Silt curtains - a review of their role in dredging projects

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Abstract

As environmental mitigation associated with dredging and marine construction activities becomes ever more a focus of attention, the use of silt curtains to contain fine material locally to the dredging operation has increased. A silt curtain is typically simple in design, comprising of a geo-textile sheet attached to floats that are weighed down to the sea floor and anchored in place. The expected result is to prevent the transport of sediment out of the work site and into the surrounding environment. However, few documents exist that consolidate the current understanding of the use of curtains and the controlling factors associated with the deployment of them, including consideration of their purpose, design, development and limitations.

A cynic's view is that silt curtains are often installed to comply with regulatory constraints and may offer limited practical value, especially when they are left unmaintained. Poor understanding of silt curtain design and limitations often means they are installed in unsuitable environments, resulting in unsatisfactory performance. Critically, once a curtain is installed; without good management and regular maintenance, the geo-textile will often perish leading to a significant reduction in its effectiveness. Different installation methods exist along with multiple configurations; consideration of the environmental conditions should be made prior to the design and installation of a silt curtain. This paper will consider a range of parameters that affect the effectiveness of silt curtains.

Keywords

Silt curtain, Environment, Geo-textile, Dredging and reclamation

1. Introduction

This paper will systematically review the key theoretical and practical aspects relating to silt curtains, principally covering their primary function and main components. The main focus of the paper is to review the best practice for those situations where a curtain could be used as an environmental mitigation measure, the corresponding deployment methodology and what type of issues could arise. The review will be supported by case studies from HR Wallingford's experience with silt curtains, along with other published literature.

The environmental conditions combined with inherent operational, installation and design considerations significantly influence the efficiency of a curtain. The paper will further consider the use of silt curtains in the context of their 'efficiency' and how 'efficiency' can be defined.

The principle behind the use of silt curtains is simple, it is "*to enclose or contain turbid water*" (USACE, 1997). The reason for their use is typically associated with dredging activities or other engineering construction activities occurring close to water where fine grained sediment may be introduced to the water column.

2. An overview of silt curtains

Silt curtains are vertical barriers positioned within the water to contain fine material (sediment) introduced into the water column by dredging or other engineering construction activities. A definition of a silt curtain is "*A floating geotextile material which minimizes sediment transport from a disturbed area adjacent to or within a body of water*" (USACE, 1997).

2.1. Purpose of a silt curtain and who uses a silt curtain

The principal purpose of a silt curtain is to provide a barrier from the water's surface to the required depth; in most cases this will be the seabed, but in deeper waters this may not be possible. This barrier aims to prevent the fine grained suspended material from migrating by advection and diffusion from the point of generation at the work site and into the wider environment. This fine grained material may reduce water quality and impact upon sensitive receivers in the vicinity of the work site area. Sensitive receivers in this context may be ecology that is sensitive to light attenuation and / or sediment deposition, for example mangroves, corals, sea grass and cockles.

Some regard silt curtains as primarily an aesthetic measure with limited practical value. In some instances the use of silt curtains does result in appreciable visual differences between low turbidity 'background' water on one side of a curtain and turbid water generated by dredging on the other. These very distinct visual differences may truly reflect a significant reduction in turbidity via the use of the curtain or the difference between inside and outside the curtain may be very limited when the whole of the water column is considered, particularly if the curtain does not extend all the way to the seabed or it is poorly maintained.

2.2. History of development

Early developments of silt curtains came about following the recognition of the need to control turbidity caused by dredging, disposal and road construction operations (USACE, 1978). Historically, silt curtains comprised of basic structures formed from tarpaulin or untreated canvas sailcloth staked into the seabed using wooden poles to provide support, with floatation achieved by using logs, lobster floats or barrels. Whilst in some cases turbidity levels may have been initially reduced, early curtains supported marine growth and rapidly deteriorated or became plugged with silt and sank. Early curtains were also often either damaged or destroyed by wave action and storms.

Designs have advanced significantly in recent times, generally assisted by advances in oil boom design (USACE, 1978) such that they now comprise of complex anchor-buoy systems utilising the latest materials technology. Screen material originally consisted of untreated canvas sailcloth, polyethylene or vinyl plastic, this has now been replaced by fabric with a woven nylon base and a flexible PVC coating to reduce the tendency for tear and abrasion. Floatation and ballast were heat-sealed or sewn into the material rather than being attached with grommets in the curtain. The poles and stakes that were used to hold the curtain in place have now been replaced by anchors.

2.3. Schematic of designs

2.3.1. Typical surface buoyancy set-up

There are principally two types of surface buoyancy set-up, each producing different curtain formations. Firstly, a 'frame set-up', which fully encloses the working area; this is often used around Mechanical Dredgers working in a static location. With this set-up the silt curtain is mounted to a string of barges or pontoons to produce an enclosed area directly connected to the dredger's pontoon as shown for a Backhoe Dredger in Figure 1. These designs can be considered an adaptation of the typical configuration in an effort to make silt curtains compatible to both the required operational work and environmental mitigation measures.

Figure 1: Photograph of an enclosed framed silt curtain

Source: Land & Water, 2011

The second is the customary silt curtain set-up, which typically covers larger areas, such as the boundaries of reclamation areas (AECOM, 2009). With this set-up, floats keep the curtain buoyant at the surface of the water, whilst ballast maintains the vertical position of the curtain. Depending on the United States Army Corp. Engineers (USACE) class of curtain (USACE, 1997), anchors may be used to increase support. Figure 2 shows the typical components for a silt curtain designed to float at the water's surface.

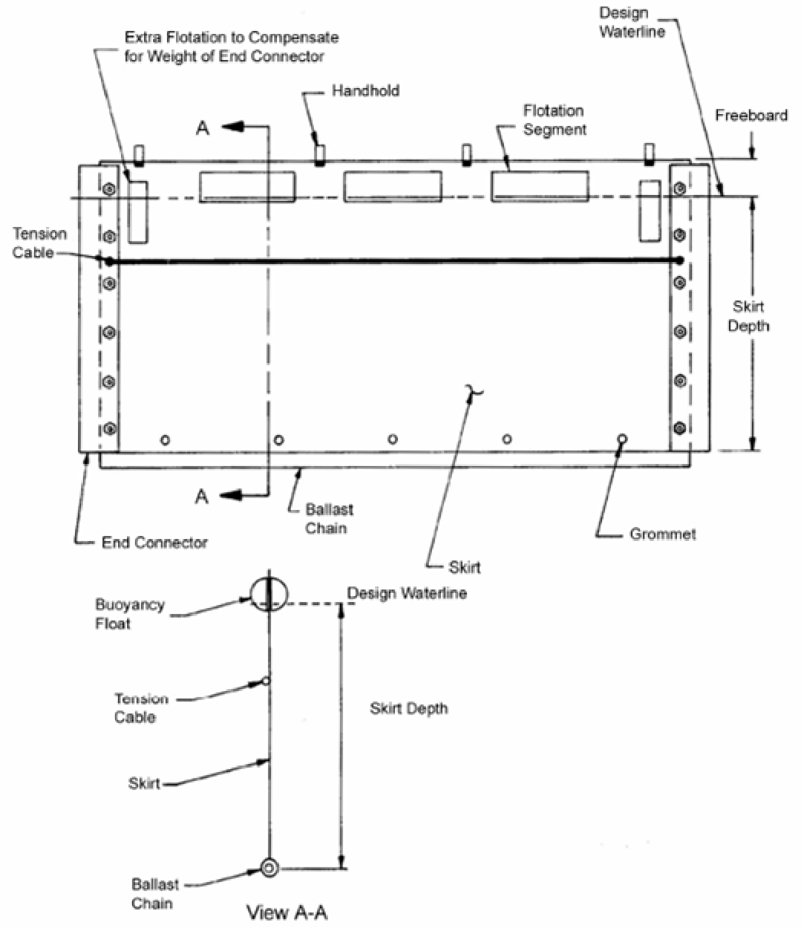

Figure 2: Schematic diagram of a typical silt curtain design outlining the key components and a cross section view

Source: taken from DOER, 2005 & USACE, 1997

2.3.2. Existing silt curtain classification systems and grades (USACE, 1997)

A silt curtain classification system was outlined in 1997 by the USACE. Silt curtains were classified into the following three types, according to the prevailing hydrodynamic and metocean conditions.

- Type I – (Light weight) this is designed for use in lower energy environments where there are no currents and the deployment location is sheltered from any wind and waves.
- Type II – (Medium weight) are suited to sites where there is only a small to moderate current of up to about 1 m/s. Wind and wave action can be present but not considered major force.
- Type III – (Heavy duty) is for sites with higher energy environments, with currents in excess of 1.5 m/s. Curtains can be deployed in a tidal region and be subject to wind and wave action.

Figure 3 shows schematic diagrams of the USACE (1997) classification types.

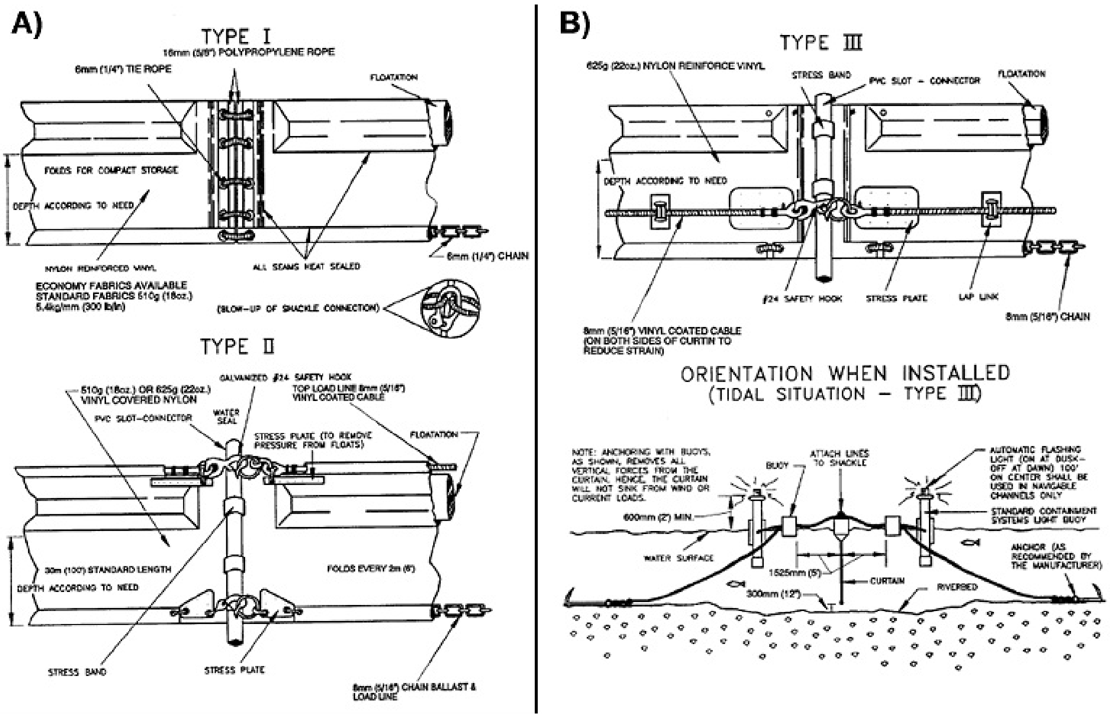

Figure 3: (A) Schematic diagrams taken from the USACE Classification of Type I and Type II silt curtains; (B) schematic diagrams taken from the USACE Classification for Type III silt curtains, displaying the installation layout for a tidal situation

Source: USACE, 1997

2.4. Components and Manufacturing

A silt curtain is typically comprised of 6 elements, these are described as follows.

- Screen (or Skirt) – can be woven, non-woven and knitted in construction with compositions varying between polyester, polypropylene fabric and geo-textile. The type of material and construction provide a range in weight from around 270 g/m^2 to >700 g/m^2 (ABBCo, 2008). The screen can be single or double layered.
- Floatation system – float diameter ranges between 0.1 m and 0.3 m depending on the type of screen being supported. The floats are held in position by an impermeable PVC sleeve which can vary in quality depending on the class of silt screen and cost associated with construction of the curtains.
- Anchoring – this keeps the curtain in position. This is a very important component of a silt curtain and if done incorrectly can cause major issues relating to effectiveness (USACE, 1978). Further detail is provided in Section 2.4.1.
- Ballast – comprises typically of steel or galvanised chain ranging in size depending on the design and class of the silt curtain. A typical chain thickness is 6 mm.
- Connection cable (or Tension member) – is not always present in all the classes or designs and is used to reduce the stress on the connection between each section.
- Connectors – designed to allow the sections of curtain to be joined together whilst preventing any leakage between them. For Type I a polypropylene rope or lace is used, for Types II and III there are a variety of different connectors available.

2.4.1. Anchoring and Mooring

Anchoring is a very important consideration relating to the use of silt curtains, if done incorrectly it can reduce the effectiveness of the structure. Anchoring and mooring systems are especially critical in situations where tides and / or waves are present causing vertical movement. It has been stated that "*Under no circumstances should the curtain be directly attached to pilings or poles driven into the bottom*" (USACE, 1978). Different types of anchors can be used to secure the curtain into position ranging in weight between 4.5 kg and 45 kg (USACE, 1978 & Granite Environmental, 2012). Figure 4 shows a simple schematic of a typical anchor system set-up.

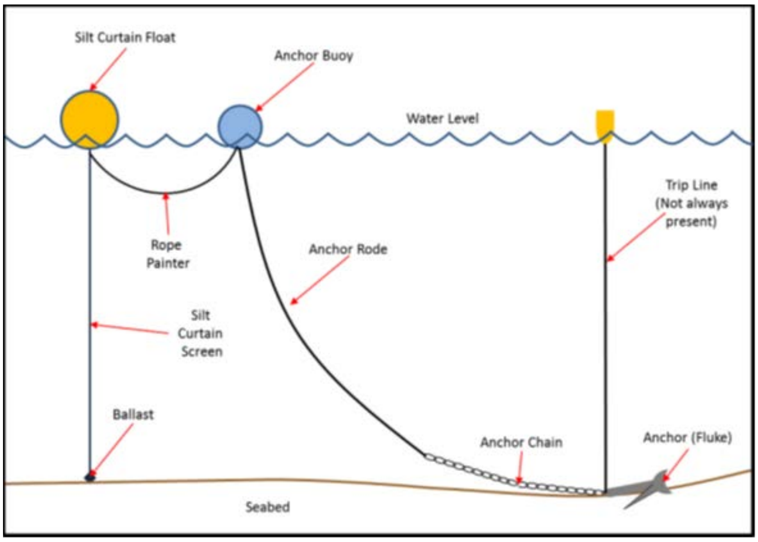

Figure 4: A schematic of a typical anchor installation

Source: after Granite Environmental, 2012

Mooring is an important component for a curtain for closing off the site to minimise the amount of material dispersion. The recommended mooring arrangement (USACE, 1978) is shown in Figure 5.

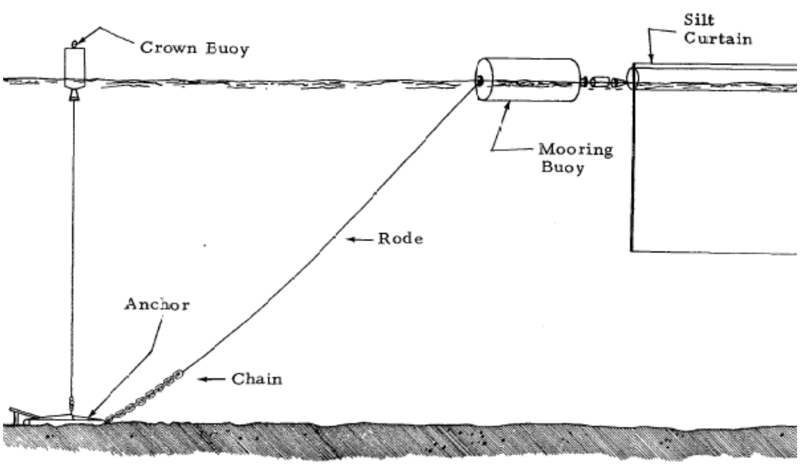

Figure 5: The recommended mooring system according to the USACE

Source: USACE, 1978

3. Situations in which silt curtains may be used

3.1. Environmental Mitigation

The primary purpose of a silt curtain is to contain or enclose turbid water. By doing this, a curtain should limit the transport of fine material towards a site where increased turbidity is undesirable, these sites may include:

- ecologically sensitive habitats, such as sea-grass meadows, corals, mangrove forests and shellfish beds;
- other sensitive areas, such as sites with socio-economic benefits; and
- water intakes used for desalination or cooling water.

The sites that are most commonly protected by silt curtains typically occur across the globe in temperate and warm water climates. They tend to be shallow water coastal environments: this is often where important habitats exist, where important infrastructure such as intakes occur and where development is sought.

3.2. Distribution of use

The generation of increased turbidity from dredging and near-shore civil engineering works can occur at any location throughout the world. However, the use of silt curtains as a mitigation measure appears not to be as universal. This is likely to be due to two main factors: the suitability of the environment for the deployment of silt curtains); and the legislative requirements or regulatory preferences in different locations.

Silt curtains are suited to shallow water environments, with water depths typically less than 10m and are generally only deployed to provide protection to the sensitive receivers identified above. There are environments where such receptors are present but the prevailing environmental conditions are not suited to the deployment of a silt curtain.

In addition to the physical conditions controlling the deployment of silt curtains, are the requirements to comply with local or national legislation or regulation. For example, the US Environmental Protect Agency has a preference for the use of curtains as a means of pollution control when dredging contaminated sediments. The requirements and specification for silt curtains also exists at State level (NY DEC, 2012 & AI, 2012). The use of curtains is also prevalent in SE Asia, with Regulators in Singapore stipulating the requirement for use in their Guideline documents (PUB, 2012).

Consideration should also be given to the operational requirements (navigation and access) around the dredging, when assessing the viability of the use of a silt curtain.

Therefore, when assessing the viability of using a silt curtain there are a number of considerations, the principal ones being:

- the presence or absence of sensitive receptors;
- the suitability of the location for the use of a silt screen given the local hydrodynamic, metocean and operational characteristics; and
- regulatory preferences and requirements.

4. Silt curtain operation

4.1. Influence of hydrodynamics

In the context of this paper 'hydrodynamics' consider the combined effects of flow and waves on the silt curtain. It is integral to the success of a curtain that the hydrodynamic loads are understood. These loads are the forces applied to the moorings and structure of the curtain resulting from inherent or applied buoyancy, weight and drag from currents and waves. During the design stage estimates of these hydrodynamic loads and a level of redundancy should be considered. The importance of this is demonstrated in Figure 6, which shows schematically the relationship between load and flow speed for typical shallow and deep draft silt curtains.

The Figure demonstrates that under a uniform perpendicular flow field that for a 10 fold increase in current speed the loading on a screen can increase by 40 fold. Consideration of this theory provides context to the US EPA recommendation (U.S. Environmental Protection Agency, 1994 & DOER, 2005) that:

"*As a generalisation, silt curtains and screens are most effective in relatively shallow quiescent water. As the water depth increases and turbulence caused by currents and waves increase it becomes increasingly difficult to effectively isolate the dredge operation from the ambient water. The St. Lawrence Centre (1993) advises against the use of silt curtains in water deeper than 6.5m or in currents greater than 0.5m/s.*"

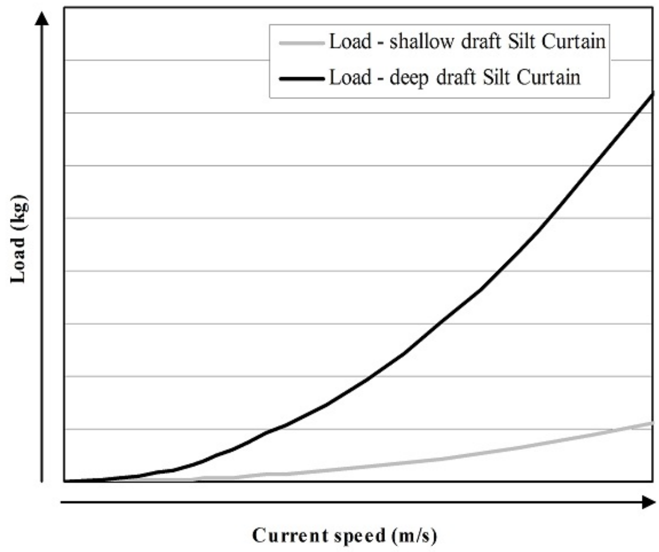

Figure 6: Schematic representation of the typical relationships between current speed and loading for shallow and deep draft silt curtains

The principal factor associated with load on a curtain is the drag induced by the screen component. An increase in porosity typically reduces the overall drag and loading, however this may also reduce the trapping efficiency, as the finest fraction of the suspended sediment material can migrate through the screen weave and there is less interference (reduction) in flow preventing material from settling.

The loading applied to a silt curtain structure during exposure to a current typically causes the structure to deform due to the opposing anchoring, buoyancy and current forces (USACE, 1978). Where buoyancy forces are sufficient this causes the screen to flare, generating a gap between the bottom edge of the screen and the seabed thus reducing the effective depth and permitting water exchange near the seabed. This phenomenon is particularly apparent in silt curtains where the bottom edge of the screen is kept in place with ballast, rather then fixed to the bed by direct anchoring. Reduction in effective depth for increasing current speed is represented schematically in Figure 7 (A). A similar but opposing characteristic is true of silt curtains that are sufficiently ballasted or anchored from the bottom and maintained upright using batons and floatation elements. Here, the loading overcomes the buoyancy forces and permits water exchange at the surface. Under increasing flow speed the curtain becomes deflected from its vertical position, as demonstrated in Figure 7 (B). Given that sediment typically settles through quiescent water to yield vertical concentration profiles which increase towards the seabed the latter situation (as represented in Figure 7 (B)) may well be preferred to the former.

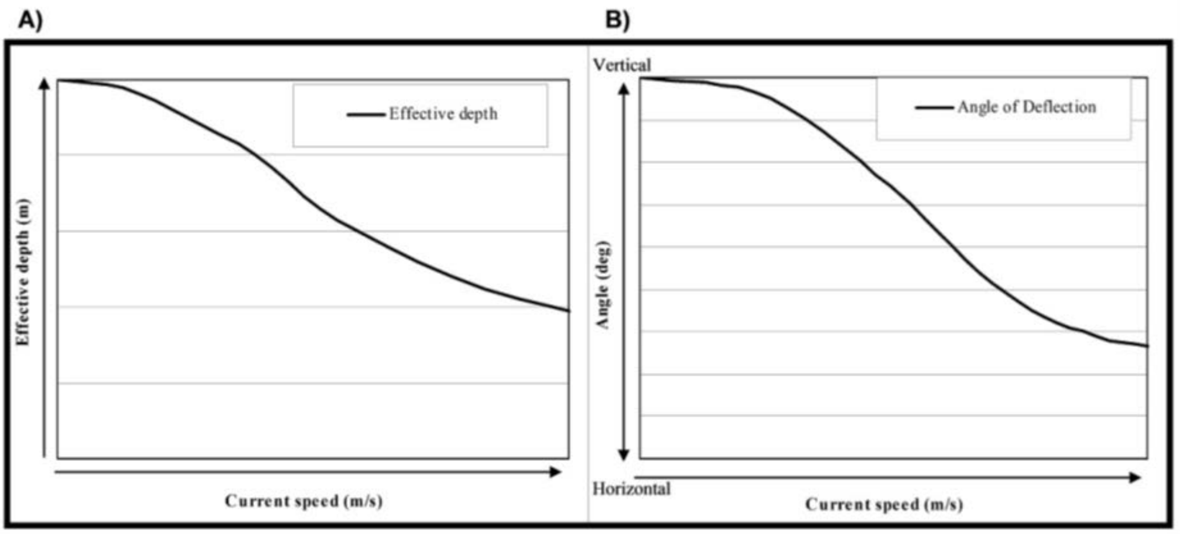

Figure 7: (A) Current speed versus effective depth for silt curtain structure; (B) Current speed versus Angle of Deflection

Waves generate additional, more complex, loading forces, including heave and surge. Under certain wave conditions the performance of a silt curtain can be compromised, allowing the uncontrolled exchange of water. The heave motion causes the screen to rise and fall through the water column as the wave crest and trough passes. The curtain will experience a surging motion induced by the orbital velocity of the passing waves and display a propensity to move in the direction of wave propagation. The combination of heave and surge can cause turbulence around the base of the curtain, prompting the re-suspension of fine material that may have settled on the seabed. Although laboratory and computational modelling methods have been used to describe the interaction of a silt curtain and the prevailing hydrodynamics (for example Vu and Tan, 2010 & Vu and Tan, 2011), few field measurements have been made.

4.2. How to measure if silt curtains work

It is considered that the efficiency of a silt curtain can simply be defined as; the ratio of suspended sediment concentration within the area confined by the silt curtain to the suspended sediment concentration in the wider environment. This is consistent with the definition offered by USACE, 1978 and DOER, 2005.

Thus, the efficiency ratio of a silt curtain is defined:

$$Efficiency = \frac{SSC\,(in)}{SSC\,(out)}$$

Where:

SSC(in) represents a measure of the suspended sediment concentration (units of mg/l) within the bounds of the silt curtain; and

SSC(out) represents a measure of the suspended sediment concentration (units of mg/l) outside of the silt curtain boundary.

Whilst the method to define the efficiency of the curtain is offered by USACE, 1978 and DOER, 2005 no information is provided on a suitable method for collecting data and determining this efficiency.

If measuring turbidity either side of a silt curtain care should be taken to ensure that local vertical and horizontal variations in suspended sediment concentration are accounted for. The flow of water around and through the screen will show strong spatial gradients, therefore when trying to quantify the efficiency of the curtain consideration should be given to capturing comparable SSC data:

- at several locations through the vertical profile
- at locations not directly affected by the dynamic plume associated with dredging
- at locations not directly affected by other factors outside of the silt curtain.

It should be remembered that if measurement is to be undertaken using a turbidity probe then it is important that this is calibrated using water samples to allow data to be provided as suspended sediment concentrations (mg/l). Different calibrations may be required inside and outside of the curtain (due to the different sediment populations). Given this requirement it may be preferable to simply use water samples to undertake the assessment.

5. Silt curtain deployment

5.1. Typical configurations

Typical silt curtain deployments can be separated into four different configurations; maze, open, closed onshore and closed offshore (USACE, 1978). Selecting the correct configuration depends greatly on the hydrodynamic conditions, the anticipated application of the curtain, and other external operational factors such as vessel traffic and potential access (DOER, 2005). Figure 8 shows the four typical configurations for silt curtains.

The maze configuration (Figure 8A) is not generally recommended as the flow will transport the suspended sediment through the open corridor; however, it may be the only solution if there is a large volume of marine traffic. The use of an open semi-circular configuration (Figure 8B) is preferential to the maze configuration, provided there is sufficient water depth near-shore for vessels to pass and potential ‘leaks’ (uncontrolled exchanges) around the ends of the curtain are minimised. When discharging from the land, the ideal configuration is closed and anchored onshore (Figure 8C). In tidal situations where currents reverse, a closed elliptical shape (Figure 8D) is preferred for locations away from the shore.

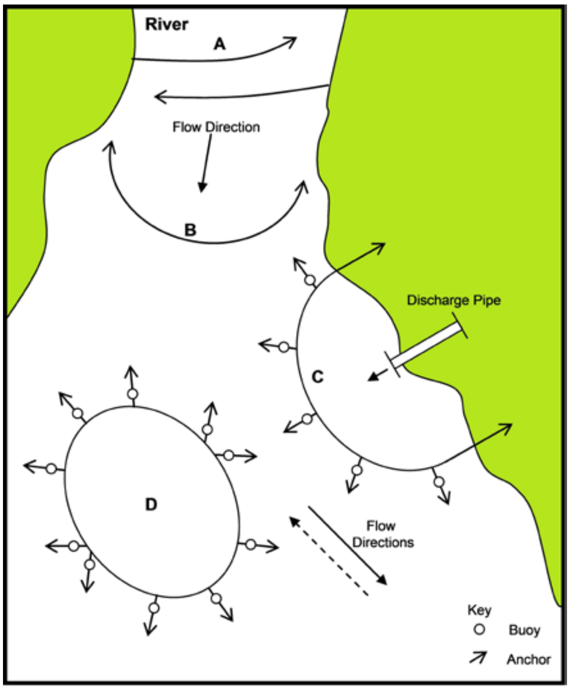

Figure 8: Adapted schematic from USACE (DOER, 2005) showing the typical designs (configurations) for silt curtains; A) Maze; B) Open; C) Closed onshore; D) Closed offshore (specialist configurations)

In addition to the typical configurations, silt curtains have been deployed in different scenarios that have required unique installations. These specialist configurations demonstrate how diverse curtain installation can be.

Backfilling of offshore pipeline trenches can cause concerns relating to increased suspended sediment load. Such dredging works would typically be undertaken by a Cutter Suction Dredger with the assistance of a spreader pontoon. In one such case the Dredging Contractor constructed a purpose-built spreader pontoon to mitigate against the effects of suspended sediment generated during the dredging activities. The pontoon, shown in Figure 9, was equipped with primary and secondary silt curtains and a moon pool allowing the vertical position of the diffuser to be adjusted (Boskalis Offshore bv, 2004).

Figure 9: Photographs taken during the construction phase (A) and operation phase (B) for the primary and secondary silt curtains around the spreader pontoon

Source: Boskalis Offshore bv, 2004

5.2. Balance of operational versus environmental design

When choosing the most appropriate silt curtain type for any given dredging works there are many considerations to take into account. For most dredging projects, key factors to consider will include: the silt curtain type; the deployment method; and the location. The requirement is always to identify a practical (workable) solution which also maintains effective mitigation of the potential adverse environmental effects. It should be noted that the cost of the deployment will usually be a factor in the choice. Other details included in the assessment process will usually be:

- the predicted (modelled) behaviour of any sediment or contaminants released;
- the existence, location and character (importantly tolerance levels to sediment and / or contaminants) of any sensitive receptors (including those with socio-economic value);
- the suitability of the silt curtain design to the type of dredging that will take place; i.e. are vessels required to move in and out of the bounds of the silt curtain;
- The practicalities associated with deploying, maintaining and recovering the curtain to ensure effectiveness; and
- any existing navigation requirements.

Consideration should also be given to the potential downstream effects of deploying a silt curtain. Whilst the curtain may help to protect certain sensitive receptors, side-effects from their use can include:

- interruption of the existing current, sediment and nutrient transport pathways; and
- trapping or obstruction of flora and fauna.

6. Problems associated with silt curtains

6.1. Installation errors

The incorrect choice of silt curtain deployment location is a common installation error resulting in failures and subsequent damage to the curtain and the environment. A key factor that should be considered when positioning a silt curtain is the flow direction and understanding how this will interact with the curtain (see Section 4.1). It has been stated that "*In most situations, turbidity curtains should not be installed across channel flows*" (USACE, 1997), making it very difficult to install a silt curtain "correctly" in rivers or areas of moving water. In all cases, the contained water should be allowed to pass freely through the screen, thus preventing the curtain from becoming submerged under the force of the flowing water. It therefore follows that the specific choice of fabric is very important but will vary depending on the site conditions and the unique deployment location. The anchoring system should be carefully chosen to suit the class of curtain as not managing excess forces can lead to the fabric becoming damaged.

For the best results to be achieved using a silt curtain, the area being dredged should be fully enclosed and water should only move through the permeable screen. A typical location where gaps can occur would be at the bottom of the screen due to the curtain not being in contact with the seabed. As discussed in Section 4, this can lead to an exchange of water and a loss of sediment from within the enclosed area. Also scour of existing seabed sediments in the vicinity of the bottom of the screen may occur.

Another common problem (particularly with Type I and II screens) is gaps opening up between the individual screen sections. During the construction of the curtain the likelihood of problems with gaps between sections can be reduced by having a greater overlap between the screen sections, reducing the spacing between eyelets and not using individual ties to join the screens together but use a continuous stitch instead. Figure 10 demonstrates how gaps can occur between the screens when hydrodynamic forces are applied.

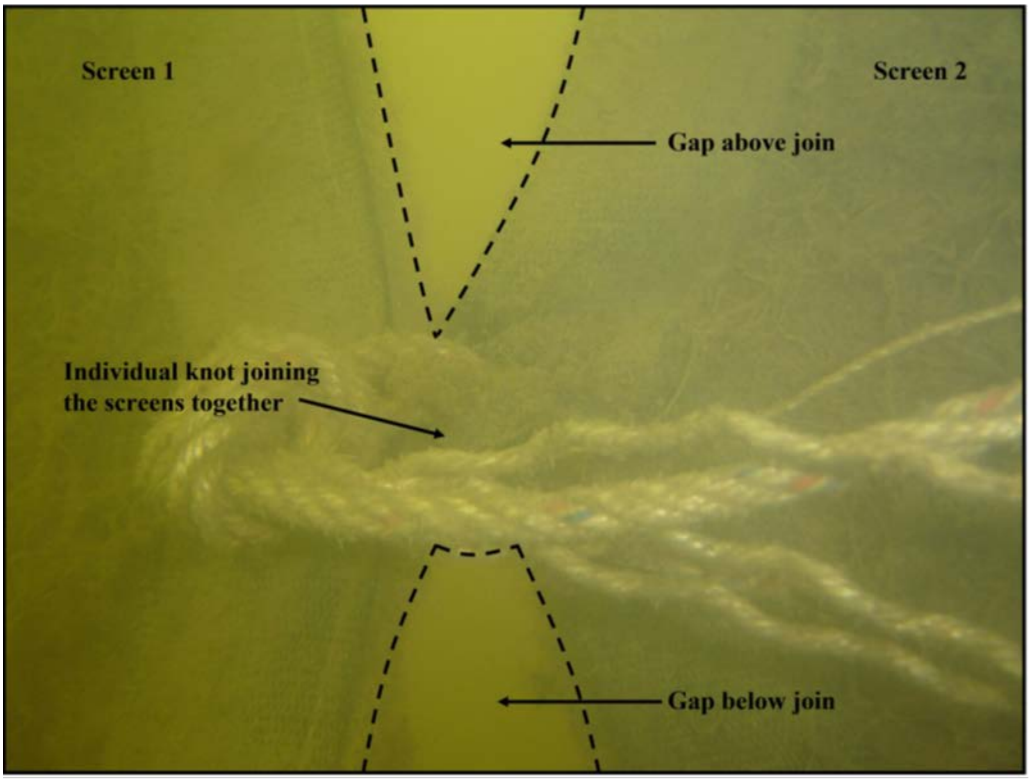

Figure 10: Silt curtain screen to screen connection using rope, the gaps have been labelled

6.2. Material failure

The materials used to construct a silt curtain vary depending on the class (Section 2.3.2). A Type III curtain is constructed with more durable and harder wearing material in comparison to Type I as they are designed to be used in harsher conditions. The main cause of failures is where the material has been subjected to too high a load which causes increased stress and strain. The part of a curtain that is most likely to succumb or be subjected to excess loads is the connection between individual sections of the curtain. For Type I curtains the sections are stitched together using rope and prefabricated eyelets punched into the PVC (or other) material. The eyelets or the rope can fail, eyelets can be ripped out and the rope can snap or become untied.

A key component of a curtain is the screen itself; if this is unable to function to its full capability the overall effectiveness of the curtain will reduce. Any rips, tears or wear to the fabric will allow sediment to escape. As the screen is underwater it is difficult to observe such failures without regular recovery and maintenance or diver inspections.

6.3. Recovery, inspection and maintenance

The recovery, inspection and maintenance of the silt curtain throughout the deployment period is a key controller of the long-term efficiency of the curtain. Recovery can be the most difficult and damaging phase of handling operations (USACE, 1978) and improper maintenance not only decreases the silt curtain's effectiveness but incurs repair costs and costs associated with re-conditioning of the curtain for future use (Interstate Products Inc, 2012). Inspection of the screen and anchoring arrangement whilst deployed can best be undertaken through a diver survey. Inspection of the flotation arrangement can be carried out by boat. The inspection process should not only monitor the physical state of the curtain, but should also include an assessment of the efficiency of the curtain by means of field measurements. The maintenance of a silt curtain most commonly involves cleaning and the replacement of sections of the screen and anchor lines that are warn or damaged. At the end of a deployment, following recovery, maintenance, repair and cleaning it is important that the curtain is properly stored ahead of its next deployment. The curtain should be stored in such a way that it is protected against physical damage and the weather.

The recovery, inspection and maintenance of silt curtains is discussed in more detail in various sources, including USACE Technical Reports or Best Management Practices (USACE, 1978, DOER, 2005 and USACE, 1997) and manufacturer's guidelines (Interstate Products Inc, 2012 & Catchment and Creeks Pty. Ltd, 2012).

6.4. Potential solutions to silt curtain problems and alternative mitigation methods

The areas where most improvements to silt curtain deployment can be made is in the design and the decision making process that determines the installation and maintenance procedures. Literature suggests that the majority of the sediment transport occurs close to the seabed. This means that once the material has settled to the bed due to the presence of the curtain, it may still wash underneath if the curtain is not in contact with the seabed. The solution to this is to change the design such that the curtain is anchored to the seabed whilst using suitably sized floats to keep it vertical in the water column and suitable height of material to maintain coverage through the full tidal range. The floats would be attached to mooring buoys allowing the top of the curtain to react to changes in water level.

The area where material failures most commonly occur is failure of the impermeable PVC sleeve which holds the floatation system together. Once this becomes damaged fragments may be released into the environment; the use of a bio-degradable material would limit the environmental implications of such a release.

Measures that could be used instead of, or together with, a silt curtain to minimise the transport of fine sediment away from a dredging or marine construction site include:

- the design of the dredging works could be varied to limit any environmental disturbance (use a different type of dredging plant for example);
- an alternative technology such as a bubble curtain or silt fence could be used;
- re-routing of outfall pipes to deeper water and / or away from sensitive receptor sites;
- the use of external bunds around a reclamation to enclose the fill area, geo-textile can be used if no impermeable material (such as clay) is available to construct such bunds;
- the use of settlement ponds with an outflow weir box; and
- the use of internal bunds within reclamations to allow a longer period of time for fine material to settle out of suspension.

7. Summary / synthesis

It is clear that when deployed in suitable environments, with due regard for correct design and deployment procedures, silt curtains may be an effective mitigation measure against the dispersion of turbidity associated with dredging activity. Perhaps unfairly, the use of silt curtains may have a poor reputation due to the lack of knowledge and experience of the users. In general, problems with the use of silt curtains can be kept to a minimum if the operational, environmental and hydrodynamic conditions are fully understood prior to the specification and installation of the silt curtain. An important question that should be asked in the planning phase of a dredging or marine construction project is whether or not a curtain is indeed required. If it is considered a requirement then there are several key questions that should be addressed to help inform the selection of design and installation, these include:

environmental questions, i.e.

- what currents/wave/tidal action can be expected in the work area;
- what is the sensitivity of the environment, can suspended sediments/contaminants be released and if so how much (what are the tolerance thresholds) and where will they go;
- what sensitive receivers exist in the vicinity of the work site and where are they located relative to the area being dredged;
- what range of water depths can be expected, is the site tidal or not; and

operational questions, i.e.

- does the dredger need to move;
- what type of dredging is taking place;
- what is the nature of the material to be dredged (high fines and / or contaminant content);
- what is the disposal methodology, whether on land or offshore;
- how easy is it to deploy, move and recover the silt curtain;
- what is the expected frequency, volume and size of marine traffic through the work area;
- what size of silt curtain is required; and
- where is the installation location and what shape does the curtain need to be.

The most protective silt curtain design / solution from an environmental perspective may not be operationally / practically possible (nor may it be necessary) and therefore it may not be the optimum solution. Predictions provided to aid the design of protection measures should be soundly based as should be the design itself.

8. Conclusion

- The use of a silt curtain as an environmental mitigation method can produce a positive outcome. To ensure a positive outcome the conditions relating to the operational activities and the site specific environmental conditions must be considered; these considerations are highlighted by the questions identified in Section 7. Understanding these considerations allows for informed decisions about the Type of curtain (according to USACE standards) and specific methods for installing, maintaining and recovering the curtain throughout the duration of the curtain's deployment. Alternatively it may highlight that a silt curtain is an unsuitable mitigation method for that particular project.

- The observed or modelled environmental condition data will assist with the correct selection for the Type of curtain as per the USACE standards. Using this standards system there are three different Types of curtain that can be used according to the severity of the environmental conditions present.
- Dominating the choice of curtain Type is the influence of hydrodynamics (including currents and waves) these should be well understood prior to installation of the silt curtain. An appropriate silt curtain should ensure a higher efficiency.
- In order for a high efficiency to be achieved (as defined in Section 4.2), the correct configuration of the silt curtain must be selected for the given environment. This is site specific and will be affected by the operational activities occurring and the volume of marine traffic in the area of deployment. The curtain must be installed correctly, in a manner that will allow for scheduled and reactive maintenance to be carried out effectively. Installation and maintenance methods should also aim to reduce damage and impacts to the curtain during the recovery stage.
- The main problems associated with silt curtains appear to occur from an inappropriate application of the curtain which leads to all types of failures. To prevent the inappropriate application of silt curtains it is important to have as much relevant information relating to a project as possible, covering the environmental and operational conditions/restraints.

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