement to SSC in the offshore areas. As the offshore disposal commences (Plot B) a plume starts to be generated at the point of release. The greatest enhancement in SSC at the offshore disposal site occurs at the end of the discharge (Plot C), with values local to the point of material release up to 665mg/l. As observed during the Stage 1 discharges, this plume starts to increase in spatial extent shortly after cessation of discharge due to advection by tidal currents (Plot D), but then very rapidly progressively reduces in concentration as some material falls relatively quickly to the sea bed whilst the material remaining in suspension starts to further disperse in spatial extent, moving in a north-westerly direction through advection by currents during the ebbing tide (Plots E - F) and is significantly reduced at timesteps thereafter (Plots G and H).

The plumes associated with Stage 3 disposal activities are generally lower in concentration than those for Stage 1, despite the larger quantities being discharged at each event during Stage 3. This is likely to be due to the coarser nature of the material, which would lead to more falling to the bed sooner than during the Stage 1 discharges.

Indeed, the plume arising from Stage 3 disposal activities fully disperses before the next subsequent discharge activity, such that after 2 hours and 20 minutes following cessation of discharge, there is absolutely no enhancement due to the initial event (and for around 1 hour and 30 minutes prior to this the enhancement is so small in magnitude and spatial extent as to be negligible in such a great depth of water in this offshore area). Due to this, there is no possibility of plumes coalescing from Stage 3 disposal operations, even if all discharges are made from a common point.

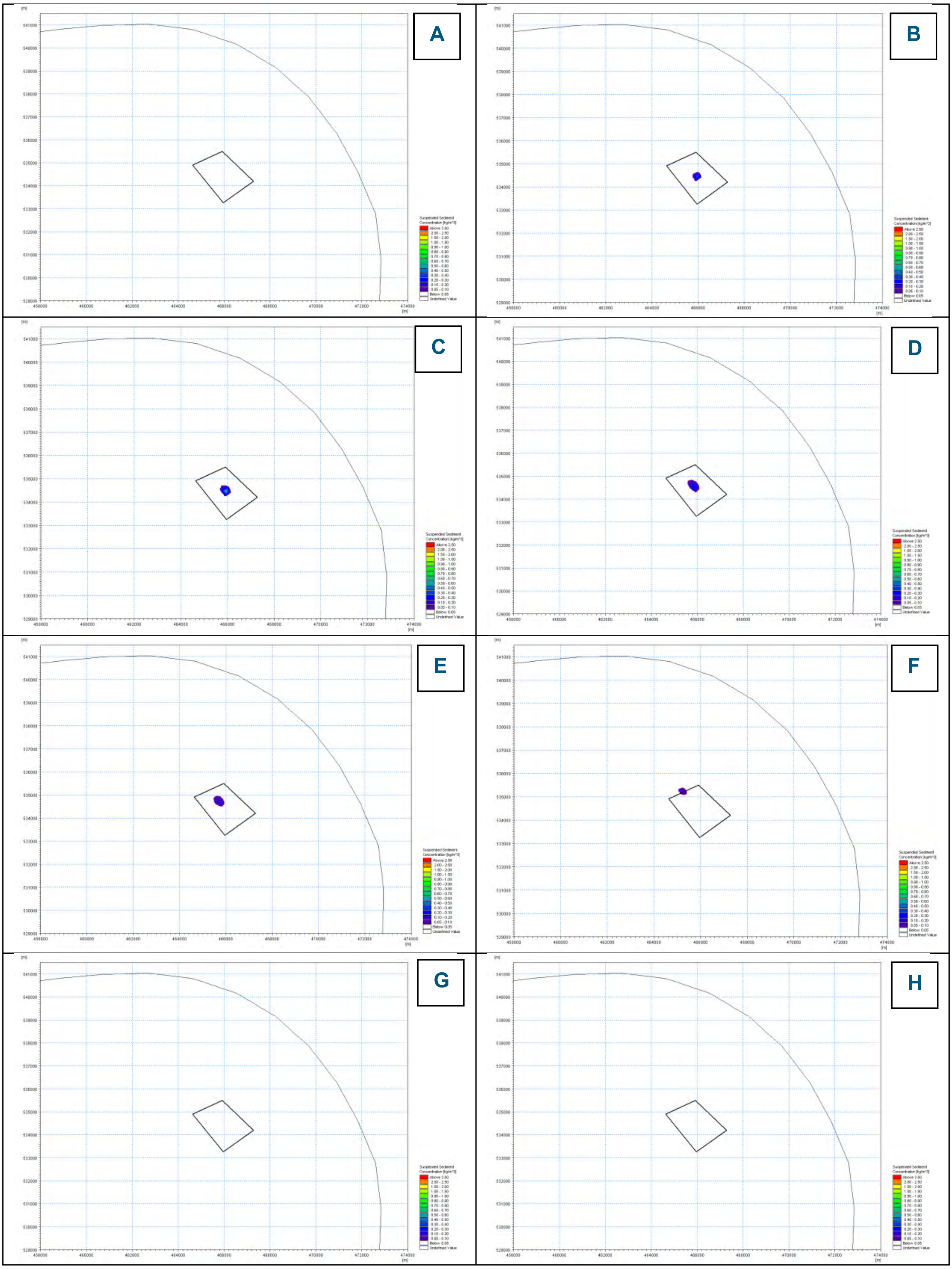


Figure 6.4 Plume of enhanced SSCs arising from disposal activities during Stage 3 of the capital dredging programme

During Stage 4 of the dredging activity (with the BHD and TSHD working in parallel to dredge the material in the Tees Dock turning circle), commencement of offshore disposal activities is repeated every 2 hours and 5 minutes for the BHD and every 3 hours and 10 minutes by the TSHD. **Figure 6.63** shows one example disposal cycle, with material release shortly after high water on an ebbing tide.

Like during Stage 2, there is potential for the plume from a TSHD discharge to coalesce with a preceding or subsequent BHD-related discharge. **Figure 6.63** shows one example of where such coalescence occurs. Plot A shows the residual plume from a TSHD disposal some 5 minutes before the commencement of a BHD disposal, which then occurs over the next two 5-minute timesteps (Plots B and C). Plot D shows two separate plumes at 45 minutes after cessation of the BHD discharge. A further 30 minutes later, another TSHD discharge is released and since the previous BHD release was around slack water, it has not been notably dispersed spatially (although it has decreased in magnitude of elevation in SSC) and so the latest TSHD release occurs within the previous BHD plume extent (Plot E). Peak concentrations from the TSHD release elevate the SSC to over 1,000mg/l above background levels locally. Then, before this coalesced plume has widely dispersed, a further BHD release is made some 50 minutes later, again within the previous (now coalesced) plumes. Despite this coalesced plume now containing elements of three separate releases, the maximum SSC elevations are around 500mg/l (Plot F). One hour later still, the remnants of the residual plume shown in Plot A coalesce with the ‘three-release’ plume (Plot G), although the SSC values at the point of overlap are very low (~10mg/l). Around 55 minutes later, the plume is now mostly containing enhanced SSC values of 10-30mg/l over most of its extent, with local levels up to 70mg/l (Plot H).

Even in the unlikely situation where successive disposal activities take place at the same location within the disposal site, leading to coalescence of subsequent plumes, the resulting temporary, short duration effects are mostly of low magnitudes within a great depth of water and are confined to along the axis of the prevailing tidal flow.

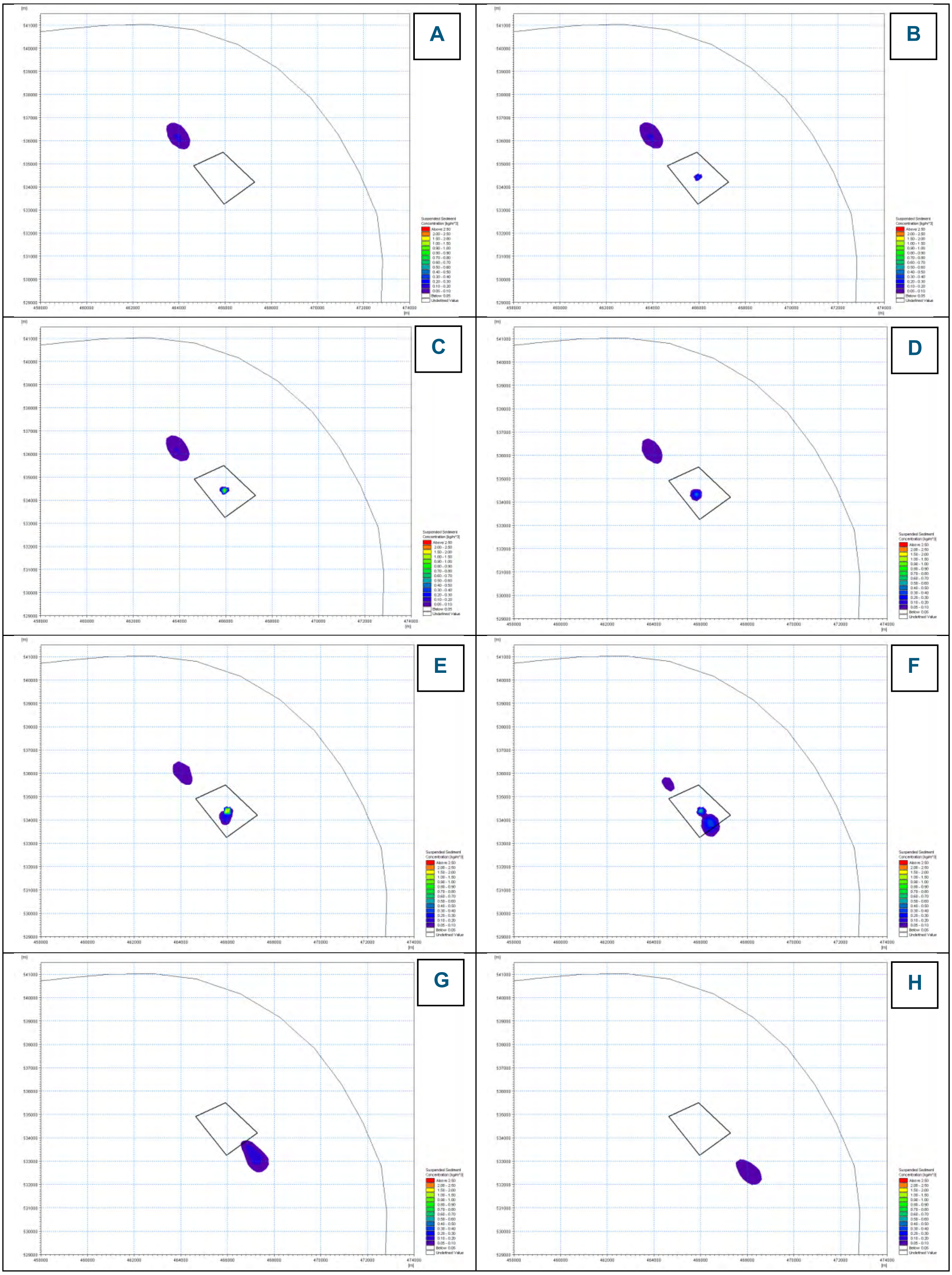


Figure 6.5 Plume of enhanced SSCs arising from disposal activities during Stage 4 of the capital dredging programme

The maximum ‘zone of influence’ from combined disposal activities during Stages 1 - 4 inclusive of the dredging programme has been plotted in **Figure 6.64** for the near-bed layer of the water column (please note the earlier caution in interpreting this type of figure). It should be noted that this represents a worst case whereby all disposal activities have occurred in the model at a single release point and the potential for coalescence of subsequent plumes is greatest. In reality, subsequent disposals will be at different parts of the release site and so the zone of influence is likely to be slightly broader in width and shorter in length, and certainly at lower maximum concentrations than shown in the worst case. Nonetheless, it can be seen that SSC values are elevated by the greatest amount at the release point (by up to several thousand mg/l), reducing to more typically a few hundred mg/l within a few km of the upstream and downstream boundaries. At the extremities of the plume extent, there are wide zones of relatively low SSC values (<100mg/l).

Figure 6.65 shows the maximum changes in seabed thickness caused by deposition of material from the sediment plume associated with one release event (this example being from Stage 1). It can be seen that much of the sediment falls to the bed within close proximity of the point of release, forming a small deposit locally on the seabed of up to around 6cm in elevation. Deposition to the west and east of the disposal point is negligible, whilst to the north it covers a similar zone to the sediment plume for this disposal event, which made the release during the ebb tide. Within 200m of the release point deposition thickness reduce to less than 1cm, whilst at the boundary of the licenced disposal area there is nowhere with deposition greater than 0.1cm. Clearly these magnitudes are extremely low within the licenced disposal site, and negligible beyond.

To provide spatial context, **Figure 6.66** shows the same deposition effects from this single disposal event plotted at a wider scale. Similar results would be obtained for deposits made during the flood tide, but with the zone of deposition extending south-eastwards from the release point. In practice, releases will be made from different points within the licenced disposal site over time, and at different states of the tidal cycle, so the resulting seabed deposition will occur at different locations across the disposal site, at relatively low magnitudes, with negligible changes anticipated beyond the boundaries of the site.

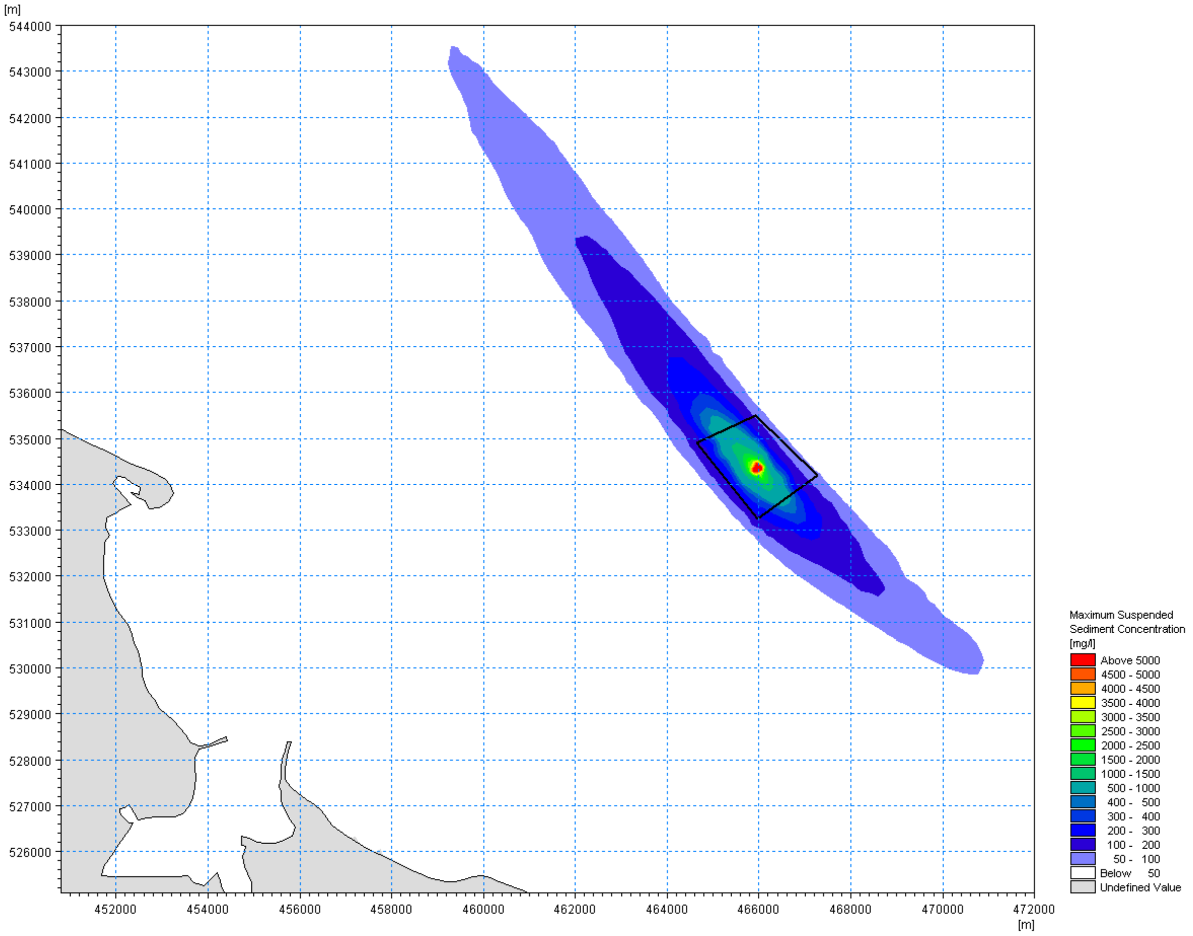


Figure 6.64 Maximum enhanced SSCs (near-bed layer) arising from disposal activities during Stages 1 - 4 inclusive of the capital dredging programme

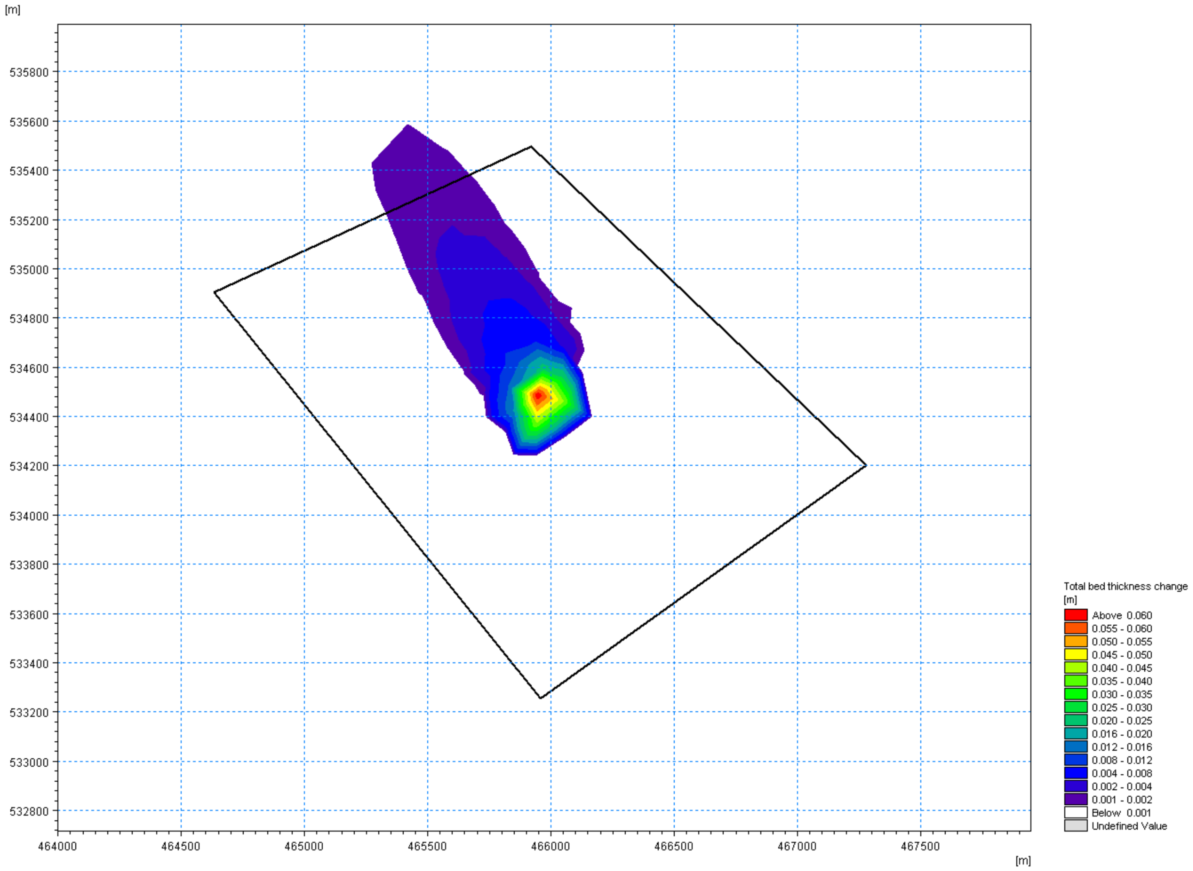


Figure 6.65 Maximum sea bed thickness change due to sediment deposition arising from one disposal event during Stage 1 of the capital dredging programme – local scale

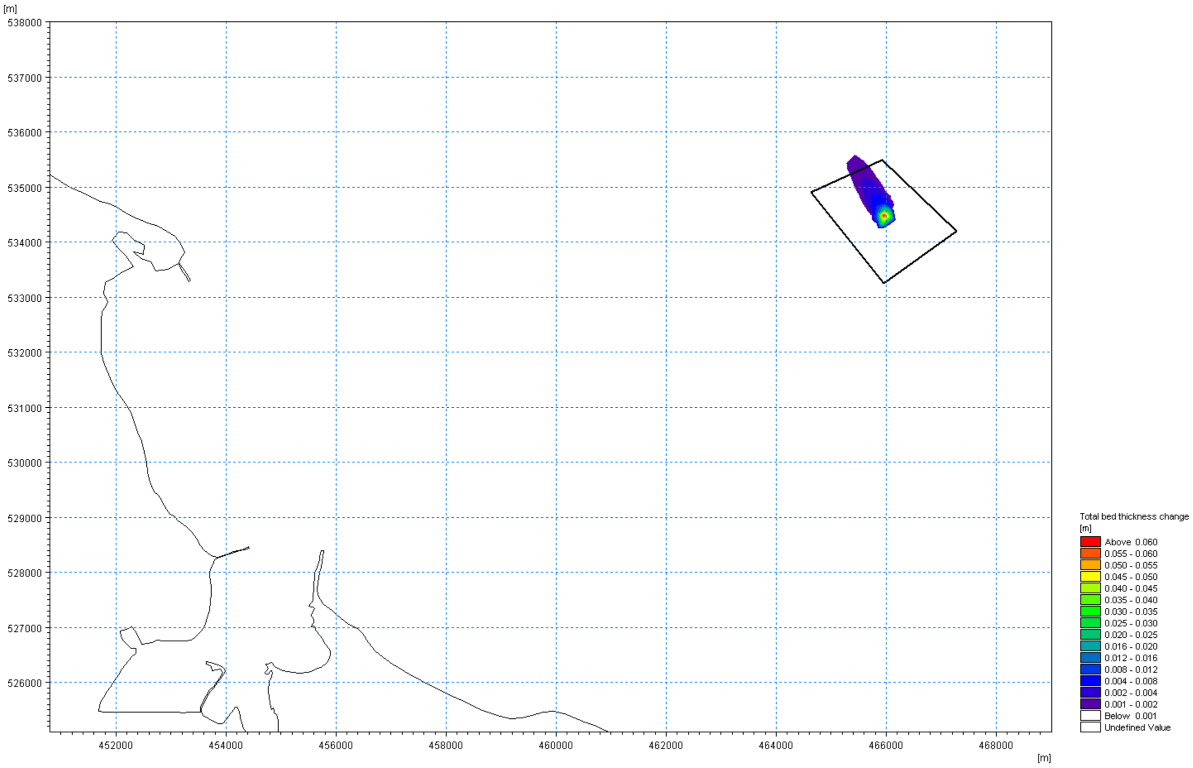


Figure6.66 Maximum sea bed thickness change due to sediment deposition arising from one disposal event during Stage 1 of the capital dredging programme – wider scale

Whilst turbidity and sediment deposition effects within the disposal site are to be expected (and indeed are monitored as part of a national programme), these effects could also potentially affect water quality and ecological receptors on the sea bed in areas that are beyond the boundaries of the deposition site. To further investigate these effects, timeseries plots of changes in SSC have been extracted from the model at a series of points around the offshore disposal site (locations are shown in **Figure 6.67**). The points are:

- Offshore Disposal Point 1 (OD1) – 50m from offshore disposal site’s eastern boundary
- Offshore Disposal Point 2 (OD2) – 50m from offshore disposal site’s southern boundary
- Offshore Disposal Point 3 (OD3) – 50m from offshore disposal site’s western boundary
- Offshore Disposal Point 4 (OD4) – 50m from offshore disposal site’s northern boundary

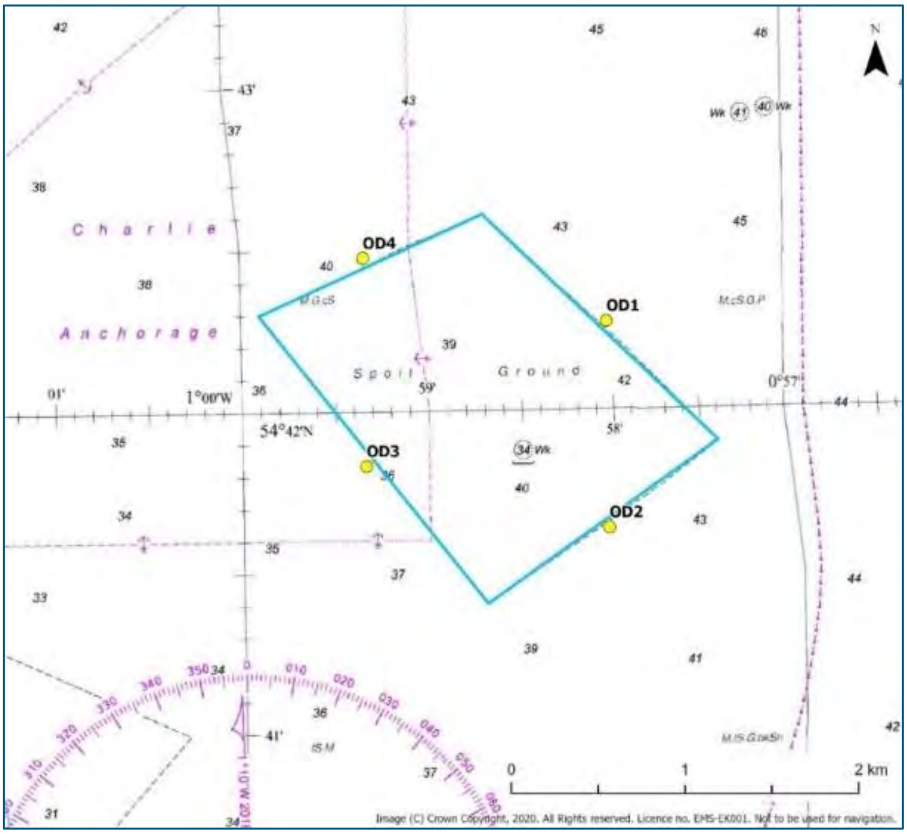


Image (C) Crown Copyright, 2020. All Rights reserved. Licence no. EMS-EK001. Not to be used for navigation.

Figure 6.67 Location of points around the offshore disposal site used for of timeseries analysis of changes in SSC and sediment deposition

It should be remembered that for a worst-case scenario, the modelling assumed that all disposals were made at a common point in the centre of the disposal site, but in reality different points will be used for subsequent deposits and therefore the maximum SSC values will be lower than those presented below. At the offshore disposal site monitoring points, SSC is enhanced by the greatest values at the points beyond the northern and southern boundaries (**Figure 6.68**). This correlates to the areas where a plume will extend along the axis of the prevailing tidal currents. Just beyond the northern boundary, peak SSC enhancement can reach 600mg/l and at the southern boundary 400mg/l. Just beyond the western and eastern boundaries the peak values are typically much lower (<50mg/l) but on occasion can temporarily reach 100-200mg/l for short durations. The effects of these changes on water quality, marine ecology and navigation in the offshore area are assessed more fully in **Sections 7. 9** and **14** respectively.

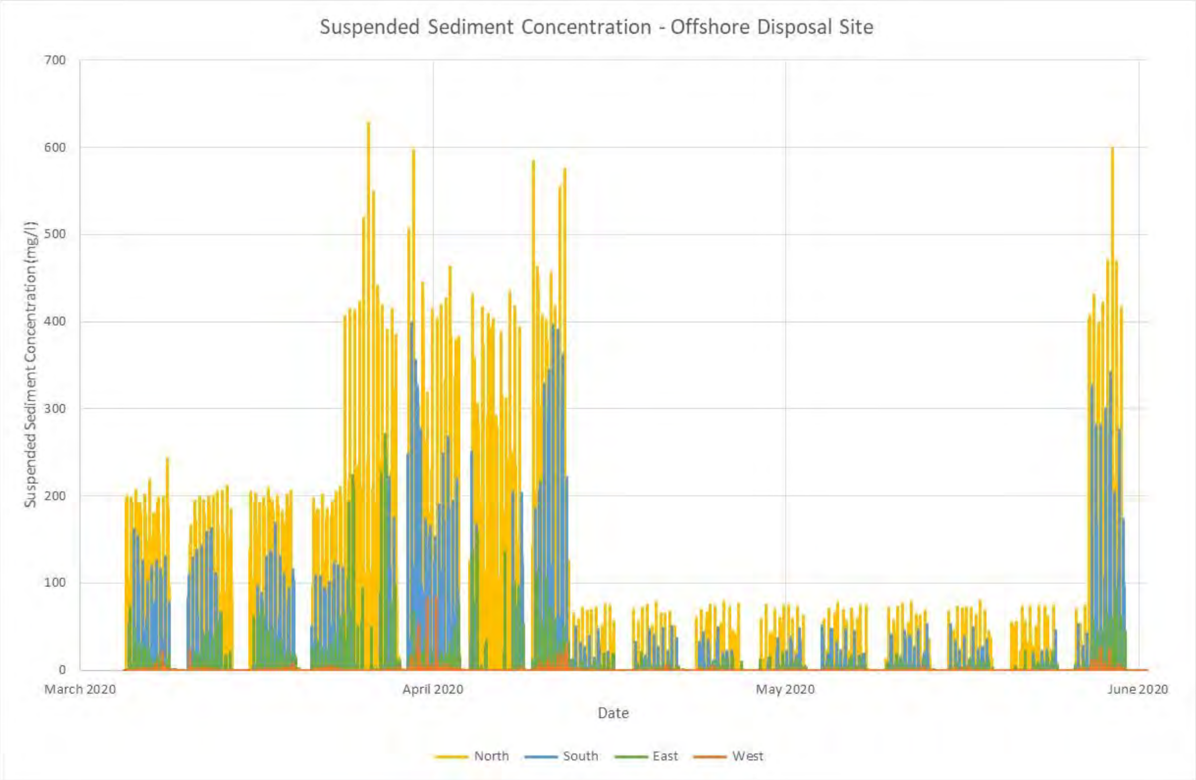


Figure 6.6 Timeseries of changes in SSC at the offshore disposal site monitoring points

Summary

The river dredging and offshore disposal activities will both cause plumes of sediment to form close to the release point of material into the water column. These plumes will disperse under wave and current action and all sediment particles suspended in the water column will eventually settle to the river or seabed, causing deposition.

During dredging, there will be a release of sediment particles from the deliberate physical disturbance to the riverbed and, more significantly, from overflow when dredged material is loaded into the dredger's hopper (for TSHD) or the transport barge (for BHD). Such releases will be ongoing through each dredging cycle until the dredging activity ceases due to downtime (e.g. adverse weather, vessel maintenance) or at scheduled breaks between stages of dredging activity. During offshore disposal, a single hopper load will near-instantaneously deposit material at the surface of the water column on each disposal visit.

Once a plume is generated, the highest SSC values will be recorded at the point of river dredging or offshore disposal, but these concentrations reduce rapidly after cessation of the activity. At distances away from the point of sediment release, the enhanced SSC values are considerably lower because the coarser material falls relatively rapidly to the bed, with only the finer proportions being retained in suspension, becoming advected away from the point of release by the prevailing currents. At the peripheries of each plume, the enhanced SSC values will be barely distinguishable from the background levels.

During some stages of the dredging and disposal activities, most notably when both TSHD and BHD are working in parallel, there could be instances where two separately formed plumes coalesce to form one (spatially) larger plume. However, the same principles of dispersion by prevailing currents applies, with peak concentrations remaining close to the point of release of the material for a short duration after its release before diminishing thereafter.

The plume effects arising from the river dredging are characterised by a short-lived localised increase in SSC by a few hundred mg/l at the point of dredging activity, followed by a general dispersion in spatial extent and reduction in concentration over following hours. Since the dredging is a near-continuous operation, the plume effects will be observed throughout much of the approximately four-month period, but at varying extents during the four different stages. During Stages 1-3 the dredging-related plume effects will be largely confined to the channel areas south of the centreline of the river and in reaches between Middlesbrough Dock and Tees Dock. During Stage 4 the dredging-related plume effects will be largely confined to the channel areas north of the centreline of the river and in reaches between North Tees Works Oil Refinery and the Oil Terminal. Other than within the dredged areas, sediment deposition on the riverbed will be of very minor magnitudes, in areas covering the same spatial extent as the sediment plumes. Where this occurs in the river channel or at jetties, it will subsequently be dredged as part of ongoing maintenance dredging regimes, whilst material deposited back into the newly dredged areas will be re-dredged during the capital works in order to achieve the desired design depths.

The plume effects arising from the offshore disposal similarly show peak concentrations at the point of release, but because a larger volume of material is near-instantaneously disposed, the peak concentrations are typically a few thousand mg/l at the point of disposal activity. Plumes become advected by tidal currents along the principal axis of tidal flow (north-west to south-east), diminishing in magnitude over a few hours after disposal. Just beyond the boundaries of the disposal site, the maximum seabed deposition can be up to 0.5m, but this is in water depths that are approximately 43.5m. Furthermore, this represents a worst case of all material being deposited at a common point within the disposal site, whereas in reality deposits will be spread around various locations within the site’s boundaries and thus this maximum potential change is highly unlikely to occur in practice.

Overall, the changes in SSC and sediment deposition arising from the river dredging and offshore disposal activities are very much in-keeping with those experienced by similar activities in other areas, which has been the subject of considerable industry-wide monitoring and assessment.

6.5.3 Construction of a new quay (to be set back into the riverbank)

The new quay will be built from land, using predominantly land-based plant, with no construction activity in the river. There will therefore be no effects during construction of the quay on the hydrodynamics and sedimentary regime of the Tees estuary.

6.6 Potential impacts during the operational phase

6.6.1 Direct effects on inter-tidal and sub-tidal morphology

The proposed scheme will result in direct effects to the existing intertidal and subtidal morphology of the following magnitudes:

- Existing intertidal = 25,000m^2 loss
- Existing subtidal = 325,000m^2 impacted
- New subtidal = 55,000m^2 created

Of the 325,000m^2 of existing sub-tidal that will become impacted, some 50,000m^2 will subsequently be covered by the proposed rock blanket. Similarly, of the 55,000m^2 of sub-tidal area that will newly be created due to the set-back alignment of the new quay, some 45,000m^2 will subsequently be covered by the proposed rock blanket. The remaining 10,000m^2 of newly created sub-tidal will remain unaffected by proposed rock blanket. This means that in total some 95,000m^2 of sub-tidal will become covered by proposed rock blanket.

The impacts of these changes in intertidal and subtidal areas upon existing habitats and species is discussed in **Section 9.**

6.6.2 Changes in hydrodynamics

Since the new quay is to be set back from the existing riverbank, there will be expected local changes to the baseline hydrodynamics due to the new alignment. Changes in hydrodynamics will also arise from absence (due to removal) of the existing wharf and jetties and deepened areas of riverbed arising from the capital dredging to the Tees Dock turning circle and approach channel and to create a berth pocket.

To determine the hydrodynamic conditions with the above aspects of the scheme when it is in its operational phase, numerical modelling during both neap and spring tides was undertaken, with a mean daily river flow through the Tees Barrage (20 cumecs). **Figures 6.69** and **6.70** show the peak current speeds during the flood and ebb phases of a neap tide with a mean daily river flow, whilst peak current speeds during corresponding phases of a spring tide with a mean daily river flow are shown in **Figures 6.71** and **6.72**. The general baseline tendencies, showing maximum current speeds being greater on the spring tides than the neap tides and an ebb dominance during neap tides and flood dominance during spring tides, remain unaffected by the scheme.

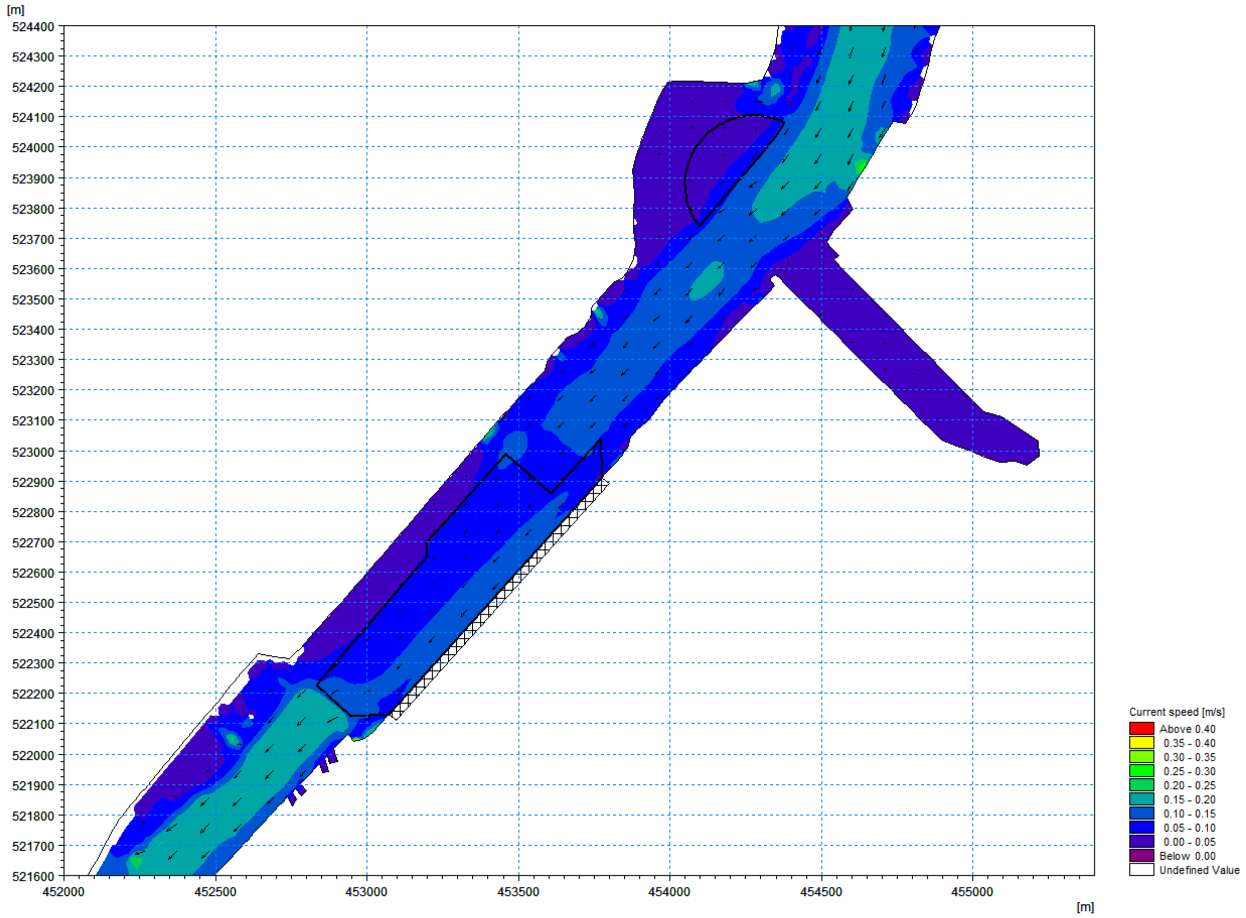


Figure 6.69 Peak current velocities during the flood phase of a neap tide with mean daily river flow – with scheme

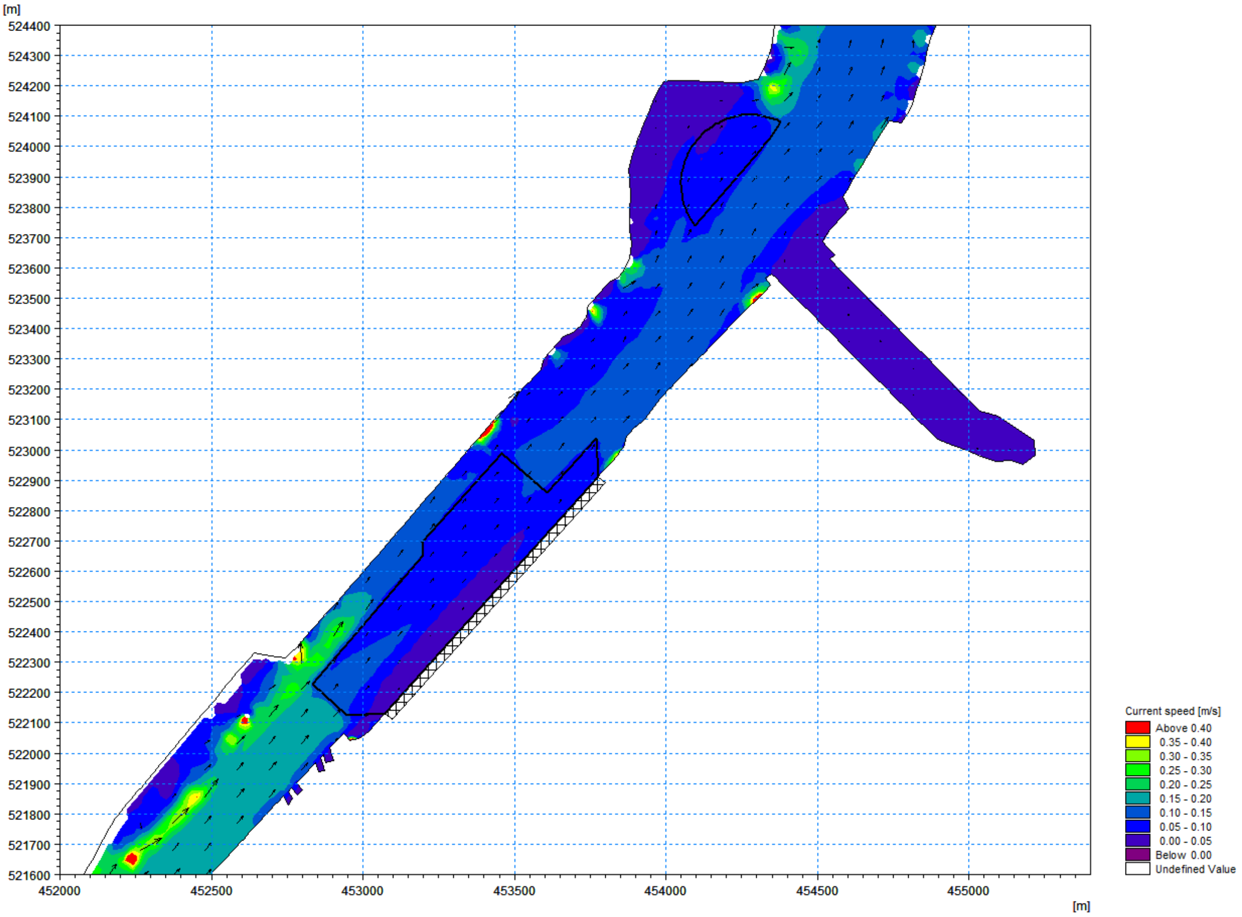


Figure 6.70 Peak current velocities during the ebb phase of a neap tide with mean daily river flow – with scheme

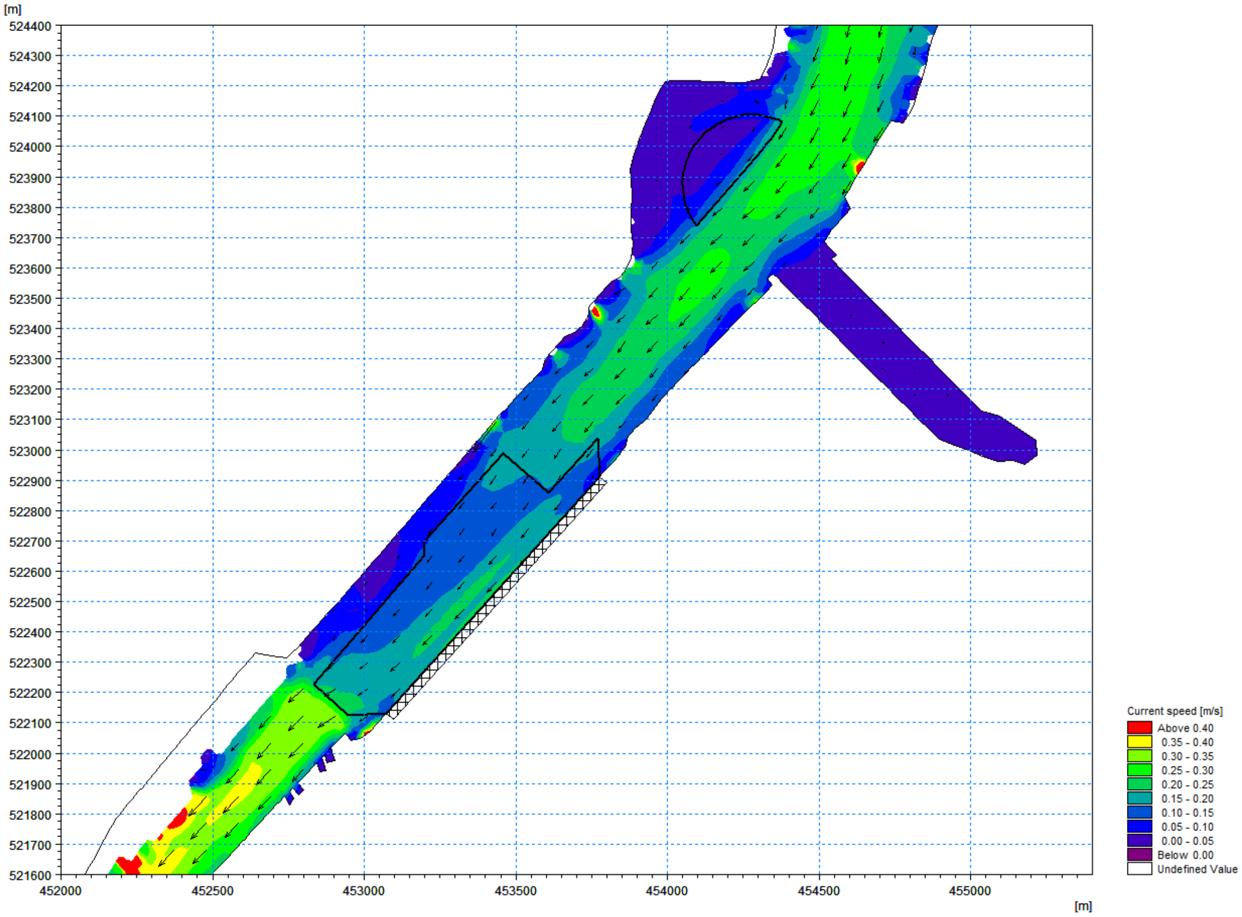


Figure 6.71 Peak current velocities during the flood phase of a spring tide with mean daily river flow – with scheme

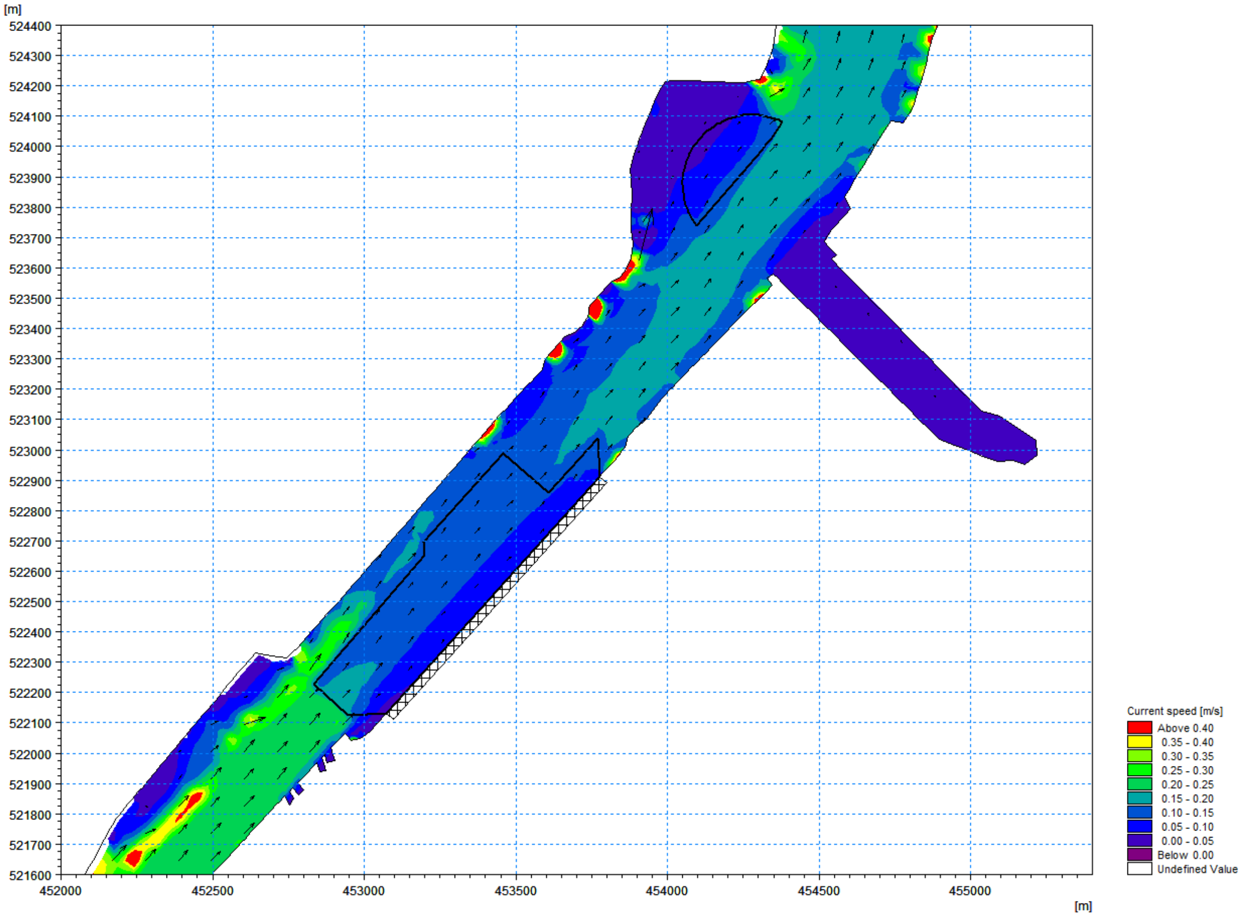


Figure 6.72 Peak current velocities during the ebb phase of a spring tide with mean daily river flow – with scheme

The 'with scheme' conditions have been compared against the baseline conditions and the resulting difference plots in **Figures 6.73** to **6.76** show the changes in peak current speeds on the ebbing and flooding phases of neap and spring tides, respectively.

During the peak of the flood phase of a neap tide (**Figure 6.73**), current velocities are newly created locally along the length of the quay's set-back alignment, mostly by 0.05 – 0.10m/s but in small areas by up to 0.15 m/s in magnitude. There are also zones of reduction in baseline flow in the centre of the channel and along the northern bank, but the magnitude of these changes is mostly 0.05 – 0.10 m/s, with up to 0.15 m/s in small areas. There is no measurable change within the Tees Dock turning circle.

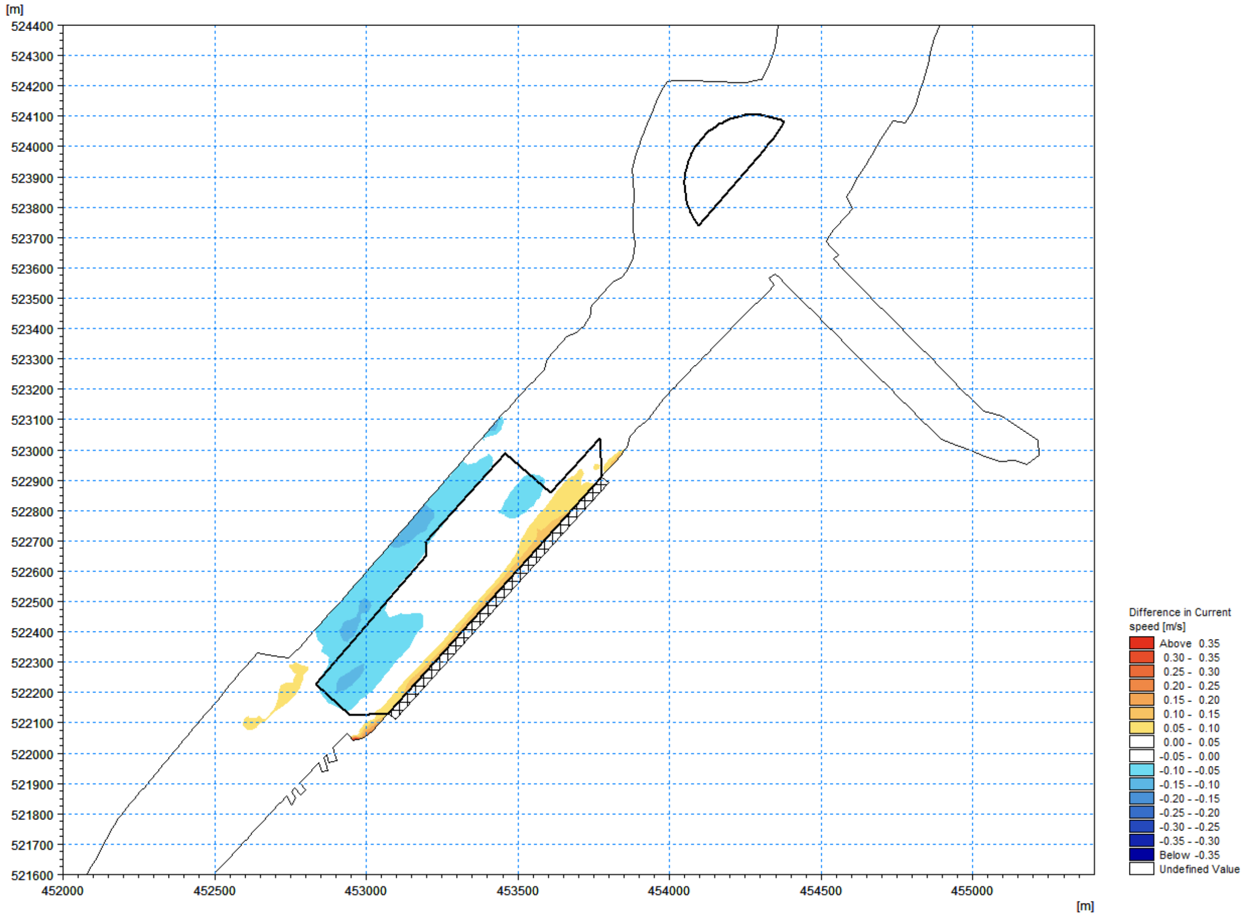


Figure 6.73 Change in peak current velocities due to the scheme during the flood phase of a neap tide with mean daily river flow

During the peak of the ebb phase of a neap tide (**Figure 6.74**), current velocities are also newly created locally along the length of the quay's set-back alignment, but the magnitude of change is less than 0.05 m/s and so is not apparent in the plot. Only in the corners at either end of the quay is a slight increase above this threshold modelled. There are zones of reduction in baseline flow towards the southern bank of the channel, with the magnitude of these changes mostly in the range 0.05 – 0.10 m/s, with up to 0.20 m/s in small areas towards the downstream end of the quay. There is minimal change in the centre of the channel and there is no measurable change at the northern bank or within the Tees Dock turning circle.

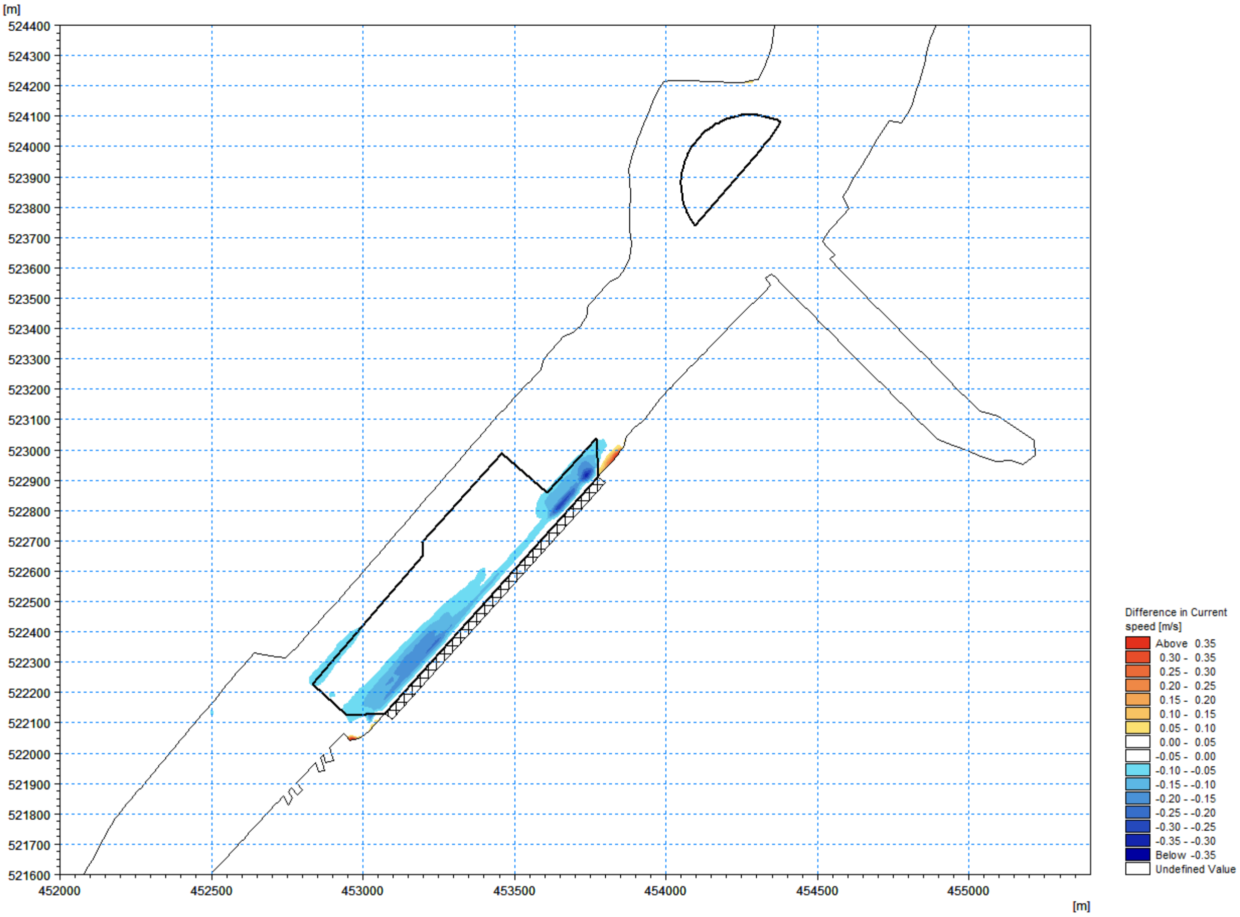


Figure 6.74 Change in peak current velocities due to the scheme during the ebb phase of a neap tide with mean daily river flow

The spring tide results for peak flood and ebb phases (**Figure 6.75 and 6.76**, respectively) exhibit similar patterns to those described for the corresponding phases of the neap tide, but the area of effect is slightly larger and, in local areas, the magnitude of effect slightly larger. Notably, however, the area of effect does not extend significantly further along the axis of the channel (i.e. upstream or downstream), just across the width of the channel opposite the new quay. For example, during the peak of the flood much of the channel immediately opposite the quay experiences a slight reduction in baseline flows, whereas under the corresponding neap conditions is was only parts of the channel width (with changes elsewhere being less than 0.05 m/s and therefore not apparent in the plots).

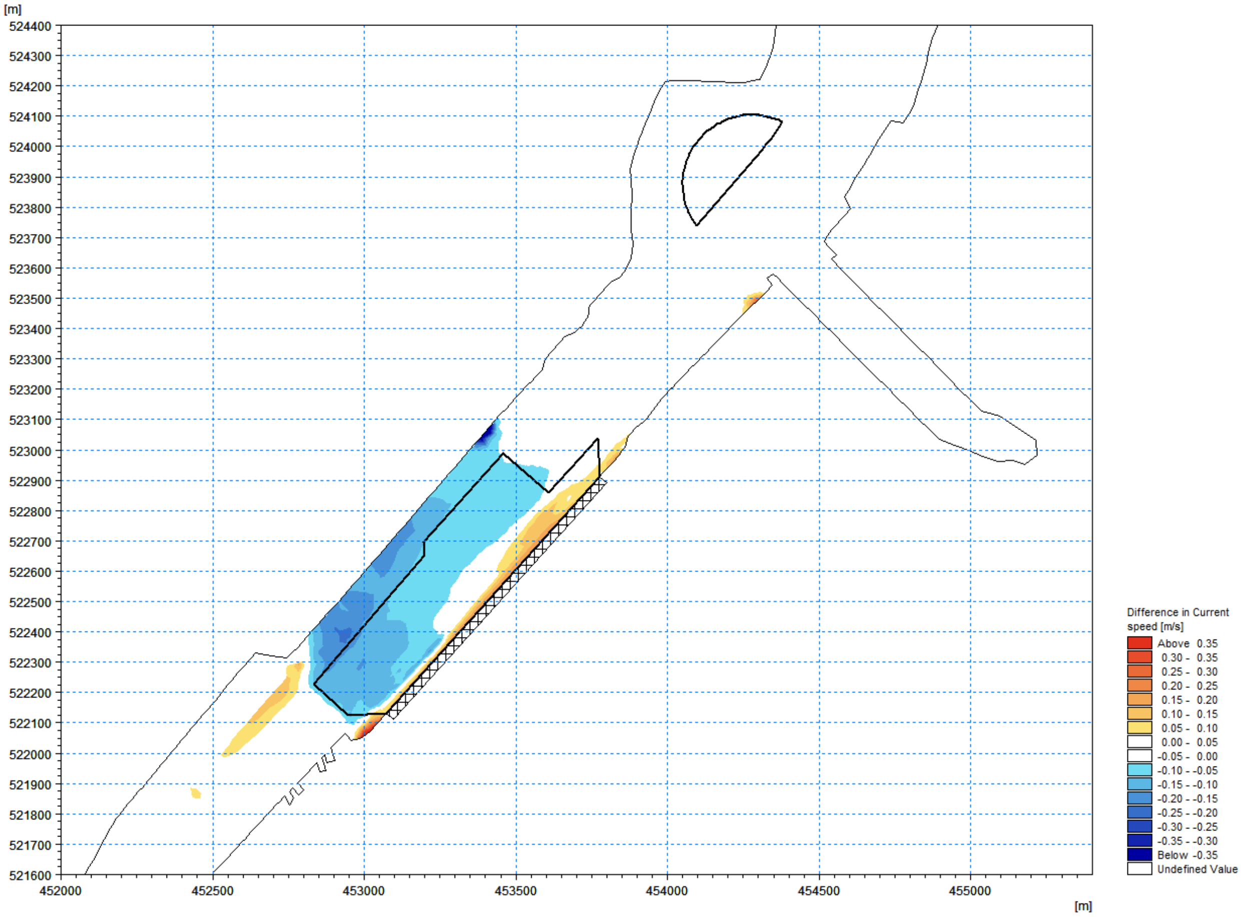


Figure 6.75 Change in peak current velocities due to the scheme during the flood phase of a spring tide with mean daily river flow

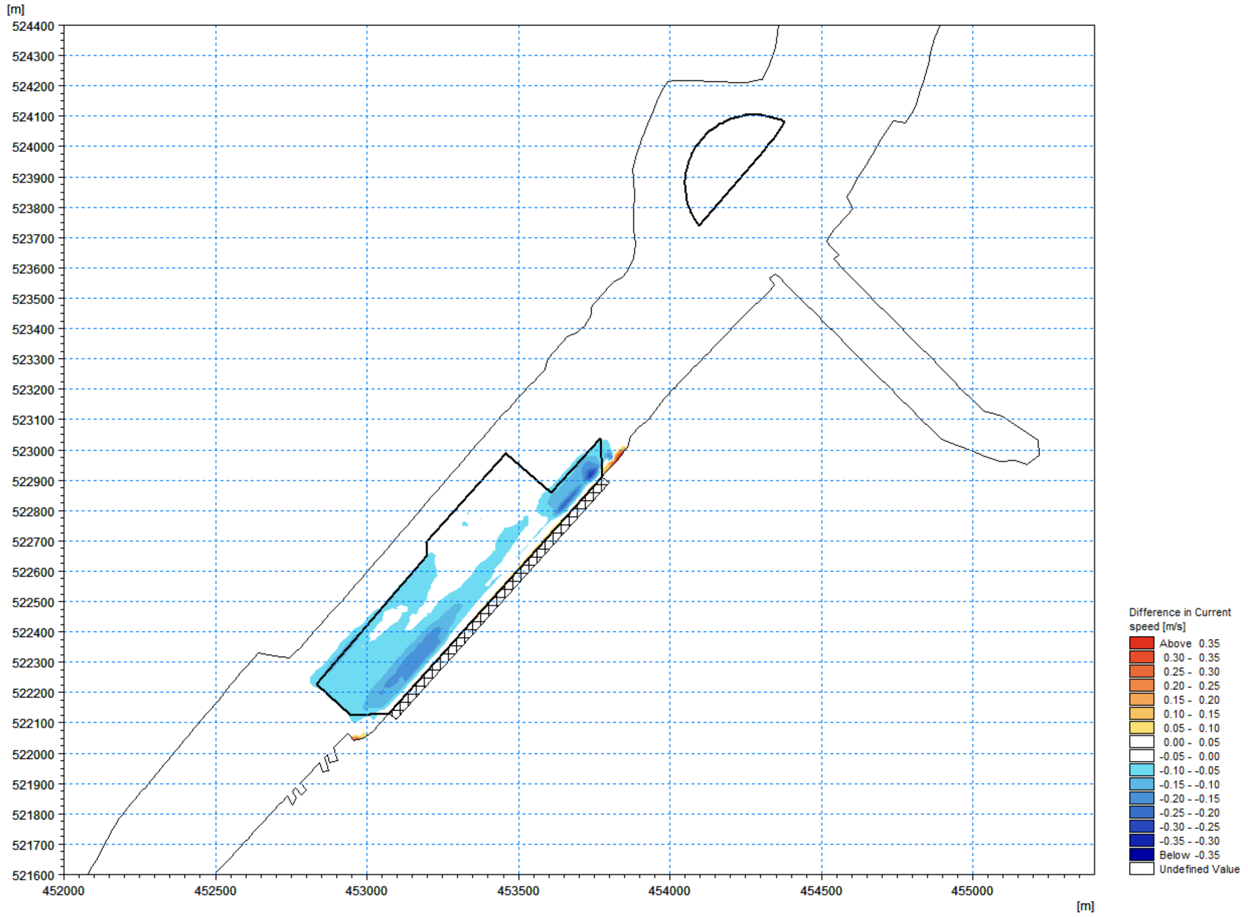


Figure 6.76 Change in peak current velocities due to the scheme during the ebb phase of a spring tide with mean daily river flow

The principal findings from the numerical hydrodynamic modelling are:

- The proposed new quay alignment and capital dredging to deepen the Tees Dock turning circle and approach channel and to create a berth pocket will not significantly affect the existing baseline hydrodynamic conditions.

- There will be flow newly occurring in the area of the new quay because it is being set-back from the existing river bank, but even the peak flows in this area will be low.

- Elsewhere, there will be a general small magnitude reduction in baseline flows varying during different phases of the tidal cycle, but always remaining largely within the reach immediately opposite the new quay. This reduction in baseline flows is caused by both a slight widening of the channel (due to the new quay alignment) and the local deepening of the bed due to the capital dredging.

- The reductions in baseline current speeds in these areas may lead to a slight increase in deposition of sediment. In areas adjacent to the north bank opposite the quay, this is positive as it will help the existing North Tees Mudflat be sustained in light of sea level rise. In the main channel the deposition will require periodic dredging to maintain the design depths.

- There is no measurable change caused by the capital dredging at the Tees Dock turning circle.

- There is no predicted effect on local wind-generated waves at the site since the changes in hydrodynamics are so small and localised.

- There are no estuary scale effects on baseline hydrodynamic conditions.

6.6.3 Changes in tidal prism of the estuary

In addition to changes in baseline current speeds, the Environment Agency particularly requested that the impacts of the proposed scheme on the tidal prism of the estuary be considered. Townend (2005) calculated the volume of the Tees estuary at mean low water to be 1.31 x 10^7 m^3 and at mean high water to be 3.23 x 10^7 m^3, yielding a mean tidal prism of 1.92 x 10^7 m^3. Design calculations for the proposed scheme show that the increase in mean tidal prism as a result of the new quay's set-back alignment and dredging of part of the existing estuary bed is 150,901 m^3. This represents an increase in the existing tidal prism of the estuary by less than one percent (0.8% to one decimal place) and is not deemed to be a cause of significant estuary-wide change in hydrodynamics.

6.6.4 Maintenance dredging and offshore disposal of dredged sediments

In order to provide an estimate of the present annual average maintenance dredging undertaken in the reach that is modelled to experience some minor change in baseline hydrodynamics (i.e. the reach local to the proposed new quay), it can be assumed that the affected area covers approximately half of dredging reach 6 and approximately one-third of dredging reach 5 (these 'dredging reaches' are shown in the earlier **Figure 6.29**).

Between 2001 and 2019 inclusive, the average annual maintenance dredging in reach 5 was 3,585m^3 and in reach 6 was 14,078m^3 (see the earlier **Table 6.14**). Assuming, for the purposes of this assessment, that maintenance dredging is evenly located through each dredging reach so that the spatial scaling described above can be applied, then the total annual average maintenance volume from the river reach where changes in hydrodynamics are modelled to occur is around 8,234m^3. This relatively low quantity of maintenance dredging is likely to be due to the low levels of suspended sediment measured in this reach of the river. By far the greatest contributions to the overall annual maintenance dredging total come from close to the barrage in dredging reaches 1-3 inclusive or towards the estuary mouth in dredging reaches 8-11 inclusive. All non-contaminated material from maintenance dredging is usually taken to the Tees Bay A licensed offshore disposal site.

The modelled reductions in current speeds in the reach of the channel local to the new quay, combined with the creation of a new berth pocket at the quay, may lead to a small increase in deposition rates and hence a requirement for more material to become from this local reach dredged annually. Recognising this, a 10% increase in annual maintenance dredging requirement may be a reasonable assumption recogising the low baseline SSCs in this reach. Even under this scenario, the maintenance dredging from this reach local to the new quay will still yield a very low overall contribution to the net annual maintenance dredging requirements from the estuary as a whole. Therefore the potential increase in maintenance dredging requirement is not expected to be significant and could easily be managed within existing maintenance dredging and offshore disposal regimes.