DEMCA
Digital Elevation Model
of Coastal Areas

STATE-OF-THE-ART 2017

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1 INTRODUCTION

Innovation procurement challenges industry from the demand side to develop innovative solutions for public sector needs. The aim of the DEMCA (Digital Elevation Models of Coastal Areas) project is to develop an innovative method to produce seamless digital elevation models of large flat coastal areas.

This document presents a state-of-the-art of the production of Digital Elevation Models (DEMs) of coastal areas and is an update of the state-of-the-art that was assessed in 2013 as a result of the Innovation Platform (attached as Annex 1). The state-of-the-art will be used to validate the assessment of the feasibility and R&D content of the DEMCA innovation procurement project.

This document follows the same structure of the original document:

- PART 1 SITUATION: Introduces the area of study and its basic characteristics.
- PART 2 ISSUE FOCUS: Introduces the goal of the project
- PART 3 STATE OF THE ART: Elaborates on the available technology for acquiring bathymetric data.
- PART 4 FEASIBILITY OF THE INNOVATION PROJECT: Assesses the feasibility of the project in relation with the nowadays context.
- PART 5 R&D CONTENT WITHIN THE PROJECT: Elaborates on the R&D requirements to achieve the expected results.

2 SITUATION

Coastal areas cover the transition area from land to sea. Tidal currents and waves characterize the shape and elevation of coastal areas, which makes coastal areas highly dynamic. Just like elsewhere Digital Elevation Models (DEMs) are a primary source of information for managers of coastal areas.

Acquiring DEMs of coast areas commonly requires the application of at least two different measurement techniques, laser-altimetric and acoustic bathymetric surveys.

As coastal areas are usually much larger than the extent of a one-day survey effort, it may take several weeks to cover the area of interest. DEMs of coastal areas are composed of data from multiple surveys from different time stamps.

The goal of the present PCP initiative (DEMCA) is the creation of a seamless Digital Elevation Models (DEM) on flat coastal areas suffering of high concentration of particles in suspension, as it is the case of the Belgian one. Within this context, the strip of the coast representing the major source of problems is the area between the line of high tide and the breaker like. This was defined in 1998 by Komar as the nearshore (Figure 1).

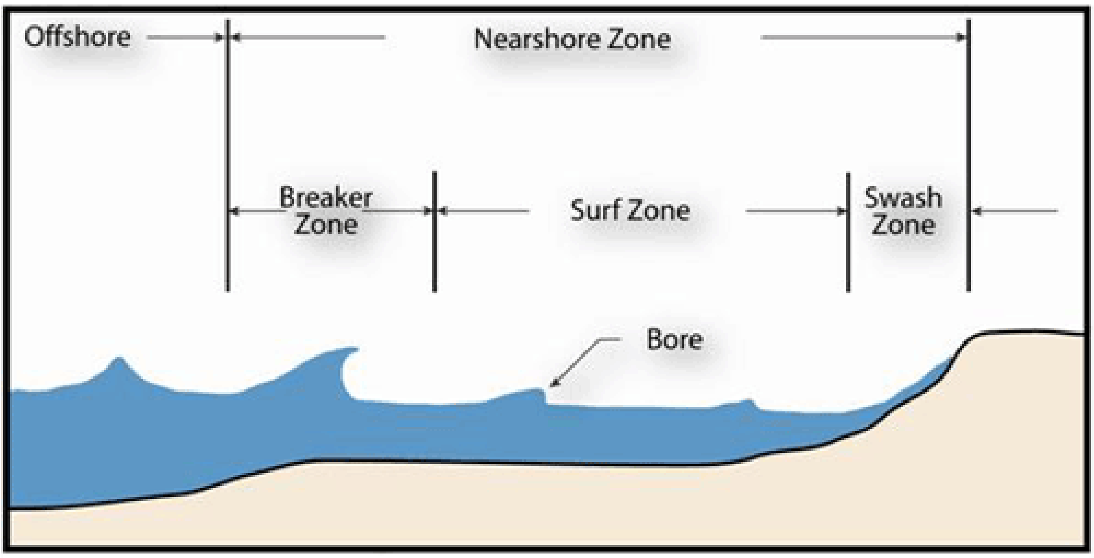

Figure 1 Terminology used to describe processes of waves and currents in the surf zone (Komar 1998), extracted from 'Highways in the Coastal Environment: Second Edition' by FHWA (US Federal Highway Administration, www.fhwa.dot.gov)

The depth known as depth of closure has been determined as the seaward limit to the focus area. This concept was introduced in 1881 by Hallermeier but detailed defined in 1998 by Krauss et al. It is defined as the most landward depth, seaward of which there is no significant change in bottom elevation and no significant net sediment transport between the nearshore and the offshore, for a given or characteristic time interval.

The solution must be valid for the entire Belgian coast, which is characterised by two different environments (see below) both affect by high concentration of particles in suspension.

- Coastal marshes on the areas related to the Scheldt river
- Sandy coast line on the area facing the North Sea

3 FOCUS

The focus of the PCP is on the development of DEMs from the Belgian coast at an acceptable cost; and within the following constraints:

- Time resolution: The nearshore data must be gathered in a time span in which the seabed has not being altered by sediment transport. Therefore, measurements must freeze the zone and provide bathymetry like it was a snap shot of the existing situation at a given time. Moreover, these snap shorts should be possible to be acquired as frequently as required and under any meteorological condition.

- Spatial resolution: The quality of the acquired nearshore data should be within the same order of magnitude as the presently available.

The currently used solutions offer a low update rate of the data, requiring long time for data acquisition and processing. Therefore, due to intense geomorphological evolution of sandy coastal areas, the different data sets do not provide a seamless DEM.

This document will not elaborate on the technology solutions which could potentially be used to solve the problem but will try to summarise the main characteristics of the existing solutions to support assessing the feasibility of the proposed concepts.

4 STATE OF THE ART

In order to synthetize the existing situation, this document zooms in into the applied technology (from a physical point of view) used to acquire the data, the platform where the measuring instrument was placed during the acquisition and the data processing. The analysis of this information independently allows determining if a given issue has its origin in the limit of the acquisition technology, in the way the sensor is carried while acquiring data or in the way the data is processed into DEMs

4.1 PLATFORM

Within this context we can differentiate 3 main platforms to carry sensors. Table 1 elaborates on the characteristic of each one regarding the goal discussed on this document.

Priority / Platform	Acquisition time	Performance on focus area (Nearshore)	Cost
Vessel (manned)	Several weeks- few months (7-12 knots) Strongly affected by weather	Dangerous navigation surf zone	In the order of several tens of thousands (subject to area to survey), approx. 15k€/day for a coastal boat (subject to instrumentation and personnel).
Vessel (unmanned)	Several weeks- few months (7-12 knots) Strongly affected by weather Lack of legislation constrains applications	Dangerous navigation surf zone	In the order of few tens of thousands (subject to area to survey), approx. 6k€/day for a coastal boat (subject to instrumentation)
Plane	several days- few weeks	Restricted flying hours	In the order or several tens of thousands (subject to area to

(manned)	Strongly affected by weather Subject to permit to fly and air space constrains.	Subject to exclusion zones (i.e. nuclear plants), ramsar, etc.	survey)
Drone (plane unmanned)	Days-Weeks Strongly affected by weather Subject to permit to fly and aerial rules	Restricted flying hours Subject to exclusion zones (i.e. navy , nuclear plants), ramsar, etc.	In the order or few tens of thousands (subject to area to survey)
Satellite	Minutes - Hours	Few options	Depending on the product and frequency required but in the other of several thousands to few tens of thousands €
Remark: ***Jet skis are other solutions, due to the safety risk to operate on the break water and surf area, it has not been considered.***			

Table 1 Most common commercial platforms to conduct bathymetric measurement for areas such as the one considered for the DEMCA PCP project.

4.2 MEASUREMENT SOLUTION

Factors / Technology	Performance on focus area	Spatial resolution
Acoustic	Footprint strongly reduced in shallow waters	In the order of centimetres (only applicable from vessels)
Visual	Strongly affected by water column conditions (suspension, bubbles, wave cusps…)	In the order of tens of centimetres to tens of meters depending on the platform (drone, plane, satellite)
Laser	Strongly affected by water column conditions (suspension, bubbles, wave cusps…) Strongly affected by reflectivity of seabed (i.e. abundance organic matter content)	From tens of centimetres to few meters (airborne, depending on the flying altitude)
Electro-Magnetic	At research state (Involves complex instrumentation systems and supporting software) Not affected by sea state Allows fast survey (60 knots) No experience in water shallower than 15m have been found	From a meter (at 15m water depth) to few meters.

Table 2 Overview of the main technologies used to study bathymetry. NOTE: Vertical resolution is generally of the same order of magnitude or worse than the horizontal one.

4.3 DATA PROCESSING

After acquisition of the data, there are two subjects which are also part of the scope to be covered:

1. Data processing and merging with other sources to produce DEM
2. Data spreading and visualization

Regarding data processing: a DEM is based on xyz values and therefore, the output with the acquired data from the nearshore should be on a similar format. The nearshore data should be easy to be combined with Lidar and multibeam data, so it can be treated with a similar work flow for the generation of DEMs.

Nowadays there are different software, commercially available, allowing to work with point clouds. No serious drawbacks are expected regarding this particular sub task. However, the spatial resolution and accuracy must avoid simple mistakes like over sampling, interpolation of unknown areas, etc.

To mention a couple of software packages leading the present market:

- QPS (http://www.qps.nl/display/main/home): part of SAAB group. It is the result of merging top solutions (Fledermaus, QuinSy…)
- Caris (http://www.caris.com/): part of Teledyne group

The data flow used at the moment by Maritime Access (Grid Data Bank project) to create DEMs from LiDAR and multibeam data looks perfectly valid for the scope.

Regarding data spreading and visualization: In order to reach as many markets as possible, data will be published via Informatie Vlaanderen (Flanders Information Agency: https://overheid.vlaanderen.be/informatie-vlaanderen/flanders-information-agency-en).

4.4 CURRENT STATE OF THE ART IN RELATIONSHIP TO THE SCOPE OF THE DEMCA PCP PROJECT

Table 3 summarizes the performance of current State of the art bathymetric measurement solutions in relation to the scope of the DEMCA PCP project. As conclusion we can state:

- Vessel based solutions fail to acquire data within the required time span. Moreover, in the case of acoustic methods, data acquisition is slow (a beam is a solid angle that at reduced water depth yields a minimum food print, resulting inefficient). Therefore, different sectors of the coast will be affected by sediment transport, failing to provide a seamless DEM. Additionally, safety navigation on surf areas is a risk hazard since survey required to follow the contour lines, living the vessel exposed to the incoming waves.

- Airborne based solutions, though an order of magnitude faster than vessel based solutions, still do not comply with the requirement to acquire data without time altering the coastal morphology at a given time. Additionally, bathymetric LiDAR has many operational constrains (white caps related to wave brake, air bubbles on the water column, permits to fly…).
- Satellite based solutions, at least the commercially available, do not offer the required spatial resolution.
- In situ measurements, will certainly provide the required time resolution. However, the spatial resolution will depend on the number of sensor, accuracy and food print of the proposed solution. There is no particular instrument, which has been found, operating on this way; therefore, this solution is subject to R&D efforts to develop the right solution for this particular scope.

Priority / Platform (Technology)	1a Time resolution Snapshot	1b Performance on focus area Nearshore	2 Spatial resolution As now or better	3 Cost As now or lower	OVERALL
Vessel (acoustic)	X	X (dangerous navigation surf zone)	√	√	X (fails at 1)
Airborne (visual)	X	X (no data breaker & surf zone)	X	√	X (fails at 1)
Airborne (laser)	X	X (no data breaker & surf zone)	√	√	X (fails at 1)
Airborne (Electro Mag.)	X	?	?	?	X (fails at 1a) Not commercially available
Airborne (other)	X	√?	X	?	X (fails at 1a and 2)
Satellite (visual)	√	X (no data breaker & surf zone)	X	√	X (fails at 1b & 2)
Satellite (Wave kinematics)	√	√	X	√	Lower spatial resolution than present
Satellite (other)	√	?	X	√	Lower spatial resolution than present
In situ (radar inverse wave refraction)	√	√ (in theory)	X	?	Lower spatial resolution than present.
In situ (radar for coastal marshes)	√	√	√	√	Good for marshes at low tide
In situ (other)	√	?	?	?	Unknown accuracy Not commercially available

Table 3 Visual summary of the analysis of the state of the art within the hydrography field vs the requirement of the present effort. X= fail. √= comply. ?= not determined

5 FEASIBILITY OF THE INNOVATION PROJECT

Based on the variables discussed on the previous chapters of this document, the scope discussed is considered to be feasible. This assessment is aligned with the result yield by the market consultation answers. The need of R&D to solve the scope defined in this document is aligned with the results from the market consultation undertaken by the Maritime Access office during the first half of 2017:

1. The questionnaire was answered by 7 people, of which 3 research institutes (2 from Belgium and 1 from the Netherlands) and 2 private companies: (1 SME, 2 survey companies).
2. While survey companies agree on the lack of existing solution for the proposed scope, the equipment developer offers a solution for part of the study area (marshes). Regarding the research institutes, though there is a division on opinion regarding the existence of right solution, none provides a suitable answer.
3. There was 100% agreement on the necessity of R&D for finding a solution to the focus of this project.

The factor we have evaluated are:

- Expected results vs existing solutions: The existing technologies look not be able to comply with the requirement to achieve the desired results. However, the level of technological evolution is sufficient for developing a new approach able to comply.
- The project lifespan of two years will provided sufficient time to allow the development of a prototype from an initial concept.
- The allocated budget provide mentioned by Maritime Access will provide the economic stability to support the required developments.
- The project team has the competences to drive the efforts on the right direction.

We believe the key of the project lays on the initial dissemination. During talks hold with different world leaders on marine equipment development held at the Hydro 2017 conferences (15th of November, Rotterdam) we determined that:

- Main equipment developers (Konsberg, Teledyne, Edgetech, R2Sonic, IXBlue, etc.) were not aware of the previous efforts undertaken by the Belgian government to set the foundation of the present project. Strong dissemination activities must be stablished.
- All contacts with these companies were driven by the commercial team. Normally this personnel is not technical and when approached, not being capable of grasping the goal of the presented information, they try to sell the existing equipment which does not compel with the requirements. Dissemination must be driven towards the R&D responsible, or someone with the technical background to understand what the goal of this effort is, that the project is an state driven innovation project and that it requires (allows and has the budget for) the development of a disruptive solution.
- The companies who knew about this project are normally Belgium SMEs or companies who has received direct information from Maritime Access at a certain moment.

6 R&D CONTENT OF THE PROJECT

The goals to achieve during the development of the project would be:

1. Data acquisition. The main constraints driving the existing solutions determine their inefficiency to fulfil the requirements; therefore, a disruptive approach looks to be the solution. The selected process will required to be eligible for IP protection.
2. Data processing will require to be optimised to accommodate for the amount and frequency in which the new data will be made available.
3. The creation of the main deliverable: a seamless DEM will require the development (or adaptation of an existing one) of a platform where the different data sources will be merged, stored and visualised. Depending on the level of dissemination planed, downgrading of the deliverable to allow its easy use and a platform to access it will also be required. Additionally, the comparison of different DEM to allow "4D" studies will have to be evaluated. This tasks will be undertaken aligning with the solutions and resources available via Informatie Vlaanderen.