A Simple Computer Program for the Analysis of Beach Morphology and Morphodynamics

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Abstract
Beach-profile surveying is a relatively long-established and widely utilised shoreline monitoring technique. Several computer programs are available to visualize the beach profile data. But in all programs, the raw field data can't be used to calculate the beach morphology, sediment volume, beach erosion and accretion. In this manuscript, we describe the development of a simple program 'THE BEACH' developed by using Visual Basic 6.0, that can store and analyze the profile data obtained from Emery pole or surveyor's level surveys. This program calculates the elevation of different points along the profile transect and the data can be stored in a Microsoft access database file which is linked with the program It estimates the beach morphological parameters such as beach width, slope and sediment volume above any user specified datum. It also calculates the beach sediment erosion and accretion made in a beach by comparing another beach profile data which is already stored in the database. This program is very useful to geologists, coastal mangers and environmentalists for coastal zone management and environmental impact assessment studies.

1. Introduction

Coastal areas have been very important geographic regions throughout human history. One feature of coastal areas that are often studied and analysed are the profiles of beaches. The cross sections through coastlines can give a good idea as to the changes that can occur over time at one point on the coast, either in the shape of a beach or cliff, or in its size and volume. Beach topography is a result of complex interactions between natural coastal processes and anthropogenic activities. The most common method for measuring beach topographic change is the beach profile. The majority of studies that have employed a geographic information system (GIS) in the coastal zone describe GIS use for mapping erosion patterns and beach sediment responses along coastal margins (Dong et al., 1999). Guillen et al., (1999), Livingstone et al., (1999) and Cooper et al. (2000) advised that beach profiles are an important tool for elucidating long-term trends, such as erosion and accretion, and for predicting the future evolution of coastal landforms. The beach profile survey is the process of making simple datasets with successive elevation and distance from a reference starting point towards the off-shore. Several techniques are available to perform the beach profile survey. The survey can easily be performed using stack and horizon method speculated by La Fond and Rao (1954). Emery (1961) described a simple and rapid method to measure the beach profiles, henceforth called the Emery-method, which has been used in numerous studies throughout the world, such as in Mexico, USA, Ecuador and Australia (Short and Tremabnis, 2004). The beach profiling can also be performed by using surveyor's level or a transit. The rod and transit is a traditional and very adequate method used in performing beach surveys (Parson, 1997). The data in a simple beach profile do not provide comprehensive information in relation to a beach of interest. More and more profile datasets encompassing different transects of beaches are needed to understand their history and forecast future trends. Hence a proper computer program and database in which all of the information relevant to each beach profile survey can be stored is needed. Several software packages are available to visualize the beach profile data. Beach Morphology Analysis Package (BMAP) is an automated set of computer analysis routines compiled at the U.S. Army Engineers Waterways Experiment Station, Coastal Engineering Research Centre (ERDC). BMAP complements and is file-compatible with the Interactive Survey Reduction Program (ISRP) (Birkemeier, 1984) used by the U.S. Army Corps of Engineers to clean, compare and analyze beach profile survey data. NIWA's Beach Profile Analysis Toolbox (BPAT) has been developed to provide an easy to use, integrated package for the input, quality checking, analysis and archiving of beach and other profile related datasets. Bradbury et al. (2004)

described the Shoreline and Near-shore Data System (SANDS), developed by Halcrow Group Ltd. 'SANDS' is a monitoring and data storage GIS, developed for coastal managers and engineers, to analyze coastal survey data. As part of the Lake Michigan Potential Damages study carried out by the U.S. Army Corps of Engineers-Detroit District, a Flood and Erosion Prediction System (FEPS) was developed by Baird & Associates (Nairn and Zuzek, 2001). In the above programs and packages, the raw field data obtained from the Emery Pole or Surveyor's level surveys can't be directly entered. They need distances from the reference point (x-values) and their corresponding reduced levels or elevations (z-values) to input the profile data to the above programs. So it is necessary to calculate the elevations of different points from the reference datum manually, after which values can be entered or imported (only with a specific file format). Thus it takes more time to analyze the erosion or accretion. Here an attempt is made in Visual Basic 6.0 to quickly handle the raw profile survey data and to analyse the beach sediment erosions and accretion.

2. Program Methodology

2.1. Beach Profile Survey

The beach profile survey can be done by using many different methods. For coastal studies, Emery pole and surveyor's level are commonly used to acquire elevation data. First a narrow transect of known length in the beach is selected. A transect has a reference point whose elevation from a reference datum is already known. Profiling can be done at regular or irregular interval of distances from the reference point along a straight line. It can be done up to a maximum low water line of the coast covering the entire beach including berm, high tide, mid tide and low tide zones. By using a Level and Staff, the back-sight and fore-sight values can be noted. If the survey is done by using graduated pole and measuring tapes then, another small pole of length 1m (back-sight value is 1m) can be used to find the foresight values through the sea-horizon. Let 'a' is the common back-sight value and 'b,c,d,...' are the foresight values. By using Back-sight, Fore-sight and Bench mark values, the elevation at any point on the beach can be calculated. Table1 Shows model beach profile survey data field book.

2.2. Calculation of Beach Width, Slope and Sediment Volume from Beach Profile Data

Figure 1 shows a typical beach profile. Let 'ABCDEF' represents the complete profile of a beach. It contains various profile segments AB, BC, CD, DE and EF. OS is the reference datum. The profile segments AB, BC and CD are fully above the datum and segment DE is partly below the datum and the segment EF is fully below the datum. So the elevation of points A, B, C, and D are taken as positive and the elevation of points E and F are taken as negative. Let us consider the segment 'AB' of the beach profile. First the slope, width and sediment volume above the reference datum of the profile segment 'AB' are to be calculated. So, the segment AB is checked to see whether the elevation of any one point is above the datum. The cross sectional area covered by the segment 'AB' is divided into a right-angled triangle (ΔAB'B) and a rectangle or square (OB'BP).

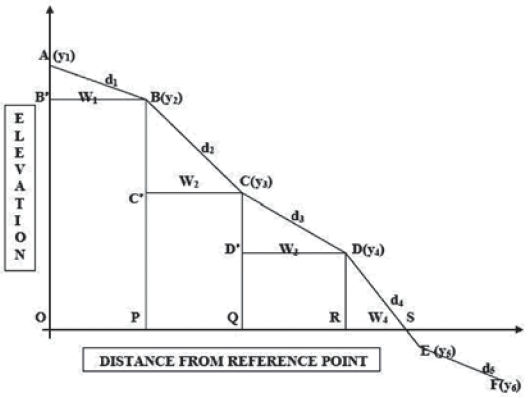

Figure 1: Typical Beach Profile

The horizontal width of the segment 'AB' (B'B) is calculated by using Pythagoras theorem. The cross sectional area of the beach covered by the segment 'AB' is the sum of areas of the triangle (ΔAB'B) and rectangle or square (OB'BP) and they are calculated by using simple arithmetic operation. The cross-sectional area of the profile segment 'AB' gives the sediment volume per unit length (in cu. m/m) under the profile segment 'AB' above the reference datum. Now the same operation is followed to the remaining segments of the beach profile to calculate the beach width, slope and sediment volume of all individual profile segments. Finally the total beach width, mean beach slope and total sediment volume per unit length above the datum can be calculated.

2.3. Algorithm for Calculating Beach Width, Slope and Sediment Volume

Take the segment AB of the beach profile.

1) Get the elevation input of points A and B (y_1 and y_2) and Ground distance of the profile segment AB (d_1)

- Calculate the distance AB' by using the formula $AB' = (y_1-y_2)$

- Calculate the width of the profile segment 'AB' by using the Pythagoras formula:

$$W_1 = B'B = [(AB)^2 - (AB')^2]^{0.5} = [d_1^2 - (y_1-y_2)^2]^{0.5}$$

Equation 1

- Calculate the slope of the segment 'AB' by using the formula:

Slope S_1 = Change in Y axis / Change in X axis = AB'/ B'B =
$(y_1-y_2) / [d_1^2 - (y_1-y_2)^2]^{0.5}$

- Calculate the volume of sediment under the segment 'AB' per unit length of the beach above the reference datum by using the formula:

V_1 = Cross-sectional area under the profile segment AB
= Area of Δ^{le} AB'B + Area of rectangle OB'BP
$= [0.5 * (y_1-y_2) W_1] + [W_1 * y_2]$
$V_1 = [0.5 * (y_1-y_2) * (d_1^2 - (y_1-y_2)^2)^{0.5}] + [(d_1^2 - (y_1-y_2)^2)^{0.5} * y_2]$

Equation 2

The above operation is followed to calculate the width, slope and sediment volume of all the individual beach profile segments BC, CD, DE, EF etc.

3. Result and Discussions

3.1. Data Input

The program is very user friendly to load the field data. The raw data from the field book can directly be entered in a visual basic data entry form (Figure 2) without any specific format. The elevations of all the profile segments, beach width and slope are automatically calculated and displayed in an MS flex grid. All these field datasets are saved in the Microsoft Access database which is linked with this program. The validity of the data can be properly verified before they are saved in the database. The stored profile data can be retrieved and edited whenever required. The beach profile survey data and other related information including wave type, wave height, wave period, wind speed; wind direction can also be entered in the program.

3.2. Data View

Once the data has been entered in the data-entry form, the user can view the complete beach profile in a chart (Figure 3). The fusion chart function of visual basic 6.0 produces attractive standard graphic charts of the profile. Future upgrades of this program will have different plotting and exporting options, zooming and other tools to perform the viewers to clearly view and analyse all the individual segments of the profiles.

3.3. Analysis Functions

This present program is committed to store and visualise the raw field survey data obtained from Emery poles and surveyor's level and also to study the standard morphological parameters of beach. It supports the analysis functions like cross-shore beach width, beach slope, cross sectional area and sediment volume. The horizontal width, slope and cross-sectional area of all profile segments are calculated. The sediment volume of beach above any user specified datum, mean beach slope, cross-shore beach width can also be calculated. Another objective of this program is to study the erosion and accretion made in a beach by using the raw field data. Various temporal or spatial survey data saved in the database can be used to analyse the sediment erosion and accretion. The program evaluates the changes in slope, beach width and sediment volume for each and every segments of the beach profile. The beach sediment erosion, accretion can also be calculated. Also the changes in mean slope and width, net erosion, net accretion, effective erosion/accretion are calculated.

4. Program Validation

This simple and easy-to-use visual basic program has been developed to load, store and analyse the raw beach profile datasets of any geographic region obtained by using conventional surveys like Emery poles and surveyor's level. The ability and accuracy of this program has been validated by using profile data obtained from the Kanyakumari beach on before and after the December 2004 Tsunami event. The survey data has been entered in the data entry form of the program (Figure 2). Once the raw data has been entered in the program, the elevation of all profile segments has been estimated and the beach profiles can be visualized by a chart (Figure 3).The morphological parameters such as beach width, slope and sediment volume has been calculated through the analysis form (Figure 4). It also estimates the beach erosion and accretion made in the beach. From the analysis it is clear that the mean beach slope is increased from 4.51 degree to 5.67 degree and the beach becomes steeper after the tsunami. The change in beach slope is 1.16 degree. The cross-shore beach width is decreased from 38.69 m to 33.16 m. and the change in beach width is 5.53 m. The volume of sediment above the mean sea level is decreased from 66.443 cu.m/m to 52.687 cu.m/m. The net erosion made in the beach is 11.10 cu.m/m and the net accretion is 1.83 cu.m/m. The overall effective erosion is 9.76 cu.m/m. The above results are manually verified and compared with the results obtained through similar programs.

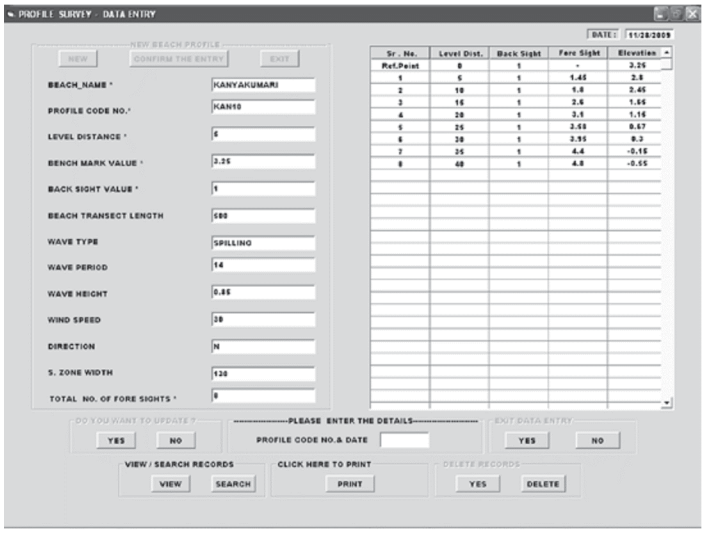

Figure 2: Beach Profile Data Entry Form

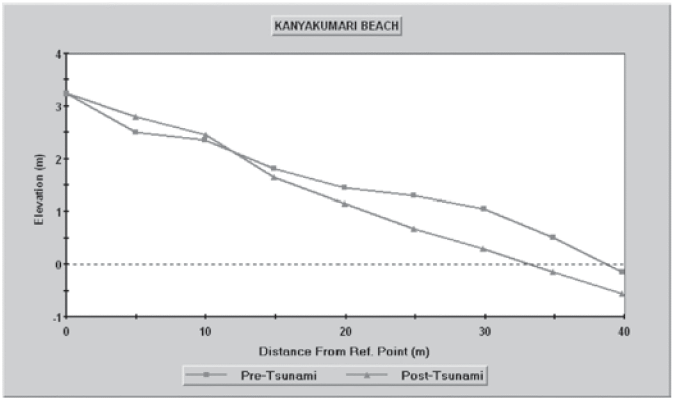

Figure 3: Beach Profile Charts

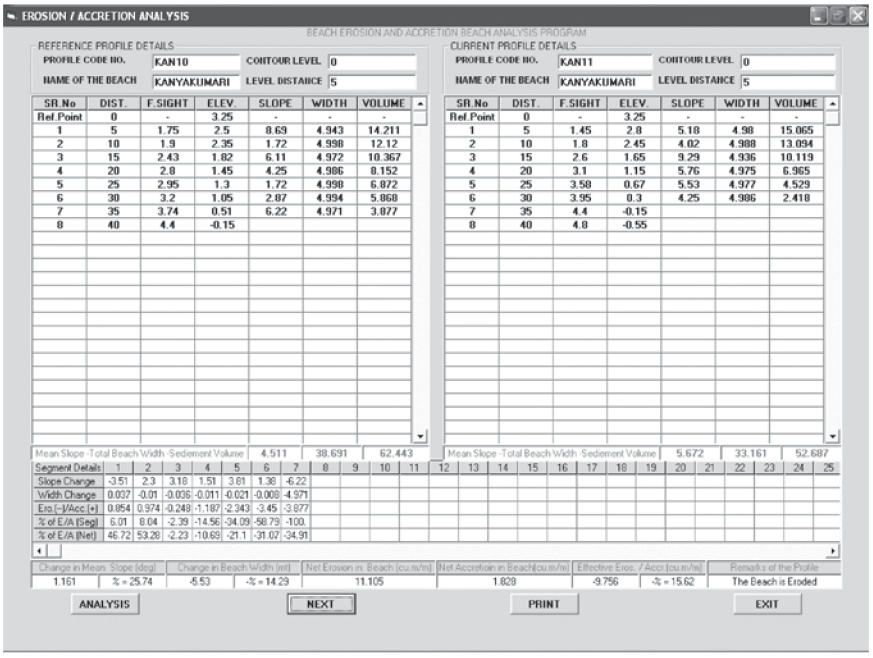

Figure 4: Beach Morphology Analysis Form

The study indicates changes on the beach morphology and morphodynamics of Kanyakumari beach after the tsunami. It also reveals that, large amount of sediments are eroded from the low tide zone of the beach, but it deposits sediments on the berm and high tide zone. Thus this program effectively handles the raw beach profile data and analyses the beach morphological parameters, sediment erosion and accretion.

5. Conclusions

Even with the latest development of survey techniques and availability of modern survey equipments, the use of conventional survey methods like Emery-method and surveyor's level still have wide applications in developing countries. Also the software programs which are available for the analysis of beach profile data are not having options to use the raw profile data obtained from the above conventional methods. This program effectively handles the raw field data obtained from surveyor's level and Emery poles and analyses the beach morphological parameters, sediment volume, erosion and accretion. Generally the calculation of morphological parameters of beach is a time-consuming work and requires lots of efforts to calculate them accurately. This computer application tries to reduce the time and effort by automation of the calculation processes. It will be very useful to the geologists, coastal mangers and environmentalists. Also it can be used as a supporting program for coastal zone management analysis and environmental impact assessment studies. Presently the program is not designed with numerical modeling and advanced engineering tools. Future upgrades of this program will include GIS capability and have sufficient engineering tools like equilibrium beach profiles, EOF's (Empirical Orthogonal Function), and cross-shore sediment transport for the wide analysis of beach profiles.

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