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DREDGING - HOW CAN WE MANAGE IT TO MINIMISE IMPACTS

J. C. Savioli [1], M. Magalhaes [2], C. Pedersen [3], J Van Rijmenant[4], M. A. Oliver[5], C. J. Fen [6] and C. Rocha [7]

ABSTRACT: Sediment plumes generated by dredging can impact sensitive receptors at significant distances from the work area. Potential impacts would normally be identified and quantified through the Environmental Impact Assessment (EIA) prior to project implementation. The EIA may also include a degree of project optimization to reduce impacts. There are, however, usually significant uncertainties in predicting the potential impacts at the EIA stage. Key components of the dredging programme such as the dredge methodology, dredge schedule, sediment spill sources and climatic conditions encountered during dredging may not be well defined, and this will typically be reflected in the accuracy of the predictions and potentially also in the choice of mitigation measures.

Proactive and informed management of the dredging programme as it is executed can often significantly reduce the risk of or minimise the negative impacts. By better understanding which components of a given programme are critical in terms of potential impacts, the programme can be optimised to minimise the risks. Through modelling and monitoring during execution, impacts may be predicted before being realized, and the dredging programme may be optimized to achieve the environmental objectives while maintaining desired production rates. An Example is presented describing a combination of monitoring, both of the dredge plume and at receptor sites, and dredge plume modeling to guide the dredging works.

Keywords: Dredging, Environmental Management and Monitoring, Sediment Spill Control.

INTRODUCTION

The increasing requirement for economic growth has derived in the need to modify the natural environment to accommodate developments than can contribute to this growth. One of the areas where development has been more significant is in coastal areas that constitute just a small percentage of the total global land; rapid development in these areas has meant increased construction of coastal infrastructure, such as urban developments, ports/marinas, airports, oil&gas pipelines and support facilities, power plants, tourist facilities, etc.

Dredging works are usually required for this type of projects, but dredging without proper management can lead to irreversible impacts in highly sensitive environments, especially near coral reef areas and other similar sensitive environments. The key impacts of dredging and port construction near coral reefs are related to (PIANC 108, 2010):

- Loss of coral reef can be caused by the removal or burial of reefs
- Spill of fine sediments during dredging operations induce elevated turbidity and sedimentation rates that can lead to lethal or sub-lethal stress to corals or other sensitive receptors
- Long-term changes in flushing and/or erosion/sedimentation patters due to current flow changes
- Impacts may be intermediate or long term and may be temporary or permanent in nature

However, if properly managed dredging works, can:

- Produce no irreversible or minimum impacts on sensitive receptors
- Produce minimal temporary impacts (transient impacts to fishing grounds, aquaculture, coral reefs and/or tourist areas)
- Minimize risks of real or perceived impacts that could lead to stoppages of the dredging works

ENVIRONMENTAL IMPACT ASSESSMENT

Before works are carried out it is common practice that an environmental impact assessment is undertaken to determine potential impacts and define mitigation measures that usually includes detailed hydraulic

[1] Head of Department DHI Water & Environment (M) Sdn Bhd. Email: jcs@dhi.com.my
[2] Vale Malaysia Minerals Sdn Bhd
[3] Technical Director. DHI Water & Environment (M) Sdn Bhd. Email: clp@dhi.com.my
[4] Environmental Engineer, Jan De Nul Email jelle.vanrijmenant@jandenul.com
[5] Managing Director. DHI Water & Environment (M) Sdn Bhd. Email: mao@dhi.com.my
[6] Hydraulic Modeller. DHI Water & Environment (M) Sdn Bhd. Email: cjf@dhi.com.my
[7] Senior Coastal Engineer. DHI Water & Environment (M) Sdn Bhd. Email: cbr@dhi.com.my

modelling. Key potential impacts addressed in an EIA are:

- **Permanent Impacts:** induced by the proposed structures/works on currents, water levels, waves, sediment transport, water quality, shoreline evolution in the area and nearby, etc. These impacts will last as long as the structures/works are in place.
- **Temporary Impacts**: Occur during construction (dredging) works. The extent and potential impacts of sediment plumes generated during the dredging works are determined by the type of dredger, dredging methodology, type of sediments and flow conditions during dredging works. These impacts are usually limited to the duration of the dredging works, however if not managed properly could lead to permanent impacts.

The assessment of the temporary impacts is usually based on a number of assumptions that include: type of dredger, dredging cycle (including dredging travel and disposal times), daily production rates, sediment characteristics, and seasonal current flows. These assumptions are based on best available information, but at the EIA stage most of these are uncertain. Some key uncertainties include:

- Exact dredging methodology and production rates (exact equipment will only be known when contractor has been appointed and planned the work in detail)
- Timing of the works, both in terms of starting and duration of works.
- Sediment properties in dredging spill[8] – there will be variable soil conditions and the settling properties of the sediment suspended in a passive plume in the water column as a result of dredging will only be exactly known after commencement of dredging.
- The current flows and climatic conditions are variable and data is usually not available to provide a complete picture of their variability and seasonality.
- The spill rates will depend on production rates, geotechnical and climatic conditions.
- Use of overflow environmental device (enviro valve), and characteristics of the dredger

To account for these uncertainties, a level of "conservatism" is usually applied in the modelling works, however it is not possible to assure that impacts will not take place at sensitive receptors due to the nature of the uncertainties.

Recognizing the uncertainties and not least the variable conditions at site, it is good practice to manage the dredging works based on actual observations during dredging to ensure that that no unforeseen impacts are realized and that dredging works are carried out with minimal disruptions.

ENVIRONMENTAL FEEDBACK MONITORING AND MANAGEMENT OF DREDGING WORKS

Ensuring that no or minimal adverse impacts are caused by dredging works requires a careful assessment of the dredging works and stresses induced on the sensitive receptors to guide the works.

Historically, dredging works have been managed in a static manner based monitoring works and compliance to single trigger values, with threshold values defined as the values not to be exceeded. This approach is quite common where developers appreciate a need to place environmental constraints . This approach has many limitations due to the limited available spatial and temporal information.

To address the limitations of static monitoring, adaptive management strategies have been developed specifically aimed at addressing the problems of a static monitoring approach to environmental management. It consists of four elements, 1. Implementation of the project and collection of baseline information, 2. Monitoring including measurements and modelling works, 3. Evaluation of data and results and 4. Adaptation. The adaptation includes not only the re-assessment of the implemented dredging strategy but also the evaluation of the objective target values that are usually quite uncertain. In this way it is possible to adapt the works to the conditions at the site minimizing impacts on sensitive receptors while optimizing the dredging works.

The adaptive monitoring is targeted to evaluate conditions at the environmentally sensitive receptors and provides a response to relevant trigger values. The adaptive management process can be proactive or reactive, the former is preferred as the best practice approach to managing and minimizing impacts from dredging and port construction around sensitive areas especially where corals are present.

The proactive approach is usually defined in an environmental feedback monitoring and management plan. This is usually based on:

[8] The fraction of sediment that is released into the environment by the dredging operations and that remains in suspension long enough to be displaced beyond the immediate project area.

- Spill budget [9]control which is used to form a first level control of potential impacts
- Results from online instrumentation (at relevant areas) are used as indirect indicators of potential health of the sensitive receptors (e.g. corals) based on tolerance limits
- Predictive numerical models are used extensively to hindcast/forecast the location of the plumes from the construction operations and for providing a detailed temporal and spatial picture of potential impacts, filling the gaps between monitoring stations and allowing a segregation of the impacts arising from the dredging activities.
- The tolerance limits are updated based on monitoring data at sensitive receptor areas. This is the so-called feedback loop. This is carried out only if the project duration is long enough to allow this evaluation as receptors reaction to impacts may require time to become noticeable and if the dredging period is short it will not allow for re-assessment of these values.

The spill budget is the first level of control set as the limit on sediment spill to ensure that set tolerance limits are not exceeded. The spill budget is typically expressed through a set of numbers at different dredge locations and potentially for different climatic conditions. This usually goes hand in hand with other mitigation measures that are included in the feedback monitoring such as:

- Reducing as much as practical the amount of sediment introduced into the water column as a passive plume for a given dredge operation. This can be achieved by using green valve technology and ensuring that well maintained equipment is used avoiding unintentional leaks
- Careful management of the dredge plume to direct it away from sensitive receptors. This is done through planning and working carefully with the current conditions to ensure that dredging with overflow in critical areas is only carried out when currents will carry the dredge plume away from sensitive receptors.

It should be noted that physical measures to control sediment spill such as silt curtains can be used, however their efficiency is largely dependent on the environmental conditions at the site (mainly current speed, water depth and wave heights).

[9] The maximum amount of daily spill which ensures compliance with the imposed environmental protection objectives.

EXAMPLE – DREDGING WORKS AT TELUK RUBIAH, LUMUT, MALAYSIA.

An environmental feedback monitoring and management plan was applied in Malaysia for the dredging works at the proposed iron ore terminal proposed by Vale Malaysia Minerals Sdn Bhd at Teluk Rubiah, Perak. The project includes the development of an iron ore distributing centre at Teluk Rubiah in Perak. This development will include a jetty which will be receiving shipments of iron ore from Brazil and exporting blended iron ore as well as pellets, and a dredged channel for access to the jetty. The project includes the following key components:

- An on-shore iron ore stock pile area
- A piled jetty extending 1.8 km offshore for iron ore import and export. Designed for iron ore import vessels of up to 400,000 DWT that require a navigation channel
- A material handling quay extending 300 m offshore
- A navigation channel dredged to access the jetty. This is dredged to -25 mCD hand has a maximum depth of approximately 6 m below the natural seabed

An overview of the project is presented in the figure below.

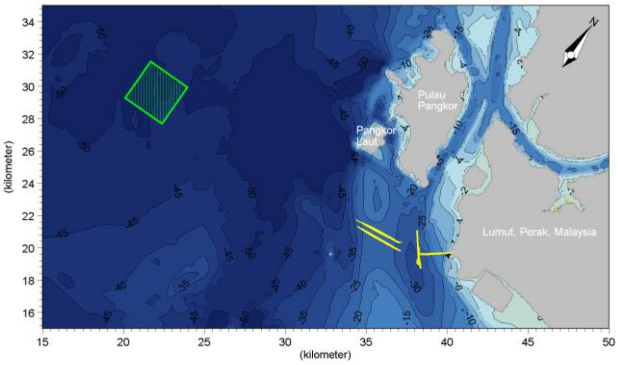

Fig. 1 Overview of the project area, including disposal site (left green area).

Environmental Conditions at the Site

The effectiveness of different mitigation measures depends very much on the hydrodynamic conditions at the site. It is critical to adopt mitigation options that are practicable and effective for the local conditions to ensure that they will get effectively implemented and achieve the objectives in terms of minimizing any impacts. Flow conditions are briefly outlined below as background for further discussions on mitigation options.

Detailed hydrodynamic modelling was undertaken to produce a detailed map of the current flows at the site in both time and space. The model was based on MIKE 21 HD that was calibrated and verified against measured data at the site.

Overall modelling showed a relative strong tidally dominated, semi-diurnal current field which flows at an angle of approximately 45 degrees to the channel.

Although the tidal currents dominate, much weaker net currents generated by wind and pressure fields can be very important in carrying the dredge plume away from the source. The tidal currents are cyclic, and will tend to carry the plume forth and back. A weak overlaying net current generated by regional wind and pressure fields may carry the plume further away from the origin.

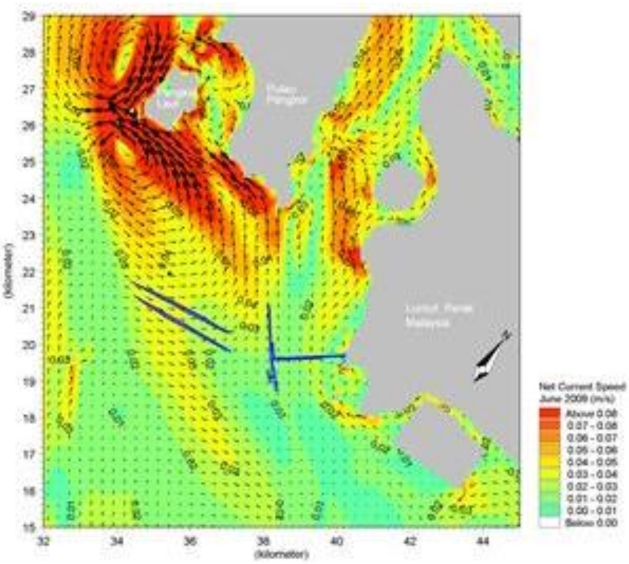

Fig. 2 Predicted net currents

The net current directions at the site have been predicted and are shown in Fig 2. As it can be observed they are relatively complex as they are not only controlled by the general net current flow in the Strait of Malacca (which in turn is even affected by the monsoon generated setup in the South China Sea and resulting net flow through the Singapore Strait), but also by eddy formations and current reversals along the coast of Malaysia to the north of Klang. Long term (years) of current measurements have not been available to obtain a clear picture of seasonality in the net currents. This emphasizes the need to carefully manage the dredge plume during implementation.

Feedback Monitoring Programme

A feedback monitoring programme was implemented to minimize impacts during dredging work with following environmental management objectives:

- No reversible impacts to primary benthic producer habitats or other environmental receptors e.g. no mortalities to corals and <u>destruction of coral reefs</u>
- Minimize impacts during dredging works
- Minimize risks of real or perceived impacts that could lead to stoppages of dredging

The following key environmental receptors were identified in the area during the EIA

- Coral reefs north of the dredging area
- Tourist resorts
- Aquaculture installations
- Fishing grounds

Monitoring Approach

A combined approach was applied at the Teluk Rubiah site to carefully manage the spill during dredging to ensure that set tolerances for environmental receptors were not exceeded. This was achieved through a spill control and feedback monitoring with the following processes:

1. Apply a spill budget approach
2. Continuous monitoring and modelling based on MIKE 21 MT (mud transport model) through the dredge period to ensure that
    a. The spill budget is adhered to
    b. The sediment transport model to describe the transport of the sediment spill is applied to evaluate the location of the sediment plume both in space and time. The model is revalidated against measured data to ensure that the predictions are as accurate as possible.
    c. The environmental objectives are met
3. Adoption of mitigation measures if required to achieve the environmental objectives

Dredging Spill Limit

The spill limit was re-assessed before the start of dredging works. This was done based on more detailed information provided by the dredging contractor and a value was defined as a starting spill limit during the dredging period that occurred during the NE monsoon. Adjustments to this spill limit value would be re-assessed during the dredging period as part of the adaptive management programme.

Plume Monitoring & Management

A comprehensive monitoring campaign was implemented that included:

- Monitoring of overflow to calculate the spill
- Hindcast modelling of all dredging operations based on actual dredging records.

This provides a detailed image of the sediment plume both in space and time

- Daily water sampling at fixed stations
- Online ADCP measurements at two locations to derive TSS levels and current flow conditions
- Current and TSS transects at three stages of the project to produce details of the spatial extent of the sediment plume for model calibration

Trigger levels

Three trigger levels were defined for the project. A first level was when a daily “spike” exceedance occurs, the second level was based on the analysis of 3-day running average values and level three based on 7 or 14 day running average values. The level 1 is unlikely to cause any impacts and no immediate action is required, however these events are analyzed to avoid any further issues. For level 2 cases the exceedance has to be investigated based on results from the monitoring and modelling works and mitigation measures have to be implemented to ensure that levels are brought back under the limit. Level 3 indicates a long term violation of the trigger values and immediate actions are required. The trigger levels were defined at the start of the feedback monitoring programme for:

- Sediment spill. The three levels were defined based on duration as a daily spike, 3-day running average exceeds the spill limit and 14-day running average exceeds the spill limit
- Modelling. Three levels were also defined based on duration e.g. excess of TSS > 5mg/l for more than 10% of the time for daily, 3-day and 14-day running periods
- Monitored data. Measured data does not distinguish between background and dredged derived concentrations, but they are important to verify the models and effects that are not resolved by the model are not missed out at the sensitive receptors. The trigger levels defined based on the type of receptor and the conditions at the site “clear” and “turbid water based on baseline data with different trigger values. These values are assessed on a daily, 3-day and 7 day running period.

Analysis

The dredging works were monitored continuously and based on daily records of the dredging works. This information was provided by the dredging contractor and included location of the dredger in time and operational status (dredging, travel time, disposal, etc.) that together with overflow sampling was used to carry out modelling works.

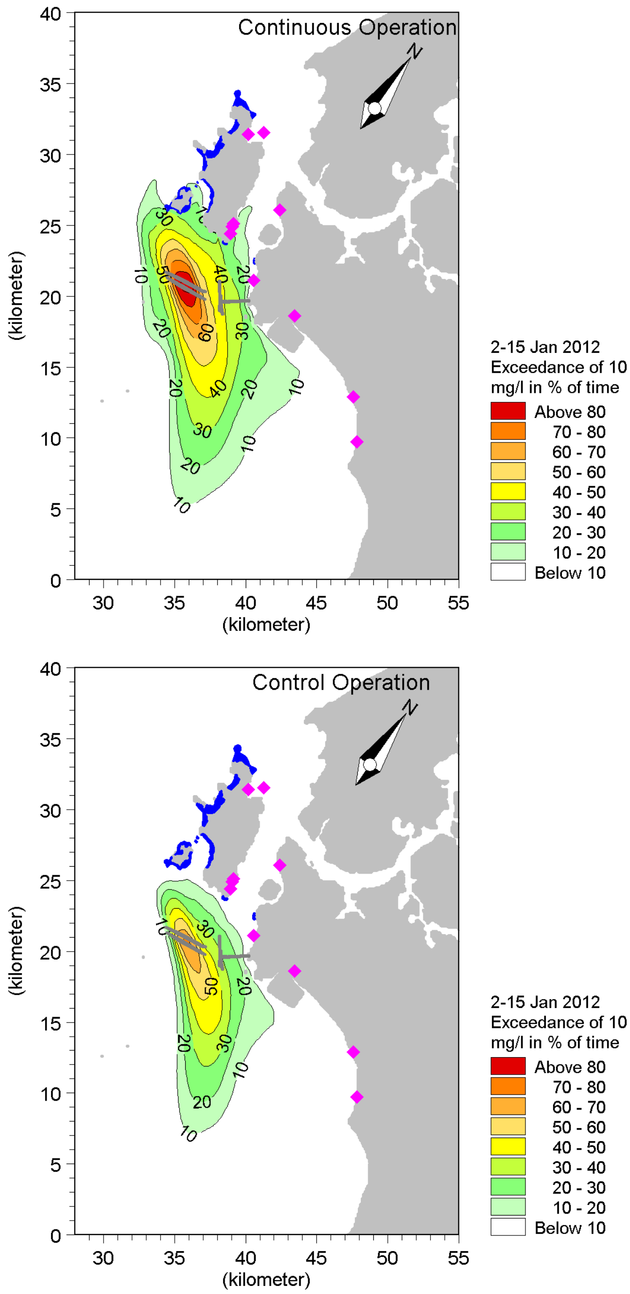

Fig. 3 Predicted TSS 10 mg/l level exceedence for continuous (above) and control (below) dredging operations.

This information, in conjunction with the daily spill records, daily monitoring data at sensitive receptors and the online TSS measurements provided a detailed picture, both in space and time, of the on-site conditions. Based on this information the environmental team evaluated the conditions on daily basis to determine if any violation occurred and, if necessary, defined mitigation measures.

A close interaction between the dredging contractor and environmental team took place which allowed for discussion of the best approaches in order to minimize impacts, especially on the northern area where the most sensitive receptors are placed. One of the mitigation actions implemented was that of dredging with overflow when currents were southward, in this way the generated sediment plume would be directed southward, away from the most sensitive receptors. A comparison of dredging works with controlled and no controlled spill is shown below in Fig 3. As it can be observed by control operation the TSS levels are reduced in the sensitive areas.

Another implemented mitigation measure was to concentrate the overflow along the outer offshore dredging areas so that the plume moves away from the sensitive receptors, this was only practical at the initial stages of the project when the dredging area included the overall channel, however at later stages when the dredging had to focus on particular sectors of the channel this option was not viable.

During the dredging works the communication between the dredging contractor and the environmental team was extremely important as mitigation measures had to take into consideration operational conditions of the dredging works. In particular conditions increase in short term dredging was necessary and this was closely followed, mainly at the sensitive receptors areas based both on monitoring data and modelling results.

The modelling works were extremely important in the analysis as it provided a link between dredging works and monitoring data, in one case an exceedance was observed at one particular station and the hindcast modelling confirmed that this was caused by the dredging due to a combination of high spill rates and overflowing for one of the trips at the eastern end of the channel just during flow reversal. This was discussed with the dredging contractor and corrective measured were taken to reduce TSS levels at the sensitive receptor area.

Governance, Compliance Monitoring and Reporting

Compliance monitoring and reporting for the feedback monitoring was carried out to confirm that the works were meeting the quality objectives. An environmental monitoring and management team was established to follow the works; this team produced a daily report that was submitted to the contractor and other parties and a summary report was produced every 14 days setting out details of the monitoring programme; this report was issued to Authorities.

Meetings were organized regularly to discuss the evolution of the project and also visits to the dredger, these visits included different stakeholders as the Department of Environment, The Department of Irrigation and Drainage and others. The main idea of the reports and meetings was to present a clear status of the situation and the approach applied in the study.

CONCLUSIONS

The implementation of an environmental feedback monitoring programme can be very beneficial during dredging operations as it provides a detailed assessment of the dredging works and the possible impact on sensitive receptors. This allows for optimization of the dredging works while minimizing impacts on the receptors and also ensures the authorities that the works are in compliance with what was proposed during the EIA.

It also minimizes risk due to uncertainties in the EIA stage as the EMP will be able to deal with the specific conditions during the dredging works such as: type of dredger, dredging method, type of dredged material and climatic conditions.

The application of this methodology in the Teluk Rubiah project has proven to be highly successful as it allowed to handle the uncertainties of the assumptions made at early stages of the project and produce accurate prediction that enable the environmental team and the dredging contractor to manage the dredging works with minimal impacts. It also allowed producing documentation of the temporary impacts that was used to address claims. It has to be mentioned that dialogue between the environmental team, dredging contractor and Authorities has been vital in order to achieve a successful outcome.

ACKNOWLEDGEMENTS

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