Computers, Environment and Urban Systems 32 (2008) 293–302

Contents lists available at ScienceDirect

Computers, Environment and Urban Systems

journal homepage: www.elsevier.com/locate/compenvurbsys

Developing a seabed resurvey strategy: A GIS approach to modelling seabed changes and resurvey risk

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ARTICLE INFO

Keywords:
GIS
Coastal
Marine
Decision support
Software coupling
Morphological modelling

ABSTRACT

There has been a steady transition towards the representation, analysis and modelling of dynamic spatio-temporal relationships in geographical information systems (GISs). These developments open up opportunities for investigating and modelling the dynamic relationships that occur in the coastal and marine environments and how these relate to human activities. Such a spatio-temporal approach is applied in this research to address an issue faced by the bodies responsible for maintaining navigation safety in territorial waters and this paper introduces the developed resurvey decision support system. The developed system models morphological change in response to hydrodynamic conditions and determines the seabed locations that require resurvey based on the modelled change and navigation characteristics. System validation tests indicate that the morphological modelling tool is under-predicting the magnitude and lateral extent of the change which then influences the locations that require resurvey. Additional sensitivity tests of the morphological modelling parameters highlight the influence of the parameters on the outputs and derived predictions. The achieved modelling results and resurvey decision indicate the applicability of utilising a GIS to model seabed change as an input into decision support systems for planning and management purposes. The results also suggest the applicability of the modelling and decision support methodology to similar problems in the coastal and marine environments.

1. Introduction

Geographic information systems (GISs) have been utilised since their invention to store, process and evaluate spatial relationships between datasets (Goodchild, 1993, 2003; Longley, Goodchild, Maguire, & Rhind, 2001). These analyses have tended to be undertaken on static snapshots in time with more recent progress towards dynamic spatio-temporal relationships and process-orientated concepts (Grenon & Smith, 2004; McIntosh & Yuan, 2005; Worboys, 2005; Goodchild, Yuan, & Cova, 2007). Such developments enable opportunities for investigating and modelling the dynamic relationships that occur in the coastal and marine environment and how these relate to human activities; for example modelling the interaction between waves, tides, seabed evolution and human activity. However, there are fewer examples for the implementation of GIS in the coastal and marine environment than in terrestrial cases. This is due to the dynamic nature of the environment, the lack of consistent datasets and problems of scale, accuracy, boundary definition and generalisation in acquiring data for analysis (Langran, Larson, & Baybrook, 1993). The increased exploitation of the coastal and marine environment calls for more intelligent and efficient methods of analysis and management. This relates to understanding the relationship between input factors (such as hydrodynamic, meteorological and environmental conditions), output factors (including morphological and biological conditions) and consequent impacts on human activities.

For morphological problems, GISs have been used to try and understand the rate of seabed change (Reeve, Li, & Thurston, 2001). These applications are restricted to comparing the differences in seabed height between successive 'snap-shot' depth surfaces and do not account for forcing inputs (waves, tide, storms and surge conditions). Although such applications are a step forward in understanding the rate of seabed evolution, they cannot provide the predictions and inputs needed by decision support systems that require information at intermediate time periods. Deterministic morphological modelling methods are an alternative approach used in the field of coastal engineering to understand the rate of seabed change. These approaches which account for varying forcing conditions involve detailed numerical calculations of the hydrodynamics and sediment transport processes using finite difference of element schemes. However due to the calculation procedures involved in obtaining a prediction these approaches do not easily conform to the flexibility required in decision support systems.

This research presents a step forward in utilising a GIS to facilitate morphological modelling with forcing conditions and evaluating the output within a decision support structure to establish

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doi:10.1016/j.compenvurbsys.2008.06.002

impact on human activity. The developed methodology and system are applied to an issue faced by bodies responsible for resurveying areas of seabed to maintain navigation safety in British territorial waters. Currently seabed areas that require resurvey are determined by qualitative knowledge of preceding seabed evolution, navigation intensity and hydrodynamic conditions (International Hydrographic Management Consulting, 2004). However there is need for a more rigorous approach to assess and determine the frequency and locations that should be resurveyed based on the hydrodynamic conditions and navigation patterns and intensity.

The objectives of the research are to:

- Develop a seabed morphological model that determines the relationship between hydrodynamic conditions and seabed response.
- Use the modelled outputs as part of a decision support structure to evaluate the risk to navigation safety based on the bed change and navigation characteristics.

A GIS is implemented for both these objectives. In the first case the GIS is used to facilitate the temporal averaging of the required input parameters and estimate the spatial seabed change based on the calculated transport. In the second instance, principles from Map Algebra (Tomlin, 1990) are used within the GIS to analyse and evaluate multiple spatial datasets at varying time scales to identify locations that match specific criteria. This paper introduces a system developed in response to the research problem. It describes the morphological modelling and survey decision methodology utilised within the framework of a GIS and assesses the validity of the approach to real world situations through the results obtained. Section 2 provides a summary of the data and software utilised within the research as well as a description of the study area used to test the application. Section 3 describes the components of the system, while Sections 4 and 5 respectively describe the validation tests and results. The applicability of the system and its results to the real world are discussed in Section 6 with conclusions in Section 7.

2. Study area, data and software

Fig. 1 illustrates the EA9 Holm Channel study area that is used to assess the validity of the morphological modelling process and resurvey decision support tool. The study area is made up of a number of dynamic sandbanks and channels that form important shipping routes for vessels into the ports of Great Yarmouth and Lowestoft. The study area was selected primarily based on the availability of repeat bathymetric data between 2002 and 2004.

2.1. Software

Instead of rewriting tried and tested hydrodynamic and sediment transport modelling tools to carry out the morphological modelling, a decision was made to dynamically couple a GIS to existing software that performed the required analyses. The software utilised included POLPRED for Windows and SEDTRANS05.

2.1.1. POLPRED for Windows

POLPRED is a deterministic tidal prediction software provided under license from the Proudman Oceanographic Laboratory (POL). It generates the tidal predictions for a particular location based on input coordinates, date, time and other prediction parameters. The outputs utilised within the morphological modelling procedure are the tidal height, speed and direction.

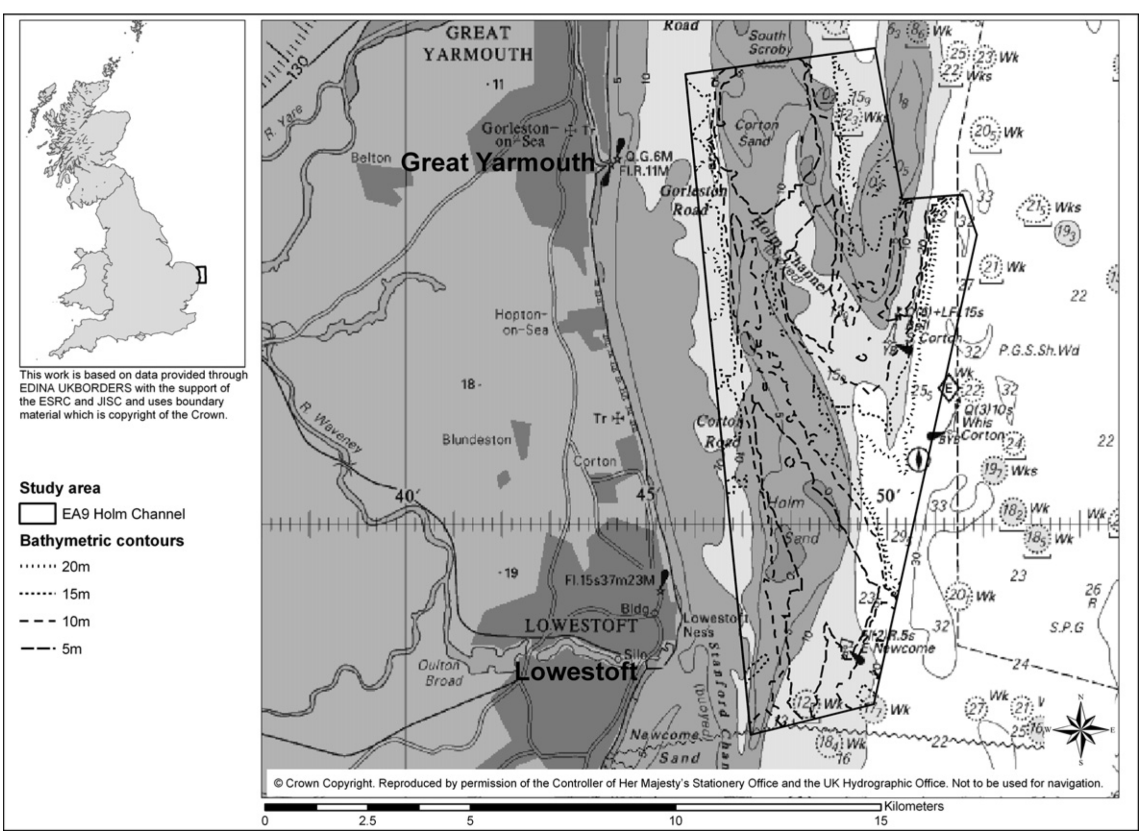

Fig. 1. EA9 Holm Channel study area.