Title

Estimating and Visualizing Marine Dredge Quantities Using ArcGIS

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Biography

Chris Shanks has over 16 years' experience in GIS with the last 11 at Bechtel. Chris is currently the GIS Supervisor and Senior GIS Analyst for Bechtel Oil, Gas, & Chemicals, Inc. in Houston, TX. Chris has a B.S. in Agriculture from Abilene Christian University (Abilene, TX) and a M.S. in Agriculture (with an emphasis on Remote Sensing & GIS) from Texas Tech University. Chris is a GISP and a member of SCAUG and GITA.

Abstract

Coastal dredging projects require an understanding of the quantity of soil to be removed during dredging operations. This involves the development of dredging limits, dredge depths, over-dredging, and uniform or composite dredge slopes that is established by marine/coastal engineers. GIS can be a valuable tool in visualizing and determining these dredging parameters. GIS also provides the capability to determine preliminary dredge quantities in addition to providing 3D visualizations of the dredge channel. For several projects in the Curtis Island/Gladstone area of Queensland, Australia, GIS was used as a tool to establish preliminary dredge quantities and view the results in a 3D scene. ArcGIS 3D Analyst and Spatial Analyst tools were used to streamline a complicated process to determine dredge quantities. This paper presents a method of using GIS as a tool for estimating dredge quantities and visualizing the results.

Keywords

GIS, Bathymetry, Dredging, 3D, Datum, 3D Analyst, ArcScene

Acronyms/Abbreviations

AHD	Australian Height Datum
DEM	Digital Elevation Model
GIS	Geographic Information Systems
LAT	Lowest Astronomical Tide
MSL	Mean Sea Level
TIN	Triangulated Irregular Network

Introduction

For large scale oil and gas construction projects that are located in coastal areas, dredging can be one of the most costly and extensive components of the project. Understanding the impact that dredging can have on your project is an import problem to controlling costs when it comes to the volume of material that needs to be removed. For dredging projects, complex marine modeling and volume calculations are usually undertaken. In the initial stages of a project, GIS can be used to determine the dredging volume, optimize the dredging parameters, and visualize the results.

Purpose & Scope

This paper presents a procedural methodology for using GIS as a tool to estimate dredge quantities and visualizing the results. This methodology establishes a baseline bathymetric model, dredge channel model and the procedure that can be used to determine the dredge quantity by evaluating the difference between the models.

Methodology Overview

In order to analyze and calculate the approximate dredge quantities, you must create a comprehensive 3D model of the nearshore environment in the area that is to be dredged. There are several key data items that you need. This includes bathymetry data, shoreline data (if available), height datum used (LAT, MSL, etc.) and the basic dredge channel shape and depth to be dredged. The dredge requirements are normally developed by coastal/marine engineers and that will be used as a basis for the dredge channel. Once the appropriate information is collected, then the following generic process methodology can be followed in order to determine the dredge quantity.

Process Methodology:

1. Build baseline bathymetry model
2. Create geometry of the dredged area
    a. Build Line Geometry – Dredge Toe & Slope
    b. Create 3D linework
3. Assessment of Dredge Quantities
4. Create 3D Visualization

Methodology:

Build baseline bathymetry model

Bathymetric data describes the seabed elevation in relation to an established height datum. For bathymetry data, the datum must be defined in order to establish a reference point for the sea level bottom. In coastal areas, especially areas near established ports or harbors, the bathymetry is usually well known for navigation purposes. Bathymetry data can be obtained through a hydrographic survey. In most cases today, multibeam echo sounders (MBES) are used to measure water depth. MBES transmit sound energy and analyze the return signal that has bounced off of the sea floor (NOAA 2012). The MBES survey can be combined with GPS to determine an accurate position of the sounding data.

The resulting information from these surveys normally produces bathymetry data in an XYZ format (within the referenced datum) that can be easily used in a GIS.

Once the XYZ data is obtained, a digital elevation model (DEM) of the seabed must be created. The DEM must be evaluated and checked. The DEM is a form of a theoretical model of the surface and caution should be taken when building the DEM. There are several methods in ArcGIS to create an elevation surface and each method can reveal different results. It is recommended that once a method is chosen, the surface be checked against the input data to determine the DEM quality.

Methodology:
Create Geometry of Dredged Areas

The designed dredge channel is normally established by the marine engineering group based on a variety of factors including the requirements of the ship vessel. The end result of these requirements is a design drawing showing the dredge channel depth and width as well as many other dredging parameters. See Figure 1, as an example of a dredge channel design for a project located in Australia.

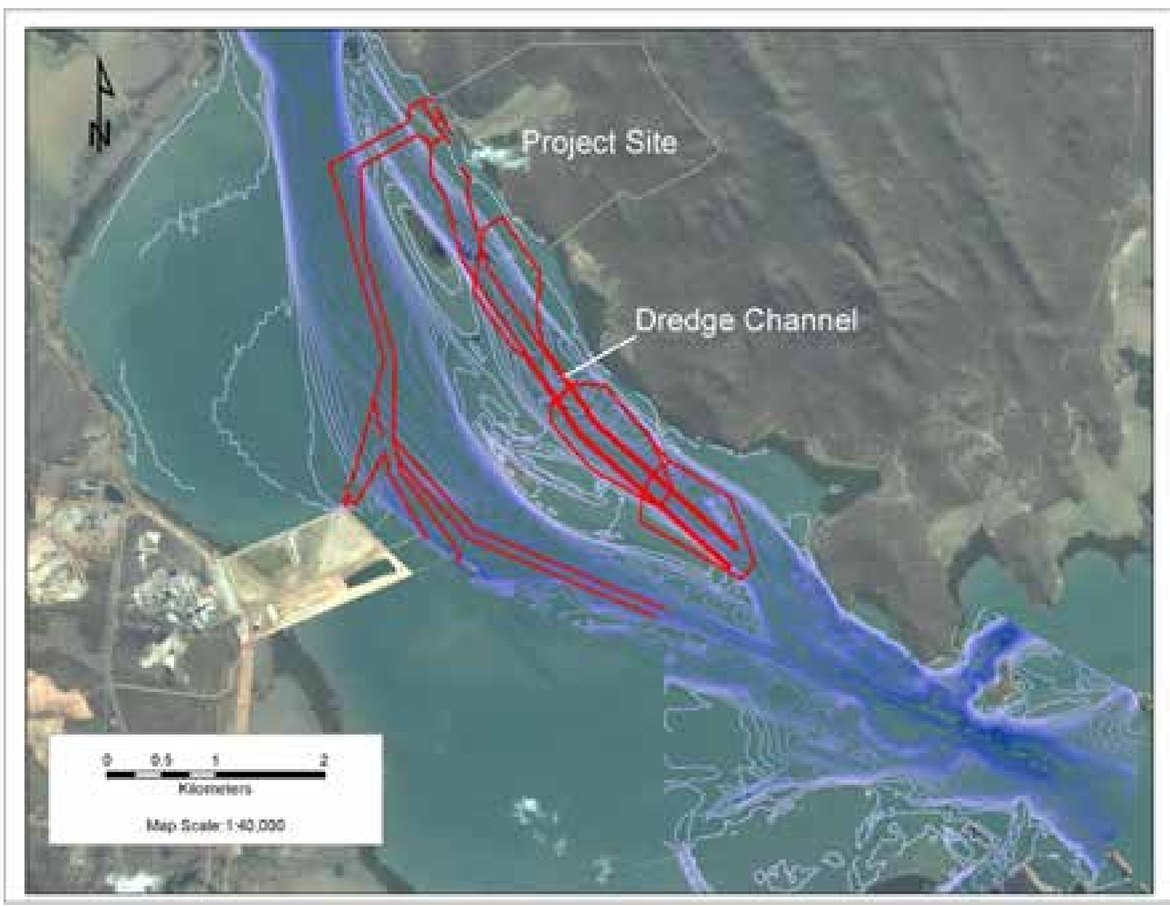

Figure 1 - Dredge Channel Geometry (image source: ©2008 Google Earth, ©2009 Digital Globe)

The linework is harvested from a CAD design drawing as 3D geometry. Three-dimensional (3D) geometry must be created to establish the boundaries of the dredge channel. The CAD linework is imported to an ArcGIS 3D polyline feature class using the CAD elevation to establish the z-value. The design linework normally describes the bottom or toe of the dredge channel which forms the inner base lines that needs to be reached during dredging. This dredging limit will need to be reached by sloping into the bottom. Geotechnical engineers along with marine engineers will determine the appropriate slope.

The next step is to create the outer slope or top dredge point based on the design requirements. To create the out distance line, you need to factor in the slope needed to obtain the dredged elevation at the toe of the channel. The depth and slope have already been pre-determined by the design engineers. In the 3D model, the outer slope wall should be high enough to include all dredging material inside the dredging area. The end result of this process is to get a 3D polyline feature class that can be used to create the dredge channel TIN model. The 3D polyline feature class (shown below in Figure 2 in red) is used to create a TIN surface model of the channel (shown below in Figure 2 in green).

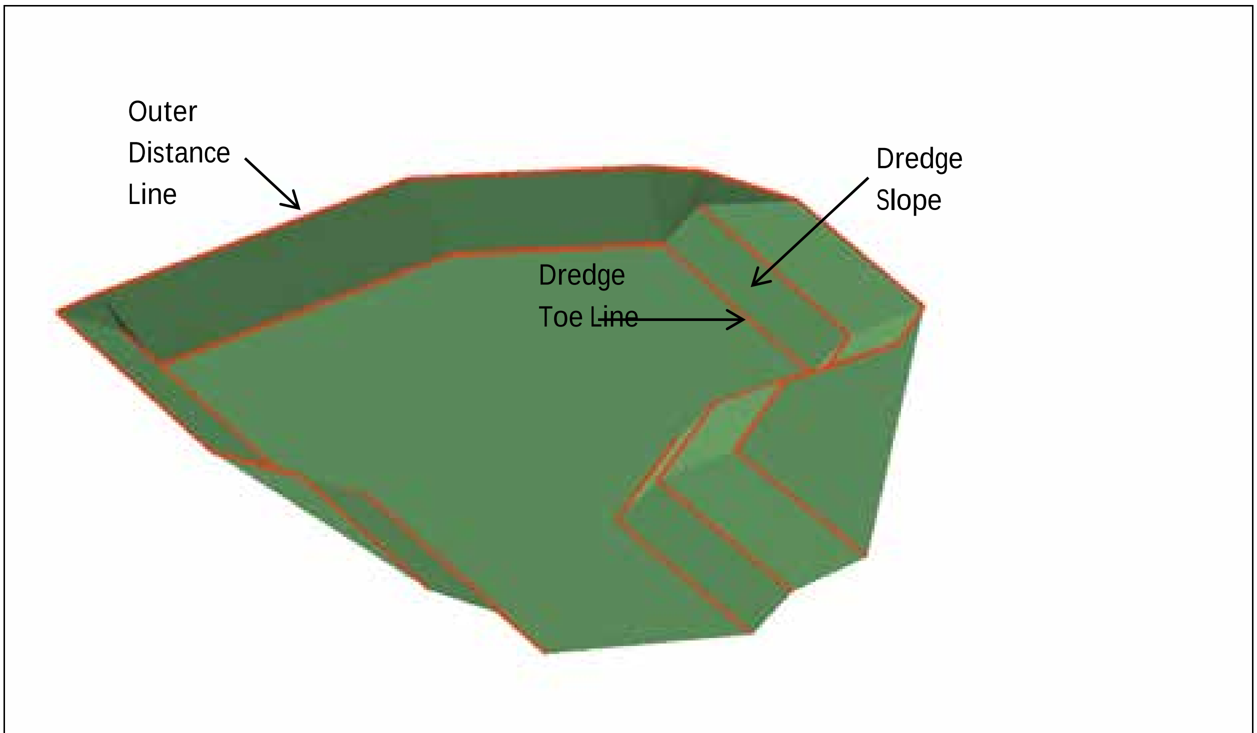

Figure 2 - Dredging Channel 3D Model

Methodology:
Assessment of dredge quantity

The results of the previous steps have constructed a digital elevation model for the seabed surface (bathymetry) and the proposed constructed channel. The difference between the two models will be the quantity that will need to be dredged. In ArcGIS, this is accomplished using the TIN Difference tool in 3D Analyst. "The Tin Difference tool calculates the volumetric difference between two different 3D

TINs" (ESRI 2008). The difference is performed in order of reference meaning the second TIN is subtracted from the first (ESRI 2008). TIN Difference works by calculating the difference in height between measurements of the two input surfaces and it is not based on triangle to triangle intersection (ESRI 2008).

The result of the difference calculation is a polygon feature class that separates each individual feature area into areas that are above or below the second TIN. Polygons that are topologically associated and have the same classification of "above" or "below" are grouped into like polygons. The volume is presented in the attribute table as a cubic volume of the input units of the feature data.

Methodology:
Create 3D Visualization

An important part of this process is the visualization of all of the input data used to develop the various models. ArcScene was utilized display the TIN models of the bathymetry and the proposed dredge channels. The 3D scene provided valuable insight into how the designed dredged channels interact with the bathymetry surface. The 3D scene can be adjusted to examine all angles of the channel to see where the dredged areas intersect the design channel (See Figure 3).

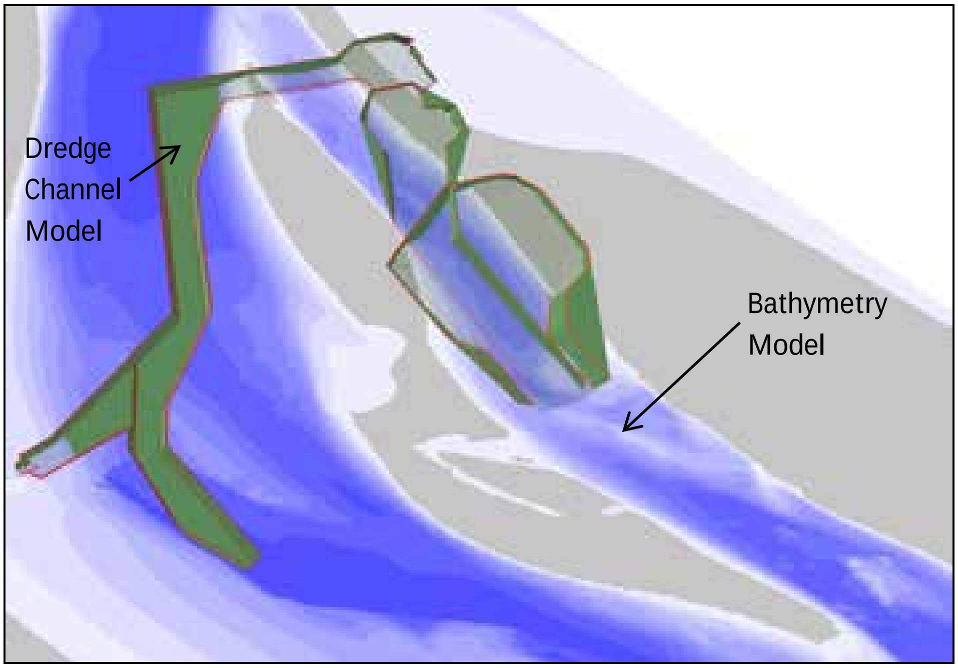

Figure 3 - 3D Visualization of the Dredge Channel and Bathymetry Model

Results and Discussion

The resulting volume calculations using the TIN difference tool in 3D Analyst can provide an estimation of dredge quantities. This can be useful especially for initial studies, quick decisions, and "what if" scenarios. Often times, marine engineers can optimize the dredge channel dimensions based on viewing all of the information in the 3D GIS model. This includes dredge channel depth, width, and slope. This dredge quantity information can be quickly processed during the initial phases of a project to determine the potential cost of dredging.

There are several key factors to consider when developing a 3D model to be used for estimating quantities in ArcGIS. The first and main factor is to know the metadata about the source bathymetry data. Understanding the height datum of the input bathymetry data is the single most important piece of information. The bathymetry data may be delivered in chart datum (CD) or LAT, MSL, or in the case of Australia, AHD. The danger of not knowing the height datum is that the channel may be designed using a different height datum than the bathymetry. If this situation is not reconciled, the quantities will be incorrect.

The second key factor to consider during this process is the development of the surface models or TINs for both the bathymetry and channel. Minor geometry errors in the design channel and incorrect input errors in the bathymetry can skew the surface TIN and can be a major source of error in the overall calculation. Additionally, sometimes it takes two or more processing steps to produce a TIN model and with each process step, inherent error is introduced. Steps should be taken to minimize data processing steps.

The third key factor to consider is the unit of measurement. The volume result in the TIN difference calculation is presented in the same units of the input data. If the data is projected into UTM and the linear units are meters, then the volume is presented in cubic meters.

Conclusion

GIS can be a valuable tool for developing preliminary dredging quantities. GIS provides the ability to calculate these quantities based on source data and input information from marine engineers. Additionally, GIS provides the ability to view and visualize the dredging scenarios in a 3D setting providing an additional dimension of information to decision makers.

Acknowledgements

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References

ESRI (2008). ArcGIS Desktop Help – "How TIN Difference (3D Analyst) works" (Version 9.3.1) [Computer Program]. Available at http://www.esri.com

Google. (2008) Google Earth Pro (Version 5) [Computer Program]. Available at http://google.com/earth/index.html (Accessed on May 5, 2009)

"Multibeam Echo Sounders." NOAA. n.d. Web. 03 Jul. 2012. http://www.nauticalcharts.noaa.gov/hsd/multibeam.html

NOAA (National Oceanic and Atmospheric Administration) 2012. Hydrographic Specifications and Deliverables (2012 Edition).