Memo

To
EcoShape BwN HK4.1

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Subject
Inclusion of a costs indicator in the interactive design tool for the Holland Coast

1 Introduction

This document describes the implementation of a costs indicator in an interactive tool, which is available for the Holland Coast (referred to as ITHK). This tool was developed within the BwN work package HK4.1 (Deltares, 2012). It is noted that the goal of the current document is to describe the implementation of the indicators and not the impact assessment of nourishment strategies. A summary of the aims of the related BwN work packages HK4.1 is given below.

Building with nature HK 4.1
The work package HK4.1 aims at “Developing a strategy for the long-term, sustainable development of the Holland Coast through extrapolation of findings from HK-projects and pilots to the scale of the entire Holland Coast”. The strategy will be based on the design philosophy of BwN aimed at maximizing the potentials of the eco-morphodynamic system. The considered coastal management strategies vary between the present management strategy and new strategies that are advised by the Delta commission (2008). The activities are (1) the development of an aggregated morphological model of the Holland Coast enabling the analysis of large scale morphological development, (2) deriving information from geological analogs of sand-engines in order to provide validation material for upscaling of the morphodynamic models, and (3) the development of a habitat - and vegetation model enabling the 'translation' of large scale morphological model forecasts into (ecological) habitat effects and (4) the development of different large scale sand mining - and nourishment scenarios.

2 Assessing cost prices

2.1 General

This section discusses the cost price of nourishments. Section 2.2 distinguishes the relevant factors that determine the cost price of nourishments. The cost prices for nourishing sediment are then discussed in Section 2.3. Furthermore, the applied cost price for structures is described (Section 2.4). The resulting cost prices for nourishments are then validated in Section 2.5 by means of a cross-reference with projects that were carried out, while Section 2.6 provides an analysis of the impact of market and fuel price developments on the cost price of nourishments.

2.2 Relevant factors

The cost price of nourished sediment depends on a variety of factors, like:

- method of nourishing,
- volume of the nourishment,
- transport distance, and
- complexity of the work.

With respect to the method of nourishing it is noticeable that placing a nourishment on the beach is more costly than rainbowing of the sand, which is on its turn more expensive than a foreshore nourishment which uses a bottom release method. The volume of the nourishment plays a role, as larger nourishment volumes can be carried out with more cost-effective dredgers. Also the indirect costs are lower for larger volumes. The transport distance between a the borrow area and the nourishment location influence both the time that the dredging material is needed and fuel costs. Last of all, more complex works may require more handling of pipes and consequent less working hours with available equipment.

A method is needed to differentiate the cost price of a nourishment in a way that includes the above mentioned cost price determining factors. Such a method would depend mainly on the volume that is nourished on the coast. For pragmatic reasons it was decided to classify beach nourishments in three nourishment volume classes for which typical historical cost prices could be found, because it will be difficult to find a continuous relation between cost price and nourishment volume.

- Small nourishments (up to 2,5 Million m^3): this coincides with most ongoing nourishment schemes in the Netherlands at present, most are even less than 1 million m^3, but 1 to 2 million m^3 large volumes do exist as well. Typical for all this kinds of nourishments is that they usually cover considerable coastal sections since such a nourishment is mostly in the order of 250 to 400 m^3/m. This implies much handling of pipes, especially in the case of beach nourishments. Smaller nourishments are entirely or to a large part beach nourishments. It is a matter of debate whether it would be more pragmatic to downscale classes, for example from up to 0,5, 0,5 up to 1 Million m^3 and so forth, since the smaller the nourishment type the higher the percentage of indirect costs. However, with the work package HK41 very small nourishments are not included in the strategies.
- Medium nourishments (up to 7,5 Million m^3). There are periodical nourishments up to 7,5 Million m^3. They often consist largely of foreshore nourishments as well but generally still nourish about 800 to 1000 m^3/m.
- Large nourishments (above 7,5 Million m^3). This class suggests mega nourishments with volumes in excess of 1000 m^3/m. A large part of the volume consist of foreshore nourishments which may be rainbowed. Furthermore, a lot of the works take place on a single location, which reduces the work. The indirect costs are smaller as well.

In addition to above distinction in volume classes of nourishments, also the actual position of the nourishments in the cross-shore profile (e.g. on the foreshore) should be provided. This parameter will have influence on the applied nourishing methods (e.g. with pipes, rainbowing or bottom release) for a specific nourishment. Two classes with respect to the location on the cross-shore profile could be chosen:

- Foreshore
- Predominantly on the beach

Table 1 provides an overview of the methods used for the distribution of sand of both types of locations in the cross-shore profile. It is noted that the larger beach nourishments are no longer placed exclusively on the beach. For example, a large part of the nourished sand for the sand engine (built on the coast of Delfland) was placed by bottom release and rainbowing. Still a substantial part of the volume was put on the beach or the sand engine itself and mainly distributed by frequent allocation of the pipes.

Table 1 Distribution of nourishment methods for different nourishment types

Nourishment type	Small Foreshore	Small Beach	Medium Foreshore	Medium Beach	Large Foreshore	Large Beach
Release (%)	100	0	100	10	100	40
Rainbow (%)	0	0	0	20	0	20
Beach (%)	0	100	0	70	0	40

Summarising, the actual determination of the cost prices of the nourishment depends on the (1) the volume class and (2) the class for the location on the profile.

2.3 Cost prices

The basic components of the overall cost price of a nourishment consist of the costs for 'take-up', 'transport', 'nourishing' and 'pipes'. Table 2 shows the difference in costs between factors like volume, transport, and nourishment type. These cost-figures were derived for the Dutch coast circumstances and 2009 pricing conditions. A handling factor (set at 1.5) was assumed to account for effective capacity of the dredgers that can be used and for the delivery factor. The mentioned basic components of the cost price (in Table 2) are described here:

- Take up: this is the factual dredging of sand in the sand pit. It takes in the order of 1 hour for different types of dredging vessels. The costs for operating three different dredgers with different capacities are also indicated. This results in a direct cost per m^3 that differs significantly between the larger and smaller dredgers.
- Transport: this is indicated as the distance between pit and nourishment location, but the costs imply a two-way transport. The velocity between different classes of vessels does not differ much, but an empty ship is faster than a fully loaded one. For transport distances of less than a few kilometers, the time needed would increase somewhat. For transport distances above 5 km this is no longer relevant.
- Nourishing:
  - Foreshore: this implies a bottom release which takes a little bit longer for the larger vessels. Often the release is not confined to a single location but needs spreading, especially in the case of smaller foreshore nourishments. This latter is not taken into account.
  - Rainbow: this requires more time than bottom release. The larger vessels have larger pumps and can cover larger distances. But this is not relevant considering the details required for long-term nourishment strategies.
  - Beach: this is done by pumping the sand to a location on the beach. There are order cost factors involved. There is a handling crew that allocates the pipes, redistributes the sand etc. These additional costs have not all been included, since we assume simple nourishment. In case coastal strengthening would be included and hence also strengthening of the dunes, nourishment costs would be significant higher (up 20 tot 25%) of simple beach nourishment.
- Pipes (handling, wear and tear): this are additional costs based on a set of limited length. The costs of pipes can be considerable especially if longer distances need to be covered. Tear and wear and handling increase. This is mainly done to cut done transport by vessel and to allow for the use of larger vessels that can not come close to

shore. These are details that differ depending upon the location and the available vessels and are not included.

Table 2 Component cost figures for a nourishment (differentiated for three volume classes)

Take up	minutes	cost/h	load effective	Euro/m3
small (up to 2,5 Mm3)	60	1250	3500	0.54
medium (2,5 to 7,5 Mm3)	60	2360	9100	0.39
large (above 7,5 Mm3)	60	3200	13500	0.36
Transport (two way)	**minutes/ kilometer**	**cost/h**	**load effective**	**add.km Euro/km**
small (up to 2,5 Mm3)	8	1250	3500	0.07
medium (2,5 to 7,5 Mm3)	8	2360	9100	0.05
large (above 7,5 Mm3)	8	3200	13500	0.05
Foreshore (bottom release)	**minutes**	**cost/h**	**load effective**	**Euro/m3**
small (up to 2,5 Mm3)	10	1250	3500	0.09
medium (2,5 to 7,5 Mm3)	12	2360	9100	0.08
large (above 7,5 Mm3)	12	3200	13500	0.07
Rainbow (shallow foreshore)	**minutes**	**cost/h**	**load effective**	**Euro/m3**
small (up to 2,5 Mm3)	55	1250	3500	0.50
medium (2,5 to 7,5 Mm3)	57	2360	9100	0.37
large (above 7,5 Mm3)	60	3200	13500	0.36
Beach (pipes)	**min/km**	**cost/h**	**load effective**	**Euro/m3**
small (up to 2,5 Mm3)	75	1250	3500	0.68
medium (2,5 to 7,5 Mm3)	75	2360	9100	0.49
large (above 7,5 Mm3)	75	3200	13500	0.45
Pipes (handling, wear and tear)				**Euro/m3**
small (up to 2,5 Mm3)				0.17
medium (2,5 to 7,5 Mm3)				0.17
large (above 7,5 Mm3)				0.17

The actual total cost price of the nourishment can then be computed by accounting for:

- Direct costs
  - Volume related costs (Take up, Nourishing and Pipes)
  - Transport costs
- Indirect costs

The volume related costs of the nourishment (part of direct costs) can be computed for each of the combinations of the three volume classes and two cross-shore location classes (see Table 3). These cost prices were determined by adding up the component cost prices (for take up, nourishing method and pipes) from Table 2. The nourishment volume class (e.g. medium) was used to find the right component cost price in Table 2, while the cross-shore location class was used to determine relative contribution of the nourishing methods (i.e. with pipes, rainbowing and bottom release) and the costs of 'handling, wear and tear of pipes'.

Table 3 Volume related costs for a nourishment type (differentiated for three volume classes and two cross-shore location classes)

	Small		Medium		Large	
Nourishment type	Foreshore	Beach	Foreshore	Beach	Foreshore	Beach
Costs	0.63	1.39	0.47	0.94	0.43	0.71

The transport cost prices (part of direct costs) are presented in Table 4 for typical distances of 5, 10, 15 and 20 km between the borrow area and the nourishment location. These distances are based on two way transport. The most common transport distances along the Dutch coast are between 10 and 20 kilometers. In the province of Zeeland also distances of up to 40 km can occur, as the position of the NAP -20m depth contour is very far from the coast.

Table 4 Transport costs

	Small		Medium		Large	
Nourishment type	Foreshore	Beach	Foreshore	Beach	Foreshore	Beach
Transport [km]						
5	0.34	0.34	0.25	0.25	0.23	0.23
10	0.69	0.69	0.50	0.50	0.46	0.46
15	1.03	1.03	0.75	0.75	0.68	0.68
20	1.38	1.38	1.00	1.00	0.91	0.91

The total direct costs (Table 5) of the work itself can be computed from the volume related costs in Table 3 and the transport costs in Table 4.

Table 5 Total direct costs for different nourishment types and transport distances

	Small		Medium		Large	
Nourishment type	Foreshore	Beach	Foreshore	Beach	Foreshore	Beach
Transport [km]						
5	0.98	1.74	0.72	1.19	0.66	0.94
10	1.32	2.08	0.97	1.44	0.89	1.17
15	1.66	2.42	1.22	1.69	1.12	1.39
20	2.01	2.77	1.47	1.94	1.35	1.62

Besides the direct costs also some indirect costs should be accounted for. These indirect costs constitute from a complex of various factors, such as engineering costs, mobilization /demobilization, unforeseen costs and risks but also VAT. They are exclusive of state taxes ('domeinvergoeding') because we assume that all nourishments will be state financed. The indirect costs are larger for the smaller nourishment types, which require often a similar degree of preparation but for far less volume handled. Table 6 shows the additional costs as a factor of the direct costs. The total costs can be computed on the basis of this information (see Table 7).

Table 6 Additional indirect costs for different nourishment types

Nourishment type	Small Foreshore	Small Beach	Medium Foreshore	Medium Beach	Large Foreshore	Large Beach
Indirect (% of direct cost)	110	110	90	90	75	75

Table 7 Total costs for different nourishment types and transport distances

Nourishment type		Small Foreshore	Small Beach	Medium Foreshore	Medium Beach	Large Foreshore	Large Beach
Transport [km]							
	5	2.05	3.64	1.37	2.26	1.16	1.64
	10	2.77	4.37	1.85	2.74	1.56	2.04
	15	3.50	5.09	2.32	3.21	1.95	2.44
	20	4.22	5.81	2.80	3.69	2.35	2.84

As indicated in Table 7 there are large differences in the cost prices per cubic meter between large and small nourishment types. A small beach nourishment at a 10 kilometer distance amounts to 4,37 Euro/m^3 while a large nourishment may cut the cost price by a half (2 Euro/m^3).

2.4 Costs of structures

The costs for structures are charged per meter length of the structure. Typically cost prices used for groynes and revetments range from € 5,000 per meter to € 30,000 per meter. A value of € 20,000 per meter is used in this document.

2.5 Cross-reference of cost prices

The indicated total costs (Table 7) can be cross-referenced with factual costs of recent nourishment projects:

- The sand engine was built for a cost of 2,3 Euro/m^3. The transport distance was between the 10 and 15 kilometer mark and classifies as a mega beach nourishment.
- The coast of Delfland was strengthened for 4,4 Euro/m^3. The volume was in the order of medium, but the work extended over 10 km of coastal section and included much work in the strengthening of dunes. The cost difference between dune strengthening and beach nourishment are in the order of 25 to 30%. If these additional costs are subtracted the remaining costs are in the order of 3 to 3,3 Euro/m^3 which comes close to the 3,2 (average transport distance in the order of 14 km).
- Scheveningen was strengthened for 3 Euro/m^3 and consisted mainly of beach nourishment at a similar distance as the strengthening for the coast of Delfland.
- West Zeeuws Vlaanderen is strengthened for 7 Euro/m^3. This project consists of a number of smaller projects that are executed in different years. So in fact it is a string of small nourishments. The transport distance is in the order of 40 km and most work consists of beach nourishment. According to our calculation table this would amount to a price of 7,2 Euro/m^3 again close to the contract price.

Most prices as calculated can be validated against contracted prices. One should take into account that there are of course differences in complexity, market conditions and oil prices that have to be taken into account as well (see Section 2.5). For the purpose of defining the costs of long-term nourishment strategies, it is considered that the cost differentiation with above method provides sufficient results.

2.6 Sensitivity for market developments and fuel prices

The cost prices of nourishments are not fixed, but related to the market conditions, available technology and fuel prices. The market related developments are very volatile and vary between years. It is probably not useful to imply a trend that should be taken into account. Contract forms can have an impact on prices. If smaller nourishments are handled in larger contracts and if there is more flexibility in timing the work with available capacity the prices may be reduced significantly, perhaps even with 20%. This holds also for the larger types of nourishment, so the possible cost reduction does not differentiate much. In order to allow for larger contract flexibility for a mega nourishment, additional volumes are needed in order to “buy time” and therefore flexibility. The additional costs related to this depend much upon the coastal foundation policy that determines annual budgets for coastal management. This is complex and it is proposed to refrain from taking these aspects into the cost-setting for different nourishment strategies.

Technology related developments lead to vessels that become increasingly cost-effective, because the hulls are built more hydrodynamically, the pumps become smarter and more effective. Overall this will lead to lower fuel consumption and higher cost-efficiency. There are however limits to the potential increase of the cost-efficiency of dredging vessels, although even electricity powered vessels may be an option in the far future. There appears to be potential for a 15 tot 25% increase in fuel-efficiency.

At present in the order of 15% of the costs of nourishment are determined by the fuel price. If fuel prices go up, which is to be expected, than also the cost of nourishment increase. A 100% increase would result in a 7,5% increase in the costs of nourishment. It is difficult to asses to what extent the fuel prices may rise, since this is determined by a complex set of factors. Typical factors that determine oil price developments are market demand, economic crises, oil shale exploitation, increased use of renewable energy sources and more. For the sake of simplicity one may argue that the increase in fuel prices may be offset by the increase in fuel efficiency of the dredging fleet. This assumption may hold for the coming decades. On the middle and long-term the fuel-related costs of nourishment become more complex. Oil based operations will need to be transformed simply because oil is becoming increasingly scarce. If electric driven vessels would be an option, directly or indirectly by using hydrogen or other forms of energy capture systems, the long term price development may be strongly linked to the price of renewable energy. For some renewable energy sources the costs are still higher than oil prices but are sinking quickly. On the other hand using renewable energy on dredging vessels certainly is a technological challenge that will come with additional costs. It is proposed for the moment to assume that the increase in fuel price is counterbalanced by the increase in fuel efficiency.

3 Implementation of costs indicator

3.1 General

This section describes the implementation of the costs indicator in the Interactive tool for the Holland Coast (ITHK). First the considered approach is described in Section 3.2 and then the changes in the code in Section 3.3.

3.2 Costs indicator

The costs indicator assesses both the cost of nourishments and other structures along the coast (i.e. revetments and groynes). For this purpose an approach is used to quantify the cost prices of nourishments as is described in Section 2.3. The assessment of the costs of structures is performed on the basis of typical prices per length unit. The characteristic cost prices for the nourishments (see Table 2) and the structures are specified in an XML-file with cost price settings. This file also contains the distinction between the type of nourishment volume classes (small, medium and large).

The program code for the costs indicator (‘ITHK_ind_costs_direct.m’) is written in matlab. It loads the cost related settings, evaluates the costs of coastal structures, calculates costs of nourishments and writes this information to a KML text format which is printed to a KML-file in the ‘ITHK_postprocessing’ routine. A schematic overview of the procedure is provided in Figure 1.

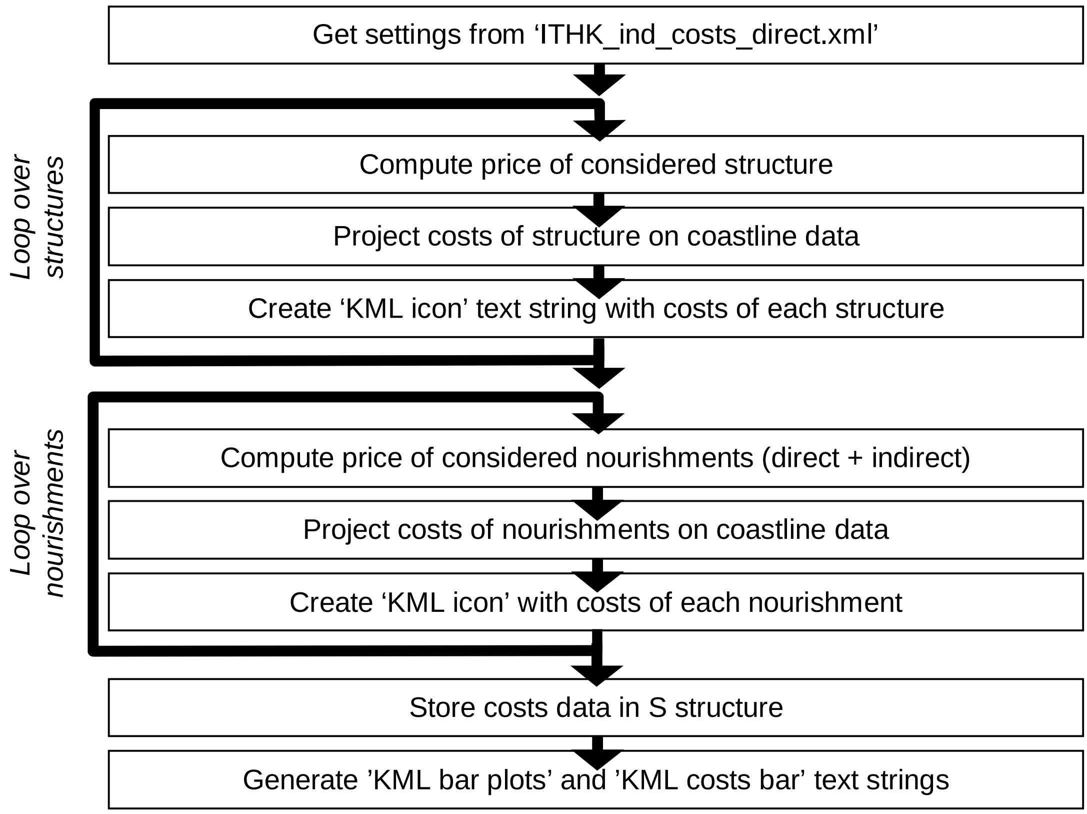

Figure 1: Approach used to assess time development of the costs

Three types of KML output are generated by the costs indicator. First a KML text string is generated with icons at the location of each nourishment (item 1 in Figure 2). Selection of such an icon will display a pop-up with information on the expected cost price for the considered nourishment (assuming a typical complexity). Secondly, a plot is made of the cumulative costs which are shown as a bulk parameter on the lower-right of the screen (item 2 in Figure 2) or in longshore distributed way (item 3 in Figure 2). The plots of the cumulative costs will change over time if the Google Earth time bar is used.

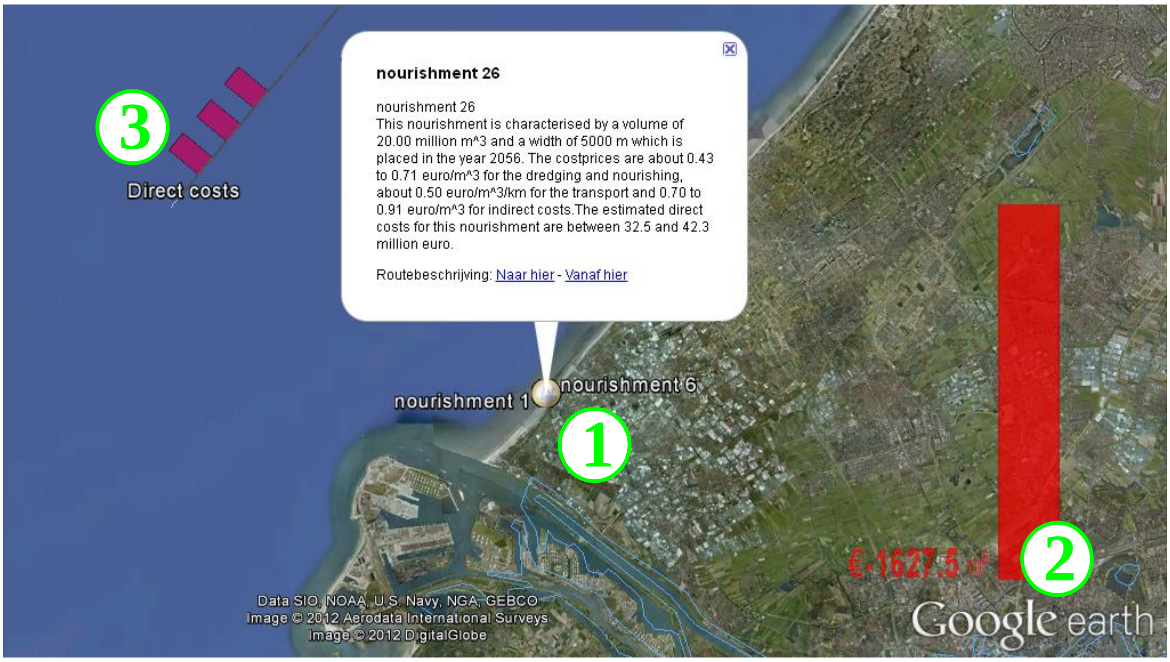

Figure 2: Visualisation of costs indicator results

3.3 Changes to the code

The changes that were made to the code of the Interactive Tool for the Holland Coast (ITHK) were made in the postprocessing directory and added to 'postprocessing\indicators\eco\'. The functions that were added are the following:

- *ITHK_ind_costs_direct.m*
  This routine computes the direct costs of a nourishment on the basis of the (1) dredging costs, (2) transport costs, (3) nourishing costs and (4) indirect costs. Furthermore, typical costs per length unit of hard structures can be taken into account. The routine uses typical component cost prices from the 'ITHK_ind_costs_direct.xml' file. Furthermore, the cross-shore location of the nourishment (foreshore or predominantly on the beach) is used from the 'ITHK_settings.xml' file.
- *ITHK_KMLbarplot.m*
  This function writes the computed impact on the indicators that was generated by one of the routines to a KML text string with bar plots. The KML text string can be printed to a KML file and presented in the ITHK web interface or directly in Google Earth.
- *ITHK_KMLcostsbar.m*
  This function writes the computed impact on the costs indicator to a KML text string with a costs bar that is displayed as an overlay on the lower right of the display. The KML text string can be printed to a KML file and presented in the ITHK web interface or directly in Google Earth.
- *ITHK_KMLcostsicons (local function)*
  This function writes the computed impact on the costs indicator to a KML text string with a icons with costs for each of the coastal measures. The KML text string can be printed to a KML file and presented in the ITHK web interface or directly in Google Earth.
- *ITHK_ind_costs_direct.xml*
  This settings-file contains the parameters used for the evaluation of the costs of the nourishments. It includes (1) a definition of the distinction of nourishments on the basis of the average volume per meter coast, (2) component cost prices, (3) distribution of sand

over the nourishment methods and (4) ratio of the indirect costs. A typical file reads like this:


```xml
<?xml version="1.0" encoding="ISO-8859-1"?>
<costs>
  <classdefinition>
    <description>Definition of classes for small, medium and large nourishment</description>
    <header> lowerbound (m3/m), Upperbound (m3/m)</header>
    <small>  0      500    </small>
    <medium> 500    1500   </medium>
    <large>  1500   100000 </large>
  </classdefinition>
  <costprices>
    <description>Cost prices in euro/m3 or euro/km (for transport)</description>
    <header> small (less than 2.5Mm3), medium (2.5 to 7.5Mm3) and large (larger than 7.5Mm3) </header>
    <take_up>           0.5400    0.3900    0.3600       </take_up>
    <transport>         0.0700    0.0500    0.0500       </transport>
    <nourish_foreshore>  0.0900    0.0800    0.0700       </nourish_foreshore>
    <nourish_rainbow>    0.5000    0.3700    0.3600       </nourish_rainbow>
    <nourish_beach>      0.6800    0.4900    0.4500       </nourish_beach>
    <pipes>             0.1700    0.1700    0.1700       </pipes>
    <description2>Cost prices in euro/m length of these structures</description2>
    <revetment>         20000        </revetment>
    <groyne>            20000        </groyne>
  </costprices>
  <distribution>
    <description>Distribution of sediment over beach and foreshore (beach or foreshore)</description>
    <beachtype>
      <description> Nourishment method (if 'predominantly beach')</description>
      <header> small (less than 2.5Mm3), medium (2.5 to 7.5Mm3) and large (larger than 7.5Mm3) </header>
      <release>        0       10      40            </Release>
      <rainbow>        0       20      20            </Rainbow>
      <beach>          100     70      40            </Beach>
    </beachtype>
    <foreshoretype>
      <description>Nourishment method (if foreshore)</description>
      <header> small (less than 2.5Mm3), medium (2.5 to 7.5Mm3) and large (larger than 7.5Mm3) </header>
      <release>        100     100     100           </Release>
      <rainbow>        0       0       0             </Rainbow>
      <beach>          0       0       0             </Beach>
    </foreshoretype>
  </distribution>
  <indirectratio>
    <description>The indirect costs as a ratio of the direct costs.</description>
    <header> small (less than 2.5Mm3), medium (2.5 to 7.5Mm3) and large (larger than 7.5Mm3) </header>
    <beachtype>        110     90      75            </beachtype>
    <foreshoretype>     110     90      75            </foreshoretype>
  </indirectratio>
</costs>
```

4 Example case

4.1 Introduction

In this section a typical example is shown of the results for the costs indicator described in Section 3.2 and 3.3. First, the Holland coast model in the ITHK is described concisely in Section 4.2. Section 4.3 then describes the reference scenarios, for which the results are presented in Section 4.4.

4.2 Holland coast model

The ITHK includes a UNIBEST coastline model that has been setup for the Holland coast (from Hoek van Holland to Den Helder). Structures were included at Scheveningen and IJmuiden to represent the harbour moles at these locations. The model has a length of 118 km and includes 113 cross-shore profile rays for which the sediment transport was computed. An overview of the longshore sediment transport is in the model is provided in Figure 3.

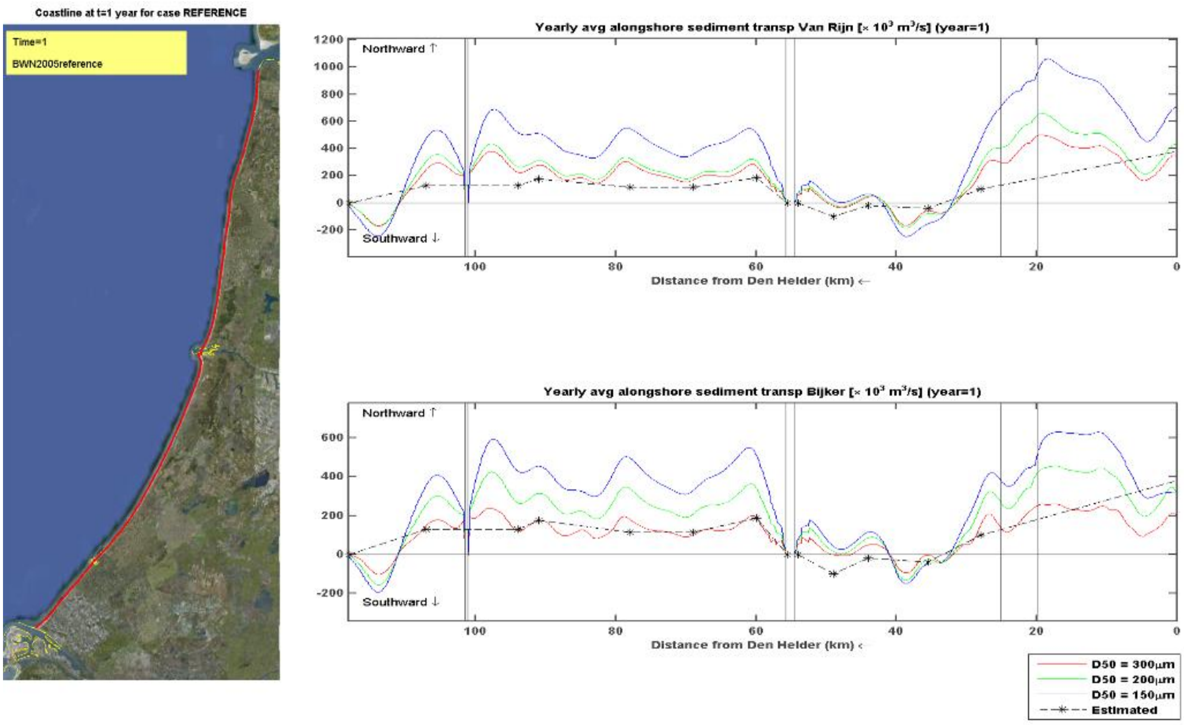

Figure 3: Computed sediment transport for 3 sediment diameters (D50=150, 200 and 300 μm) and two sediment transport formulae (Top: Van Rijn, 2004, Bottom: Bijker, 1977) (Deltares, 2010)

A detailed description of this tool is provided in the memo 'Evaluation of nourishment strategies Cycle 1 : HK4.1: Long-term sustainable strategies for the Holland Coast' (Deltares,2010).

4.3 Reference scenarios

This section provides an overview of reference scenarios for the maintenance of the coast, which are summarised here:

1. *Autonomous*
   Autonomous development without measures
2. *Minimal consolidation: Continuous nourishment*
   Minimal consolidation of the coast at coastal settlements with 5 million m^3/yr of continuous nourishments.
3. *Minimal consolidation: Five yearly nourishments*
   Minimal consolidation of the coast at coastal settlements with 2.5 million m^3/yr of nourishments with an interval of 5 years.
4. *Seaward*
   Seaward extension of the coast with sand engines of 20Mm3 and a return interval of 10 years at 5 locations along the coast (Vlugtenburg, Katwijk, Zandvoort, Egmond and at the Hondsbossche zeewering).
5. *Revetments*
   Revetments protecting the coastal settlements (no additional nourishments)

The model simulations cover a period of 95 years until the year 2100. A moderate sea level rise (2 mm/yr) is included for all scenarios by means of an additional coastal retreat that was computed for a profile with an average slope of 1:500. The resulting costs indicator is presented only for the situation with ‘predominantly beach nourishments’. The results are expected to be similar, but with somewhat total costs, for a situation with foreshore nourishments. It is noted that the aim of these scenarios is to evaluate the presentation of the costs indicators rather than the actual coastal changes. Furthermore, it was assumed that the average sailing distance between a coastal nourishment and the borrow area is 10 kilometers.

4.4 Results

This section presents the results of the model run for the reference scenarios (Figure 4 to Figure 8). The Figures show the coastline position as a yellow line on the coast and the change in coastline position with red and green bars (which improve the visibility of the coastline changes).

In offshore waters the indicator for the distribution of the cumulative costs along the coast is shown (purple bars). The cumulative costs for the whole costs are presented with the red bar on the lower right of the screen. Furthermore, the costs per nourishment can be presented by clicking on the ‘euro icons’ at the location of the nourishment. It will then show indicative characteristic cost prices of that particular nourishment.

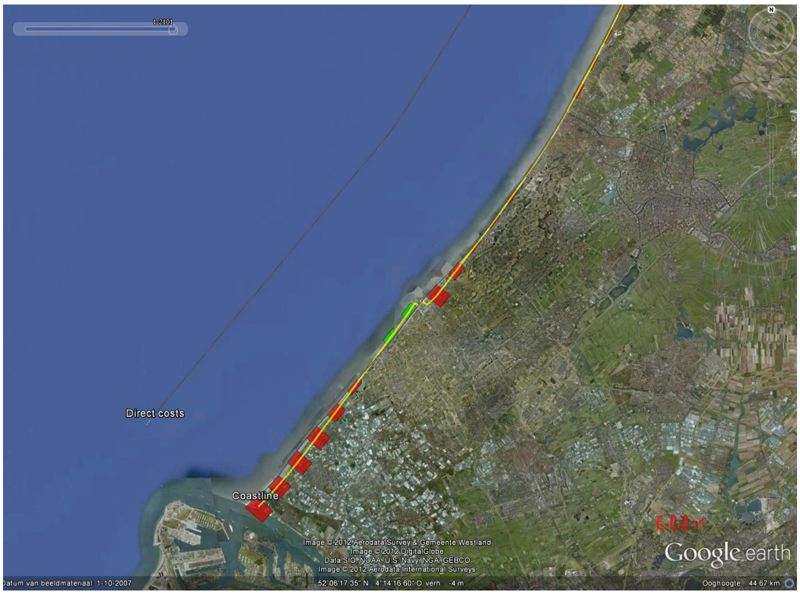

Figure 4: Coastal development and coastal indicators for reference scenario 1 (Autonomous).

Figure 4 shows considerable erosion along the coast, which is to be expected for a scenario without any coastal protection measures or costs. Note that the purple bars with cumulative costs along the coast are therefore not visible.

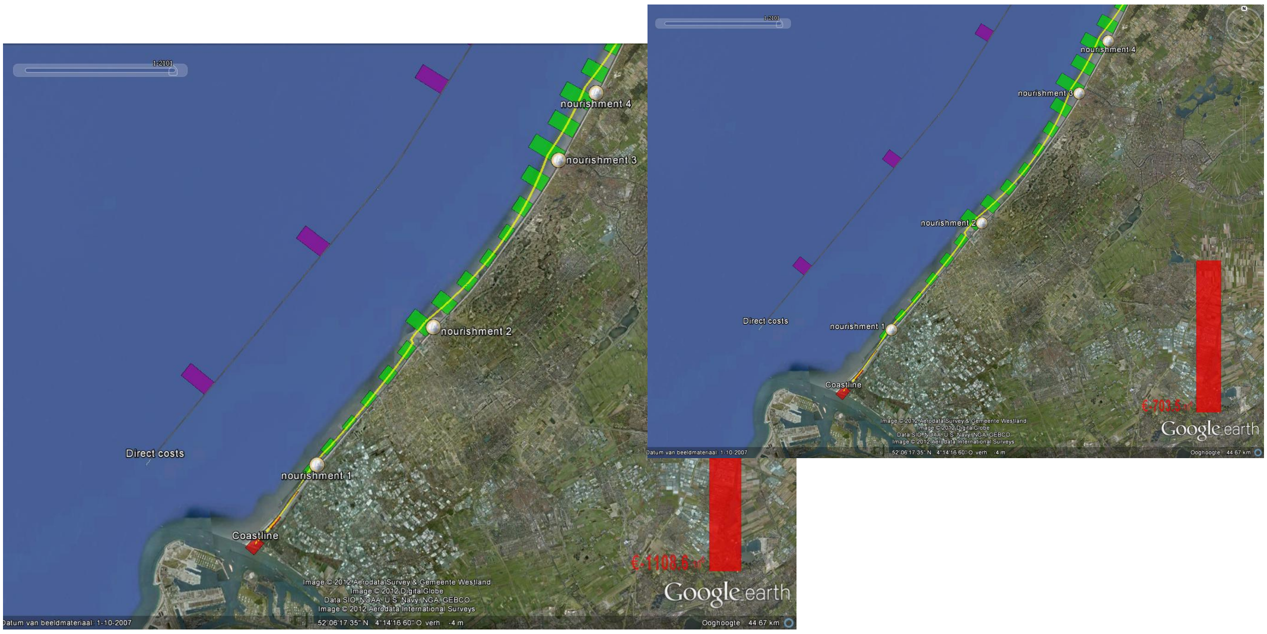

Figure 5: Coastal development and coastal indicators for reference scenario 2 (Minimal consolidation: continuous nourishment). Nourishment on the beach (left) or on the foreshore (right).

A scenario with continuous (i.e. yearly) nourishments clearly showed where the nourishments were placed (Figure 5), as the costs are attributed to these locations (purple bars). The total costs of this scenario are estimated to be about 7.5 and 12 million €/yr respectively for nourishments on the foreshore or on the beach (for 10 km transport distance). It is noted that the prices may rise by 30 to 50% if transport distance doubles. The foreshore nourishment clearly shows smaller costs than the beach nourishments, which is according to expectations.

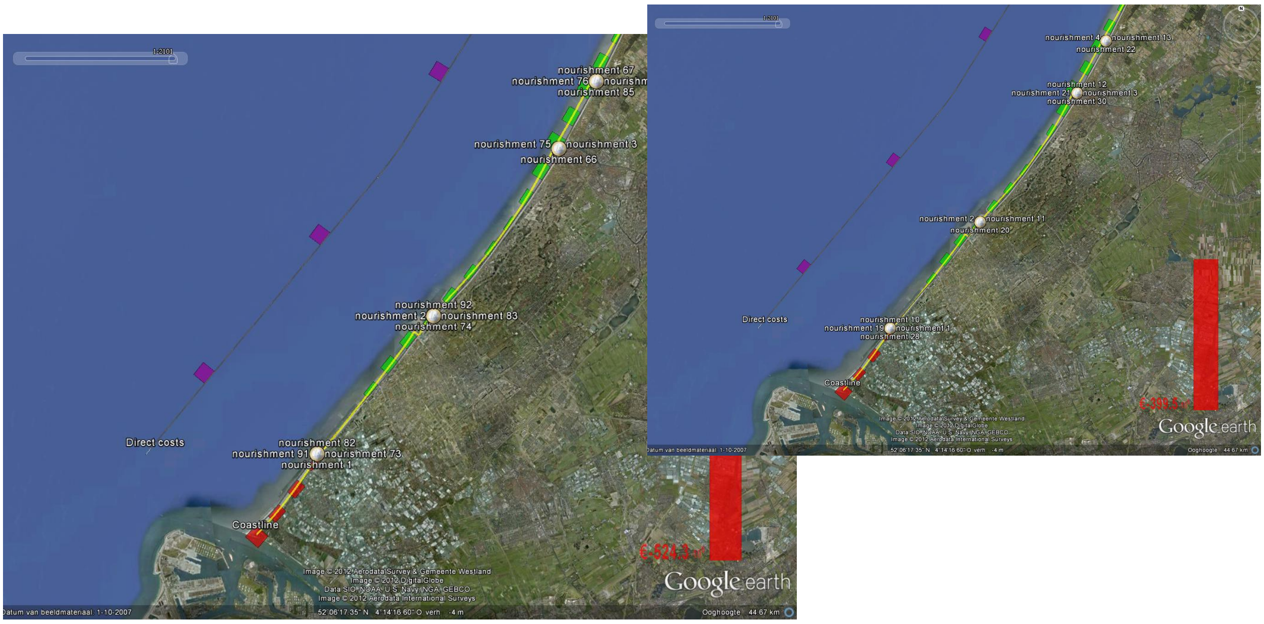

Figure 6: Coastal development and coastal indicators for reference scenario 3 (Minimal consolidation: Five yearly nourishments). Nourishment on the beach (left) or on the foreshore (right).

The nourishments with regular intervals of five years (Figure 6) showed has smaller costs than the scenario 2 with continuous nourishments, which is mainly due to the smaller total nourishment volume. The costs, however, are The total costs of this scenario are estimated to be about 4 and 5.5 million €/yr respectively for nourishments on the foreshore or on the beach (for 10 km transport distance). It is, however, noted that prices may rise by 30 to 50% if transport distance doubles.

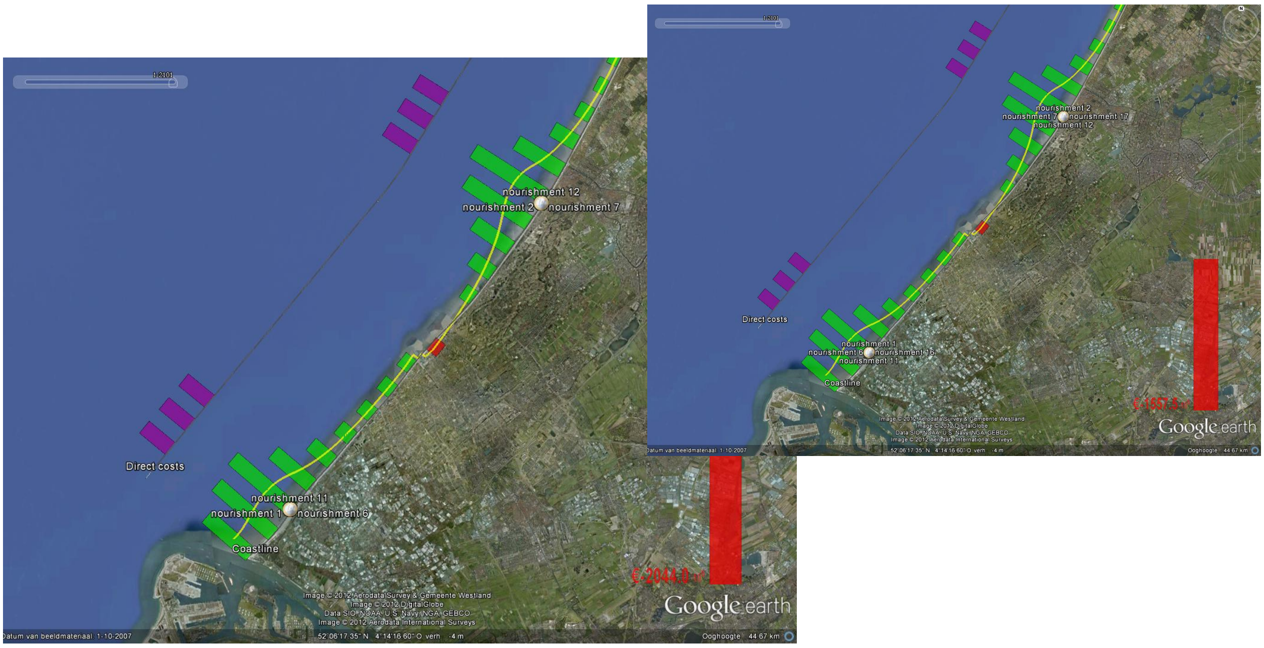

Figure 7: Coastal development and coastal indicators for reference scenario 4 (Seaward). Moments in time before and after a nourishment took place. Nourishment predominantly on the beach (left) or on the foreshore (right).

The coastal development for a seaward scenario (Figure 7) showed that the coast can be build out considerably in such a period. The costs, however, are considerable. The total costs of this scenario are estimated to be about 15 and 20 million €/yr respectively for nourishments on the foreshore or on the beach (for 10 km transport distance). It is, however, noted that prices may rise by 30 to 50% if transport distance doubles.

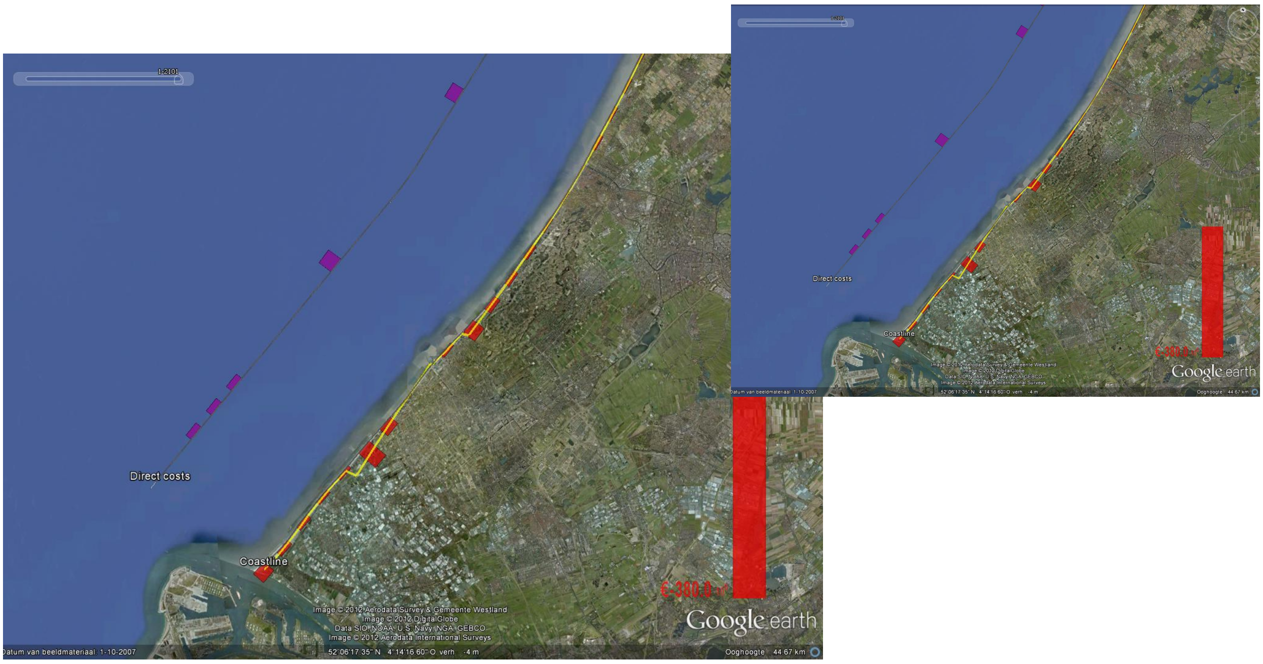

Figure 8: Coastal development and coastal indicators for reference scenario 5 (Revetments). Nourishment predominantly on the beach (left) or on the foreshore (right).

The scenario with revetments (Figure 8) shows smaller costs than the scenarios with nourishments. It is, however, noted that these measures should be taken on a short term. The costs for the construction of the revetments are therefore initial costs, while the nourishment costs of spread more evenly over the considered time period.

5 Conclusions

The implementation of a costs indicator in the interactive tool for the Holland Coast is described in this document. A description of the methodology of valuing of this indicator is provided in this document. An application for a test case provided realistic results.

Version	Date	Author	Initials	Review	Initials	Approval	Initials
1.0 (Draft)	July 2012	B.J.A. Huisman J. Fiselier W.P. de Boer		A.P. Luijendijk		K.J. Bos	

References

Deltares, 2010
Evaluation of nourishment strategies Cycle 1 : HK4.1: Long-term sustainable strategies for the Holland Coast'. Prepared for EcoShape. Projectnumber 1200893. Authors B.J.A. Huisman & A.L. Luijendijk, Delft, 2010.

Deltares, 2012
Model validation report for the Interactive Tool for the Holland Coast.