Data Fusion for Inland Dredging

Present-day hydrographic surveys can result in many types of information that are used for planning inland dredging projects. Novel geophysical survey systems provide detailed information on sediment composition and pollution levels of dredge spoil. Each data set alone does not give all information needed for proper planning. The combination of data from different sensors provides practical results that can help to reduce the costs of dredging and disposal, reduce risk and improve the quality of the dredging work.<P>

Inland dredging activities require careful planning. Many inland water systems are dredged for nautical reasons, but the pollution levels of the sediments often require remediation. Debris such as stones, shopping trolleys and bags of litter can hamper dredging operations and the presence of unexploded ordnance can even result in dangerous situations during dredging.
The textural composition of sediments can vary strongly within a river or canal system. Because sandy materials can be reused in construction, proper information on the clay and sand content of the dredged material is valuable.

For inland dredging projects, present-day hydrographic surveys result in many types of information, each pointing to one specific aspect of the information package. Proper use of this information in the dredging process requires cross-sections of these data sets to provide valuable information needed to reduce the costs of dredging and disposal, reduce risk and improve the quality of the dredging work. Data fusion is one of the approaches of combining sensor information for practical applications.

This paper describes the current practice of how results of modern hydrographic and geophysical survey methods are fused to geographic information used in the dredging process. A case study of dredge site investigation in a Dutch canal and harbour system shows how data fusion can be used to direct dredge spoil to the appropriate disposal site.

Zoning Before Sampling

Much information is necessary fordredging in inland waters. Apart from location aspects and information on accessibility, proper dredging also requires information on:

- sediment quantity
- sediment quality (chemical)
- sediment texture
- presence of debris
- presence of cables and pipes
- presence of unexploded ordnance.

In general, many of these types of data are obtained by ‘traditional methods’ such as sediment sampling and sediment profiling with a plumb-line. Today most of these methods can be combined with geophysical and hydrographic data-acquisition systems. These geophysical and hydrographic survey methods are a fast way to zone the area of study so that the sediment bed can be subdivided in homogenous regions. Each of these regions needs, for example, different methods of remediation, different types of dredging material or different risk assessment studies to comply with health and safety regulations. The size of the zones can vary from lengths in the order of 100m to several kilometres of waterway. Additional investigation by sampling or by divers helps to improve the quality and reliability of data.

In the following section, we present several zoning methods that are presently used in western European water systems.

Sediment Quantity

The hydrographic world is, of course, familiar with methods of mapping sediment levels in a water system. A broad range of multi- and single-beam systems is used for mapping the height of the water column. In several cases, multi-frequency echosounder systems, sub-bottom profilers or ground-penetratingradar are used to measure the thickness of the silt layer. However, in many projects in the Netherlands, manual probing of silt thickness remains common practice.

Sediment Quality (Chemical)

In most cases, information on sediment quality is only based on elaborate and costly sampling of the sediment bed. However, with the variable nature of the underwater environment, it is almost impossible to cover an area properly with sediment samples alone. Therefore, geostatistical approaches are used to describe the spatial variation of the pollution. These geostatistical methods use indirect proxies (a parameter that acts or behaves similarly to the parameter required)SEnDfor example, erosion and deposition patterns or plume dispersion modelsSEnDas an indicator of the heterogeneity and distribution of pollution in the sediment. Today, geophysical methods are also used as proxy for sediment pollution. The concentrations of radionuclides in sediment (potassium, uranium, thorium and caesium) are strongly correlated to the diffuse distribution of heavy metals and organic micropollutants. The concentrations of these radionuclides can be measured in situ in the field by towing a gamma spectrometer over the sediment bed behind a vessel. These line measurements are used to generate large-scale but detailed maps of sediment pollution in a river system or canal.

Sediment Texture

The sand content of dredged material is important for re-use of the material. Indicative mapping of sand content and grain size or sediment classification by reflection analysis of acoustic signals provides information that can help to zone the river system and can point to locations of erosion and sedimentation. Another method applies the strong correlation between naturally occurring radionuclides measured in situ and the clay content of sediments. These measurements with an underwater gamma spectrometer result in a rapid and quantitative measure of the clay and sand content in sediments.

Presence of Debris

The Dutch Ministry of Transport, Public Works and Water Management investigated urban dredging operations that exceeded their budget due to the presence of unexpected debris in the waterway. This research showed that, in various projects, the total project costs were 20% above budget. Better information on the distribution and concentration of debris can help to select appropriate dredging methods, locate disposal facilities that accept the sludge and, in the end, reduce costs. Survey systems used for locating debris are sub-bottom profilers, ground-penetrating radar, magnetometers, multi-beam echosounders or side-scan sonar.

Cables, Pipes and Unexploded Ordnance

The presence of cables and pipes in the sediment can hamper dredging operations; locations where cables might be present have to be dredged very carefully to avoid loss of power in a nearby town. The potential presence of unexploded ordnance not only hampers the dredging operation, but can also be a risk to the neighbourhood, especially inurban areas. Cables, pipes and unexploded ordnance are often mapped by combining geophysical methods (such as sub-bottom profiling, ground-penetrating radar, magnetometry) with historical information.

Data Fusion: a Case Study

The Dutch canal and harbour system of Groningen Seaports and the city of Delfzijl)?needs regular dredging for nautical reasons. Due to past industrial activities, the sediments of the canal are polluted with heavy metals such as mercury.

Disposal of the dredge spoil is the most costly part of the dredging cycle and proper selection of disposal sites can improve the cost-effectiveness of dredging. The acceptance criteria of different disposal sites depend on the sand content, pollution level and presence of debris. To make a cost-effective dredging plan, a multi-sensor sediment survey was conducted. In this survey, various parameters were measured, interpreted and combined on a map showing the locations of sediment disposal (Figure 5). The sand content and pollution levels of the sediment were determined from the in situ distribution of the radionuclides in the sediment, measured with the Medusa gamma spectrometer system; sediment volumes above nautical depth were measured with multi-beam sounders; the presence of debris was measured with ground-penetrating radar and with the Medusa system.

The geophysical and hydrographic systems provide a detailed image of the composition and structure of the sediment bed. This information is far too detailed for the dredging process. Given that only full barges are sent to a disposal facility, the measurements are used to zone the location in compartments with homogenous characteristics with a volume that will at least fill a barge. The averaged information for each compartment is integrated and fused in a geographic information system (GIS). A query is used to characterise the information on pollution level, sediment texture, sediment volume and debris content to classes for each disposal site.

The resulting map with the classification shows how a combination of different hydrographic and geophysical data sets can result in an efficient and cost-effective way of sediment handling.

References

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2. Van der Graaf, E. R., Koomans, R. L., et al., 2007: In situ radiometric mapping as a proxy of sediment contamination: Assessment of the underlying geochemical and -physical principles. Applied Radiation and Isotopes, 65(5), 619-633.

Radionuclides as Proxy for Sediment Texture and Contamination

Pollution in surface sediments can be the result of historical input from a point source or it can originate from the diffuse distribution of heavy metals and organic microcompounds in the water column. The local variation in the concentration of pollution levels is strongly determined by the physical characteristics of the sediment. Towed underwater gamma-ray detectors can be used to generate maps of natural or anthropogenic radionuclides (40K, 238U, 232Th, 137Cs) in the sediment. Various studies have shown that these radionuclides are a proxy for sediment texture (grain size, clay content [1]) or sediment contaminants such as heavy metals or organic microcompounds [2]. A selection of sediment samples can be used to calibrate the proxy maps to detailed maps of sediment texture and pollution.