GUIDELINES FOR ASSESSING AND EVALUATING ENVIRONMENTAL TURBIDITY LIMITS FOR DREDGING

CEDA Webinar#10

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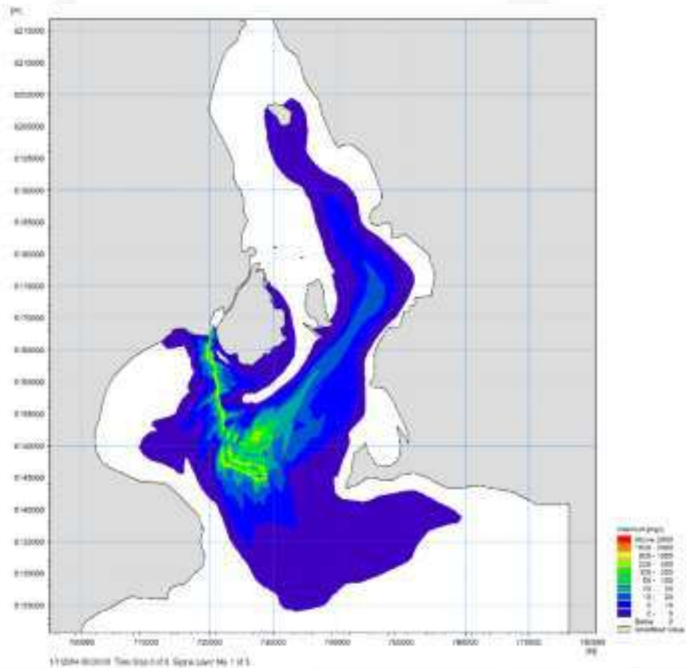
NIRAS

CEDA
Central Dredging Association

Introduction

- CEDA environmental committe issued a process on this topic
- Starting wit a questionnaire at dredging days
- The responses showed that turbidity limits are widely used but often unclear what the basis is.
- Often turbidity is misunderstood as a unique proxy for environment
- Often the implcations of having a turbidity limit are underestimated
- Correctly set limits are highly beneficial for the environment but incorrect limits may lead to undesired environmental impacts or excessive costs
- Need to evaluate and discuss an approach



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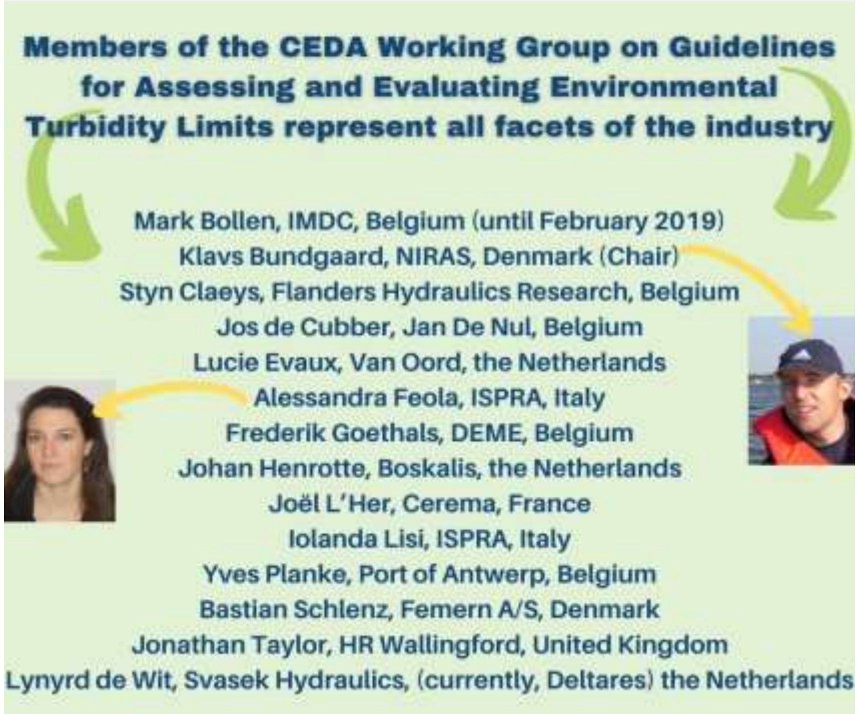
CEDA Working group



The presentation is based on
a Working Group product,
with experts from different countries
with a broad range of experience.
The CEDA information paper was
released in May 2020.

The Central Dredging Association
(CEDA) Working Group on Assessing
Environmental Turbidity Limits
(WGETL) was initiated by
the CEDA Environment Commission.

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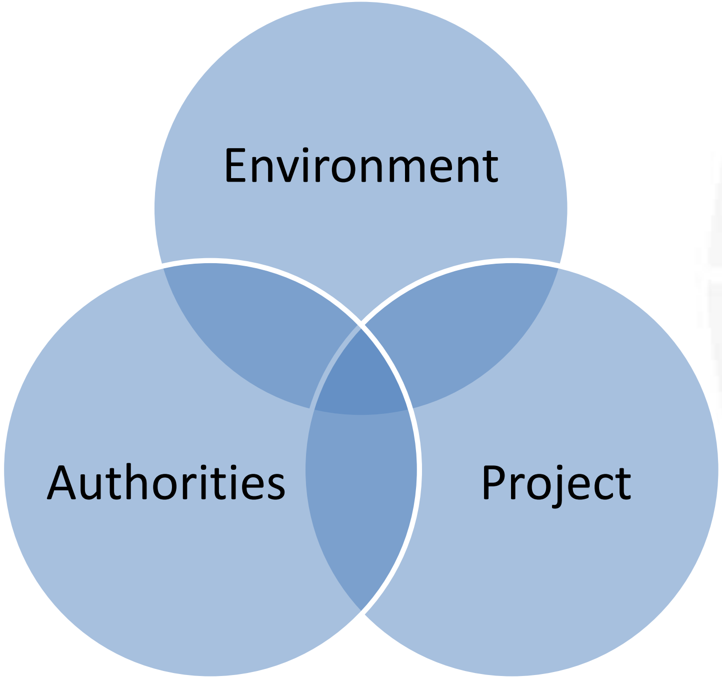
Interests



Authority requirements:

- Achieve objective
- Follow rules
- Auditable/documentable

Environmental requirements:

- Minimum stress on sensitive receptors

Project requirements:

- Low project costs
- Minimize risks
- Manegable

Approach

This presentation is based on the assumption that setting turbidity limits requires a general understanding of dredging processes as well as the surrounding

environment. The approach is thus an integrated approach that takes all aspects into account. The main required aspects for a general integrated approach is an understanding of:

- The baseline conditions for hydrodynamics, sediments and biology;
- The dredging operations in terms of locations, volumes and spills;
- The sensitive receptors and their tolerance levels;
- Possible monitoring programmes;
- Possible response options.

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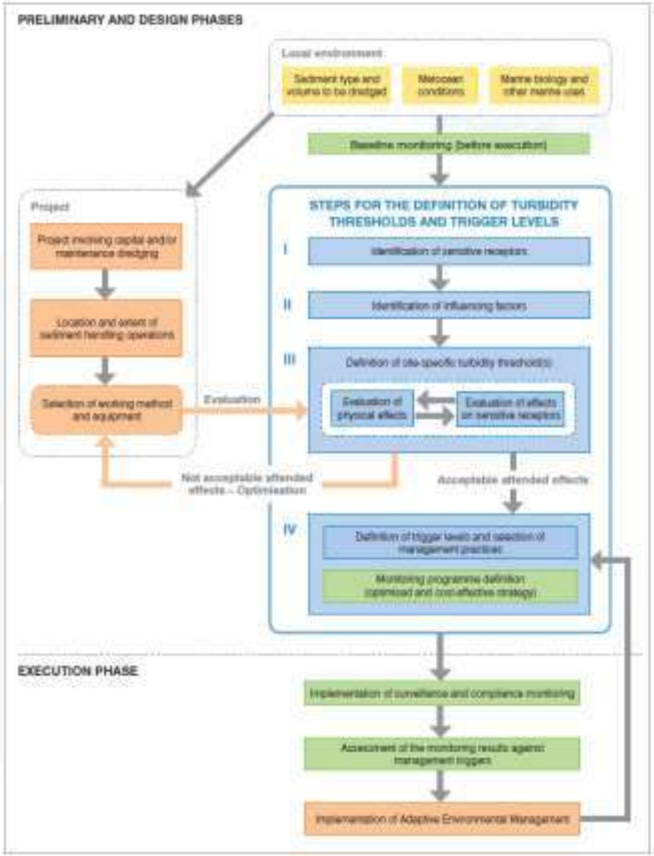
Approach basis

To implement this approach, a typical flowchart for managing environmental turbidity limits in a dredging operation is developed. In this figure the different parts of the flowchart and the interactions between them are highlighted.



Definition of Turbidity

The term ‘turbidity’ is often used for a number of aspects related to sediment in the water, from actual concentrations to water clarity.

In US EPA (2012) definition, “Turbidity is a measure of water clarity that indicates how much the material suspended in the water decreases the passage of light through it”.

In its correct usage, the term ‘turbidity’ solely refers to the effect of suspended sediment measured by a turbidity sensor (ISO, 2014).

Therefore, one must understand that ‘turbidity’ is a proxy for ‘suspended sediment concentration’.

Definition of Turbidity

For this context, the term 'turbidity' refers to the popular use of the word and thus covers all kinds of measurable environmental parameters (e.g. turbidity, suspended solids, sedimentation, light attenuation) that can be directly linked to the creation of suspended sediment plumes and associated environmental impacts.

Turbidity can be measured and reported in terms of:

NTU	**optical**	**light scattering in the water**
FTU		
SSC	**concentration**	**amount of sediment suspended**
TSS		
PPT		
several other ways	**…**	

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System understanding

Before setting any limits, it is important to understand the physical and biological patterns of the local system in term of its background turbidity, natural variations and adaptation of local sensitive receptors. The following factors need to be investigated:

- Metocean conditions
- Sediment dynamics
- Biological aspects
- Anthropogenic conditions

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Metocean

- Wind
- Waves
- Currents
- Water levels
- Salinity
- Temperature


Sediment dynamics

- Behaviour of background concentrations
- Behaviour of deposition and erosion

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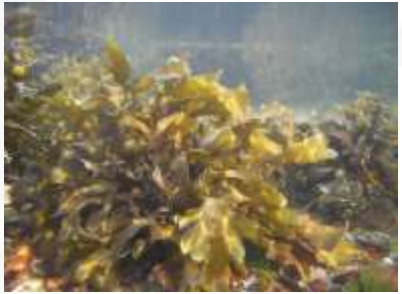
Biology

- Crustaceans
- Algae and Plants
- Fish
- Birds
- Mammals



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Antropogenic

- Beaches
- Water intakes
- Water quality
- Appearence
- Smell

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Planned works

- Dredging method, location and planning;
- Dredged volume;
- Dredging production rates; and composition and optical and physical properties of dredged material.
- Spill amounts and distribution
- Timing of dredging

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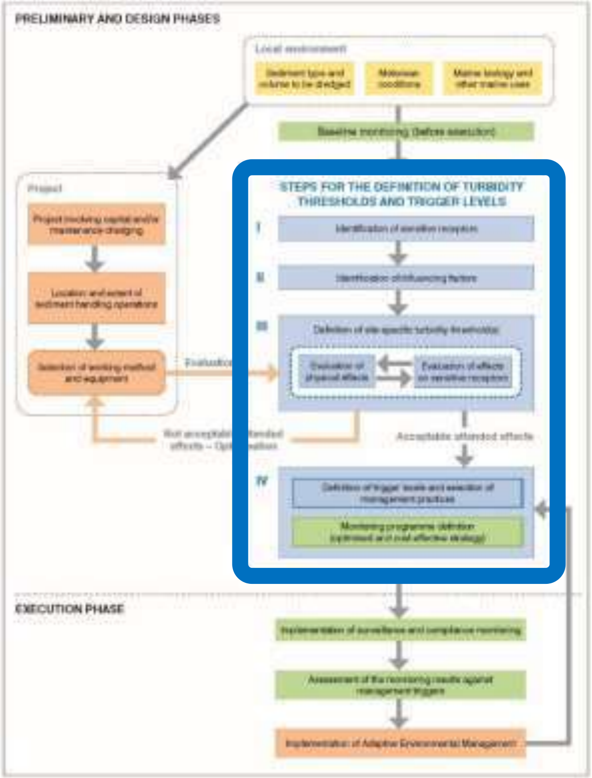
Sensitive Receptors, Threshold and Trigger Levels

In the early phases of a project, a crucial step is to identify the presence of **sensitive receptors**,

and to build a proper system understanding, in order to:

- assess turbidity-related **influencing factors**,
- identify **threshold levels** (critical stress levels),
- finally select **trigger levels** to protect the sensitive receptors.



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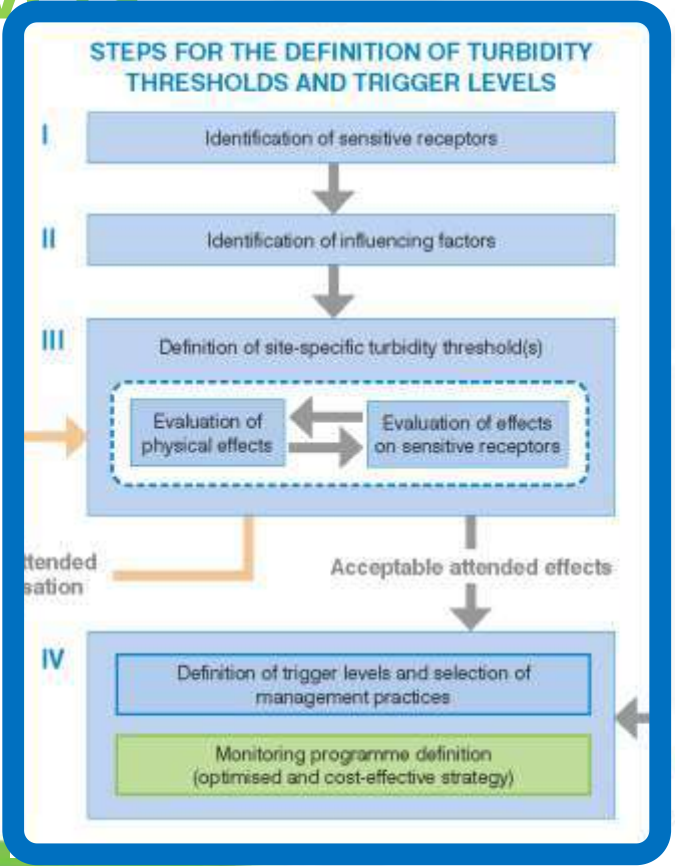

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Sensitive Receptors, Threshold and Trigger Levels

I – IV Four-step process

This is a four-step process and each step will be defined in the following

Sensitive receptors → Influencing parameters → Threshold values → Trigger levels

This approach should be performed based on **local knowledge:**

- **available** (local consultants, research institutes, users of the water body in question, and historic information)
- or **collected** trough the implementation of environmental baseline survey(s).

Sensitive Receptors, Threshold and Trigger Levels

I – Identification of sensitive receptors

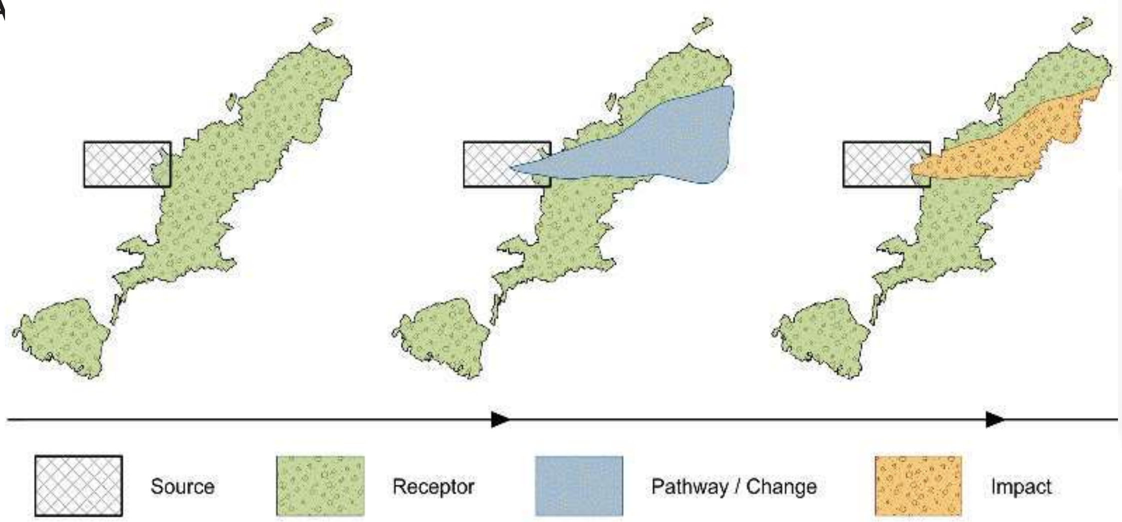
The first key aspect is the identification of sensitive receptors

Sensitive receptors → **Influencing parameters** → **Threshold values** → **Trigger levels**

Sensitive Receptors, Threshold and Trigger Levels

I – Identification of sensitive receptors

As reported in the CEDA Information Paper "Environmental Monitoring Procedures", April 2015



a **source**-pathway-**receptor** (S-P-R) model can be used to present the theoretical linkages (i.e. pathways) between the sources (i.e. dredging activities) and the receptors **which** are identified as being of importance and **may be impacted by the works**.

Sensitive receptors (receivers) may include species, habitats, resources and activities or items located in the area of influence of the project

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Sensitive Receptors, Threshold and Trigger Levels

I – Identification of sensitive receptors

Any change can be characterized by

- intensity (values of increasing turbidity/deposition)
- duration (hours/days/month/…)
- and frequency (ones/every day/…)

https://it.freepik.com

Changes induced by dredging can be described in terms of physical effects

- ✓ on water column
- ✓ and seabed

Sensitive Receptors, Threshold and Trigger Levels

I – Identification of sensitive receptors

Any change could affect the sensitive receptors **inducing** effects comparable with local background, a moderate **impact** or even lead to **irreversible damage**, depending on the receptor and its **sentivity**.

The identification of the **presence** of **sensitive receptors** is crucial to properly assess the **relationship** between the **physical effects** induced by dredging and the **effect/impact** levels on **environment**.

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Sensitive Receptors, Threshold and Trigger Levels

I – Identification of sensitive receptors

The potential **sensitivity** of the receptors to dredging works is determined by the **combination** of:

- their **own characteristics and functionalities**
- the characteristics of the **natural system**, in which they are located and where the works will occur.

Sensitive receptors are generally **adapted:**

- to their **local ecosystem** (e.g. offshore, coastal waters, coastal lagoon)
- and its **natural variations** (e.g. season, tide, flood).

Sensitive Receptors, Threshold and Trigger Levels

II – Identification of influencing factors

It is important to recognize the **factors** related to the works **influencing or stressing** each **receptor** in order to plan proper monitoring and management measures.

Sensitive receptors → Influencing parameters → Threshold values → Trigger levels

Elevated turbidity due to dredging can affect the sensitive receptors for example through light reduction, sediment deposition, contaminant/nutrient release or burial phenomena.

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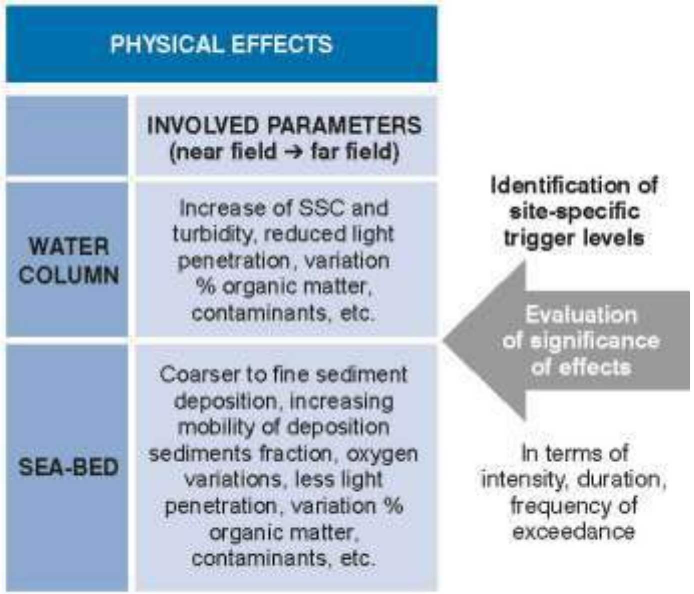
Sensitive Receptors, Threshold and Trigger Levels

II – Identification of influencing factors

Physical effects induced by dredging activities
on water column and sea-bed can be synthetized as follow:



They have to be described in term of intensity, duration and frequency of perturbation

Sensitive Receptors, Threshold and Trigger Levels

II – Identification of influencing factors

A **list of receptors** that are **potentially sensitive** is presented and the **factors that influence** them are outlined:

- turbidity
- re-deposition

Two main groups are identified:

- **Habitat and species** (seabed habitats, benthic communities, coral reef, seagrass, fish, etc.)
- **Marine uses** (bathing water quality, aquaculture, recreational areas, navigation, cultural heritage, etc.)

Sensitive receptor(s) type	How changes in turbidity or re-deposition may have negative impacts on sensitive receptor(s)	Sensitive to turbidity	Sensitive to re-deposition	Fixed receptor	Mobile receptor
Habitats and species					
Seabed habitats/ benthic communities	Increased turbidity and re-deposition may have temporary or permanent effects in terms of smothering, damage to feeding and respiratory systems, and changes in benthic community structure and composition (e.g. abundance, diversity, biomass).	•	•	•	
Coral reef	Increased turbidity may affect photosynthetic ability. Re-deposition may lead to smothering and burial of polyps, and growth of bacteria in coral mucus. Turbidity and re-deposition may also reduce recruitment and survival of coral larvae.	•	•	•	
Aquatic macrophytes/ seagrasses	Increased turbidity may lead to light attenuation with significant effects on seagrass plants, microphytobenthos and macroalgae. Increased re-deposition may result in burial phenomena on plants and reduce vitality or death among associated benthic fauna.	•	•	•	
Mangroves	Increased turbidity does not *per se* affect mangroves unless the sediments are contaminated. In addition, excessive re-deposition may smother the mangrove roots.		•	•	
Shellfish	Increased turbidity and re-deposition can affect filter-feeding systems of shellfish (e.g. oysters, mussels), with possible effects on pseudo-faeces production, the amount of algal food ingested and on bivalve gills (clogging).		•	•	
Fish	Increased turbidity can affect visibility, reducing feeding and hunting ability, and growth rate in juveniles. High suspended sediment concentrations can affect fish gills, eggs and larvae.	•	•	•	•
Wildlife	Increased turbidity may affect the predatory capacity of wildlife (e.g. marine mammals, turtles, seabirds). Other potential effects may be related to noise production, food availability and collision risks.	•			•

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Sensitive Receptors, Threshold and Trigger Levels

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Sensitive receptor(s) type	How changes in turbidity or re-deposition may have negative impacts on sensitive receptor(s)	Sensitive to turbidity	Sensitive to re-deposition	Fixed receptor	Mobile receptor
Marine uses					
Bathing water quality	Increased turbidity can lead to temporary changes in water colour. Presence of contamination (e.g. faecal bacteria) associated with suspended sediment can directly affect public health, especially during the bathing season.	•		•	
Aquaculture/ shellfish farms	Increased turbidity can affect primary production and bivalve growth. Sediment re-deposition can damage farm structures (see fish and shellfish).	•	•	•	
Recreational areas and tourism	Increased turbidity can lead to temporary or long-lasting changes in water colour. Moreover, even in the absence of contamination, possible misunderstandings and complaints from beach users may see tourism and associated activities affected.	•		•	•
Infrastructure, navigation	Excessive re-deposition near structures (e.g. quay walls, jetties, outlets) and navigation channels may lead to functional issues (e.g. operability, maintenance).		•	•	
Fishery	For extensive dredging, increased turbidity can hinder some fishery practices. Fishery areas may be modified: on a short-term basis, if fish communities temporarily avoid turbid waters; on a long-term basis, if fish are affected during sensitive stages of the life cycle. Particular attention must be paid to the presence of nursery and reproduction areas (in particular for demersal species with commercial value).	•		•	•
Cultural heritage	Increased turbidity can lead to change in water colour and re-deposition, with socioeconomic impacts on cultural heritage and historical sites.	•	•	•	
Water intake	Increased turbidity and re-deposition can lead to water supply shortages (e.g. industrial/drinking water supply) with both socioeconomic and sanitary impacts (e.g. public health).	•	•	•	

Receptors are classified as fixed or mobile (ability to move away from disturbance)

Sensitive Receptors, Threshold and Trigger Levels

II – Identification of influencing factors

The table should be considered as
 a **guidance tool** to be **completed and confirmed** with **site-specific information**, gathered during the **environmental impact assessment** studies performed during the design phases of the project.

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Sensitive Receptors, Threshold and Trigger Levels

II – Identification of influencing factors

Some sensitive receptors are **more vulnerable** during **critical periods** that must be taken into account to identify the optimal periods (i.e. **environmental windows**) in which dredging can be performed with acceptable impact on biological resources.

Making examples...

- ✓ for benthic species, critical or sensitive periods of the life cycle are recruitment, deposition, reproduction;
- ✓ some mammals are only present seasonally;
- ✓ seagrasses are most vulnerable to coverage during the growth period;
- ✓ water quality in bathing areas is most important during the bathing season.

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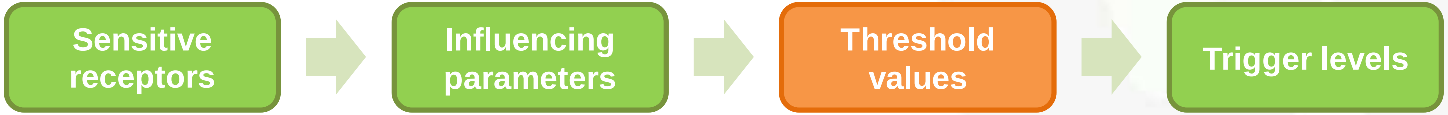
Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

The next step is to define **threshold values** at which the sensitive receptors may exhibit **increasing effects/impacts**.



The threshold values can be defined in **many ways**.

Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

Threshold values must be **defined starting from**:
- information about site-specific environmental parameters
- their natural variation
- the tolerance of specific sensitive receptors.

When a **tolerance threshold** value is **exceeded**, the sensitive receptor is expected to experience a certain amount of **stress** or **disturbance**.

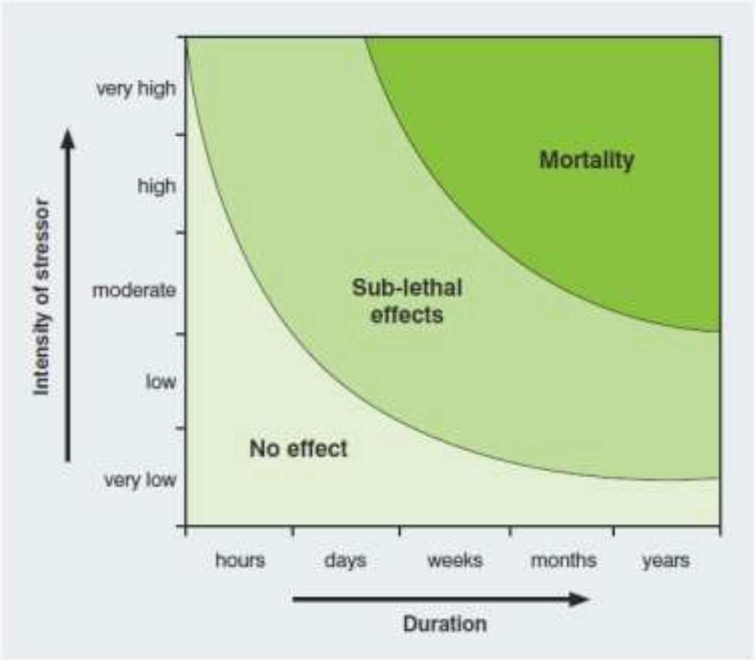
The **acceptability** of such effects must always be evaluated **against the characteristics of the system** where the dredging activities occur.

Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

Threshold levels are often defined as stress levels for a given receptor.

A scientifically sound approach is the use of **species response curves** that describe the response of individual species as a function of the **intensity** and the **duration** of increased stress.



Intensity-duration relationship (after Erftemeijer et al., 2012) based on the species response curve for species and biological sensitive receptors.

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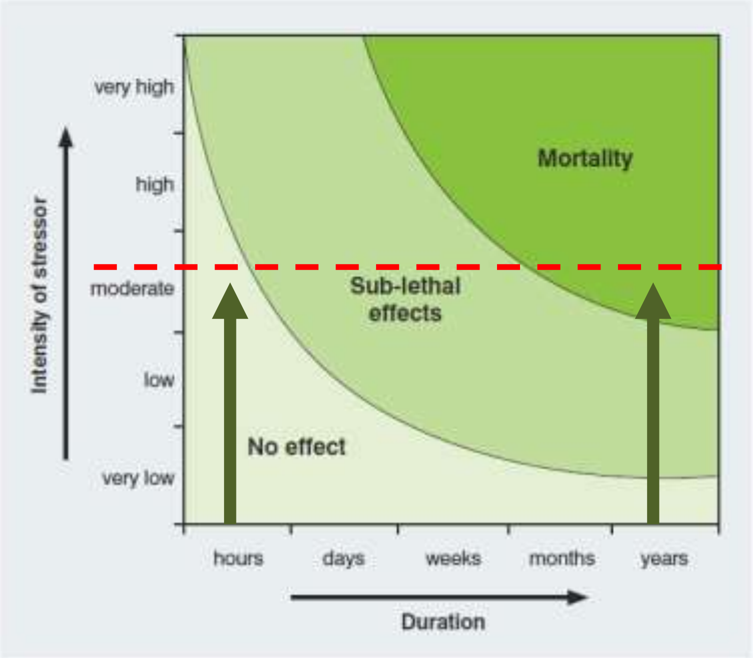
Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

A **temporary moderate** turbidity may be considered **unlikely to cause serious effects** on a sensitive receptor while a moderate turbidity over a **long period** of time may ultimately have **extreme consequences** on the same receptor.



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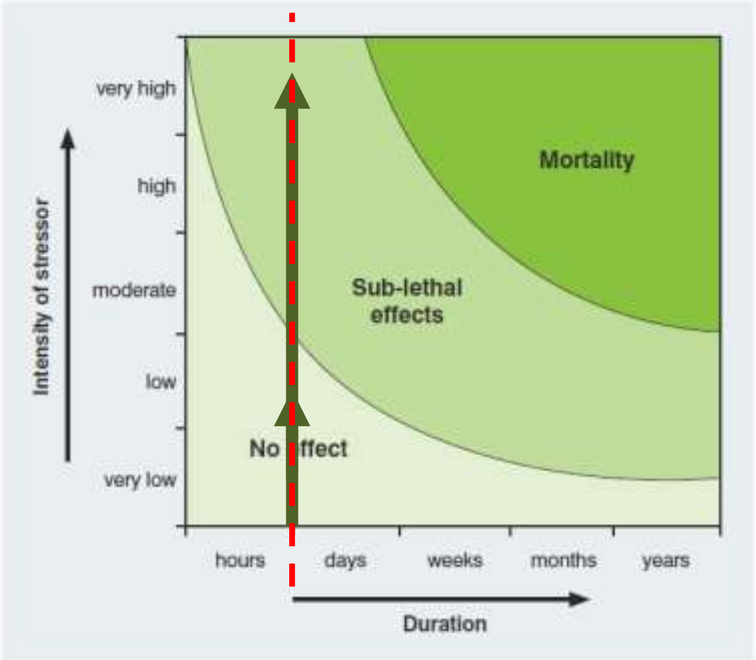
Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

A **temporary moderate** turbidity may be considered **unlikely to cause serious effects** on a sensitive receptor while a short, **high peak** of turbidity may again have **serious consequences** on the same receptor.



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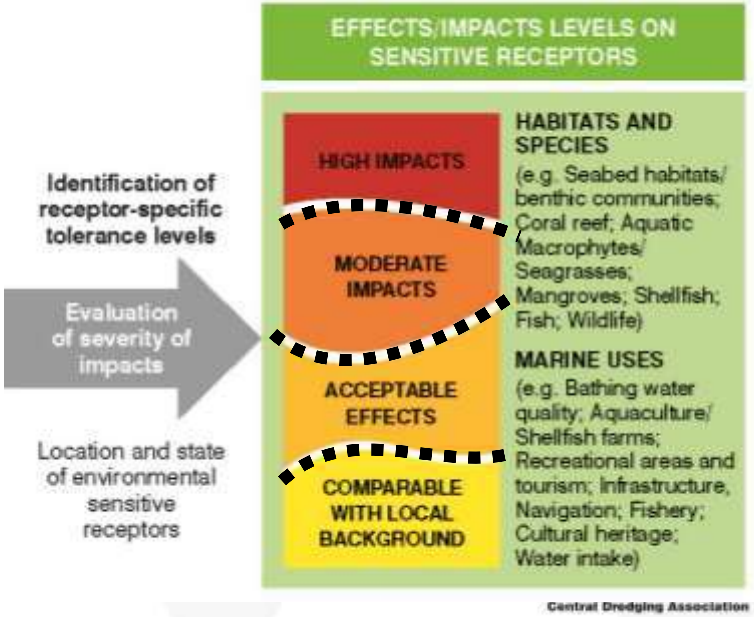
Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

Using:
- the species response curve approach
- the classification proposed by the Australian Environmental Protection Agency (2016) → acceptable effect, moderate impact, high impact

the next step is to define the specific **threshold levels** at which the receptor undergoes **effects/impacts** with **increasing severity**.

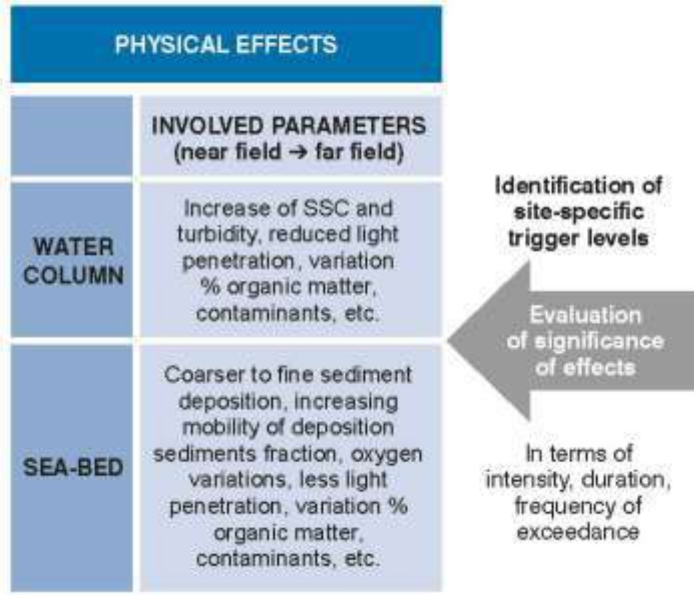
Modified from Lisi et al. (2019)



Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

The relationship between **physical effects** of changes induced by dredging on water and sea-bed



Modified from Lisi et al. (2019)

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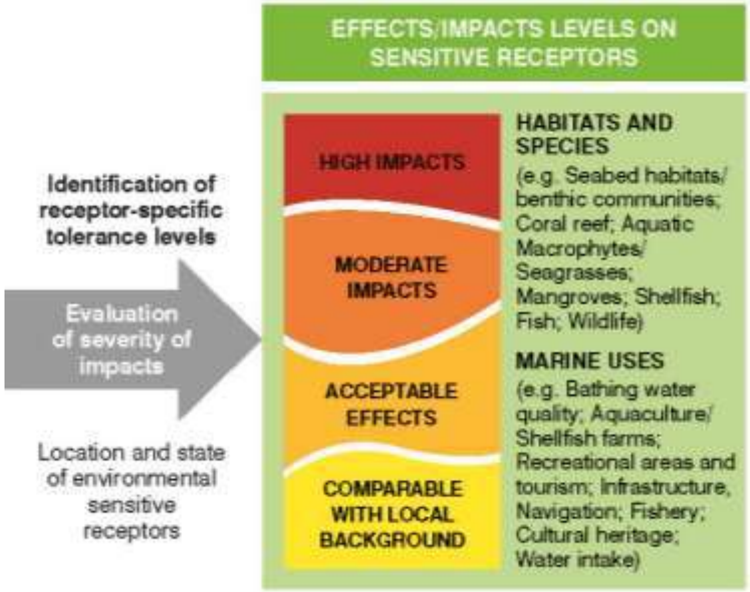
Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

and the **associated environmental effects/impacts** on the specific receptors, considering their specific tolerance levels

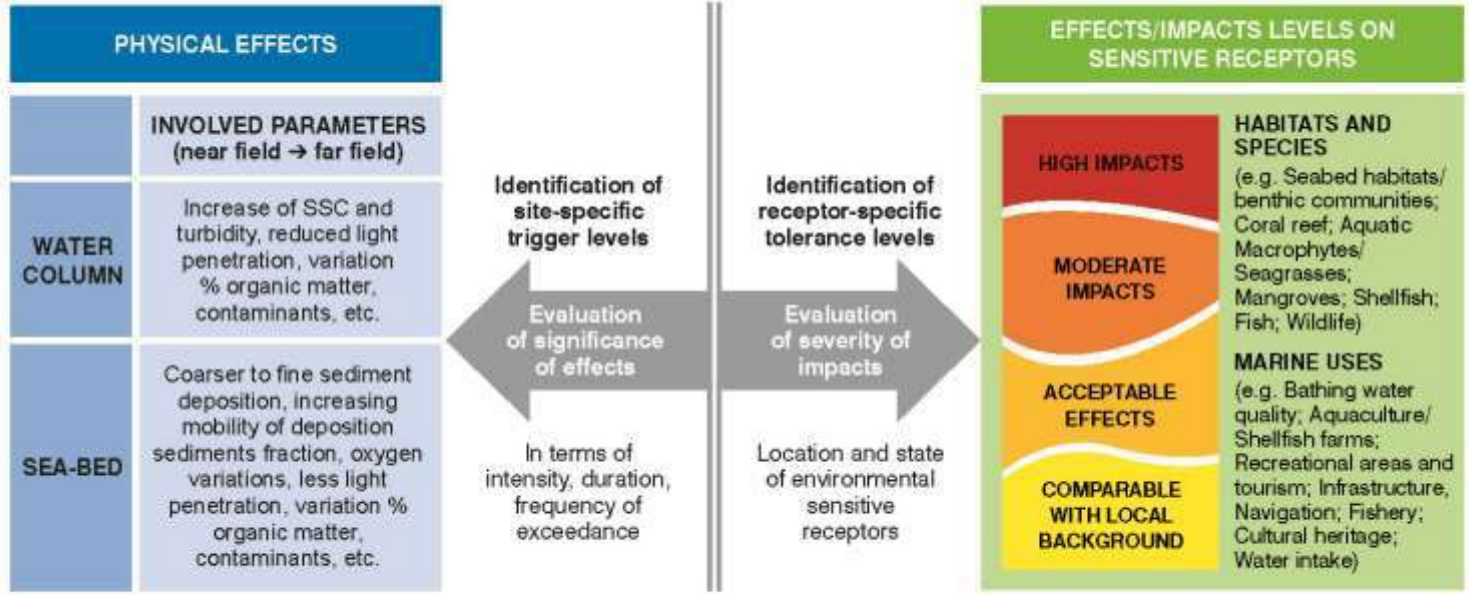


Modified from Lisi et al. (2019)

Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

can be derived on the basis of site-specific data, literature data or by expert judgement



Modified from Lisi et al. (2019)

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Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

For this purpose, **site-specific data** should be available and/or inferred by:

- either **direct experience** of dredging **from previous projects** in the same context
- or **specific tests** performed on sensitive receptors.

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Sensitive Receptors, Threshold and Trigger Levels

III - Definition of threshold values

CRITICAL ASPECT: site-specific data are often NOT available or useful!!!

It may therefore be **necessary** a **baseline monitoring campaign**, in order to determine, before the execution of the dredging works:

- the **variation in the natural levels** of turbidity
- **reasonable and realistic thresholds**.

NOTE: the processing and the interpretation of a baseline monitoring data set **represents a complicated matter!!!**

This is a task that requires **local insight and specialist knowledge**.

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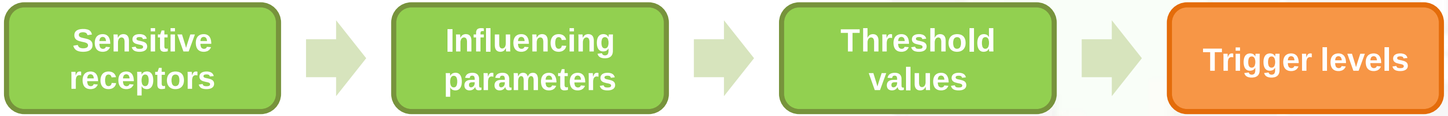
Sensitive Receptors, Threshold and Trigger Levels

IV - Definition of trigger levels

It is good practice to define a **set of trigger levels** for each receptor.



The **trigger level** is the turbidity level that **needs to be respected** to ensure that the **threshold levels are not reached**. It is a specified criterion used for the **management** of the dredging operations.

When a trigger level is exceeded, the need for a **management action** will be assessed and, if necessary, **implemented to prevent undesired/negative impacts**.

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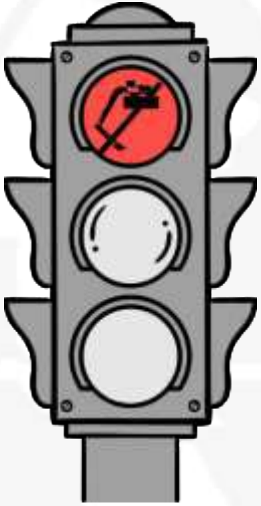
Sensitive Receptors, Threshold and Trigger Levels

IV - Definition of trigger levels

A typical approach is to define three different types of trigger levels:

- <u>warning level</u>: indicating an **increase in turbidity levels**, providing **time to investigate** the causes and anticipate/identify possible solutions;
- <u>action level</u>: indicating that the **levels have continued to rise** and that mitigation **measures need to be taken** to prevent the impact level from being reached;
- <u>impact level</u>: indicating that the **increased** turbidity **levels** have the **potential to harm** the sensitive receptors and that **urgent action needs to be taken** to reduce them below the impact level or the action level.



Trigger levels should be monitored either at the receptor or at a location at which the response of the receptor is known.

Sensitive Receptors, Threshold and Trigger Levels

Trigger level evaluation and monitoring program definition

There are **many different ways** in which trigger levels and monitoring programs are defined worldwide.

The **elements** to provide a **clear definition of limits** and to develop a **monitoring program** that can **effectively** be **implemented** are:

- monitoring parameters (paper par 6.6);
- intensity and duration (paper par 6.7);
- location (paper par 6.8);
- frequency (paper par 6.9);
- depth (paper par 6.10).

A good monitoring strategy involves the analysis of the sensitive receptors at risk
(CEDA, 2015; CEDA/IADC, 2018).

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Turbidity monitoring

Turbidity measurements can roughly be divided into **direct** and **indirect** measurements. Direct measurements are measurements that do not require transfer functions.

Examples include:

- Water samples as well as sediment analyses (e.g. SSC) in the laboratory; light dampening and scattering of light (e.g. NTU, FTU);
- Sediment traps as well as sediment analyses in the laboratory; and grain-size distributions (LISST, Malvern).

Indirect measurements can be derived from transferfunctions. Typical examples are:

- Calculated SSC values (typically from NTU or ADCP);
- Remote sensing (e.g. satellite images).

Transfer functions

NTU ←→ SSC Requires Watersamples

SSC ←→ NTU Requires measurements of light

Point is all indirect measurements require direct measurements to establish a transfer function. Must be local!

Typical devices

- Watersamplers
- OBS (Optical backscatter)
- Lisst
- ADCP (Sound)
- Sediment traps

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Monitoring strategy

- Always choose a strategy that fits both the environment you want to protect and the operation you want to monitor.
- Define a sufficient, practical and cost-efficient monitoring strategy

Discussions and recommendations for setting turbidity limits

Briefly, the turbidity limit should be:

- Based on a system understanding of local hydrodynamics, sediments and biology;
- Manageable in a dredging operation and provide reasonable response times;
- Based on a clear definition of where to measure and what to measure;
- Site-specific and based on the critical stress levels for the local sensitive receptors.

We propose the following steps, which can be derived from a dedicated study, an ESIA, or a local survey undertaken in connection with the project. All of these steps are applicable in time and space:

- Develop a system understanding.
- Identify receptors sensitive to turbidity.
- Determine critical stress levels for sensitive receptors (threshold value).
- Choose a measurable turbidity limit based on the critical stress levels for the receptors and select a relevant measurable parameter.
- Determine the trigger levels that need to be respected to avoid reaching the threshold levels and related management.
- Determine where the turbidity limit applies based on the influence areas, the sensitive receptors and the dredging plan.
- Define a sufficient, practical and cost-efficient monitoring strategy.

Thank you for your attention!

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http://bit.ly/DfSICourse2020

Save the date for our next event!

CEDA webinar #11:

Effective Contract-type Selection for Dredging Works

- Date: 19 October 2020
- Time: 14:00 – 15:00 hrs. (CET)
- Free of charge, registration required

http://bit.ly/CEDA-webinar-contracts

CEDA Central Dredging Association