

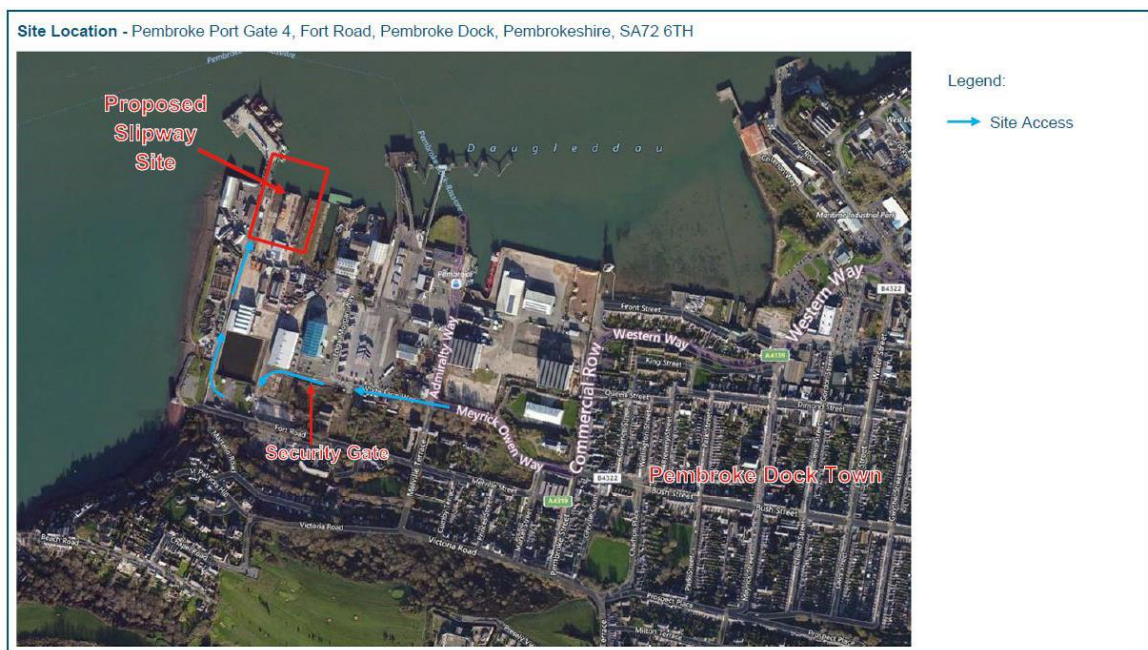
# PEMBROKE DOCK INFRASTRUCTURE TECHNICAL NOTE - SEDIMENT PLUME MIGRATION ASSESSMENT

## Introduction

In its response to statutory pre-application consultation regarding the above dated 1 April 2020 (reference: CAS-110371-R3T9) and during the following pre-application discussions, Natural Resources Wales indicated it required further detail on the transport and fate of material which may be released to the water column during the course of the proposed dredging activities associated with the formation of an enlarged slipway. Due to the limited nature of the works and the relatively small volume of associated spill material, a full 3-dimensional sediment plume modelling exercise was considered unnecessary and instead a desk study was undertaken and is reported below.

The desk study was based on the information provided within the Haskoning Dredging Report (reference: PB8556-RHD-ZZ-XX-NT-Z-0001 P01.04) together with background data on the Haven to provide a quantitative indication of the sediment transport within the waterway. The analysis was undertaken by examining the current speed and direction in the vicinity of the dredging location over the course of the spring and neap tidal cycles, using data from a calibrated model available from a number of previous studies undertaken by RPS, including South Hook thermal discharges and Murco outfall modelling. The grading of the sediment (available from the aforementioned Haskoning Dredging Report) was used to determine the settlement rate of each sediment fraction within the dredge footprint and hence derive the extent of the sediment plume and transportation prior to settlement. These extents coupled with bathymetry data also allowed estimation of the potential increase in suspended sediment levels.

The site of the dredging and material to be dredged (below mean low water spring) are presented in **Error! Reference source not found.** and Table 1: respectively.



**Figure 1: Slipway and Disposal site Location** (source: PB8556-RHD-ZZ-XX-NT-Z-0001 P01.04)

**Table 1: Material above the Rock Layer below MLWS**

Material Type	Volume m <sup>3</sup>
Soft Silts	3,551
Coarse Sandy Sediment	680
Gravel	315
Gravel / Clay Bound Mudstone	2,499
Mudstone	1,859
<b>Total</b>	<b>8,904</b>

## Sediment characteristics

The sediment characteristics associated with each material type were examined. By definition each class consists of a range of particle diameters (for example using the Wentworth classification scale). In each case the maximum, minimum and average particle size were examined in terms of the associated settling rate and the average water depth of 2.9m was used to calculate the settlement time of each particle class. This data is summarised in Table 2 along with the conservative anticipated spill volumes which were provided within the Haskoning Dredging Report (reference: PB8556-RHD-ZZ-XX-NT-Z-0001 P01.04).

**Table 2: Material above the Rock Layer below MLWS**

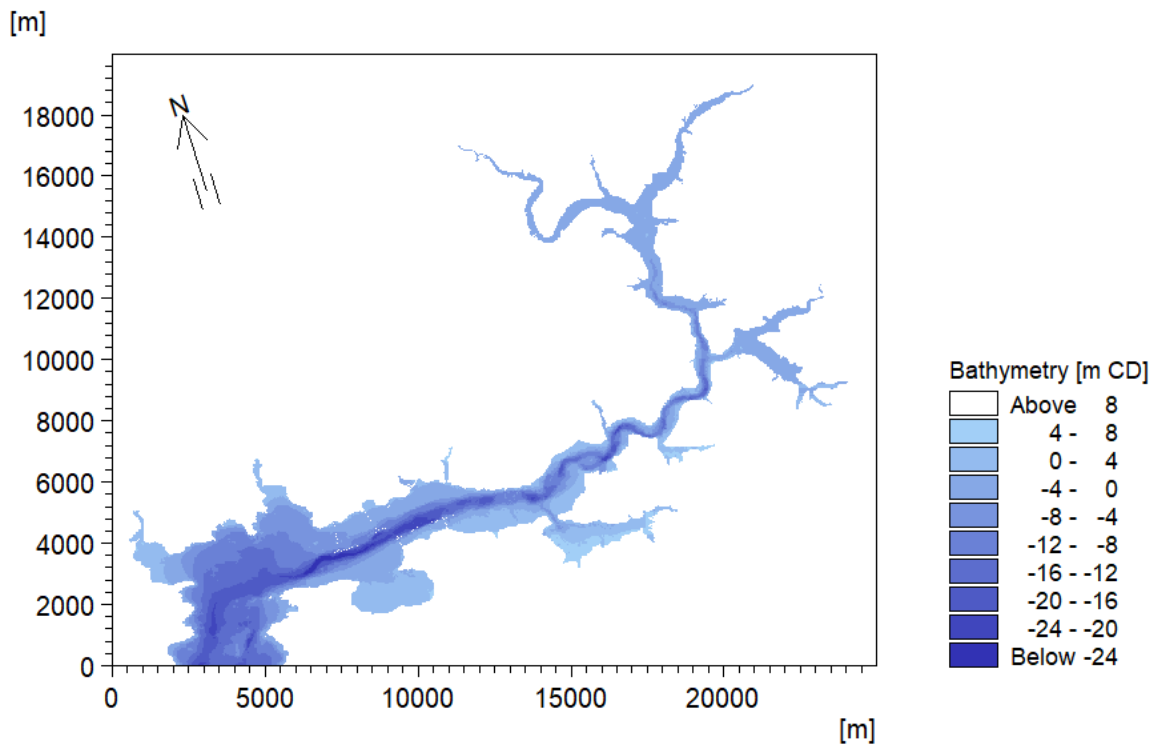
Material type	Diameter (mm)	Fall velocity (m/s)	Time to bed	Total Volume(m <sup>3</sup> )	Spill Volume (m <sup>3</sup> ) (5%)
Silt	Min 0.002	2.7 e-6	>12hours	3551	176
	Avg 0.03	0.00061	1.3hours		
	Max 0.05	0.00169	30 mins		
Coarse sand	Min 0.05	0.00169	30 mins	680	34
	Avg 1	0.09623	30 sec		
	Max 2	0.143	20 sec		
Gravel	Min 2	0.143	20 sec	315	16
	Avg 40	0.6568	4.5 sec		
	Max 75	0.8995	3 sec		
Gravel / clay	This material is too coarse to spill			2499	n/a
Mudstone	and undergo dispersion			1859	n/a

## Tidal currents

An existing calibrated numerical model of Milford Haven was used to infer tidal currents in the vicinity of the dredging site. The model is a rectangular mesh with a 30m grid resolution which was used to simulate tidal currents for a period of 20 days through spring and neap tidal cycles. The location of the site is shown in Figure 2 whilst the model extent is shown in Figure 3.

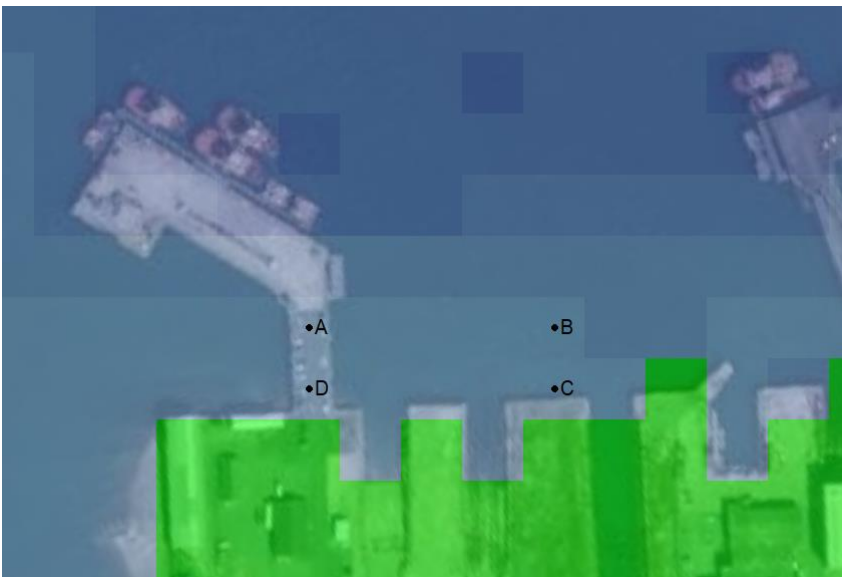


**Figure 2: Location of Pembroke Dock**

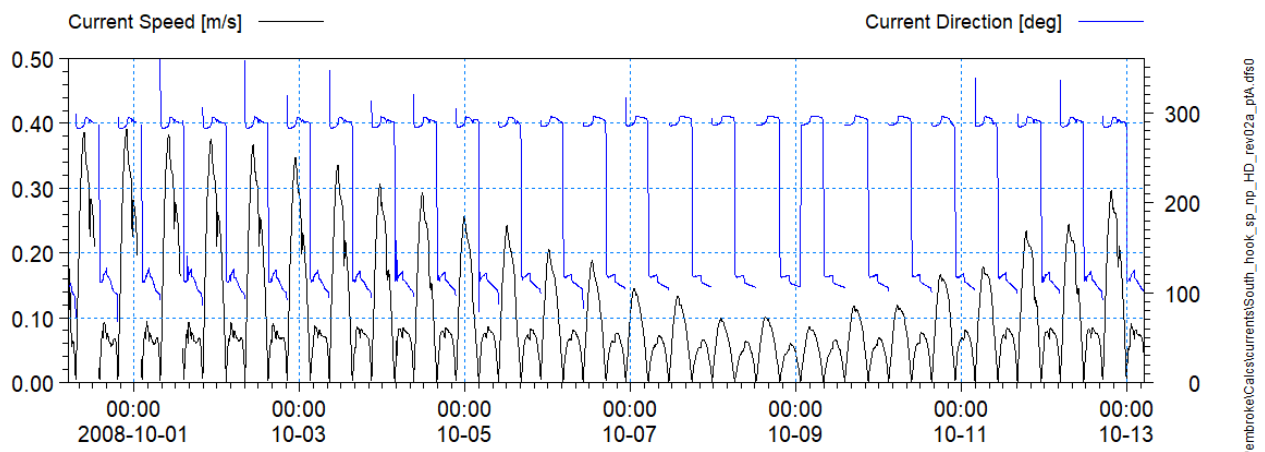


**Figure 3: Model domain**

The characteristics of the tidal flow were extracted from the model at four points located at each corner of the dredging area. These locations are shown in Figure 4 whilst Figure 5 presents the current speed and direction at Point A through spring-neap cycles.



**Figure 4: Location of extracted datapoints**



**Figure 5: Current speed and direction at Point A through spring-neap cycle**

It was noted that at all four locations, the ebb and flood directions were parallel to the shoreline at  $300^{\circ}$  and  $110^{\circ}$  respectively. Ebb tidal current velocities were typically two to four times that of the flood tide. There was a large variation in current speeds between spring and neap cycles, where the tidal range constitutes a large proportion of the water depth in these shallow areas.

Table 3 presents the characteristics of each of the four points. Generally, the values at Point A are used in the further assessments, as this constitutes the location with the greatest sediment transport potential.

Table 3: Flow characteristics

Point	Average depth (m)	Spring flood max velocity (m/s)	Spring ebb max velocity (m/s)	Mean Velocity (m/s)
A	3.2	0.1	0.4	0.1 Flood tide 0.056 Ebb tide 0.147
B	3.5	0.1	0.3	0.1
C	2.7	0.05	0.15	0.04
D	2.3	0.05	0.3	0.07

## Assessment of transport and fate of spill

Each of the sediment classes were examined in terms of transport potential.

### Gravel

Gravel makes up the smallest potential spill volume of 16m<sup>3</sup> using the most conservative backhoe dredger spill value of 5%. Using the data presented in the previous two sections, it can be seen that the coarsest material would reach the bed in well under 10 seconds if it were spilled at the average water depth. In this time under the strongest currents, the material would be transported <2m during ebb tide and <1m during flood tide. Similarly, the finest gravel of 2mm could potentially be transported 10m in ebb and 2m in flood conditions.

A typically sized gravel particle would be transported 2m from its origin at the mean sea level under peak current flows. However, these peak flows will not persist throughout the tidal cycle and this would largely constitute spilled gravel falling back within the dredging area and being retrieved on subsequent dredging loads. The gravel fraction would therefore not impact on the surrounding environment.

### Coarse sand

Using the same hypothesis, the coarsest sand (which is the same as finest gravel) would be carried 10m on peak ebb and 2m on peak flood. The finest of the sand fraction may take up to 0.5 hours to settle out, which may extend the plume 700m during peak ebb flows and 180m during peak flood flows. Under typical current speeds, a sand particle would be transported 260m and 100m respectively. An indication of the potential plume extent is shown in Figure 6. It should be noted that the plume would extend into areas with currents of greater magnitude and this is a simplified assumption to establish the upper bounds for sedimentation.



**Figure 6: Potential plume extent for coarse sand fraction**

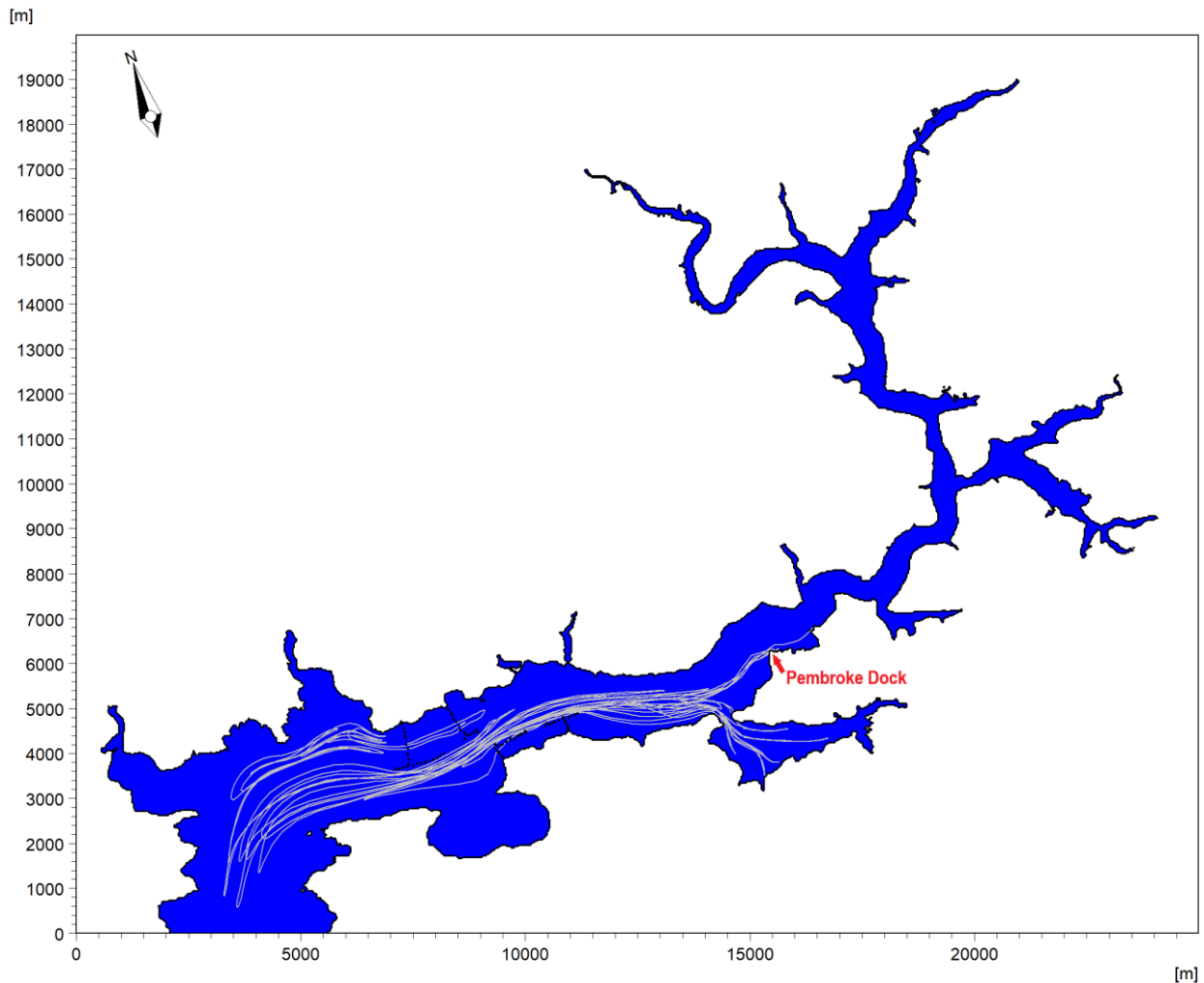
In order to provide further context in terms of sedimentation, average sand particle transport during mean ebb and flood tides can be considered. With a settlement time of 30s and currents of 0.147m/s and 0.056m/s, the plume and settlement envelope would extend 5m to the west (ebb) of the site and 2m (flood) to the east. If it is assumed all sand has this grading and the dredging is carried out over the course of at least one tide, the area affected would be circa 9400m<sup>2</sup>. The average settlement depth from 34m<sup>3</sup> of sand is 3.6mm, most of which is located within the dredge area. If fine sediments are assumed the settlement is 1.1mm. This indicates that the sand fraction is not likely to impact on areas beyond the immediate vicinity and where settlement takes place it is of limited magnitude.

## Silt fraction

As previously discussed, the finest sand exhibits the same characteristics as the coarsest silt. This material takes approximately 0.5 hours to settle and may be transported 700m during peak ebb flows and 180m during peak flood flows. The silt fraction has a wider range of characteristics with the coarsest material settling relatively quickly with respect to the finest material which may remain in suspension for much longer periods and would be more widely dispersed.

In order to examine the fate of the finest material, particles were introduced into the model at the four locations (each corner of the dredging area) and the transport paths were generated over the spring-neap tidal cycles using the flow visualisation tool. The paths assume that the particles are advected by the tidal current present in each cell and no settling occurs.

Figure 7 shows the particle tracks when material is released mid-ebb tide and illustrates how the finest material which remains in suspension would be carried into the strong tidal currents within the Haven and would be widely dispersed over subsequent flood and ebb tides for the following two weeks. This track covers an area of 15km<sup>2</sup> and constitutes 0.2km<sup>3</sup> of water and if all the silt fraction is assumed to be comprised of the very finest grading within this class and therefore remains in suspension the resulting increase in suspended sediment would be circa 1mg/l.



**Figure 7: Particle track over spring-neap tides – ebb release**

**Error! Reference source not found.** shows the tracks when particles were released on the flood tide, and the subsequent advection over the following tidal cycles. The particles released at the south and east of the site were transported directly inshore to dry areas as a result of the circulating flows around the headland as presented in **Error! Reference source not found.**. At these locations the infrastructure coupled with very low flows restrict the dispersion on flood tides. Only particles released at the north west of the site remain in suspension and these were circulated in the vicinity of the site before being carried downstream on the outgoing tide.

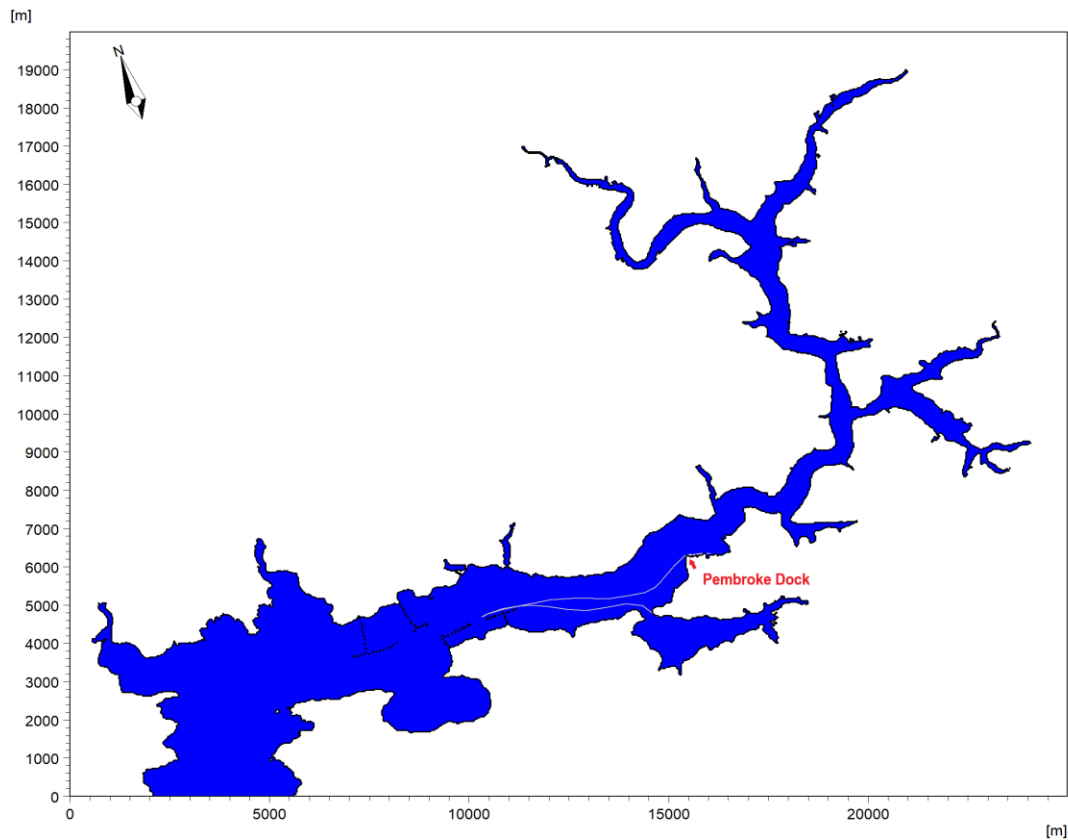


Figure 8: Particle track over spring-neap tides – flood release

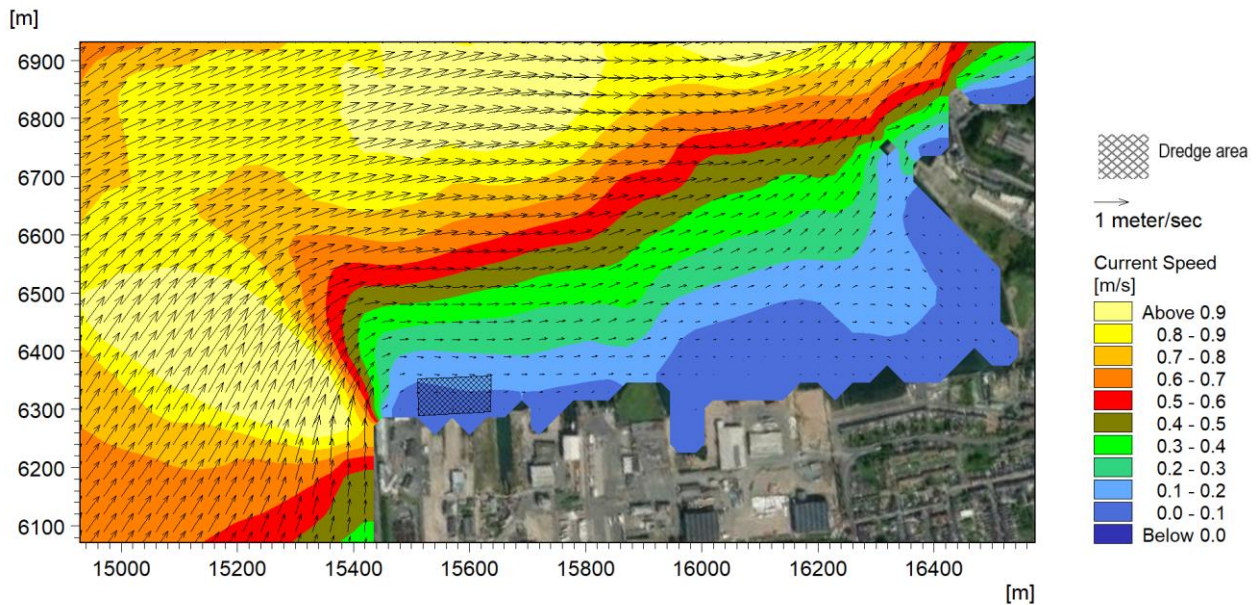
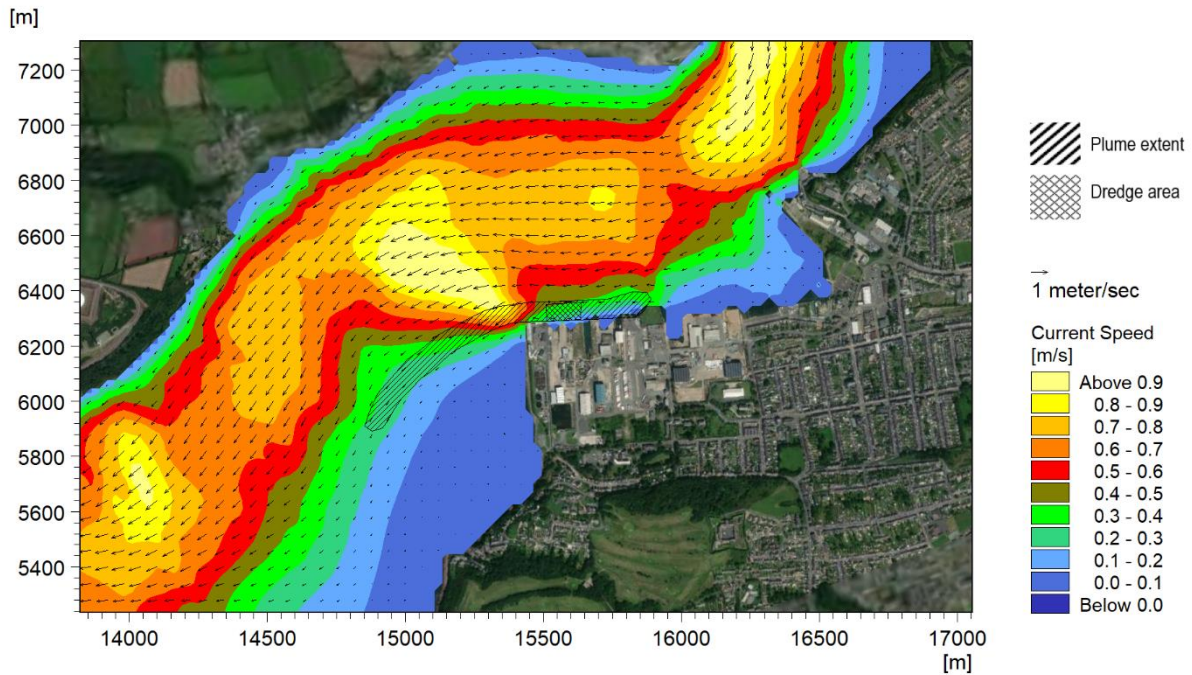


Figure 9: Flood tide current flows in the vicinity of Pembroke Dock

Having examined the transport of the silt fraction at either end of the particle size range within this class it is pragmatic to consider an average particle size to represent the typical behaviour. An average silt particle of 0.03mm diameter would settle from mean sea level to the bed in around 1.3 hours with no stimulus. When exposed to maximum spring currents the transport may be 1800m on ebb and 500m on the flood. However, it is clear that peak currents only last for a fraction of the tide, therefore with average current speeds this is reduced to 690m and 260m respectively. It should also be noted, excursion to the east would bring particles

in lower current speeds with reduced dispersion whilst to the west the reverse is true as the strong channel currents would be encountered.

This is illustrated in Figure 10 which shows the simplified plume (for both ebb and flood tides) along with the ebb current pattern; the plume would clearly undergo greater dispersion when current speeds approaching 0.9m/s are encountered and suspended sediment concentrations would be greatly reduced. For completeness Figure 11 illustrates the plume with background mapping for clarity.



**Figure 10: Ebb tide currents with simplified typical silt plume overlaid**



**Figure 11: Potential plume extent for typical silt fraction for average current speeds**

By way of illustration using this simplified hypothesis, if the dredging operation is undertaken over the course of both ebb and flood tides the settlement area under these conditions would be circa 66,000m<sup>2</sup> with an associated sedimentation depth of 2mm. It is anticipated that the dredging works will be undertaken over a 2 day period, i.e. circa 16 hours. Then the release rate of silt would be 11m<sup>3</sup>/hour with a settling period of 1.3 hours and the plume may consist of 14.1m<sup>3</sup> of the silt fraction. If the plume is assumed to be of the dimensions shown above, i.e. extending 260m to the east of the site and 690m to the west and diminishing in height within the water column with increased distance, then the average excess suspended sediment concentration would be circa 200mg/l during and for a limited period following the dredging works.

## Conclusion

This study has shown that gravel and coarse sand spilled as a result of the dredging activities would remain in the immediate area of the works. In terms of the spill of silt into the water column, it may be concluded that in the immediate vicinity of the dredging, sedimentation levels would be in the order of 2-3mm which declines significantly with increased distance from the site. Elevated suspended sediment levels would be experienced in the locality of the site due to the silt fraction, similar to those experienced during a storm event<sup>1</sup>. However, beyond 500m from the site, the large tidal currents would provide increased dispersion and the finer material would be indiscernible from the background levels<sup>1</sup>.

<sup>1</sup> Sediment Contaminants and Transport Review, Little, D.I, Milford Haven Waterway Environmental Surveillance Group, 2009