WORKING WITH NATURE:
APPLYING THE PHILOSOPHY TO MAINTENANCE DREDGING

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Abstract: The 'Working with Nature' philosophy (PIANC, 2011) was developed to apply to the planning of new navigation infrastructure projects. This case study illustrates how elements of the philosophy can be applied to ongoing activities such as maintenance dredging.

For many years, most of the material dredged by the Mersey Docks and Harbour Company (MDHC) from the docks, river entrances and approach channel to the Port of Liverpool has been taken to an offshore licensed disposal site. Much of the remainder has been deposited closer to the Port, within the estuary.

MDHC's maintenance dredging and disposal regime has been assessed and shown to be compliant with both the EU Habitats Directive and the EU Water Framework Directive. No adverse environmental effects have been identified.

Notwithstanding this compliance, several factors including potential cost and carbon savings led to MDHC organising a stakeholder meeting at the end of 2011 to discuss whether opportunities might exist to use the maintenance dredged materials beneficially – whether for environmental or engineering purposes. This initiative represented a significant departure from 'the norm' for MDHC who, in common with most other UK harbour authorities, have powers under their Local Act to carry out maintenance dredging, and regard such activities as 'internal' matters. It also represented a challenge for the stakeholder organisations as this was not a capital development project requiring compensation – a situation in which such organisations often 'call the shots' – but rather a voluntary initiative, the success of which would depend on collaboration, cooperation and compromise.

This paper elaborates on the background to, and presents progress to date with, the Mersey sediment management study as it moves from option identification and assessment to implementation - based on the principles of Working with Nature and adaptive management.

Keywords: Working with Nature, win-win, maintenance dredging, beneficial use.

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1. INTRODUCTION

Mersey Docks and Harbour Company (MDHC) is the statutory navigation authority for the Mersey estuary in north-west England. In this capacity, the authority carries out maintenance dredging of the Mersey approaches, the river entrances and the Liverpool and Birkenhead Docks. Up 1.5 million tonnes of sand and around 800,000 tonnes of clean silt (i.e. suitable for sea disposal) are dredged annually. Most of this material is disposed to 'Site Z' some 20km offshore in the southern part of Liverpool Bay. Much of the remainder it disposed at the Mid River disposal site near New Brighton at the seaward end of the Mersey Estuary (see Figure 1).

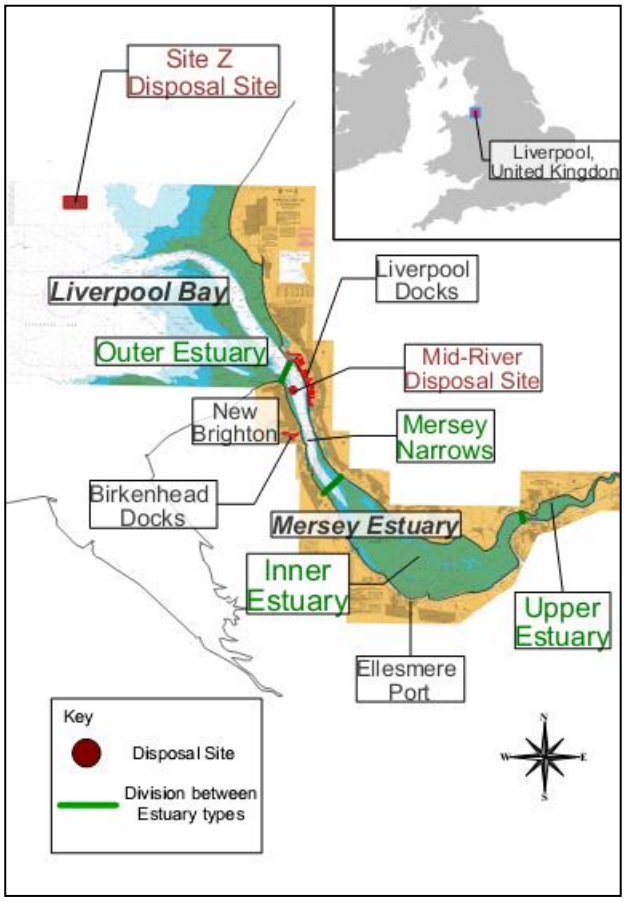

Figure 1. Location of Docks' dredging and disposal sites

Maintenance dredged material has been disposed to Site Z and to the Mid River site for many years with neither evidence of any adverse effects nor any concerns being expressed by stakeholders about the dredging and disposal operations. Notwithstanding this, in 2011 several factors combined to persuade MDHC to consider whether options might exist for the beneficial or alternative use for some or all of their maintenance dredged material. These factors include:

- the Environment Agency's 2006-2008 classification of ecological potential under the EU Water Framework Directive (WFD) identified that the 'sediment management' mitigation measure was 'not in place' for the Mersey transitional water body. The water body is designated as a heavily modified water body in part because of its use for navigation. MDHC as a statutory body must 'have regard to' the WFD river basin management plan. Therefore, whilst MDHC's maintenance dredging has been demonstrated (through application of the methodology set out in the Environment Agency's Clearing the Waters guidance (Environment Agency, 2012)) to be compliant with the requirements of the Directive (J. Brooke, 2010), there was nonetheless an incentive to investigate whether beneficial uses might exist for some or all of the maintenance dredged material;

- MDHC's Maintenance Dredge Protocol (MDP) baseline document (ABPmer, 2013), which was prepared to help demonstrate compliance with the EU Habitats Directive, has been signed off as being acceptable by Natural England (the statutory nature conservation agency for England). The associated Appropriate Assessment has been agreed by the Marine Management Organisation (the regulator responsible for licensing dredging and disposal activities). As part of the MDP approval process, however, Natural England had noted that they would welcome any initiative to retain sediment within the estuarine system. This provided a further incentive for the desk study;
- MDHC is aware not only of the cost implications of transporting material to a disposal site 20km away, but also of the associated emissions. If beneficial or alternative uses could be found for the sediment closer to the point of dredging, both costs and emissions might be reduced.

There were therefore also potential benefits to the port in taking forward a sediment management initiative. However, there were also concerns. As with most UK ports, MDHC's maintenance dredging is carried out under their own powers. There is no formal requirement for consultation, and decisions on these 'routine operational activities' have therefore tended to be regarded as an internal matter. That said, initiatives such as the preparation of the Maintenance Dredge Protocol baseline document had already introduced some level of external scrutiny through stakeholder engagement.

MDHC opted to take this initiative forward applying PIANC's Working with Nature philosophy. Whilst the Working with Nature philosophy was originally developed to be applied to new navigation infrastructure projects, it seemed to MDHC to provide a useful framework within which to explore possible beneficial uses for maintenance dredged material (that is, to consider dredged material as a resource rather than as a waste). Working with Nature was also attractive both as a way of demonstrating good practice and because the philosophy clearly emphasises identification of win-win solutions which meet the objectives of both the project promoter **and** environmental stakeholders.

However, MDHC also acknowledged that the application of the Working with Nature philosophy to a maintenance activity was previously 'untested'.

2. THE WORKING WITH NATURE PHILOSOPHY

2.1 Establish need and objectives

The first step in the Working with Nature philosophy (PIANC, 2011) is to establish the need and objectives of the 'project'. In this case, the objective of the study was to explore possible options for mutually beneficial or alternative uses of maintenance dredged material – with a proviso that these should be no more expensive than current practice unless additional funding from third parties was available. In undertaking this study, however, MDHC also:

(i) anticipated that the sediment management mitigation measure (identified in the WFD river basin management plan as being 'not in place' for the Mersey heavily modified water body) would be delivered;

(ii) intended that options aimed at retaining fine sediments within the natural estuarine system would be explored and evaluated; and

(iii) hoped that options might be identified which would reduce the carbon footprint of MDHC's maintenance dredging and disposal operations.

2.2 Understand the environment

The second step in Working with Nature is to understand the environment. The MDHC study was a voluntary initiative being undertaken in a situation where there are no known problems associated with the 'status quo'. Unlike a new navigation infrastructure project which may be undergoing a full Environmental Impact Assessment (with associated opportunities for data collection) very few extra resources were therefore available for new work. The relatively recent preparation of the Maintenance Dredge Protocol baseline document did, however, already provide a comprehensive insight into the natural system and the physical processes operating, and some further information was provided by stakeholders.

This review of the key environmental characteristics of the study area confirmed that:

- much of the study area is subject to national and/or international nature conservation designations (this is not uncommon in UK estuaries), and
- there is plenty of evidence demonstrating that, historically, the estuary has been an accreting system: however there are also some recent indications of a possible move towards an eroding system. This could potentially be of concern to those with nature conservation interests, but
- only a modest rise in sea level is currently projected to result from climate change (this is different to many estuaries on the East coast of England, where climate change is compounding the loss of protected intertidal habitat already threatened by coastal squeeze).

2.3 Engage stakeholders

Effective stakeholder engagement, the third element of the Working with Nature philosophy, was critical to the success of the desk study. Regulators, statutory and non-statutory environmental groups and local government representatives were invited to a series of meetings at the port. As explained above, maintenance dredging and disposal are established, ongoing operations in the estuary and its approaches and are carried out under the port's own powers. It was therefore important from the outset to ensure that the objectives of the study were made clear and that stakeholder expectations were managed. Some effort was put into explaining the objectives of the study and the limits on the investigation:

- the demonstrated lack of adverse impacts associated with the existing maintenance dredging and disposal regime;
- the opportunity to identify possible beneficial uses but the relative lack of resources for data collection; and
- the likely need for an adaptive management type approach to implementing any new options.

There were some initial challenges associated with adopting this new way of thinking, but an understanding was reached sufficiently early in the project for these not to become major issues. Once these differences were overcome, there was some very positive dialogue about potential win-win options.

2.4 Develop win-win solutions

The final step in the Working with Nature approach involves identifying and developing potentially viable, win-win solutions. For the sediment management study, this was achieved through the identification and evaluation of a long-list and then the more detailed assessment of a short-list of options. The subsequent process of developing potentially viable solutions is explained in the following sub-sections.

3. BENEFICIAL AND ALTERNATIVE USES OF MAINTENANANCE DREDGED MATERIAL DESK STUDY METHODOLOGY

At an early stage in the process, MDHC provided stakeholders with details about their existing maintenance dredging and disposal activities, including maintenance dredge material types, dredging and disposal methods, quantities and current disposal locations. A review of published (e.g. PIANC 2009a; 2009b) and grey literature was then undertaken to establish the range of potential options for beneficial or alternative uses, and to develop assessment criteria.

3.1 Long list of options

A stakeholder group comprising Natural England, the England and Wales Environment Agency, Royal Society for the Protection of Birds (a leading national NGO) and two local councils and their advisors was convened. MDHC worked with this group to prepare and evaluate an initial long-list of possible beneficial or alternative use options.

This long-list was categorised *inter alia* according to the objective of the possible use (environmental, engineering or both) and its location (terrestrial, intertidal, estuarine or offshore). Information was collated on the main potential benefits / opportunities and the main risks or constraints. The following criteria, to be used for a high level 'screening' assessment of likely viability, were also discussed and agreed:

- sediment size and silt content
- chemical characteristics including contaminants
- volumes (available and required)
- distance (from the dredging location to the potential use site, if known)

- seasonal or tidal constraints
- costs and benefits, and
- the regulatory regime.

A second stakeholder meeting provided an opportunity for MDHC to explain the assessment criteria for the long list of options and to set out a number of key principles. It also enabled stakeholder organisations to identify their main issues of concern. Some of the points clarified at the meeting were:

- to be viable, any option must be no more costly than the current maintenance dredging and disposal regime (unless third party funding is available)
- this is not a capital project: collaboration and cooperation will be vital
- the training walls which define and protect the approach channel to the Mersey Estuary are considered by MDHC to be a critical asset
- the existing disposal of maintenance dredge material to Site Z may have a role in supplying sediment to the Sefton frontage
- there is a known sediment divide at Formby Point: any initiative which leads directly or indirectly to the 'loss' of sediment to the north would be considered undesirable
- any option which promotes the retention of more fine sediment within the estuarine system would be welcomed
- a new marine licence will be needed for any new disposal or placement site.

3.2 Short list of options

Comments were received from stakeholders and a short-list of around a dozen viable options was prepared according to the following four headings:

1. Use of sand/coarse sediment to provide physical support to the approach channel training walls; these options would also be likely to enhance the supply of sediments to nearby sites of nature conservation importance in Liverpool Bay
2. Provision of sand for use in flood and erosion risk management projects including beach nourishment
3. Retention of fine sediments within the estuary to support intertidal habitat, for example by placing dredged silt in a location where natural processes would distribute the sediments within the estuary
4. Engineering uses, for example in reclamation or the ongoing provision of sand for the construction industry.

3.3 Taking forward potentially feasible beneficial use options

If dredged material is to be used in flood and erosion risk management initiatives such as those identified under Option 2 above, this work would need to be led by the relevant local authorities. The other three categories (1, 3 and 4) would likely be led by the port. However, during the preparation of the sediment management desk study report, it was announced that the development of the Liverpool 2 container terminal would be progressed. As some of the potential uses of maintenance dredged material identified under Options 1 and 4 could be equally relevant to the use of capital dredged material from the Liverpool 2 development, a decision was taken that the follow up to the desk study would focus on Option 3.

4. RETENTION OF FINE SEDIMENT WITHIN THE ESTUARINE SYSTEM

Placing a greater proportion of the fine sediments dredged from the Docks in a location where natural processes would then distribute it within the estuary was perceived as being of potential benefit from a nature conservation perspective for a number of reasons. These included:

- retaining material which has originated from the estuary within the estuary (rather than disposing of it offshore), thus avoiding exacerbating any shift from an accreting towards an eroding system
- maintaining the supply of sediment available to enable intertidal habitats in the Inner and Upper Estuary to continue accreting in the face of climate change-induced sea level rise (albeit that projections for the latter are relatively modest compared to those in the south east of the UK).

The desk study identified three options for beneficially retaining the fine sediments dredged from the Docks system within the estuarine system:

- additional deposit at the existing Mid River disposal site;

- additional deposit at the existing Middle Deep disposal site; or
- depositing material at a new disposal site, possibly further upstream.

A new site would require a marine licence - with associated costs for characterisation and investigations, and related uncertainties. Discussions with stakeholders confirmed that it was therefore preferable to start by exploring the viability of depositing additional material at the existing licensed sites. Both of the existing sites have the potential to realise the objective of retaining sediment within the natural estuarine system and both – particularly Mid River - are closer to the Docks than Site Z so transport costs and emissions could be reduced. Both options offer the possibility of a real win-win solution.

4.1 Mid River site

Sediment from the estuary enters the Docks via the two impounding pump stations and lock entrances. The Docks currently undergo a focussed dredging campaign three times per year with additional local dredging as required on an emergency basis. In recent years, typically around one-third of the total Docks' dredging has been deposited at the Mid River site (i.e. 160,000 – 260,000 tonnes per annum against a licensed provision for the site of 900,000 tonnes over three years). The option of increasing the proportion of dredged material deposited at this site was particularly appealing to MDHC because of its proximity to the Docks and hence the opportunity to save costs and to reduce the carbon footprint of their maintenance dredging activities.

Consultation with stakeholders had identified some specific sensitivities related to the increased use of the Mid River site. These did not appear insurmountable but – consistent with the application of the Working with Nature philosophy - MDHC were keen to develop an improved understanding of any risks before committing to any change in their existing maintenance dredging and disposal regime.

Information provided in the Maintenance Dredge Protocol baseline document (ABPmer, 2012) confirms that the Mersey is a dynamic estuary with a large tidal excursion (i.e. with the potential to transport sediment deposited at Mid River on the flood tide up into the Inner Estuary). Indeed the Mid River site has been used as a dispersive disposal site for many years without any concern being expressed about its use. The desk study report (J. Brooke, 2012) had, however, noted concerns about changes in patterns of sedimentation following the construction of the groynes along the New Brighton frontage, and questions had also been raised about changes in the seabed in the area used for small boat mooring off New Brighton beach.

MDHC therefore decided to undertake some additional work to help establish the fate of the dredged material deposited at the Mid River site. Tracer studies were preferred as offering an 'on-the-ground' opportunity to simulate the behaviour of silt deposited at the Mid River, specifically to determine whether silt sized particles showed any tendency to accumulate at certain defined sensitive locations. An existing computer model was also used with similar objectives to provide an alternative perspective to the tracer studies.

Depending on the outcomes of this work, MDHC would then propose to begin placing additional material at the Mid River site on the flood tide taking an adaptive management approach. Such an approach would need to be agreed with stakeholders but would likely involve ongoing monitoring at sites identified as being particularly sensitive. There would also need to be an agreed understanding that MDHC would revert to existing (i.e. pre-2013) disposal practices in the event that such monitoring identifies significant adverse effects.

5. TRACER STUDIES

Having obtained broad support from stakeholders for the principle of depositing a greater proportion of the fine maintenance dredged material at the Mid River disposal site, MDHC were keen to move forward with as much confidence as possible. The main concerns of stakeholders related to the potential for increased deposition and accumulation of fine sediments in areas identified as being particularly sensitive for the reasons discussed in Section 4.1 above. Thus it was the likely fate of the sediment rather than necessarily the transport pathways which needed to be determined. Following lengthy discussions about the variety of options available, it was decided to use tracer studies to help provide an indication of the likelihood of such accumulation. As an existing hydrodynamic model was already available, this was used to provide supplementary information. The modelling exercise is described in the following sub-section.

Tenders were sought for the tracer studies and further liaison with Natural England took place to determine exactly where samples should be recovered to ensure that the exercise would meet their needs as the statutory nature conservation body. A sampling regime was then devised taking into account the following:

- identified sensitive areas, not only the northern part of the nationally important Site of Special Scientific Interest (SSSI), but also the small boat mooring areas, and the Langton and Gladstone river entrances to the Liverpool Docks (see Figure 2);
- available understanding of the physical regime in the estuary, including 'reference' areas where it was known or suspected that fine sediments are already deposited: this included the New Brighton foreshore where there have been issues with the deposition of fine sediment since the construction of the groynes, and also selected upstream areas where it was apparent from previous coastal process studies and/or from geological/geochemical information that fine sediment should be deposited and/or accumulate.

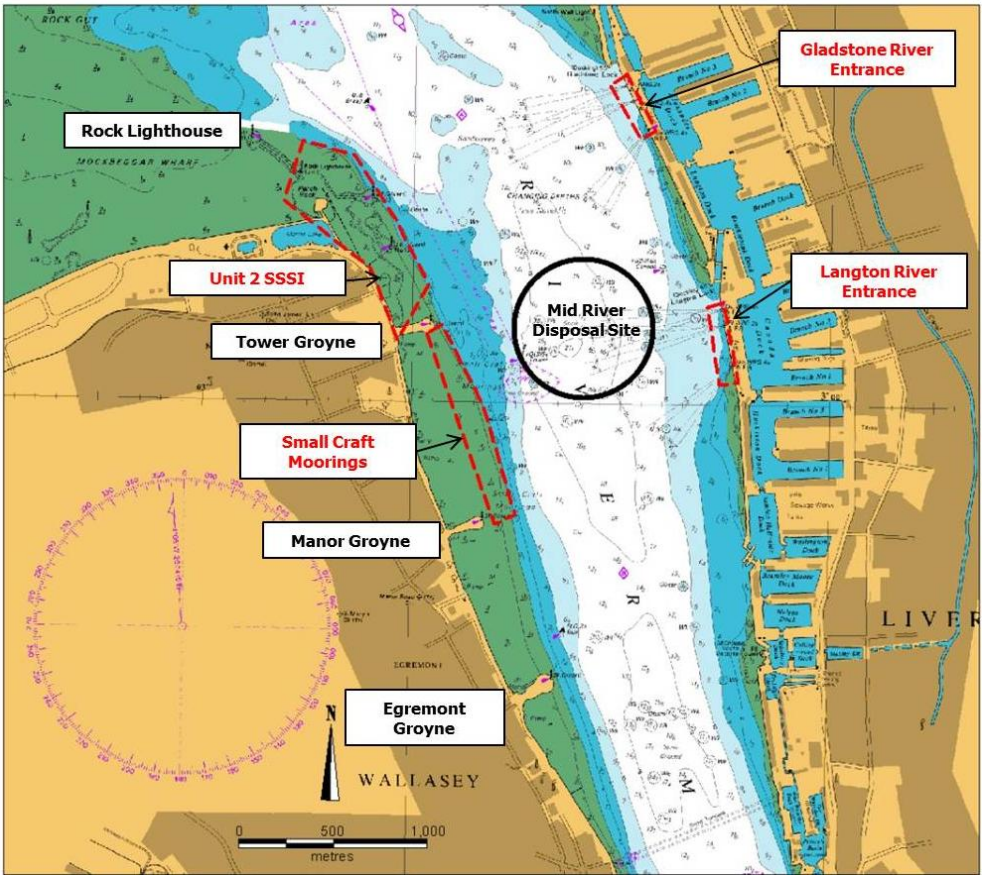

Figure 2. Location of sensitive areas sampled for evidence of tracer (source: ETS, 2013)

The contract for the work was let to ETS Ltd. Baseline samples were undertaken and some of the proposed sampling locations were modified as a result. On 26th September 2012, 100kg of fluorescent, Yellow, silt-sized tracer particles were released into a dredge hopper load and in turn into the estuary at the Mid River disposal site at the start of the flood tide. Thereafter, the contractors collected grab and core samples from the agreed sampling locations over a four-week period. Samples were collected by boat wherever practical. However, it was necessary (with the permission of Natural England) to access some of the sampling sites on foot in that part of the SSSI which was identified as being particularly sensitive. In the latter case, those carrying out the sampling specifically looked for and sampled areas of recently deposited mud.

Whereas weather conditions and tidal restrictions meant it was not always possible to collect samples at every site on every occasion, 295 samples in total were collected over five sampling events (days 0, 1, 7, 14 and 28 post-release) (ETS, 2013).

The Day 1 sampling clearly showed there was very wide and immediate dispersal of the fine material from the Mid River site, with (temporary) deposition being apparent both within the Mersey Narrows and the Inner Estuary. Positive results were detected in at least one sample in each of the sampling areas while dispersal was particularly evident along the western side of the estuary up towards the Manchester Ship Canal. From Day 1 onwards to Day 28, positive samples were recorded in most of the reference sites upstream of the release site with many samples indicating continued but local presence of tracer over time (ETS, 2013). Insofar as the sensitive sites were concerned, Yellow tracer particles were detected on Days 7 and 14 in the identified area of the SSSI but by Day 28 no positive samples were recorded. Similarly, whilst positive samples were recorded in the small craft mooring area on Day 7, no positive samples were recorded on Days 14 or 28. Sampling conditions and success varied significantly in the river entrances, highlighting not only the dynamic physical processes but maybe also the benefit of carrying out sampling at similar tidal states if this is practicable. Nonetheless, whilst Yellow tracer particles were identified in the river entrances on Day 1, no tracer was found thereafter. By way of an example, Figure 3 shows the Day 7 sampling results.

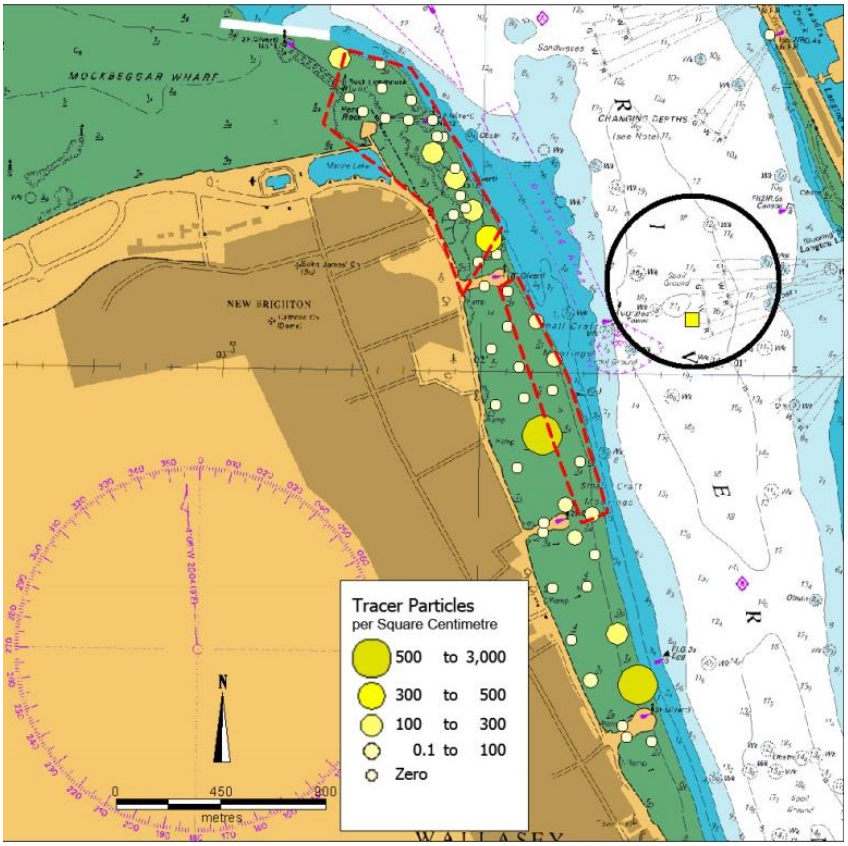

Figure 3. Example of results of tracer sampling: Day 7 (source: ETS, 2013)

As part of their investigations, ETS Ltd. carried out a mass budget calculation to estimate the proportions of silt-sized particles that are transported and deposited within specified areas as a proportion of the total number of particles released. This was done knowing that the specific objectives of the study (i.e. sampling targeted at specific locations rather than trying to establish the fate of all the material deposited a Mid River) effectively precluded accounting for 100% of the tracer. Nonetheless, based on a generalised calculation of the total areas of the Mersey Narrows and Inner Estuary and the average tracer concentration for each location, ETS were able to

account for between 30% and 80% of the tracer throughout the study. The mass budget analysis overall confirmed that the largest percentage of tracer particles were accounted for at sampling sites in the Inner Estuary such as Devils Bank and adjacent to Ellesmere Port rather than in areas closer to the disposal site. In the vicinity of the Mid River site, the mass budget calculations suggested any impacts would be minimal and short term.

Finally, the sampling identified some marked variations in the presence and content of silt in certain locations, confirming the dynamic nature of the estuary and the mobility of the material. Silt was observed to be transitory at many locations, both on a daily basis and over the spring-neap cycle. This confirmed that the material deposited at the Mid River site is likely to be dispersed widely in the estuary, quickly returning to become part of the natural sediment budget.

6. HYDRODYNAMIC MODELLING

In addition to commissioning the tracers studies, MDHC contracted ABPmer to provide an indication, through numerical modelling and expert opinion, of the extent to which material deposited at the Mid River site might be expected to accumulate at prescribed sensitive sites. The study used an existing calibrated and validated Delft3D hydrodynamic model of the Mersey Estuary, coupled with the particle tracking module for plume dispersion to simulate the dispersion of suspended sediment inputs. The resolution of the model mesh varies but is greatest in the areas of primary interest to the MDHC study (i.e. the SSSI and the vicinity of the small boat moorings).

Numerical modelling was undertaken to simulate a period of 20 days following the release of sediment at the Mid River site at the start of the spring flood tide on 26th September (i.e. the same date and time as the release of the tracer particles in the study described above). The model assumed a two-phase dispersion: the dynamic phase as sediment is released from the dredger and the passive phase where the movement of fine particles in a plume is controlled by current velocities. Some of the subsequent assessment points for the model were selected by MDHC to represent the sensitive and reference locations discussed above; others were selected by ABPmer.

The results of the modelling are presented in a report to MDHC as suspended sediment concentrations and as sedimentation results. The former confirms that the strong tidal flows through the Narrows initially carry the sediment up-estuary. The sediment plume continues to move up-estuary on the flood tide until high water slack whereupon there is potential for the material to settle to the bed. Following high water, both the sediment still suspended in the water column and that re-suspended from the bed are transported seaward on the ebb tide. ABPmer's report (2013) differentiates, for example, between the movement of the sediment released near the bed and that released to the water column but concludes that over time, there is a general movement of sediment back and forth both in and out of the Mersey and along the estuary, with the extent determined by the tidal excursion.

As the sediment is dispersed across the Mersey, modelled sedimentation takes place in low energy areas and increases in suspended sediment concentrations decay rapidly until they become indiscernible from normal levels. Across the sensitive areas, concentrations are no greater than 5mg/l above normal (when sediment is remobilised during the flood), and typically less than 2mg/l on average. During the larger spring tides, the modelling indicates that some sediment is transported higher up the intertidal where it remains over the smaller (neap) tides.

As a result of the single load modelled, sedimentation rates across the Mersey Estuary are concluded to be indiscernible from natural conditions. To put this into a wider context, however, ABPmer also considered the likely implications of disposing, at the Mid River site, of 100% of the fine material dredged from the Docks over the period of a year. This highlighted that, taking a currently hypothetical situation where all the fine material dredged from the Docks over a year is placed at the Mid River site, sedimentation rates across the New Brighton frontage and within Unit 2 of the SSSI would be considerably less than 1mm per annum. This is further considered to be a 'worst case' scenario as it assumes the sediment is not remobilised. Increases in sedimentation rates elsewhere in the Inner Estuary – for example in the Garston Channel - are predicted to be less than 2mm per annum.

The ABPmer report concludes that sedimentation rates of this magnitude are insignificant given the natural variations within the estuary.

7. COMPARING THE TRACER STUDIES AND THE MODELLING OUTCOMES

The purpose of both these investigations was to determine whether depositing a higher proportion of the fine material dredged from the Docks system, at the Mid River site on the flood tide was likely to result in unacceptable levels of accumulation at a number of defined sensitive locations. The conclusions of the tracer studies and the modelling are reassuringly consistent.

Both pieces of work concluded that the sediment deposited at the Mid River site disperses quickly and widely within the estuary (where background levels of suspended solids are already high: 20-450 mg/l at the surface and 70-1500 mg/l near the bed). Both pieces of work similarly concluded that increases in sedimentation rates in the sensitive areas are negligible. Whereas the tracer studies did identify some of the Yellow particles in the sensitive areas in the days immediately following the release, repeat sampling suggested both that the particles remained somewhat mobile and that tracer concentrations reduced over the period of the study to the point where no tracer particles were identified in the area noted by Natural England as being of particular concern. This is consistent with the results of the modelling.

Both investigations also concluded that relatively more sedimentation would be expected to occur upstream in the Inner Estuary than in the vicinity of the Mid River site; and both highlighted that silt-sized sediments are transitory (or are prone to frequent remobilisation), particularly in the Narrows where tidal streams are greater.

The ABPmer study further concluded that increases in sedimentation rates resulting from the disposal of 100% of the silt-sized sediment arising from the Docks' maintenance dredging at the Mid River site over the period of a year, would be indiscernible from those occurring naturally. Although ETS did not explicitly consider the implications of such disposal, nothing in their report seems to contradict this conclusion.

8. ONGOING ROLE OF STAKEHOLDERS

Following MDHC's receipt of the consultants' reports on the tracer studies and hydrodynamic modelling, a further meeting was held with stakeholders where the results of these investigations were presented. Given the small scale of the predicted changes, there was a consensus that conventional monitoring methods would neither be appropriate nor cost-effective. Rather, it was agreed that those stakeholder groups who already carry out regular surveys of the sensitive areas (e.g. bird counts, coastal defence inspections) would undertake a 'watching brief', asking their established surveyors to make additional visual inspections to identify any new (i.e. atypical), persistent and significant accumulations of fine sediment.

Future meetings of the sediment management stakeholder group will provide an opportunity to discuss any such evidence and, if appropriate, to determine whether action is required.

9. CONCLUSIONS

Applying the Working with Nature philosophy to identify possible beneficial or alternative use options for MDHC's maintenance dredged material has worked well. Adjusting to a different way of thinking was not without initial challenges on all sides, but the outcome to date has been a positive and constructive dialogue with stakeholders which has been appreciated by all parties. Several potentially viable possibilities have been identified, with the option of depositing more material at existing dispersive sites within estuary being preferred in the immediate term.

Since the completion of the sediment management study in 2012, MDHC has therefore focussed on taking forward the disposal of a greater proportion of fine dredged sediment from the Docks system at the existing Mid River disposal site. Amongst other benefits, this would:

- save costs and carbon when compared to the existing disposal regime
- retain sediment (which in fact came from the estuary) within the natural system, in turn reducing the possibility that maintenance dredging might exacerbate a shift towards an eroding system
- maintain the supply of sediment available to supply intertidal habitats in the face of projected sea level rise.

Tracer study and hydrodynamic modelling investigations were therefore undertaken to determine whether depositing a higher proportion of the fine material dredged from the Dock system, at the Mid River site on the flood tide, was likely to result in unacceptable levels of accumulation at a number of defined sensitive locations. The conclusions of the tracer studies and the modelling are reassuringly similar. Both highlight the transitory nature of silt-sized sediment and the tendency for such material to move upstream into the Inner Estuary rather than being retained in the Narrows; and both confirm that significant accumulations of sediment in sensitive area are very unlikely.

Given that the Mid River site has been operational as a dispersive dredged material disposal site for many years without any evidence of unacceptable consequences, these findings are not entirely surprising. However from MDHC's point of view, it is not only the individual outcomes but also the consistency between them that is important. The similarities between the tracer study results and those of the modelling - together with the corroboration both these investigations provide with the previously largely anecdotal understanding of the fate of material placed at Mid River – give MDHC much greater confidence in taking forward an adaptive management approach to the increased use of the site.

Inviting stakeholder engagement in routine port activities and operations can be challenging, but in this case adopting the Working with Nature philosophy has proved very useful in identifying a potential option for the disposal of maintenance dredged material which not only supports nature but may also lead to significant savings in both cost and carbon. The port has agreed to implement the changes using an 'adaptive management' approach; stakeholders have agreed to contribute to the low-level monitoring which has been agreed as being appropriate.

The story is not yet finished, but a 'win-win' solution seems to be a real possibility.

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