Harwich Haven Authority, Dredging with Nature™ using the Tiamat

Introduction

Ongoing siltation is common in dredged channels and berths at ports around the world. The siltation is often a result of natural suspended sediment being deposited in the artificially deepened area where current speeds are lower. Over time, the deposited sediment builds up, resulting in a reduction in depth in the dredged areas which can pose a risk to shipping. Therefore, to ensure safe navigation it is necessary for sediment management activities to be undertaken to remove sediment which has been deposited and could potentially pose a safety risk.

The Port of Felixstowe located on the east coast of England is the UK's largest container port. The approach channel and berths of the Port are subject to high ongoing sedimentation, with on average between 2 million and 3 million m^3 of sediment requiring management each year. The deposited sediment is made up of around 85-90% silt and clay with the remainder being sand and gravel. The sedimentation is focused within the confluence of the Stour and Orwell Estuaries at a location known as Harwich Harbour (Figure 1). Harwich Haven Authority (Authority) is the port authority for the Port of Felixstowe and is responsible for maintaining depths required for safe navigation.

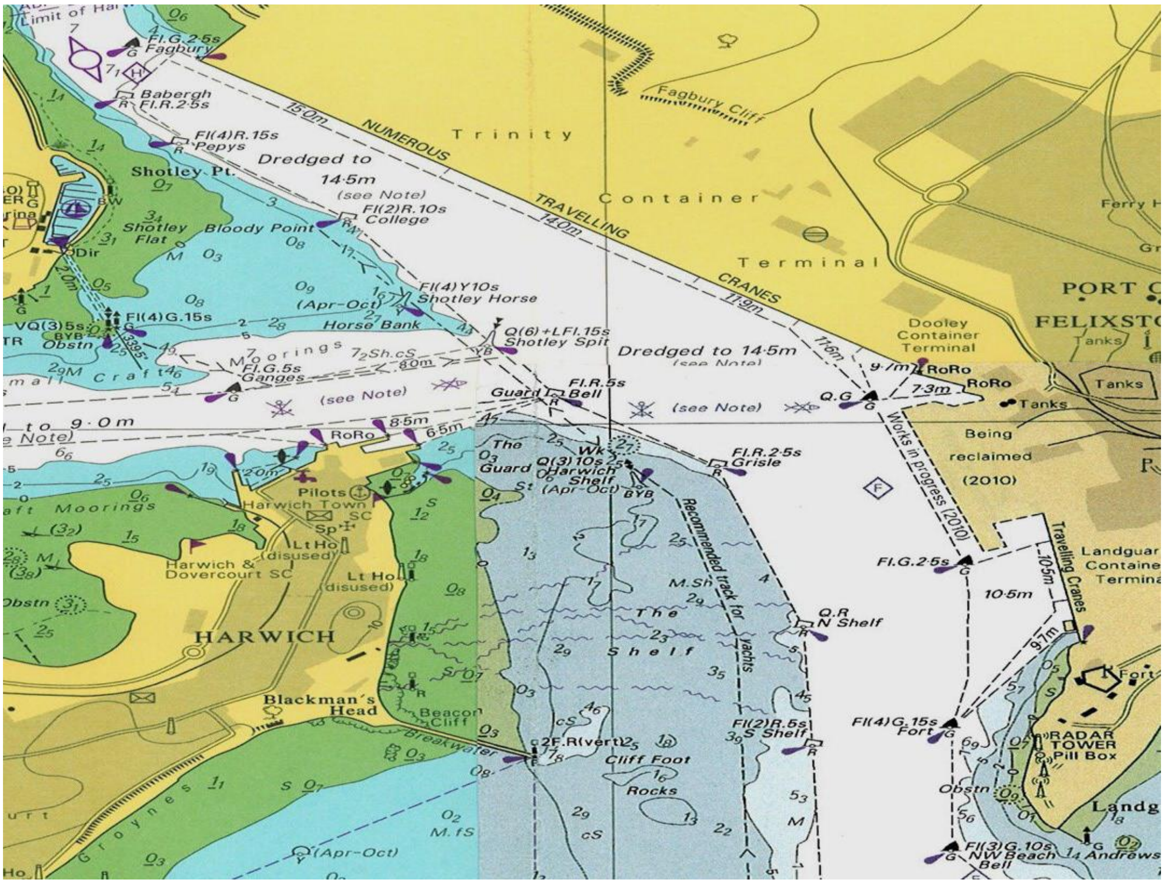


Figure 1. Areas where regular sedimentation occurs and dredging is required in Harwich Harbour

Sediment Management

The most common approach to manage ongoing sedimentation in a port is maintenance dredging. There are numerous different types of dredgers with Trailer Suction Hopper Dredgers (TSHDs), Cutter Suction Dredgers (CSDs) and Backhoe dredgers (BHDs) being the most commonly adopted for maintenance dredging.

The selection of the dredger type is dependent on multiple aspects including the sediment type, volume requiring dredging, accessibility, and depth, but regardless of dredging type they all involve removing the deposited sediment from the seabed and relocating it elsewhere.

The sediment is typically relocated to a designated offshore placement site which is located away from the dredged areas to ensure the sediment isn't subsequently redeposited into the dredged areas. The removal of sediment deposited in artificially deepened channels and berths from the local sediment system by dredging and offshore placement can result in long-term impacts from depletion of sediment in the system (Spearman et al, 2014; Gailani et al, 2019).

Historically, sediment management at Harwich Harbour has been primarily undertaken using a TSHD. While slowly navigating around the areas requiring dredging, the dredger lowers its draghead(s) onto the seabed and uses pumps to suck a slurry of seabed sediment and seawater into a hopper on the dredger.

The vessel then sails to a licensed offshore disposal site, which is located 20 km from the Port, where the sediment in the hopper is placed by opening the hopper doors.

A plough is also used in combination with the TSHD in the berths to move the deposited sediment to areas where the TSHD can more easily access it.

As the annual maintenance dredging volume of up to about 3 million m3, combined with the distance to the disposal site has meant that both the greenhouse gas emissions and the cost of using a TSHD are high.

The Problem

With the Authority aiming to achieve net zero by 2035 it needed to reduce the environmental impact of its operations and with maintenance dredging costs of 20 to 25% of its annual revenue there were multiple potential benefits from considering alternative dredging approaches.

The Authority tested alternative dredging approaches to assist in managing its maintenance dredging volume which did not require such a large dredge vessel, and which did not require to repeatedly sail to and from the offshore placement site. One alternative is using a Water Injection Dredger (WID), but this approach was discounted as it would just form a cloud of lighter material that quickly become reconsolidated; in addition, due to the deep flat seabed and effective density current would not be created in the areas that are required to be dredged.

The Solution - Tiamat

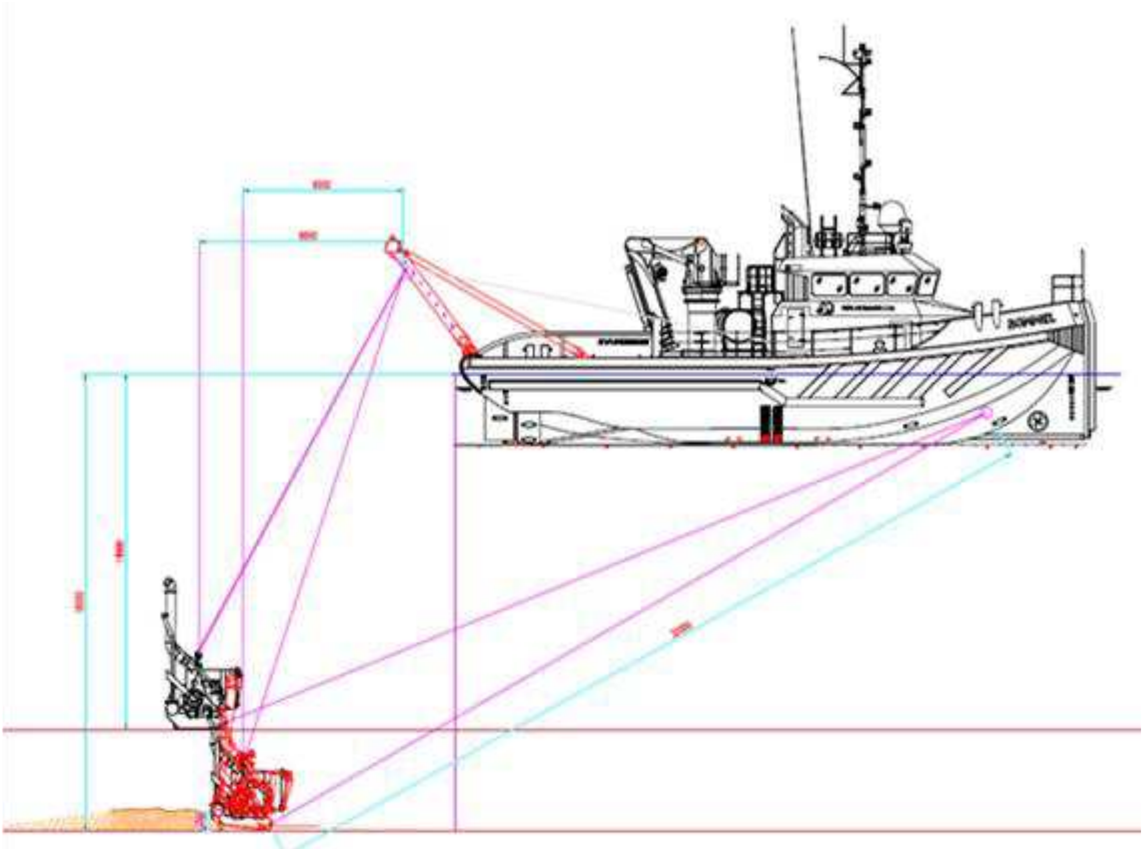
The Authority was not able to identify any viable existing alternative approaches and so they developed a new type of agitation dredging which adopts aspects of multiple other dredging approaches. The approach was based on the assumption that the dredged sediment did not need to be relocated to an offshore placement site and instead could be suspended into the water column to allow tidal currents to naturally transport it away from the dredged areas.

This approach was deemed to be "Dredging with Nature"™ as it utilises dredging to replicate the processes which naturally would occur whereby sediment deposited during slack water would be resuspended as currents increase during the flood and ebb stages of the tide.

Designs for this new type of dredger were developed and the device, called the Tiamat, was subsequently built by a Dutch specialist contractor, Maarten Van Oord.

It was designed so that it could be towed behind a relatively small vessel such as a 25 to 27 m workboat or multi-cat with an A frame.

The principle behind the Tiamat is to dilute the silt/clay on the seabed using low pressure water, similar to a WID, and then a suction pump is used to pump the diluted silt/clay up a pipe where it is released into the water column above the natural bed level where tidal currents are higher than those at the bed.



Tiamat has the following benefits compared to dredging using a TSHD:

- no requirement to dispose of the sediment offshore which could significantly reduce the greenhouse gas emissions by reducing the need for TSHDs;
- keeping sediment within the local sediment system, reducing the need for beneficial placements and a deficit of sediment in the adjacent estuaries;
- a reduction in cost; and
- as the Tiamat is self-contained and does not need a specialist dredging vessel, the use of a small workboat/multi-cat would enable the Authority to use Hydrated Vegetable Oil (HvO) that has significantly lower GHG emissions than traditional Marine Gas Oil

Tiamat - Trials

A series of four trials were undertaken in 2020 and 2021 to test the new dredging approach. Extensive monitoring which included monitoring the sediment density, bathymetry and water quality was undertaken during the trials to better understand the following:

- what speed the workboat was able to operate at when towing the Tiamat and based on this how effective was the approach at covering larger spatial areas;
- how effective the Tiamat is in removing sediment from the dredged areas of the port and whether the dredged sediment is subsequently redeposited back into the dredged areas;
- what production rates are possible using the Tiamat and how these relate to production rates using a TSHD; and
- whether there are any environmental impacts resulting from the approach either due to increased turbidity from the suspended sediment released into the water column or due to increased sedimentation from deposition of the suspended sediment.

Testing during the trials found that the workboat could steam at 2 to 3 knots when the Tiamat was operating.

This speed is comparable to the speed that a TSHD steams when dredging and as the width of the Tiamat is slightly larger than a TSHD drag head (8 m compared to up to 4 m for a small to medium TSHD) the Tiamat covered a slightly larger spatial area as a small to medium TSHD, with all areas of Harwich Harbour where sedimentation occurred covered multiple times over a four-week campaign.

Although the dredge pumps on the Tiamat are smaller than on a TSHD, the Tiamat can dredge continuously while a TSHD needs to stop dredging to sail to and from the offshore placement site to dispose of the sediment.

During the trials the Tiamat was typically operating continuously for 12 hours a day, while TSHDs undertaking maintenance dredging at Harwich Harbour will operate continuously 24 hours a day but will spend around 80 to 85% of the time sailing to and from the offshore disposal site and the remaining 15 to 20% of the time dredging (i.e., around 4 hours of dredging per day).

The high sedimentation which occurs in Harwich Harbour results in a layer of fluid mud forming on top of more consolidated layers of silt and clay.

As a result of the presence of fluid mud, a combination of volumetric changes of bathymetry and changes in thickness of different bed density layers has been used to calculate the mass of sediment removed from the seabed during the trials.

Figure 2. Sideview of the Tiamat on the surface at the stern of a workboat.

Tiamat - Productivity

Based on this approach the Tiamat, when operating for 12 hours per day, has been estimated to have had an average production rate of 9,800 tonnes dry solids/day (TDS/day), which equates to an in-situ volume change of 23,500 m^3/day (HR Wallingford, Spearman and Benson 2022).

In comparison, TSHDs undertaking maintenance dredging at the Port, when operating for 24 hours a day (without overflowing), have been estimated to have production rates of between 25,000 and 40,000 m^3/day depending on the size of the dredger (rates are for hopper sizes of 4,500 to 7,500 m^3). Based on this, when operating for 12 hours per day, the Tiamat has a comparable daily production rate as a 4,500 m^3 TSHD operating 24 hours a day and just over 60% of the production rate of a 7,500 m^3 TSHD operating for 24 hours a day.

Tiamat - Cost Savings

Using the production rates detailed above along with vessel costs from recent Tiamat trials and TSHD dredge campaigns the relative cost of dredging using the Tiamat compared to a TSHD per cubic metre of sediment has been calculated. The cost of using the Tiamat is £0.33/m^3, while the cost of using the 7,500 m^3 TSHD is about £2-3/m^3. Although these costs will vary over time and between different dredge vessels, this shows that the cost of the Tiamat is approximately a third of the cost of the TSHD for removing a cubic metre of sediment from the seabed.

Tiamat - Greenhouse Gas Emissions

The predicted comparative GHG emissions associated with two dredging approaches over a representative 24-hour dredging period are detailed in Table 2.

The results show that the predicted daily GHG emissions are just over five times larger when dredging is undertaken using the TSHD of about 5K cubic metres compared to the Shoalbuster 2709 towing the Tiamat.

The reason that the difference between the two is not larger is partially because the TSHD Medway is only spending 16% of the time dredging every 24 hours (which utilises the dredge pumps as well as the vessel power), while the Tiamat is spending 50% of the time dredging every 24 hours.

If the emissions are normalised based on the dredge production rates of the two approaches (40,000 m^3/day for a 5K cubic metre TSHD and 23,500 m^3/day for the Tiamat) then the Tiamat GHG emissions are approximately one third of the GHG emissions from the TSHD per cubic metre of sediment dredged.

Table 2. Predicted GHG emissions from the sediment management approaches considered.

Approach	Scope 1 CO_2e Emissions over 24 hours (Tonnes)
TSHD (5K cubic metre)	50
Shoalbuster + Tiamat	9

The Authority have advised that in the future they could adopt Hydrotreated Vegetable Oil (HVO) as fuel for the vessel towing the Tiamat and for the Tiamat pumps.

Research by Volvo Penta has shown that the use of HVO 100 fuel can reduce GHG emissions of CO_2 by up to 90%[1].

In addition, studies by the Port of London Authority have shown that the CO_2 emitted during combustion of the fuel can be deemed to have been offset by the absorption of CO_2 during the growth of the biomass which forms the biofuel[2].

Based on these findings the actual GHG emissions associated with the use of the Tiamat could be reduced to 1 t/day, which when normalised based on production rates would be 30 times lower than the emissions associated with the TSHD Medway.

In addition, the emissions could potentially be offset due to the absorption of CO_2 during the growth of the biomass which forms the fuel.

[1] https://www.volvopenta.com/about-us/news-page/2022/jun/volvo-penta-case-study-on-hvo-fuel-in-all-demo-and-test-boats/
[2] https://pla.co.uk/Environment/Alternative-Energy/Emissions-and-Performance-of-Alternative-Diesel-Fuels-on-PLA-Harbour-Service-Vessel-Kew

Tiamat – Turbidity and Dispersion

As the Tiamat is constantly pumping sediment from the seabed into the water column a potential concern relating to the approach was whether the suspended sediment would be directly deposited back into the dredged areas of the Port.

Bathymetric surveys undertaken during and after the trials did not show significant deposition, indicating that the tidal currents transported most of the suspended sediment away from the dredge areas as intended.

The trials were also used to monitor potential environmental impacts from the new agitation dredging approach using the Tiamat. Specific concerns were raised by regulators associated with the Tiamat dredging compared to dredging using a TSHD.

These were related to potential impacts associated with the plume generated by the dredger and the potential for increased deposition to occur at adjacent mudflats which could suffocate benthic fauna. Results from the monitoring showed the following:

- a high suspended sediment concentration (SSC) plume occurred immediately behind the Tiamat. The plume was found to rapidly disperse across the harbour and was shown to only be a localised effect.
- The plume from the Tiamat was rarely visible at the surface while the plume from a TSHD is typically visible at the surface which indicates that the turbidity created by the Tiamat is less than that created by a TSHD; and the before and after surveys of the mudflat height were carried out at multiple sites close to the harbour using a ground radar system.
- At all sites the before and after results were almost identical, with erosion and accretion of up to a few millimeters observed.
- The results therefore suggest that the Tiamat has not resulted in high rates of deposition occurring at mudflats close to where the dredging was undertaken, which is expected to be comparable to dredging with a TSHD.
- This agrees with numerical modelling results presented by Spearman and Benson (2022) which predicted that some of the sediment suspended by the Tiamat would be deposited along mudflats in the adjacent Stour and Orwell estuaries and would result in a growth of mudflats in these areas (0.6 ha/yr above mean low water assuming five campaigns a year, each with a duration of four weeks).

Future Plans

The environmental impact assessment presented to the UK regulators following the trials has now been agreed by those organisations. and as a result, HHA now plans to introduce the Tiamat into regular use to maintain depths in the Port of Felixstowe. Although the Tiamat has been found to be effective at removing silt and clay it is not less able to remove sand and so TSHD campaigns will still be required to prevent a build-up of sand sized sediment on the seabed. Moving forward it is planned that a combination of campaigns using the Tiamat and a TSHD will be undertaken each year by the Authority to maintain depths at the Port. At this stage it is estimated that two campaigns of around 10 days in duration will be undertaken by a TSHD each year, and four campaigns of up to a month in duration will be undertaken by the Tiamat each year. Without the Tiamat in operation HHA have typically undertaken between four and six TSHD campaigns of approximately 10 days each per year, depending on the natural siltation rates. It is expected that the use of the Tiamat will result in a cost saving of between 30 and 50% for the Authority.

Suitability Elsewhere

The Tiamat is in the process of becoming commercially available.

The suitability of Tiamat depends on the dredging problem that needs to be solved. To disperse sediment, the ideal location to be dredged would be predominantly silt and clay and for there to be relatively strong tidal currents (> 0.5 m/s) to ensure that the suspended sediment is transported away from the dredged areas.

Where the issue is the navigability of the sediment, then tidal range is less important as Tiamat is excellent in reducing the sheer strength of silt and mud.

Due to the ability to adapt the size and power of Tiamat it can also be used in locations where conventional dredging methods are either too expensive or in accessible, such as reservoirs, canals, and small waterway. Here the Tiamat can help to keep the sediment in suspension for longer periods and deposited in the estuarine system if required.

Each location would have to be assessed to determine the best way that Tiamat can value to the dredging strategy and maintenance dredging protocol. The power and permission to dredge and disposal will vary from country and location and therefore the process for using Tiamat may vary. Therefore, it is important that the necessary environmental and regulatory organisations are engaged when assessing the suitability of using Tiamat and Dredging with Nature.

References

Spearman, J., and Benson, T., 2022. Evolution of nature-based dredging solutions at Harwich, UK. World Dredging Congress and Exhibition 2022. May 2022.

Titan, 2020. Maintenance Dredge Trial Monitoring, Dredge Monitoring Survey: VMADCP and water sample Survey on Spring and Neap tides, Project CS0589, December 2020.