UPDATING THE SURFACE AREA AND VOLUME EQUATIONS OF LAKE NASSER USING MULTIBEAM SYSTEM

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ABSTRACT

Lake Nasser is the main reservoir for Egypt in which the water is stored during high flood to cover the shortage of water in low flood. It is very important to determine the water volume of water stored in Lake Nasser to calculate the water balance of the Lake and also the surface area to calculate the evaporation losses. The equations of the surface area and water volume of the lake according to the water level have been delivered several times in several researches but theses equation are based on a very few bed level data. The lake was surveyed once a year with a cross section every about 26 Km in the Egyptian border and about 10 Km in the Sudanese border. During years 2011 to 2013 a first time intensive survey was done in Lake Nasser using a new survey technology (Multi Beam Echo sounder). By using this new technique, the spacing between the cross sections were between 250 m and 2 Km. it means that the area covered by this survey is about 20 times the old survey. According to the new data from the latest survey of Lake Nasser an update was made to the equations governed the relation between the water level and both the surface area and water volume. A digital elevation model was made to the lake bed so the area and volume of the lake were calculated for deferent water level. By comparing the old and new equations, it has been noticed that there is a remarkable deference in the results for the area and volume.

Keywords: Lake Nasser, Multi Beam, Hydrographic Survey, Water Resources.

1. INTRODUCTION

The equations governing the relation between water level of lake Nasser and both the surface area and storage capacity are very effective in calculating the water balance of the lake. They are also essential for estimating the evaporation losses and the operating rules of the lake. Some equations were performed by several researchers using the available data.

Abu Atta (1978), by using air survey contour maps of lake Nasser area before the construction of high Aswan dam, an estimation of the water level and storage capacity relation using old techniques. The results of this study was used as a reference for a long time because of leakage of survey data.
Figure (1) shows the water level vs surface area and water level vs storage capacity relations.

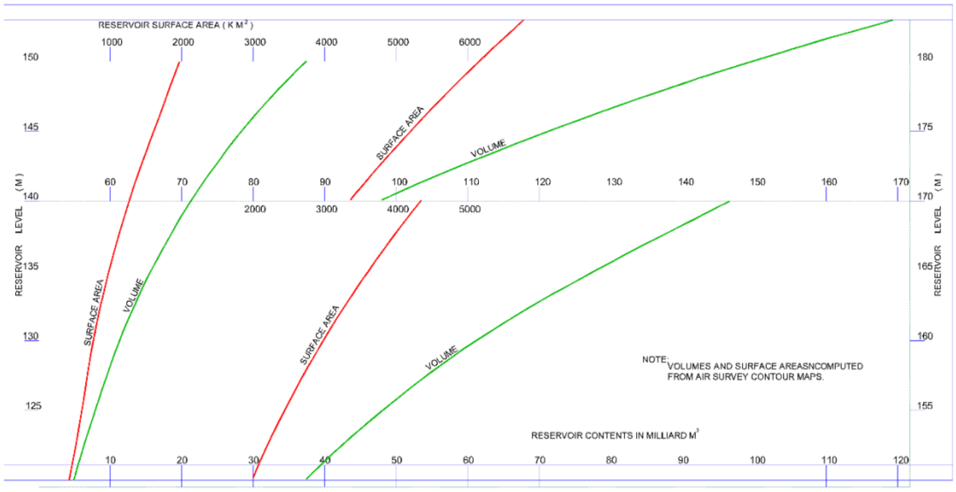

Figure 1. The chart of Abo Ata for area and storage capacity against water level of lake Nasser

From the construction of High Aswan Dam until late 90s, a few cross sections were surveyed periodically in lake Nasser, about 1 cross section per 20 Km, in order to monitor the sedimentation depths but not enough to calculate the total storage or the surface area.Figure (2) contains the cross sections locations along the lake.

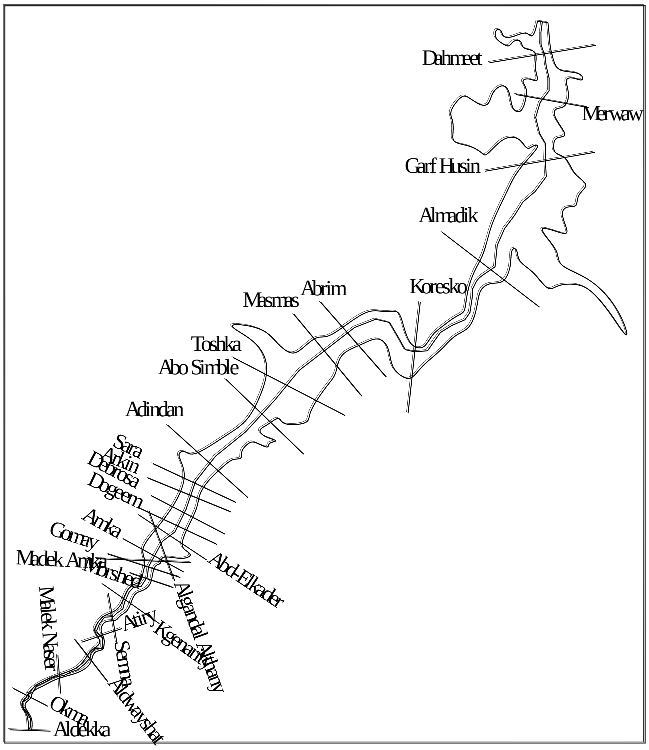

Figure 2.The Name and Location of the surveyed cross sections of lake Nasser

After the expanding of using GPS technique the field trips to Lake Nasser were collecting more cross sections, about 1 cross section per 20 km in the Egyptian part and 1 cross section per 3 km in the Sudanese part, by using this data in addition with remote sensing analysis of satellite images some researchers tried to implement the relation between water level and storage capacity.

Shafik (2005), by using satellite images for deferent water levels, the surface areas were extracted from the images and the researcher conclude to an equation between the water level and surface area valid only for water levels between (158m to 182m). Figure (3) shows the calculated data with the best fitting curve and the equation governing the relation between the surface area and water level of lake Nasser.

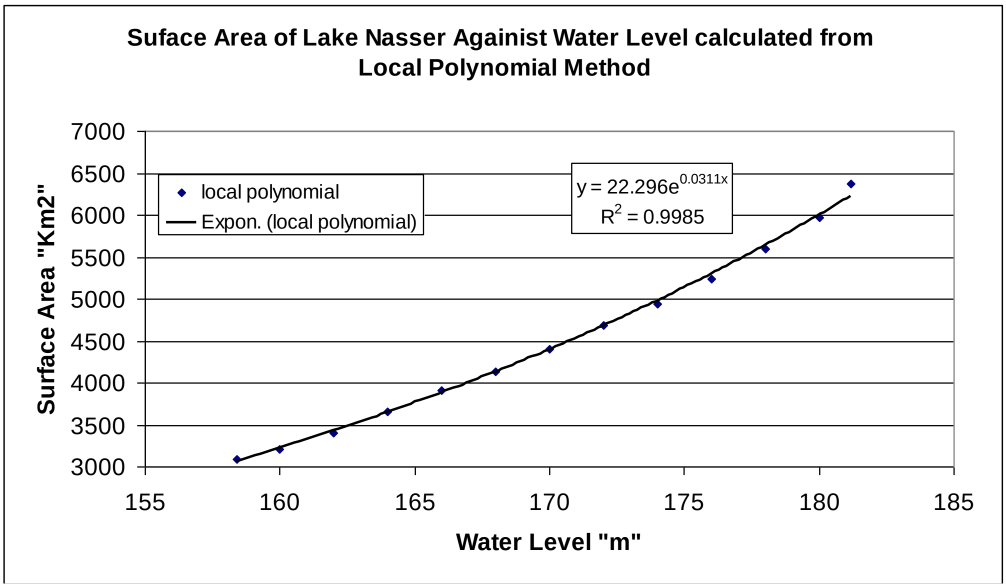

Figure 3. The relation between the surface area and the water levelsof Lake Nasser

Eric Muala& Others (2014), this study evaluated the feasibility and accuracy of using satellite altimetry and imagery data to estimate stored water volumes and, combined with limited in situ data. The surface area was estimated from Landsat images using NDWI, while the water level was from satellite altimetry, the water volume of the reservoirs was derived from the integration of a lake-specific area-level relationship.Figure (4) showsthe area (*A*)-water depth (*d*) relationships for Lake Nasser were derived from altimetry water levels and surface area (Landsat) data of Hydroweb (blue) and GRLM (red). The water depth refers toabove the lowest water level (h_{min})

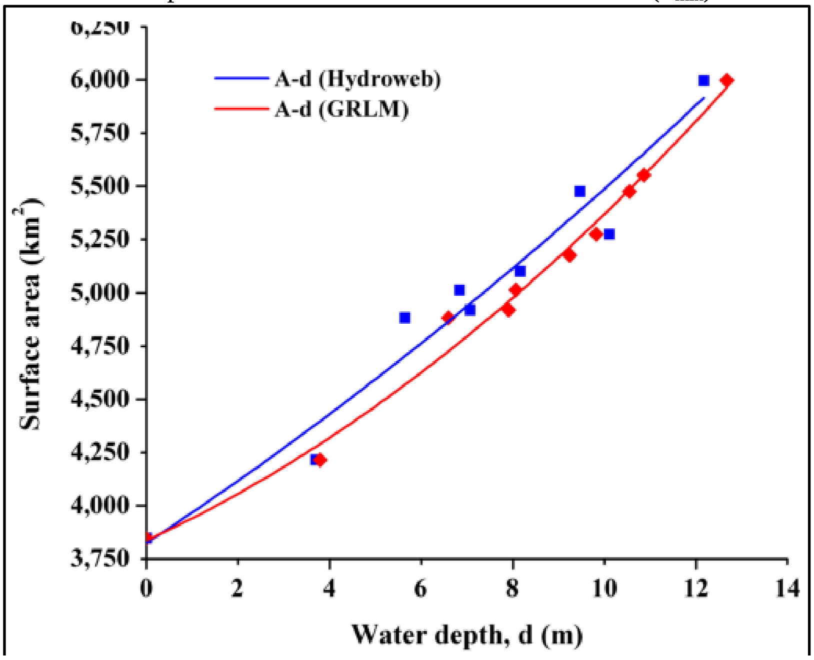

Figure 4. The relation between the surface area and the water depthof Lake Nasser

2. SINGLE AND MULTI-BEAM ECHO SOUNDER

Echo sounding is a type of SONAR used to determine the depth of water by transmitting sound pulses into water. The time interval between emission and return of a pulse is recorded, which is used to determine the depth of water along with the speed of sound in water at the time.Figure (5) shows the diagrame of the single beam echosounding and the data colected by it.

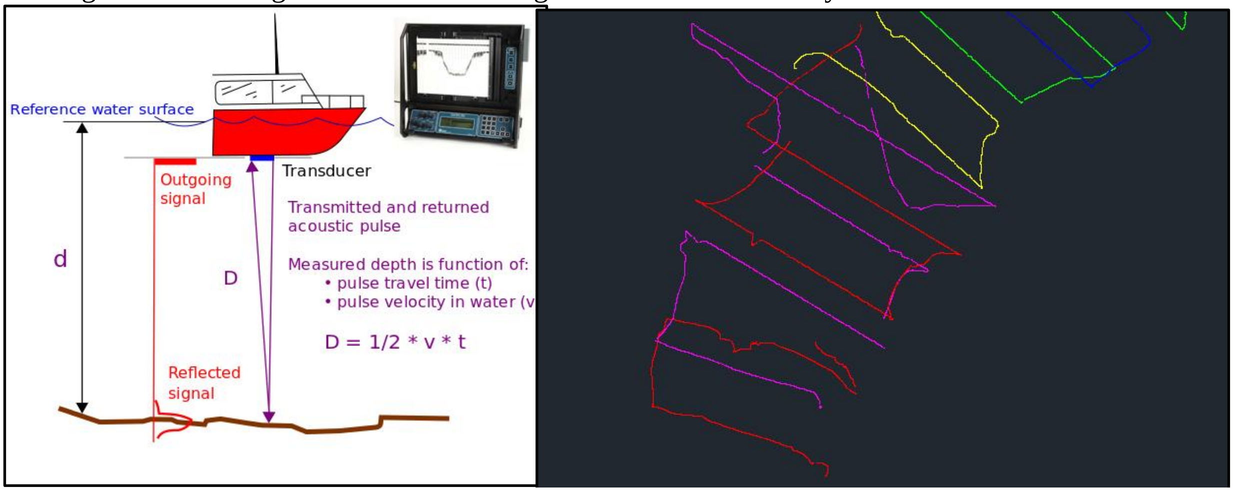

Figure 5.The single beam echo sounder

The multi-beam echo sounder is a device typically used by hydrographic surveyors to determine the depth of water and the nature of the water stream bed. Most modern systems work by transmitting a broad acoustic fan shaped pulse from a specially designed transducer across the full swath across

track with a narrow along track then forming multiple receive beams (beamforming) that are much narrower in the across track (around 1 degree depending on the system). From this narrow beam a two-way travel time of the acoustic pulse is then established utilizing a bottom detection algorithm. If the speed of sound in water is known for the full water column profile, the depth and position of the return signal can be determined from the receive angle and the two-way travel time.
In order to determine the transmit and receive angle of each beam, a multi beam echo sounder requires accurate measurement of the motion of the sonar relative to a Cartesian coordinate system. The measured values are typically heave, pitch, roll, yaw, and heading.
To compensate for signal loss due to spreading and absorption a time-varied gain circuit is designed into the receiver. Figure (6) shows the multi-beam acquisition software and the diagram of multi-beam scanning area.

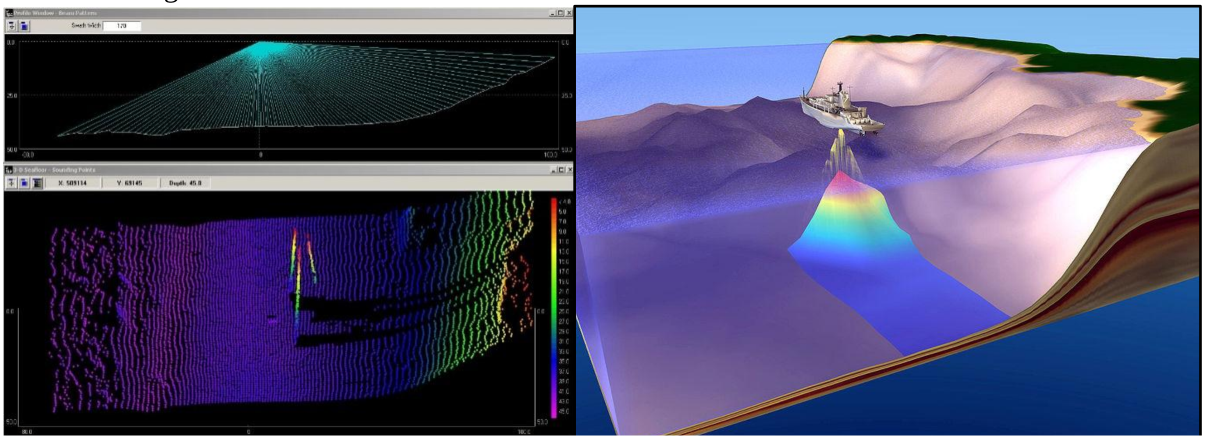

Figure 6. The multi-beam echo sounder

3. DATA

The data used in this study were collected in four field trips in years 2012 and 2013, the first and second trips were in 2012 covered the area of about 290 Km in the Egyptian border from km 60 to km 350 measured from high Aswan dam. The third one was held in January 2013 covered 150 km in the Sudanese border from km 350 to km 500. The last trip was in September 2013 and covered the two major khores in Lake Nasser (Kalabsha and Allaqui).

The area from km 0 to km 60 was taken from the old contour maps done before the construction of the High Aswan Dam. Also the contour lines 180m and above were taken from the same maps.
All the field trips used the multi-beam survey technique and the total points after processing are about 10 Million points.Figure (7) shows the areas covered by the trips and the contour map.

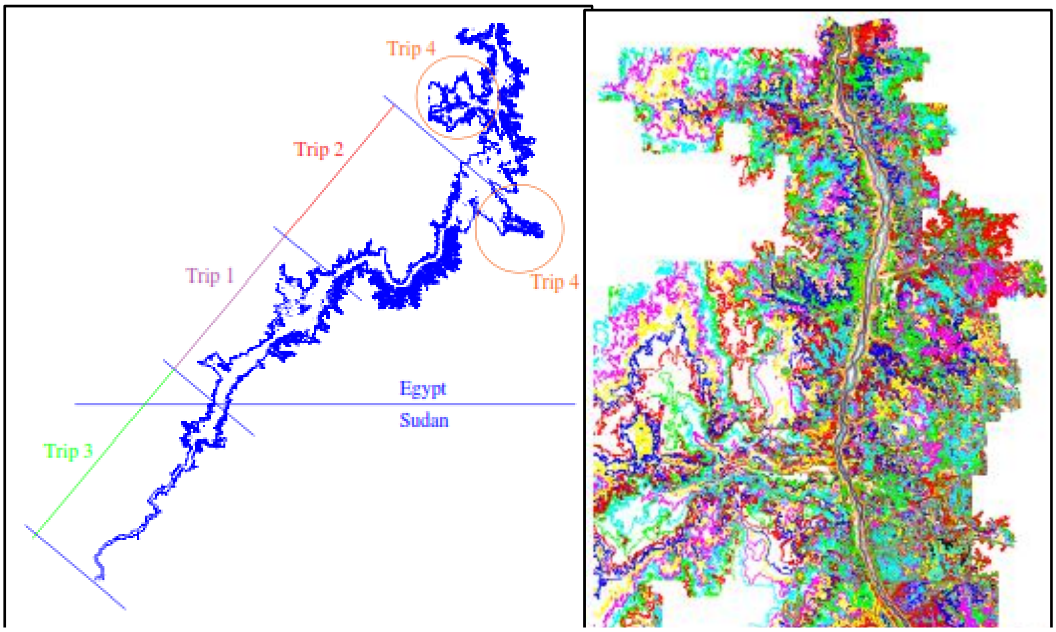

Figure 7.The trips areas and the contour map

4. METHODOLOGY

Two deferent software(Surfer V.12 and ARC MAP 10) were used to calculate the storage capacity and surface area for each water level.

4.1 SURFER

First stage is creating a grid file with grid size 50m in both easting and northing directions. There are several methods of gridding.Both kriging and triangulation with linear interpolation gridding methods are used to create the grid.

Second stage is to use the volume module to calculate the cut and fill volume for each water level from level 100m to level 160m with 2m increment and from level 160m to 185m with 1m increment. A volume report created by the program include the storage capacity as filling volume and water surface area as filling planner area.

4.2 ARC GIS

First stage is to import the data points in the project, second stage is to create digital elevation model for the data using create TIN from 3D analyst tools. Third stage is to convert the TIN to raster.

For every water level - from level 100m to level 160m with 2m increment and from level 160m to 185m with 1m increment - a constant raster surface with the same extents of the original data were created from raster create in spatial analyst tools.
By using cut and fill module from 3D analyst tools a raster layer will be created for every water level contains the fill volume which represent the storage capacity and the area represent the surface area of the lake. The results of the two method are very close to each other so the average of the two methods was taken to estimate the equations.
Table (1) shows the values of storage capacity and surface area for each level as an average of both Surfer and ArcGIS methods.

Table 1.The Surface area and storage capacity for each water level in Lake Nasser

Water Level (m)	Area (Km2)	Storage Capacity (BCM)	Water Level (m)	Area (Km2)	Storage Capacity (BCM)
100	30.53	0.12	161	2668.54	51.98
102	52.74	0.21	162	2754.93	54.69
104	67.71	0.33	163	2840.22	57.49
106	85.67	0.48	164	2932.38	60.38
108	104.11	0.67	165	3080.56	63.37
110	125.62	0.90	166	3242.09	66.56
112	154.85	1.18	167	3346.48	69.86
114	188.07	1.52	168	3451.72	73.26
116	225.34	1.94	169	3566.30	76.77
118	269.29	2.43	170	3758.45	80.41
120	326.26	3.02	171	3962.00	84.30
122	375.30	3.73	172	4098.19	88.34
124	411.36	4.52	173	4231.67	92.50
126	451.22	5.38	174	4374.27	96.81
128	489.60	6.32	175	4760.62	101.27
130	536.67	7.35	176	5285.48	106.48
132	599.65	8.49	177	5430.80	111.84
134	681.54	9.77	178	5571.57	117.35
136	831.92	11.28	179	5716.33	123.00
138	923.06	13.04	180	5994.69	128.80
140	1045.02	14.99	181	6304.76	135.03
142	1180.98	17.25	182	6455.78	141.41
144	1285.72	19.71	183	6608.45	147.95
146	1426.83	22.43	184	6772.22	154.64
147	1480.14	23.88	185	7069.17	161.52
148	1535.68	25.39			
150	1688.54	28.59			
152	1848.88	32.16			
154	1973.44	35.99			
156	2144.83	40.11			
158	2282.05	44.54			
160	2502.69	49.35			

4.3 EQUATION ESTIMATION

A curve fitting software “Table Curve V5“was used to calculate the best fitting curve equation for the calculated surface area and storage capacity data. The software calculates 280 equations with deferent formats. The best correlation coefficient (r^2)was for a polynomial equation with 4^{th} degree. Equation (1) describe the relation between storage capacity and water level.

$$\textbf{Storage Capacity} = 958.45087 - 30.632448\,(WL) + 0.37035544\,(WL)^2 - 0.0020274561\,(WL)^3 + 4.2951753\text{e-}06\,(WL)^4 \quad (1)$$

Where Storage Capacity in Billion Cubic Meter (BCM)and WL in Meter (m).

Figure (8) shows the best fitting curve for storage capacity against water level and also shows the equation parameters and r^2

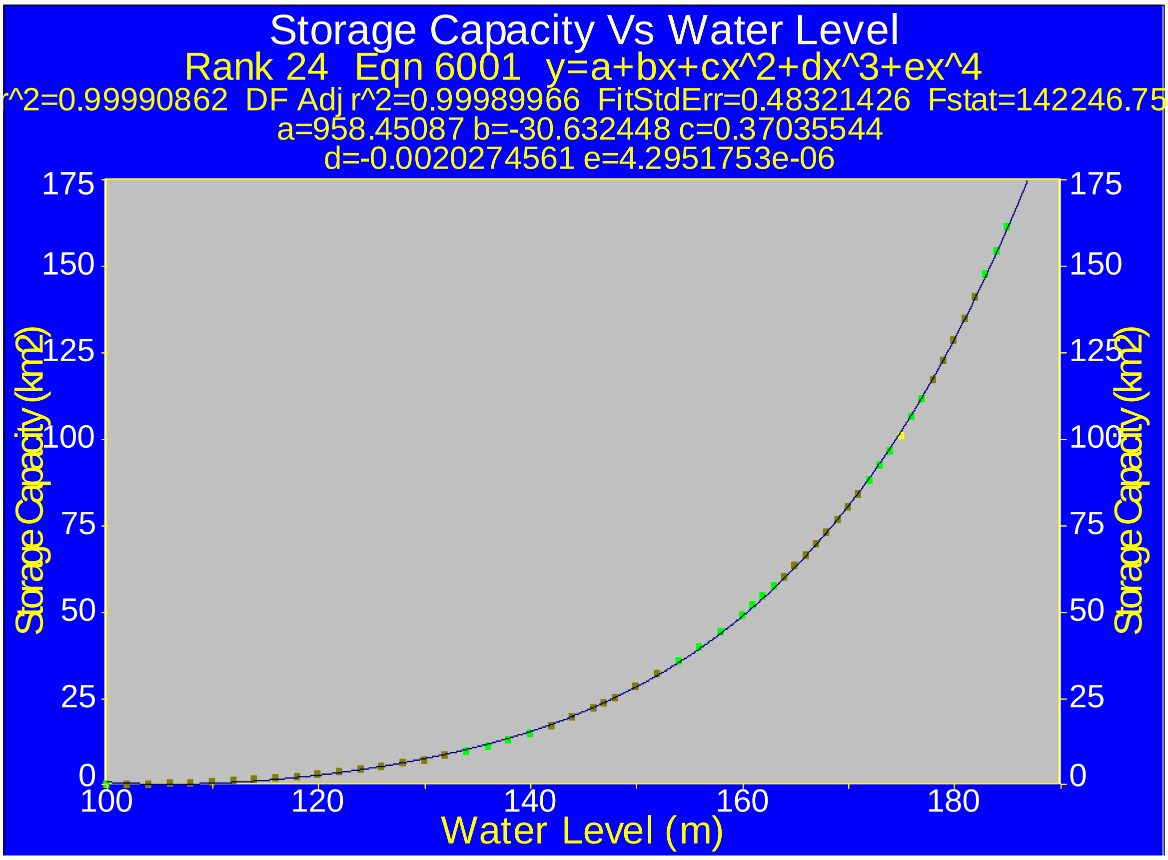

Figure 8. The table curve software output for storage capacity curve fitting

Equation (2) describe the relation between storage capacity and water level.

$$\textbf{Surface area} = 55979.564 - 1763.753\,(WL) + 20.777787\,(WL)^2 - 0.1094812\,(WL)^3 + 0.00022164498\,(WL)^4 \qquad (2)$$

Where Surface area in Square Kilometer (Km^2) and WL in Meter (m).

Figure (9) shows the best fitting curve for surface area against water level and also shows the equation parameters and r^2

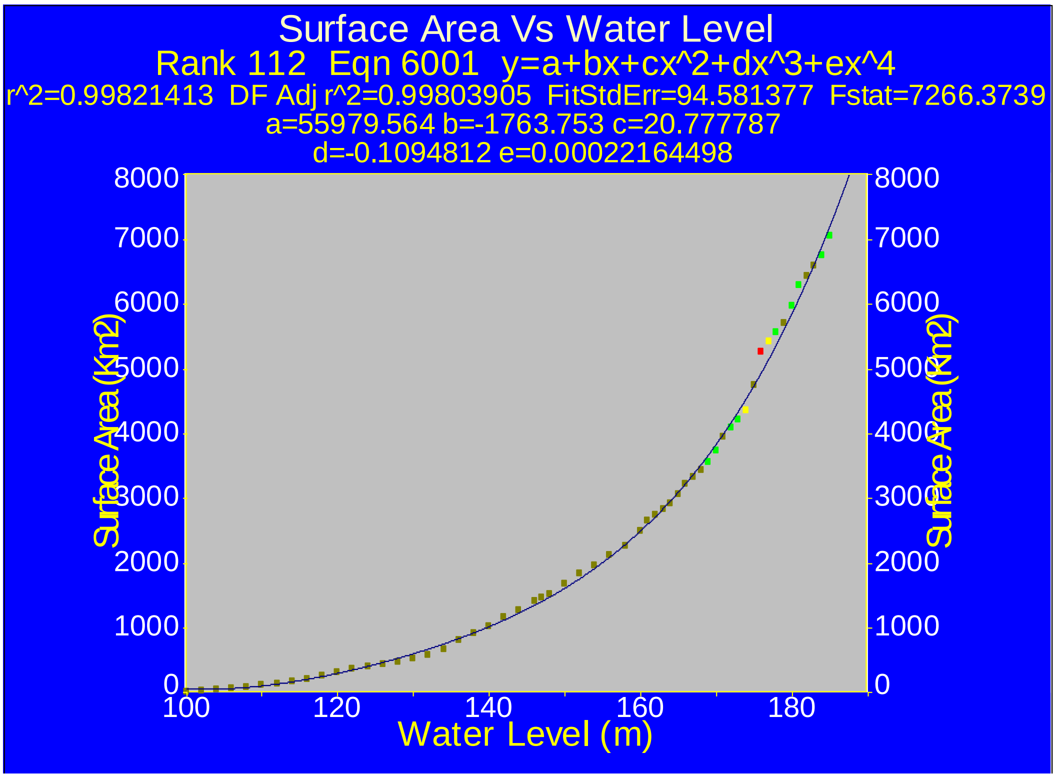

Figure 9. The table curve software output for surface area curve fitting

Both of the equations are valid for water level from 100m to 185m.

5. COMPARISON AND DISCUTTION

Figure (10)show the comparison between the two storage capacity-water level equations for year 1969 data which is made by Abo Atta (1978) and year 2013 data made in this study. It is clear that the storage capacity of lake Nasser are decreased according to the sediment arrived to the lake.

Figure (11) show the comparison between the two storage capacity-water level equations for year 1969 data which is made by Abo Atta (1978) and year 2013 data made in this study. The areas also decreased because of the sedimentation along the lake.

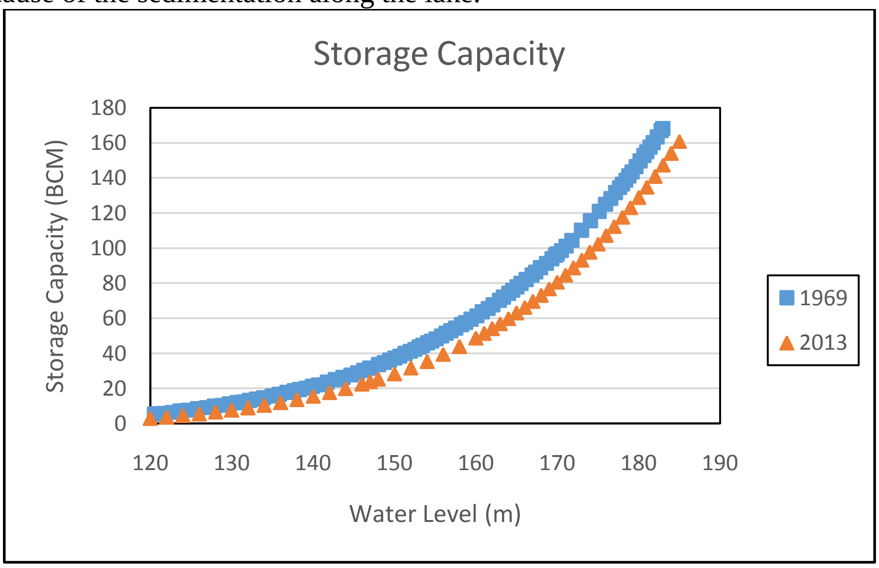

Figure 10.A Comparison between old and new data of storage capacity

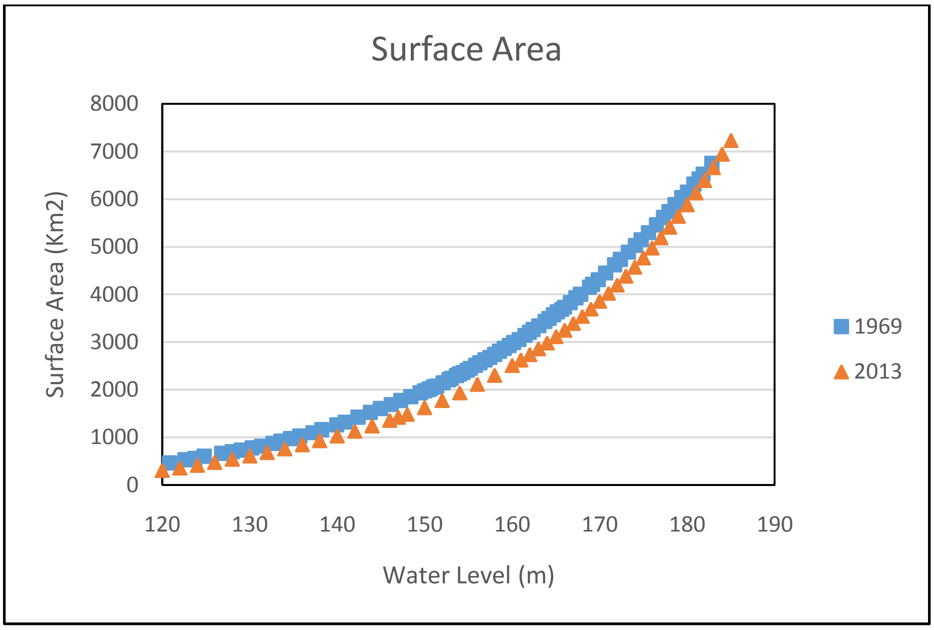

Figure 11.A Comparison between old and new data of surface area

6. CONCLUSION AND RECOMMENDATION

It can be concluded that the equations governing the relation between the water level and the surface area of lake Nasser is

Surface area (km^2) = 55979.564 – 1763.753 (WL) + 20.777787 $(WL)^2$ – 0.1094812 $(WL)^3$ + 0.00022164498 $(WL)^4$

The equation governing the relation between the water level and the storage capacity of lake Nasser is

Storage Capacity (BCM) = 958.45087 – 30.632448 (WL) + 0.37035544 $(WL)^2$ – 0.0020274561 $(WL)^3$ + 4.2951753 e-06 $(WL)^4$

These equations must be updated regularly after each field survey. The survey of the lake must be complete full scan and in a short period within maximum 2 years because the sediment comes every year with the flood affect the storage capacity.

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