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**DEVELOPMENTS IN NORTH SEA WIDE RESURVEYING AND CHARTING  
OF DYNAMIC SAND WAVE AREAS (*DRAFT VERSION OF 11 FEB 2013*)**

**THEME 1: BEDFORM EVOLUTION; THEME 5: FIELD DATA COLLECTION; THEME  
6: PRACTICAL APPLICATIONS AND HUMAN INFLUENCES; THEME 7: RIVER,  
COASTAL AND MARINE MANAGEMENT**

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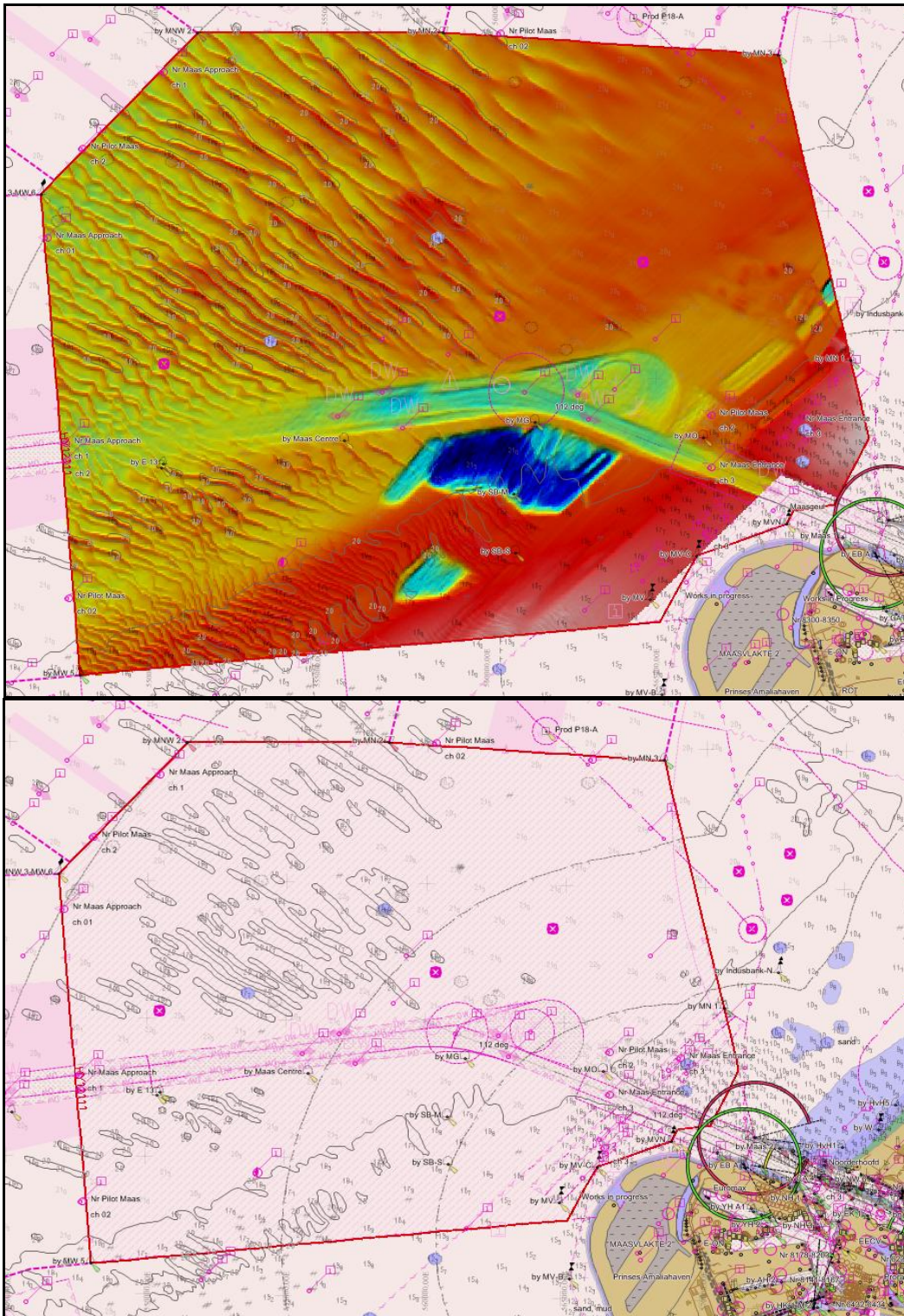
**Introduction**

Hydrographic offices around the North Sea are faced with the challenge to resurvey and rechart areas with rhythmic patterns on the sea floor. It is mostly unknown whether the observed patterns are dynamic, although time series of modern high resolution surveys have become available for more and more areas [Van Dijk et al., 2012-1].

The most common change of a sand wave pattern is a migration, due to e.g. asymmetries in the tidal currents [Németh et al., 2002]. In such a situation, the charted depth values may change their positions but remain constant, according to the nautical charting principle of shoal biasing [Smith et al., 2002]: the shallowest values are selected for visualisation in the chart, implying that these values represent the shallowest values that are likely to appear in the surrounding area. Consequently, the mariner will not notice the migratory character of the sea floor, and has to trust the prudent monitoring of pattern development by the hydrographic office.

This practice is acceptable as long as the hydrographic office is able to maintain a safe resurvey frequency for the area, and as long as there are no large scale human interventions in the greater region of the sand wave field, with the potential to disturb the morphodynamic processes that have created the migratory sand wave field. National hydrographic survey budgets are under pressure though, which translates into a reduction in bathymetric survey capacity [Ward, 2012].

Yet the mariner expects accurate and recent information, especially in digital products. Ship owners are aiming for a maximum quantity of cargo, allowing for a minimum under keel clearance, also along coasts with heavy maritime traffic, sensitive ecosystems and a flourishing tourism industry. The Southern North Sea is a perfect example of such a combination of risks.



**Figure 1:** Bathymetric survey of the approach area to the Port of Rotterdam, HNLMS Snellius, May-July 2012 (top): notice the presence of the dredged channels, the emergency turning zone, and the sand pits for infrastructural projects like the Maasvlakte 2 (lower right) and the Zandmotor (not visible). Bathymetry of the approach area to the Port of Rotterdam in Electronic Navigational Chart NL400122 (bottom): notice the absence of the rather recent sand pits. A new edition is expected in the Summer of 2013. *(figure courtesy of crew HNLMS Snellius)*

The hydrographic offices that constitute the North Sea Hydrographic Committee (NSHC) react to these developments by intensifying their cooperation. This takes place on different levels. We present some developments on three levels: global, European, and North Sea wide.

### **An example**

An example of an area with a challenging mix of uses and critical depth values is the approach area to the Port of Rotterdam. The larger ships can only enter during high tide, which puts serious constraints on the quality of the survey and the chart, both in terms of measurement accuracy and in terms of update frequency. The sea floor is characterised by a dredged channel through an extensive field of rhythmic patterns with different wavelengths [Knaapen et al., 2001]. An example of a survey of the area and the current large-scale chart are given in Figure 1, and the current contents of the bathymetric database in Figure 2.

The patterns in the deeper, Western part of the area are believed to be hardly dynamic [Van Dijk et al., 2012–2; Dorst et al., 2011], while the pattern in the shallower Eastern part shows a clear migration [Van Dijk et al., 2012–2; Dorst et al., 2008]. The height of the sandwaves are generally assumed to be constant [Van Dijk et al., 2008; Knaapen, 2005], which implies that the shallowest likely depth values in the area do not change in value [Dorst et al., 2012–1]<sup>1</sup>.

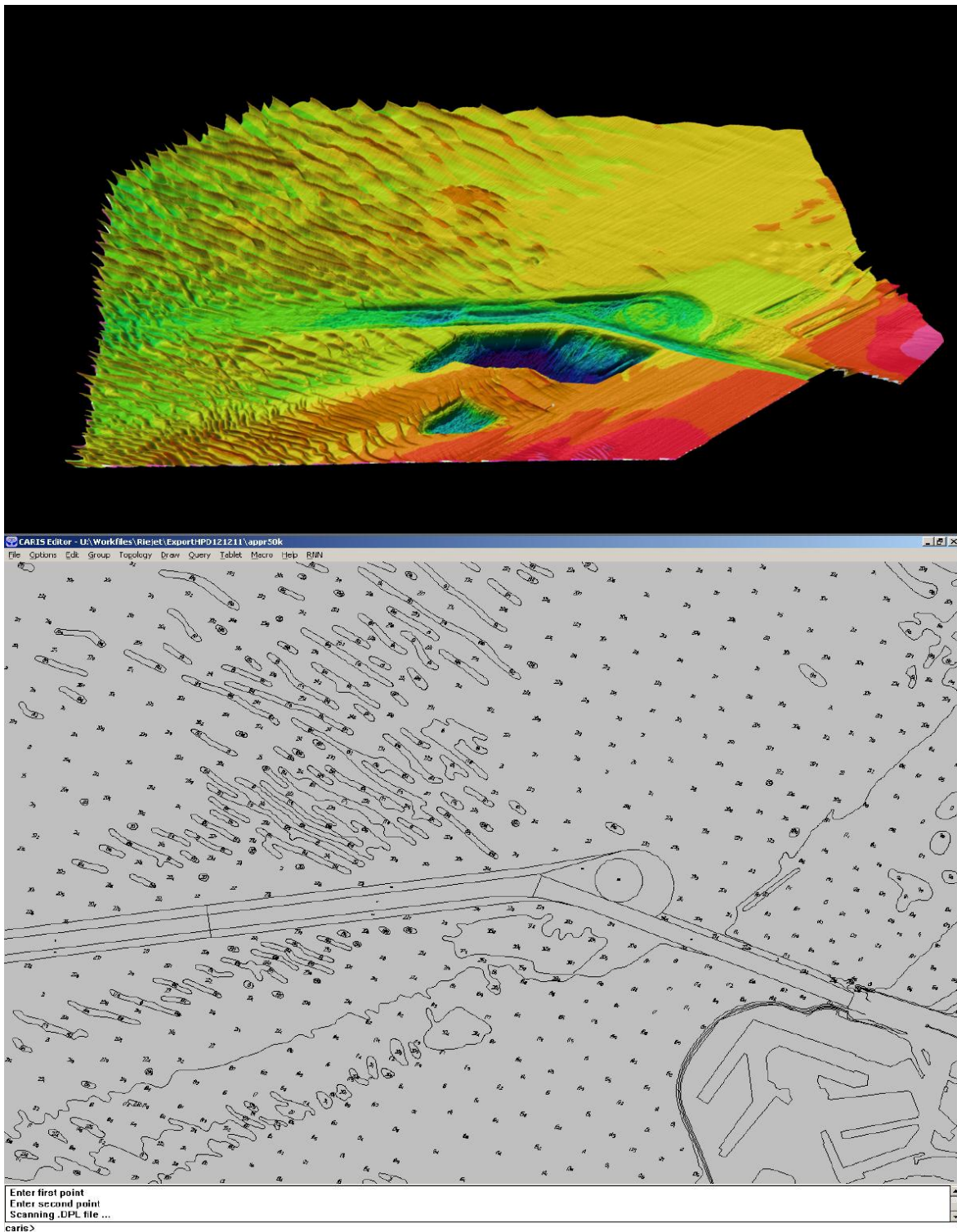
In the area of the example, several human interventions are in progress. The coastline changes, due to the Maasvlakte 2 extension to the Port of Rotterdam and the Zandmotor megascale beach nourishment project, are of a scale sufficient to change the tidal currents [Dorst et al., 2012–2]. The sandy sediment that the two projects use is taken out of sand pits (Figure 1) that are sufficiently extensive to affect hydrodynamic conditions, potentially inducing a corresponding change in morphodynamic conditions [Roos et al., 2008].

### **Global scale developments**

Within the International Hydrographic Organization (IHO), it is broadly agreed that the visualisation of the limited quality of bathymetric data in Electronic Navigational Charts (ENCs) needs to be improved [Dorst & Howlett, 2012]. For future ENCs, the S-101 data model containing a hierarchical series of new quality indicators is under development. For current ENCs, produced in the S-57 data model, the “Zone Of Confidence” indicator will be populated in a more consistent manner by the national hydrographic offices.

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<sup>1</sup> In the terminology of Dorst et al. [2012–1], the overall shoaling rate of the area is zero, while the maximum shoaling rate at a location within the area is larger than zero.



**Figure 2:** Bathymetry of the approach area to the Port of Rotterdam in the database of the Netherlands Hydrographic Service: digital terrain model (top) and isolines (bottom). Notice the presence of the sand pits. The isolines will be published in new chart editions expected in the Summer of 2013. (figure courtesy of Data processing department, Netherlands Hydrographic Service)

An important consistency aspect is the assignment of a category for the Zone Of Confidence (CATZOC) in case of a mobile seafloor. Six categories can be distinguished, five of those are ranging from A1 (best quality) to D (worst quality), and the sixth is U (unassessed) [Johnson, 2004]. Currently, a proposal to degrade CATZOC to category C in such a case is under discussion, even in case of a recent, accurate survey without gaps. This category is described with the words “Depth anomalies may be expected.”

For a migrating sand wave field, one may argue that depth anomalies cannot be expected, as the charted depth values remain constant. Such an argument justifies ignoring the changes in surveyed depth values by pointing out that CATZOC applies to the charted product, not to the observed data set. A degradation of such a “safe” sand wave area to a CATZOC of C could even tempt mariners to enter other CATZOC C areas with insufficient care.

On the other hand, one may argue that the mariner should be informed about the mobile character of the sea floor, especially if human activities may change the hydrodynamics that drive the sea floor mobility. Hydrographic offices may not have the resources to resurvey the area with a sufficient frequency to detect changes in the behaviour of the pattern in time, or may otherwise not be willing to accept the risk of assigning the area with a high value for CATZOC. This argument would satisfy the desire to indicate the potential danger of mobile areas, rather than give a potentially false indication of a highly accurate depiction of the seafloor.

Given the challenges that the example provides, we are inclined to, at least, allow hydrographic offices to artificially degrade CATZOC to a category C. Perhaps the ideal of an internationally fully consistent assignment procedure is not feasible for CATZOC, and the specifics of each sea area, as known at the national hydrographic office, have to be taken account.

### **European scale developments**

On the European scale, the INSPIRE directive contributes to a European Marine Spatial Data Infrastructure (SDI) by setting requirements to publish bathymetric data in a unified and automatic way. The European EMODNet project will take this one step further by creating a single portal from which marine datasets, like bathymetry, can be viewed and downloaded [Longhorn, 2012]. These new facilities will create new opportunities for morphodynamic research, provided that researchers have powerful analysis tools at their disposal to analyse large volumes of spatial data.

### **North Sea scale developments**

The North Sea Hydrographic Commission (NSHC) established a Resurvey Working Group, which has been active since 2007. National hydrographic offices share their resurvey plans, with the aim to unify survey efforts at their maritime boundary areas and for international shipping routes. These routes cross several international maritime boundaries, which makes access to all major ports dependent on the survey and charting efforts of neighbouring countries<sup>2</sup>. It is a potential waste of resources to survey more frequently than your neighbour, and a potential risk to survey less frequently.

At present, Belgium, Germany, the Netherlands and the United Kingdom have agreed to publish their resurvey prioritization together, in a single online map, for at least a part of their North Sea area. The current status of this plan is shown in Figure 3.

### **Application of the developments to the example**

The dredged channel to the Port of Rotterdam currently has a CATZOC value of A1, and the sand wave field a CATZOC value of A2. Category A indicates that “significant seafloor features [were] detected and [their] depths measured”. Subcategory A1 and A2 differ only in their requirements for survey accuracy [Johnson, 2004]. The Netherlands Hydrographic Service is confident that these requirements are met, as frequent resurveys are done by Rijkswaterstaat (the dredged channel, several times a year to once a month) and the Hydrographic Service (the sand wave field, once every other year).

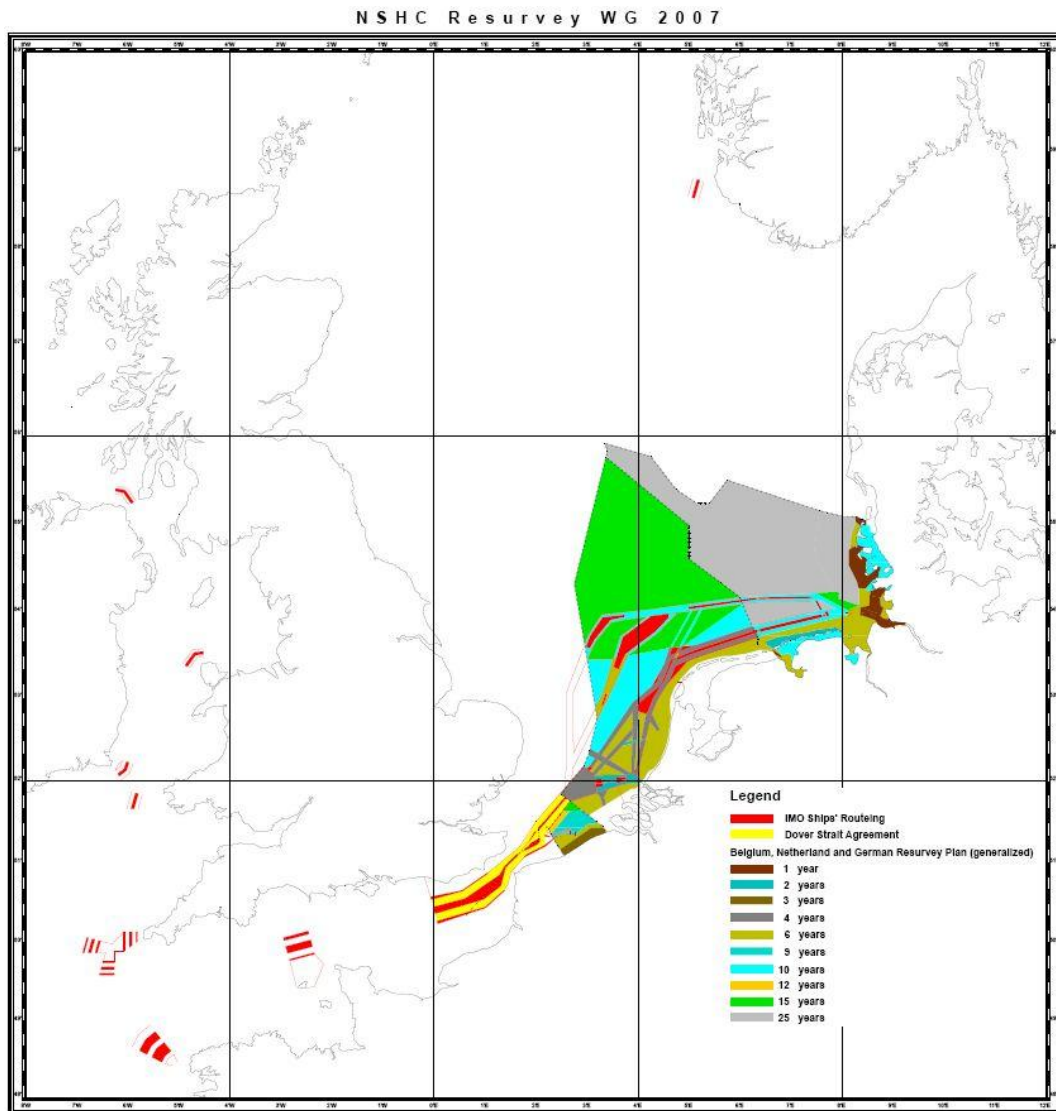
Deep draught ships are lead into the channel by pilots, taking advantage of the maintained depths in the channel. This guarantees that ships with a critical depth will not access the sand wave field. Although considerations like shipping intensity and draught are not included in the assignment process of an indicator in a nautical chart, they do play a role in the determination of a safe resurvey frequency, especially when such information is available through AIS data [Ward & Gallagher, 2011; Van Dijk et al., 2011].

The assignment of a CATZOC value of C to mobile sand wave field would require an assessment of a boundary where the migration becomes significant. This could for instance be done by a comparison of the CATZOC position accuracy requirements to the expected migration between consecutive surveys. This immediately leads us to a requirement to accurately predict migration.

As it currently is not feasible to make reliable predictions for large parts of the sand wave fields in the North Sea, we either need to set CATZOC to a value of C for all these sand wave fields, or accept that sand wave migration is excluded from the assignment process of a CATZOC value. We reject the option to only assign a CATZOC value of C to those areas, like our example, where the migration is known and deemed significant, as this option would indicate the areas of known migration as less safe to the mariner than areas of unknown migration.

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<sup>2</sup> Until 2012, the four countries around the English Channel had agreements in place to do transboundary surveys around the selected track for deep draught ships. The so-called Dover Strait Survey Policy was revised, in order to better reflect the national responsibilities of each country to survey its waters.



**Figure 3:** Resurvey prioritization map of the NSHC Resurvey Working Group. (figure courtesy of BSH)

The area does not only facilitate intercontinental shipping through the English Channel. There is an inshore traffic zone towards Belgian and French ports, the Maas Northwest Traffic Separation Scheme (TSS) towards English and Scottish ports, and the Maas North TSS towards German and Danish ports<sup>3</sup>. In the virtual case that the Netherlands would decide to reduce resurveying efforts, there would come a moment that it is no longer defensible to classify the area with a CATZOC value of A. It would be in the interest of the national economies around the North Sea to prevent such a reduction in accessibility of their ports. But, in the absence of accurate predictions on the development of the sand wave field in the presence of the sand pits, the moment that the CATZOC value has to be degraded cannot be determined with any certainty, and such a decision cannot be discussed between the North Sea countries with factual evidence.

### Conclusion

These two examples of international cooperation can only be successful if it is understood and agreed how the sea floor develops. For both of them, it is very relevant to distinguish between growth of a pattern, and its migration.

<sup>3</sup> The TSS structure in the Netherlands EEZ will change per 1 July 2013.

Within the North Sea, all national hydrographic offices have an interest in the decisions that the other hydrographic offices make. Poor decisions could lead to dangers to the coasts around the North Sea, or limit the accessibility of the ports of each country.

Scientific progress will enhance the insights of the hydrographic community into marine sand wave behaviour, opening up opportunities to improve survey efficiency and correct use of quality indicators in nautical charts. Hydrographic office need accurate morphodynamic models, an appropriate set of methods for the analysis of time series of bathymetric data, and versatile remote sensing techniques.

Meanwhile, European policy decisions allow scientific institutions easier access to bathymetric data. This could facilitate further progress in scientific knowledge on sand wave dynamics.

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