Case study: This document presents one example of information to be collected from real case in order to realise LCA.

Aquatic cell description for LCA

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CEAMaS

Civil Engineering Applications for Marine Sediments

Table

Qualitative description

Location and capacity

The case study for the aquatic cell is the location “Put van Cromstrijen” in the Netherlands. The “Put van Cromstrijen” is located in the water body “Hollands Diep”. The remaining storage capacity in 2013 for (contaminated) sediments for “Put van Cromstrijen” was 11,5 million m^3 sediment(*).

> (*) The capacity is a volume capacity after consolidation, assuming a consolidated density of 1,650 kg/m3 with a mineral density of 2,350 kg/m^3. Therefore, the consolidated solid weight per m3 is 1,131 $kg/m^{3.}$ Taking an uncertainty margin of 10%, a translation of **1 ton sediment (dry weight)/m^3** is a safe lower level.

The location (an underwater sand quarry; an aquatic cell) is exploited in combination with a closed sludge deposit “Hollands Diep”. Sand rich material and heavily contaminated material goes to the deposit, clay rich material with an acceptable (**) sediment quality is stored in the aquatic cell “Put van Cromstrijen”.

> (**) The acceptable levels for Put van Cromstrijen are given in the Appendix, Table 2. Many of those values exceed the MTR for sediment and are specifically derived for this location based on the allowed emission to surface water.

Origin of material

Most material to be stored in either the deposit or the aquatic cell comes from locally (Hollands Diep related) dredged sources:

- Clean up Hollandsch Diep West (400 ha)
- Mitigation: Clean-up of Sassen plate and bank
- Rietbaan / Strooppot: 500.00 m3 contaminated sediment
- Reuse of sand fraction for Suppletion at Hoogezandsche Gorzen
- Northern bank: Dredging of shipping lane Hollands Diep

The concept is a closed sediment balance as much as possible, but the total capacity exceeds the sum of the works above.

Distance to location

Hollands Diep and the neighbouring lake Haringvliet have a total length of 50 km. The city of Dordrecht (meeting point for the rivers Maas and Rhine, many shipyards) is at 20 km. Shell Moerdijk (chemical industry) is at 5 km. On average the transport of most sediment:

- Will be by ship, typical capacity of a “beun” ship is 1.000 – 2.500 tonnes (average 1.500 tonnes)
- Will be within **20 km** of the aquatic cell
- Will be dredged with either a hopper (large volumes, margin of +/- dm on dredged layer, some spill, dilution with water) or a hydraulic crane (small volumes, high accuracy (cm’s), minimal spill, undiluted)
    - Hopper: density in beun +/- 1.150 kg/m^3:
        - Dry weight sediment: 260 kg/m^3
        - Dry weight capacity at 1.500 tonnes: 392 tonnes dry weight sediment
    - Hydraulic crane: density in beun +/- 1.350 kg/m^3
        - Dry weight sediment: 610 kg/m^3

    - Dry weight capacity at 1.500 tonnes: 913 tonnes dry weight sediment
- Unloading is done by opening the hatch (free fall, no pumping)

History and cost of location

The cost in 2009 for the construction of the neighbouring deposit was € 49 mln.

The aquatic cell was bought in 2000.The cost for the aquatic cell site is € 7.7 mln (acquisition price in 2000).

The Put van Cromstijen was a natural part of the lake (former estuary) Hollands Diep. From 1953 to 1963 sand was mined near Cromstrijen to repair the dikes after the flooding of 1953. The site was used from 1963 to 2000 as a sediment storage site (from 1983 to 2000 only with local sediments). In 2000 RWS (Dutch Ministry of Infrastructure and the Environment) was given the ownership of the site for € 7.7 mln.

Additional costs were limited to the construction of an underwater threshold (sand) of 1.000 meters in length and a height of 2.5 meter (+/- 20.000 m^3 sand, or 36 tonnes of sand). The cost is negligible.

Fuel consumption

A report from 2013 (***) on the Eemshaven (in the Northern part of Holland) reports on the fuel consumption of 3 medium sized dredging vessels (12.000 tonnes, 9.000 tonnes effective loading capacity).

(***) Verruiming Vaarweg Eemshaven-Noordzee Milieueffectrapport, 9 december 2013

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The effective sediment capacity of the dredging vessels is 9.000 tonnes, with a volume of 5.000 m^3 of sediment. This yields a bulk density of 1.800 kg/m^3 (high for sediment, the dry weight content is 1.400 kg/m^3). This means that a <u>hydraulic crane</u> was used for dredging.

Reported average fuel (diesel) consumption for <u>dredging:</u>

- per m^3: 0.34 litre
- *per ton: 0.24 litre / ton dry weight (sediment)* (assuming ρ = 1.800 kg/m^3)

Fuel (diesel): ρ= 0.832 kg/l

- per ton: 0.20 kg fuel / ton dry weight (sediment)

<u>Ship movement</u> fuel consumption: Based on STREAM (translated for efficiency in 2018)

Tabel F.5: Emissiefactoren binnenvaartschip 12.000 ton conform STREAM International Freight 2011

		2018
Capacity	Load capacity (tonne)	12000
TTW	MJ/ tkm	0.22
TTW emissions (g/tkm)	CO2	16
	SO2	0.0018
	PM2.5	0.0067
	NO_x	0.20
	PM_{10}	0,0081*

Tabel F.2: Emissiefactoren per type brandstof, conform CBS statline

NO_x emissie [g/kg brandstof]	**PM_{10} emissie [g/kg brandstof]**
43,4	1,4

Fuel (diesel): ρ= 0.832 kg/l

NOx = (0.2 gram tonnes/km)/(43.4 gram/kg fuel)

= 0.0046 kg fuel per ton (bulk) per km

= 0.0055 l fuel per ton (bulk) per km

= *0.0040 l fuel per ton dry weight (sediment) per km*

Reported average fuel (diesel) consumption for <u>unloading (dumping):</u>

- per m³: 0.052 litre
- *per ton: 0.037 litre / ton dry weight (sediment)* (assuming ρ = 1.800 kg/m^3)
- per ton: 0.022 kg fuel / ton dry weight (sediment)

Table 1 Overview of fuel consumption (litre) dredging, transport and dumping for aquatic cell "Put van Cromstrijen"

	dredging (litre/ton dry weight)	**transport** per km	**20 km**	**dumping** (litre/ton dry weight)	**Total fuel** (litre/ton dry weight)
Fuel cost contribution (%)	0.24 75%	0.0040	0.080 24%	0.0040 1%	0.33

Step by step input

1) Preparation work for creating the aquatic cell:
    a. € 7.7 mln initial cost (acquisition)
    b. no additional preparations cost
2) Dredging, transport by ship (see distance to location) and unloading:
    a. Average distance from sediment site to aquatic cell 20 km
    b. Total fuel consumption: 0.33 litre/ton dry weight (0.27 kg fuel/ton dry weight)
    c. Wear on dredging vessel (lifespan vessel = 30 years)?
3) Transport (terrestrial): none
4) Work on site: none (see unloading, disposal at site)

5) Maintenance: negligible on materials (no active pumping):
   i. yearly survey with side scan sonar
   ii. monitoring of turbidity (automated sensor)
   iii. groundwater monitoring (divers and water quality samples)
6) Close down scenario: capping with 1 meter of ‘living layer’.
   i. This is a 1 meter thick sediment layer with background concentrations of contaminants
   ii. This also means that the aquatic cell has an extra capacity of 10 mln. m^3 sediment for in system sediments
   iii. Same cost/benefit criteria as for the contaminated sediment, but
7) Land use before: none (partly filled under water sand mine quarry)
8) Land use after filling: nature conservation area
   i. ecotope/habitat not yet defined

In short

The aquatic cell “Put van Cromstrijen” is a passively managed location (no pumps, pipes, dewatering, etc.) with a capacity of well over 11 mln. m^3 sediment, no loss of system function before the activity, a supply of sediment in a relative close by (20 km) region (although there is +/- 1 mln. m^3 capacity for material from outside the region), all transport can be done by the same vessel (dredging, transport, dumping). The acceptance levels are well above the MTR of sediments. After filling up the allowed capacity with contaminated sediments, the site can be used for normal dredging disposal (at background levels) for an additional 10 mln. m^3 sediment. After filling the cell the site will be transformed to a nature conservation area (probably alluvial forest), creating habitat and improve the WFD ecological status for the lake.

The relative cost for Put van Cromstrijen compared to other solutions is given in Table 3.

Appendix

Table 2 (**) Acceptable concentration Put van Cromstrijen versus MTR values for sediment

	Acceptatie slib kwal. Put van Cromstrijen mg/kg	MTR sediment verontr. zw. stof t=0 mg/kg
Metalen		
Cadmium	**35**	12
Kwik	**17**	10
Koper	**345**	73
Nikkel	**90**	44
Lood	**510**	530
Zink	**2520**	620
Chroom	**545**	380
Arseen	**145**	55
Organische verbindingen		
PAK		
Naftaleen	**--**	0.10
Anthraceen	**--**	0.10
Fenanthreen	**--**	0.5
Fluorantheen	**--**	3.0
Benz(a)anthraceen	**--**	0.4
Chryseen	**--**	11.0
Benzo(k)fluorantheen	**--**	2.0
Benzo(a)pyreen	**--**	3.0
Benzo(g,h,i)peryleen	**--**	8.0
Indeno(1,2,3-cd)pyreen	**--**	6.0
Som 10-PAK (Som 7 + abc)	**50**	
PCB		
PCB-28 (norm in zwevend slib)	**--**	0.0080
PCB-52 (norm in zwevend slib)	**--**	0.0080
PCB-153 (norm in zwevend slib)	**--**	0.0080
som 7 PCB	**2**	
Vluchtige halogeen koolwaterst.		
Hexachloorbenzeen	**0.15**	0.005
Organochloor bestr. Midd		
Aldrin (*)	**--**	0.006
Dieldrin (*)	**--**	0.450
Endrin (*)	**--**	0.004
Isodrin	**--**	--
Telodrin	**--**	--
som drins	**0.10**	
DDT	**--**	0.009
DDD	**--**	0.002
DDE	**--**	0.001
som DDT-DDE	**1.0**	
Alpha-HCH	**--**	0.290
Beta-HCH	**--**	0.920
Gamma-HCH (lindaan)	**--**	0.230
som HCH	**0.20**	
Heptachloor	**--**	0.068
Heptachloorepoxyde	**--**	0.00002
Hexachloorbutadieen	**--**	--
Overige stoffen		
Minerale olie (GC)	**4700**	--
EOCl	**24**	--

Table 3 Cost comparison of sediment treatment (top) and sediment storage sites (bottom)

Verwerkingstechniek	Zandig	Matig zandig	Kleiïg	Venig
Verspreiden op land	€ 0,-	€ 0,-	€ 0,-	€ 0,-
Op de kant zetten	€ 0,-	€ 0,-	€ 0,-	€ 0,-
Verspreiden in zout water	€ 0,-	€ 0,-	€ 0,-	€ 0,-
Verspreiden in zoet water	€ 0,-	€ 0,-	€ 0,-	€ 0,-
Direct toepassen in werk	€ 3,63	€ 3,63	€ 3,63	€ 3,63
Rijpen	€ 13,07	€ 19,64	€ 34,11	n.v.t.
Landfarmen	€ 18,99	€ 28,52	€ 49,55	n.v.t.
Sedimentatiebekken / nat storten slib	€ 13,38	€ 18,53	n.v.t.	n.v.t.
Sedimentatiebekken / droog storten slib	€ 23,31	€ 42,96	n.v.t.	n.v.t.
Sed.bekken/hydrocycl. / nat storten slib	€ 23,72	€ 35,27	n.v.t.	n.v.t.
Hydrocyclonage / droog storten slib	€ 25,81	€ 46,75	n.v.t.	n.v.t.
Koude immobilisatie	€ 34,06	€ 51,70	€ 63,50	n.v.t.
Omrekeningsfactor tds/m3 ex situ	1	0,7	0,4	0,3

Bron: MKBA Waterbodems.

Het verspreiden van baggerspecie en het direct toepassen is uiteraard het goedkoopst omdat hier nauwelijks verwerkingskosten worden gemaakt. Het eenvoudig verwerken (rijpen, landfarmen en zandscheiden door sedimentatie) en nat storten van baggerspecie zitten qua verwerkingskosten in de middenmoot. Zandscheiden door hydrocyclonage, ontwateren en immobilisatie gemiddeld genomen de duurste bestemmingen.

De tarieven voor reguliere stortplaatsen liggen tussen de € 30 en 60 per ton droge stof (exclusief BTW). Voor de natte stort is in het MKBA uitgegaan van de volgende storttarieven.

Depot	**Mm3 restcapaciteit per 01/01/2005**	**Kosten per m3 ex situ (€)**
Slufter	93,3	8,30
Hollandsch Diep	10	13,61
Seaport Groningen	1,5	22,69
Averijhaven	1,9	13,61
Drempt	0,72	24,50
IJsseloog	22,8	13,61
Cromstrijen	11	6,81
Amerikahaven	12	12,60
Kwaliwaal	4	20,42

Bron: MKBA Waterbodems.

CEAMaS brings together eight partners from Belgium, France, Ireland and the Netherlands in order to develop knowledge and consensus to raise new solutions for reuse of marine sediments applicable to all of Europe. The project aims to promote the beneficial re-use of marine sediments in civil engineering applications, in a sustainable, economical and socially acceptable manner. The partnership expertise covers civil engineering, geosciences, coastal and maritime engineering, dredging and sediment management, geography, sustainable construction and environmental monitoring.

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