CORRELATING THE VELOCITY PROFILES TO THE SEDIMENT PROFILES OF THE ACTIVE SEDIMENTATION ZONE of ASWAN HIGH DAM LAKE

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ABSTRACT

The main focus of this paper is to investigate the possible correlation between the velocity profiles and the sediment accumulation profiles in the active sedimentation zone of the Lake which is located in Nubia Lake (Sudanese part of AHDL). To enable this investigation, the remote sensing (RS) and (Geographic Information Systems) GIS techniques are used to build the 3-D profile of the Lake portion where most of the sediment accumulate. The period from 2004 to 2010 where the data are available are used for the present study. Also, the accumulated sediment during this periodis computed using the developed 3-D profile and using the cross section method as conducted by Aswan High Dam Authority (AHDA).Results indicated that the difference between the present approach and the method used by AHDA is 7% where the method of AHDA produce lower amount.On the other hand, the measured velocity patterns are mapped, analyzed and its 2-D profiles are correlated to the erosion and sedimentation patterns perfectly.

Keywords: Aswan High Dam Lake, Velocity profile, Sediment profile, Nubia Lake, Remote sensing, GIS

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1 INTRODUCTION

The Ministry of Water Resources and Irrigation (MWRI), Egypt, is very interested to monitor the changes in AHDL capacity especially after the construction of Grand Ethiopian Renaissance Dam (GERD). The lake water capacity is affected directly by the changes in the lake's bed surface. Monitoring these changes is vital as it provides the decision maker with sufficient information to manage the storage capacity of the lake.

Satellite observations data have been combined with in-situ measurements, using GIS analyst tools, to estimate and analyze changes in lakes bed surfaces, with successful applications in different parts of the world.

The morphological changes related to erosion / sedimentation processes occurred in San Giuliano Lake which located in Basilicata Region (Southern Italy), in the period 1984 – 2004 were analyzed using RS data integrated in GIS technique (Curzio et al., 2013). El-Sammany and El-Moustafa (2011) proposed a method for calculating the changes in AHDL bed from year 1953 to 2004. They suggested the use of GIS to make processing of the field measurements (bathymetric data). The GIS tools are called geo-spatial analysis and 3D analyst tools to form and analyze the Digital Elevation Models (DEMs) for the study area. Negm et al. (2010) studied the scouring and silting processes in AHDR by applying a two-dimensional numerical model. Schultz (1997) detected the changes in sediment and erosion in the upper region of Lake Kemnade in the Ruhr River valley in Germany using remote sensing techniques and echo sounding data for eight years.

Concerning the flow velocity characteristics and distribution in AHDL, very limited research works were conducted. Both of Sallam et al. (2015); Moustafa (2013); and El-Sammany and El-Moustafa (2011) are among those researchers.

This paper focuses on the correlation between the inflow velocity on sediment and erosion patterns via the comparison between changes in the lake bed profiles and the corresponding 2-D inflow velocity profiles. Also, the paper presents and discusses the results of detecting the changes in AHDL active sedimentation portion bed surface (sediment / erosion) and their amounts from the year 2004 to 2010 using GIS / RS techniques.

2 STUDY AREA AND DATA COLLECTION

2.1 The study area

The AHDL consists of two main parts. Egyptian part with a length of about 350 Km and called Nasser Lake and Sudanese part with a length of 150 Km. The present study focuses on the most active portion of the AHDL, which is located in the Sudanese part of the lake (Lake Nubia). Also, from the studies and observations done by the repetitive field survey missions, which successfully carried out through the joined efforts of the Aswan High Dam Authority (AHDA) and the Nile Research Institute (NRI), it is obvious that this area represents the area with most intensive sediment deposition. Moreover, the total amount of sediment deposited in the study portion of AHDL is about (50%-70%) of the total amount of sediment in AHDL, NRI (2010). However, this portion represents only about 6% of the total area of AHDL, " MWRI, 2012". For thus this reach is called (the active sedimentation portion).The study area of the present research extends between latitudes 21°44′30″N and 22°00′00″N (upstream AHD). It contains six cross sections (28, 27, 26, 25, 24 and 22) from the South to the North respectively as indicated in Figure 1.

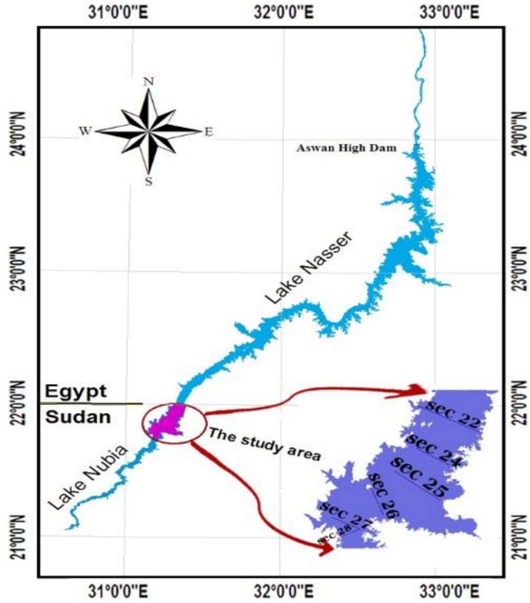

Figure 1. Location of the study area in AHDL

The geometric characteristics of AHDL (large area and high depth) make the lake volume estimation critical and needs to be as accurate as possible for operational and social purposes

2.2 In-situ data

2.2.1 Hydrographic survey data

The hydrographic survey data which describe the geometry of AHDLwere conducted by using the eco-sounder via field trips provided by (AHDA and NRI). The lake geometry presented by Easting, Northing, and Elevation (E, N, and Z) was used for hydrographic survey data of years 2004, 2006, 2008 and 2010 for the study area are used (NRI, 2010).

2.2.2 Water levels data

The water levels upstream AHD which recorded by AHDA gauge stations in the different dates of the year are collected to be used to detect the water surface levels at the dates of acquiring the satellite images.

2.2.3 Inflow velocity data.

The inflow velocity data -which represents the velocity magnitudes - were measured by using the Vale port velocity meter device via the above mentioned field trips. These data are available at the locations of the cross-sections shown in Figure 1. In this study, the inflow velocity magnitudes data of years 2006, 2008 and 2010 were used by NRI (2010).

2.3 Satellite images (Remote Sensing data)

Three Landsat ETM+ images (Path/Row=175/045) were used in this research. The three images were acquiredat different dates (September 2000, March 2006, and March 2009) from the GLCF website in GeoTIFF (systematic correction) products (GLCF, 2014). The acquired images were used to extract the lake boundaries. The satellite images were shot in September 2000 where the water level in the lake was (178 m) amsl, March 2006 where the water level was (173 m) and in March 2009 where the water level was (176.60 m).

3 METHODOLOGY

To achieve the objectives of the present paper, the tasks presented in Figure 2 are conducted. The major tasks are explained in the following subsections:

3.1 Water surface areas extraction

The unsupervised classification technique of Landsat images to obtain the water body class of AHDL is performed, because it is considered the best technique for water texture recognition, Elsahabi et al. (2015) and Elsahabi et al. (2016).

The extracted lake boundaries, obtained from the satellite images, were used to form the shape of the surface and also, to form a group of scattering points (x,y,z) using the WGS84, UTM Z36N as a defined projected coordinate system. These points are used,combined with the hydrographic survey points in the generation of the 3D bed surfaces of the study area for all available years (2004, 2006, 2008, and 2010).

3.2 Prediction of the 3D bed surfaces

To predict the original lake 3D bed surfaces from year2004 to 2010, the available hydrographic survey data combined with the points that represent the water surface areas which derived from Landsat satellite imagesare used in the interpolation process. Also, the water surface, that represents the highest surface for all predicted bed surfaces was of the 2000 Landsat image. The interpolation process is performed with the Radial Base functions (RBF) method, ESRI (2008).

To assess the accuracy of the interpolation methods, the Mean Absolute Error (MAE) is used. For accurate interpolation process, the MAE should be near zero as the error here represents the difference between measured and predicted value.

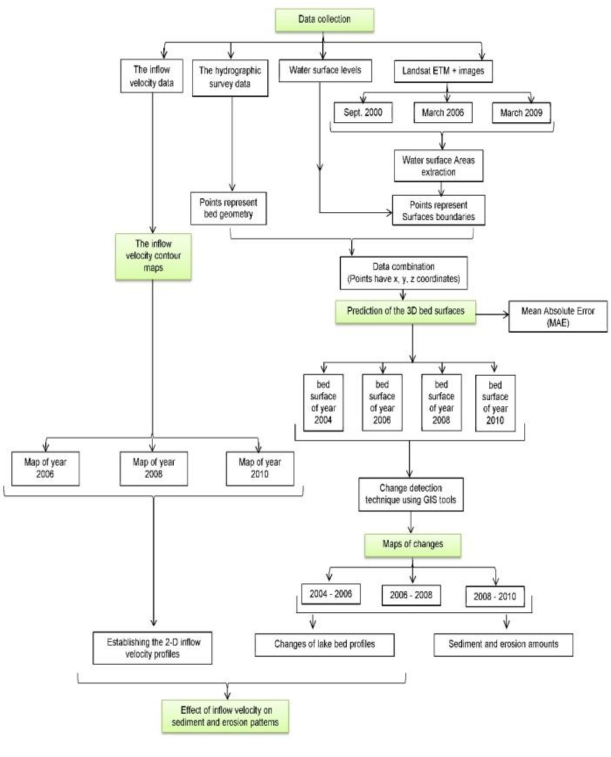

Figure 2.Flowchart of the procedures adopted to detect the correlation between the 2-D velocity profiles and sediment accumulation in the study area

3.3 Change detection technique

This technique is a digital overlaying technique that depends on detecting the changes in the lake's bed levels by overlaying every two sequent predicted bed surface using (cut / fill) tool in ArcGIS Software.

3.4 Establishing maps of changes

The The maps of changes derived from the change detection technique represent the changes (sediment / erosion) zones. These maps are generatedto quantify the changes amounts in the study area through the period from 2004 – 2010.

3.5 Generation of the inflow velocity contour maps

To establish the inflow velocity contour maps for years 2006, 2008 and 2010, the available inflow velocity magnitude data were used in the interpolation process. This process is performed by using ArcGIS software. These contour maps are producedto explain the effect of the velocity magnitudes on the erosion and sedimentation patterns.

4 RESULTS

4.1 Creation of the 3D bed profiles

The extracted water surfaces by the unsupervised technique from all available Landsat images from the year 2000 to 2012 are used in the creation of the 3D bed surfaces .To predict the 3D bed surfaces, the Radial Base functions (RBF) method for interpolation is used as it produces good results for gently varying surfaces such as elevations (ESRI, 2008).

To assess the accuracy of the used RBF method, MAE was computed which is almost near to zero for all studied years. The MAE for the year 2006 equals 0.02363 indicating high accuracy of the interpolation process.

The 3D bed surfaces are predicted for the years 2004, 2006, 2008 and 2010. Sample results is presented in Figure 3 for the year 2006 and year 2008.

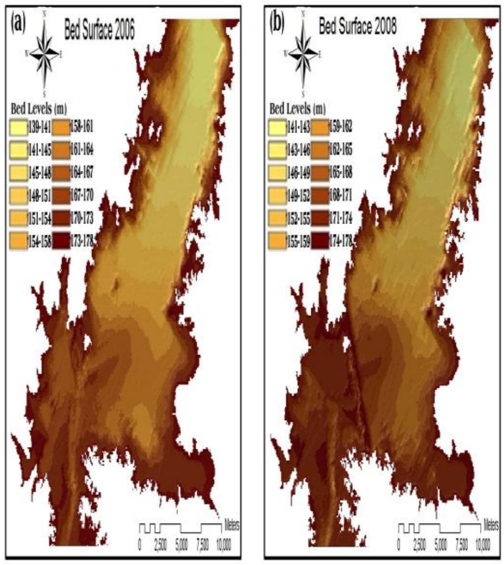

Figure 3.Typical sample results of the predicted bed surfaces for the years 2006 and 2008.

4.2 Maps of changes

To detect the changes in bed levels between every two sequent years, predicted bed surfaces are generalized by three broad change categories:

- No change: the levels that have the same values in the old and new bed surface.
- Sedimentation: the old bed surface levels that were increased in the new bed surface.
- Erosion: the old bed surface levels that were decreased in the new bed surface.

Maps of changes for the years 2004-2006, 2006-2008 and 2008-2010 are produced. Typical samples for the years 2006-2008 and 2008-2010 are presented in Figure 4.

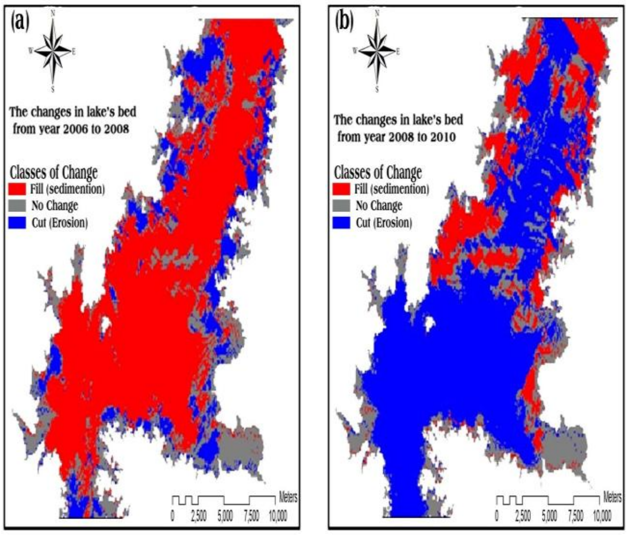

Figure 4.Typical sample for maps of changes for the years 2006-2008 and 2008-2010.

4.3 Velocity maps

The collected field data about the inflow velocity values for years; 2006, 2008 and 2010 are interpolated by using Arc GIS software. Afterward, the velocity contour maps were produced. Figures 5 show typical sample results for the year 2006 and year 2010 respectively

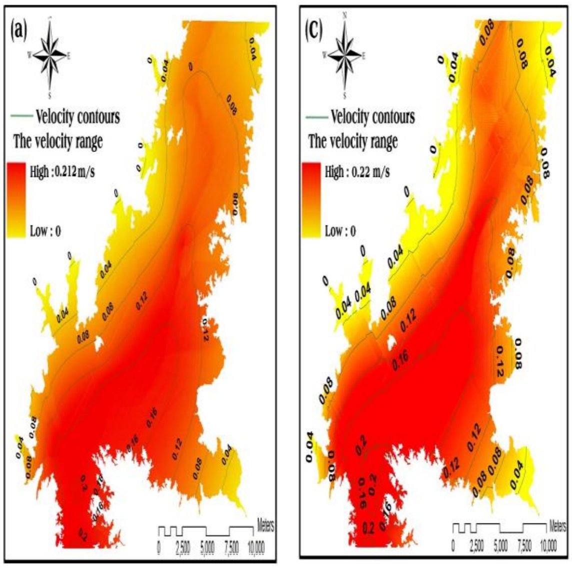

Figure 5.Typical sample for the inflow velocity contour maps for the years 2006 and 2010.

5 DISCUSSION

5.1 Sediment and erosion change

Table 1 shows the change in sediment and erosion amounts from the year 2004 to 2010, as estimated by using the statistics of the change categories (classes) in the maps of changes. It is obvious from this table that there is an increase of sediment from the year 2006 to 2008 accompanied with a decrease of erosion in the same periods. Otherwise, there is a decrease of sediment from the year 2008 to 2010 accompanied with an increaseof erosion in the same period. From the year 2004 to 2006, the amount of sediment is nearly equal to the amount of erosion.

Table 1. Sedimentation and erosion amount from (2006-2010).

Time period	amount of Sediment (B.m³){1}	Erosion amount(B.m³){2}	Total change amount (B.m³) = {1} –{2}
2004-2006	0.328	0.282	0.046
2006-2008	0.674	0.117	0.557
2008-2010	0.182	0.779	-0.597

5.2 Comparisons

Table 2 illustrates that the total amount of sediment from the years 2004 to 2008 was about 0.603 billion m^3 as given by Table (1), and the estimated sediment amount by AHDA (the traditional method) was equal to 0.561 billion m^3 in the same period, NRI (2010).Consequently, the present approach overestimate the sedimentation capacity by about 7% compared to the the method used by AHDA. This low percent indicates the present approach to estimate the accumulated sediment data are trustful and reliable.

Table 2.Comparison of results between the present and traditional methods of AHDA for estimating sediment capacity from the years 2004 to 2008.

Time period	Amount of sediment by GIS/RS method (Bm^3)	Amount of sediment by AHDA method (Bm^3)
2004–2008	0.603	0.561

5.3 Effect of inflow velocity on sediment and erosion (lake bed surface)

Figures 6 and 7 presents the variation of the bed profile (in the transverse direction) for the three years 2006, 2008 and 2010 and the corresponding velocity profile for the same years at sections 22 and 26 (Figure 1). It can be noticed that; the increment in the velocity rates is associated with a decrement in bed surface levels (high amounts of erosion), as it occurred during 2008 to 2010. On the other hand; the decrement in the velocity rates is accompanied by increment in bed surface levels (high amounts of sedimentation), as it occurred during 2006 to 2008.

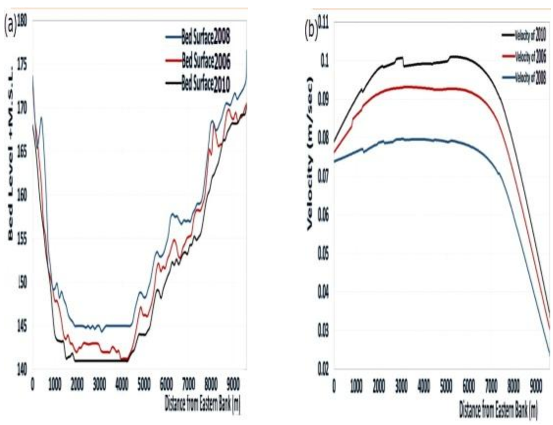

Figure 6. Comparison between bed surfaces and velocity profiles at section 22 (337.5 Km U.S AHD): (a) Bed surfaces cross sections; (b) Velocity distribution

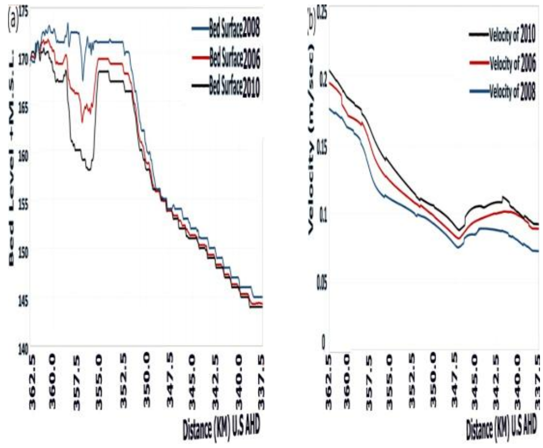

Figure 7. Comparison between bed surfaces and 2-D velocity profiles at section 26 (357 Km U.S AHD): (a) Bed surfaces cross sections; (b) Velocity distribution

Similarly, Figure 8 presents the variation (in the longitudinal direction) of the bed surface for the same years and the corresponding variation of the velocity profile for the same years of 2006, 2008 and 2010. The analysis of this Figure confirmed the previous resulted for the transverse direction.

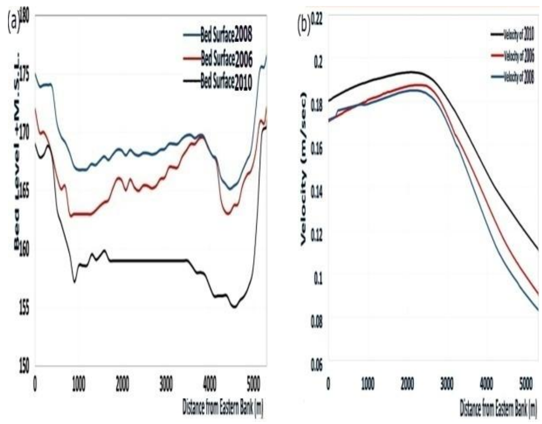

Figure 8. Comparison between bed surfaces and 2-D velocity profiles for the longitudinal section :(a) bed surfaces (b) velocity distribution, for the year 2006, 2008 and 2010.

6 CONCLUSION

This paper presents and discusses the possible correlation between the 2-D velocity profile and the sediment profiles of the active sedimentation zone of AHDL. According to the present results, it is concluded that the increment in the inflow velocity rate is the main reason to cause the erosion phenomenon. On the other hand, the decrement in the inflow velocity rate is accompanied by the sediment accumulation phenomenon. Also, the change detection in bed surface (sediment / erosion) of the active sedimentation Portion of Aswan High Dam Lake is made using RS/GIS techniques. Moreover, results indicate that the method used by AHDA, based on the complementary cross sections, underestimates the sedimentation amount by about 7% from the year 2004 to 2008 compared to the results of the present approach as estimated from the developed 3D profile of the Lake Nubia.

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