# RESPONSE OF RIVER NILE DREDGING ON WATER LEVELS

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## ABSTRACT

River transport is one of the main activities that affect the national economy; however, it is affected by the available water depths on the River. The water depths of the River Nile depend upon the morphological characteristics of the River and the water flow release. The River Nile flow varies seasonally during the same year. Safe navigation along the river is considered an important task for different low water levels scenarios. Therefore, it was decided to dredge many locations along the River Nile to achieve the required water depth in the low flow season. However, the dredging in some cases may have some negative impacts on river water levels. The purpose of this paper is to study the impact of dredging on River Nile water levels. The considered study reaches are extending from Old Aswan Dam to Delta barrages. Actual water levels and discharges were considered to monitor the changes of water levels. More detailed study was applied on the reach from Esna to Naga Hammadi using mathematical model to study the water level changes along the reach. Actual cross sections before and after dredging were considered. Study results, conclusions, and recommendation were illustrated at the end of the study.

**Keywords:** River Nile, Navigation, Dredging, Water levels.

## 1. INTRODUCTION

River Nile is one of the oldest rivers in the history. Its history goes back more than six million years ago (Saied [1]). River Nile in Egypt is controlled by the High Aswan Dam and other major barrages. Since the construction of the High Aswan Dam, the river morphology has been subjected to more erosion and subsequently sedimentation due to trapping of the suspended sediment upstream the High Aswan Dam. For example, the suspended sediment concentration peaks at EL-Gaafra Gauging Station downstream the dam have dropped from about 3000 ppm before the construction of the dam to only about 50 ppm after the construction of the dam (Shalash, [2]). There are several hydraulic structures controlling the flow along the river from Aswan to the Mediterranean Sea. These structures are Old Aswan Dam, Esna Barrage, Naga Hammadi Barrage, Assiut Barrage, Delta Barrages, Zefta Barrage, and finally near to the Mediterranean Sea; Edifna and Damitta Barrages. This paper focuses on studying the change of water levels which may occur due to river dredging. This study includes the reaches from Old Aswan Dam to Delta barrage.

## 2. RIVER NAVIGATION

River navigation is considered one of the important activities for tourism and transportation purposes. One of the most important River Nile water management basics is to avoid discharging extra water for navigation in low flow periods to secure water for other vital demands. Yet, it is also important to secure a safe navigation depth during low flow periods. Due to river meandering and morphology, some navigation bottle necks appeared along the navigation path. Nile Research Institute produced one of its earliest working papers [3]. In this working paper, it was concluded that the river is stable and that some of the dredged areas were not refilled and some was refilled due to poor planning or not completing the dredging and it was concluded also that the dredging to deepen the navigation channel requires careful study. A comprehensive study was performed in 2001 to evaluate the requirements to develop the inland navigation system in Egypt [4]. It was highlighted in this study, the required survey work, the infra structure for inland navigation in Egypt, the establishment of maintenance plan, and the installation of navigation aids. The impact of dredging on The Nile Branch (Damieta Branch) was investigated by Attia and Fahmi [5]. They concluded that the drop of the water level downstream Zefta Barrage was evident as a result of dredging activities. Moreover, Raslan et al. [6] concluded that there was a significant water level drop after dredging downstream Delta and Zefta Barrage in Damieta Branch. The performed approach during the past ten years (since the beginning of the twenties century) was to dredge some parts of the river to achieve a safe navigation depth during the low water levels. The effectiveness and negative impacts of this approach along the River Nile has to be evaluated. On the other hand, other approaches should be studied and considered to solve navigation problems in addition to the used approach of dredging. A very good example of these other alternatives is to limit the draft during very low flow period if required. Some researchers proposed using structural solutions to solve navigation problems. Attia et al. [7] proposed using submerged weirs to raise water level for navigation in Damietta Branch. The structural solutions should be studied carefully to avoid any future side impacts.

## 3. RIVER NILE WATER LEVELS

The River Nile from Aswan to Delta Barrages is divided into four major reaches between each two hydraulic structures as shown in Figure 1. These four reaches are (NRI [8]); First Reach is located between Old Aswan Dam and Esna Barrage with a total length of 167.00 kilometer. Second Reach is located between Esna Barrage and Naga Hammadi Barrage with a total length of 192.00 kilometer. Third Reach is located between Naga Hammadi Barrage and Assiut Barrage with a total length of 186.00 kilometer. Fourth Reach is located between Assiut Barrage and Delta Barrages with a total length of 409.00 kilometer. The variation of water levels, along the River Nile from Old Aswan Dam to Delta Barrages, was evaluated during the period 1995 to 2009 to investigate the dredging effect. The analysis was performed for each reach.

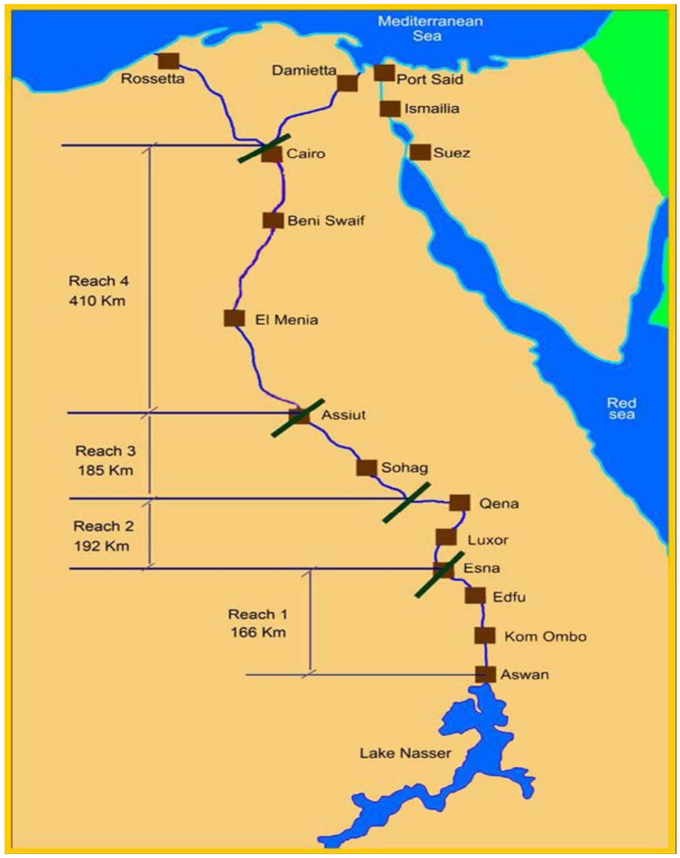


**Fig. 1 River Nile Map**

## 3.1 First Reach

Figure 2 shows the rating curves for water levels and discharge downstream Old Aswan Dam (OAD) during the period 1995 to 2009 (NRI [9]). Figure 3 shows the water level changes for each year. Table 1, illustrates the changes in water level for discharges from 60 to 270 million cubic meters per day. It can be observed from this table that a rise on the water levels took place during the period 2005-2009, compared with the period 1995-1998. This water rise ranged from 3 to 12 cm. This phenomenon might be attributed to some morphological changes and man-made activities. However, the water levels at year 2009 were dropped, in low discharge season (60 to 100 m.$m^3$/day), compared with those at year 2005. This water drop may be attributed to dredging works (about 140000 $m^3$) conducted in this reach through the year 2008. However, the resulted values of the water level in 2009 are not less than the water levels during the starting of the study period from 1995 to 2003.

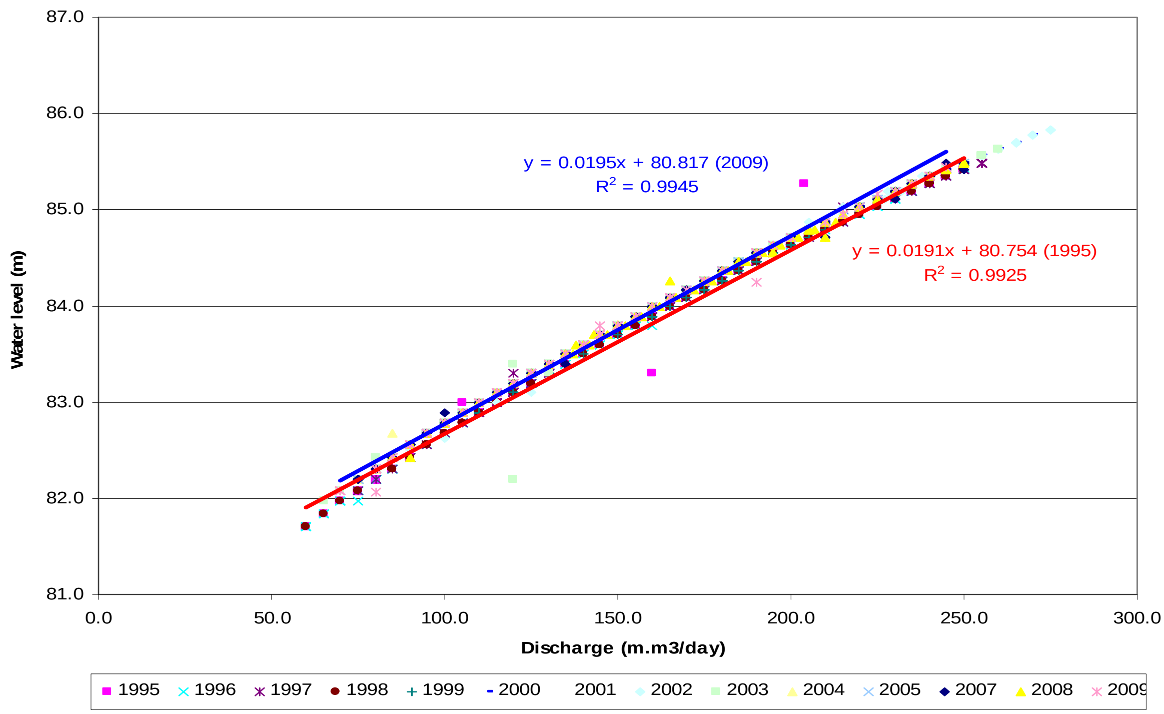


**Fig. 2 Down stream Old Aswan Dam rating curve**

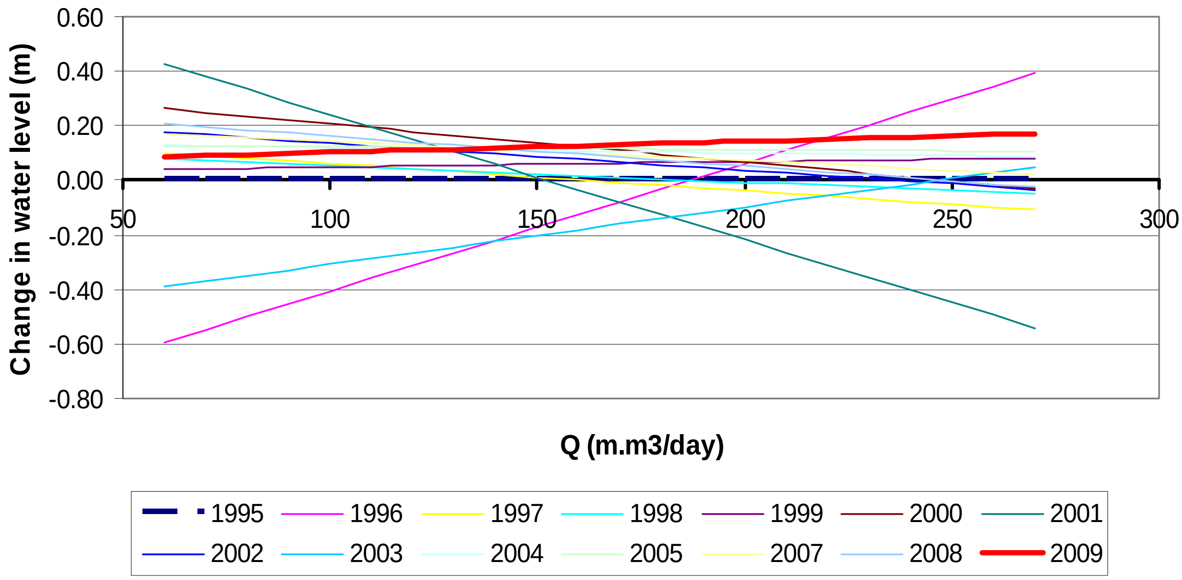


**Fig.3 Water level changes down stream Old Aswan Dam**

**Table 1 Water level changes downstream OAD**

| Q | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **60** | -0.595 | 0.102 | 0.077 | 0.04 | 0.263 | 0.426 | 0.177 | -0.392 | 0.128 | 0.127 | 0.17 | 0.206 | 0.087 |
| **70** | -0.548 | 0.092 | 0.071 | 0.042 | 0.249 | 0.38 | 0.167 | -0.371 | 0.126 | 0.126 | 0.163 | 0.195 | 0.091 |
| **80** | -0.501 | 0.082 | 0.065 | 0.044 | 0.235 | 0.334 | 0.157 | -0.350 | 0.124 | 0.125 | 0.156 | 0.184 | 0.095 |
| **90** | -0.454 | 0.072 | 0.059 | 0.046 | 0.221 | 0.288 | 0.147 | -0.329 | 0.122 | 0.124 | 0.149 | 0.173 | 0.099 |
| **100** | -0.407 | 0.062 | 0.053 | 0.048 | 0.207 | 0.242 | 0.137 | -0.308 | 0.12 | 0.123 | 0.142 | 0.162 | 0.103 |
| **110** | -0.360 | 0.052 | 0.047 | 0.05 | 0.193 | 0.196 | 0.127 | -0.287 | 0.118 | 0.122 | 0.135 | 0.151 | 0.107 |
| **120** | -0.313 | 0.042 | 0.041 | 0.052 | 0.179 | 0.15 | 0.117 | -0.266 | 0.116 | 0.121 | 0.128 | 0.14 | 0.111 |
| **130** | -0.266 | 0.032 | 0.035 | 0.054 | 0.165 | 0.104 | 0.107 | -0.245 | 0.114 | 0.12 | 0.121 | 0.129 | 0.115 |
| **140** | -0.219 | 0.022 | 0.029 | 0.056 | 0.151 | 0.058 | 0.097 | -0.224 | 0.112 | 0.119 | 0.114 | 0.118 | 0.119 |
| **150** | -0.172 | 0.012 | 0.023 | 0.058 | 0.137 | 0.012 | 0.087 | -0.203 | 0.11 | 0.118 | 0.107 | 0.107 | 0.123 |
| **160** | -0.125 | 0.002 | 0.017 | 0.060 | 0.123 | -0.034 | 0.077 | -0.182 | 0.108 | 0.117 | 0.100 | 0.096 | 0.127 |
| **170** | -0.078 | -0.008 | 0.011 | 0.062 | 0.109 | -0.08 | 0.067 | -0.161 | 0.106 | 0.116 | 0.093 | 0.085 | 0.131 |
| **180** | -0.031 | -0.018 | 0.005 | 0.064 | 0.095 | -0.126 | 0.057 | -0.14 | 0.104 | 0.115 | 0.086 | 0.074 | 0.135 |
| **190** | 0.016 | -0.028 | -0.001 | 0.066 | 0.081 | -0.172 | 0.047 | -0.119 | 0.102 | 0.114 | 0.079 | 0.063 | 0.139 |
| **200** | 0.063 | -0.038 | -0.007 | 0.068 | 0.067 | -0.218 | 0.037 | -0.098 | 0.100 | 0.113 | 0.072 | 0.052 | 0.143 |
| **210** | 0.110 | -0.048 | -0.013 | 0.070 | 0.053 | -0.264 | 0.027 | -0.077 | 0.098 | 0.112 | 0.065 | 0.041 | 0.147 |
| **220** | 0.157 | -0.058 | -0.019 | 0.072 | 0.039 | -0.31 | 0.017 | -0.056 | 0.096 | 0.111 | 0.058 | 0.030 | 0.151 |
| **230** | 0.204 | -0.068 | -0.025 | 0.074 | 0.025 | -0.356 | 0.007 | -0.035 | 0.094 | 0.110 | 0.051 | 0.019 | 0.155 |
| **240** | 0.251 | -0.078 | -0.031 | 0.076 | 0.011 | -0.402 | -0.003 | -0.014 | 0.092 | 0.109 | 0.044 | 0.008 | 0.159 |
| **250** | 0.298 | -0.088 | -0.037 | 0.078 | -0.003 | -0.448 | -0.013 | 0.007 | 0.09 | 0.108 | 0.037 | -0.003 | 0.163 |
| **260** | 0.345 | -0.098 | -0.043 | 0.080 | -0.017 | -0.494 | -0.023 | 0.028 | 0.088 | 0.107 | 0.030 | -0.014 | 0.167 |
| **270** | 0.392 | -0.108 | -0.049 | 0.082 | -0.031 | -0.540 | -0.033 | 0.049 | 0.086 | 0.106 | 0.023 | -0.025 | 0.171 |

## 3.2 Second Reach

Figure 4 shows the rating curves for water levels and discharge downstream Esna barrage during the period 1995 to 2009, the dredging amount for this reach is about 500,000 cubic meters. (NRI [9]). Figure 5 shows the water level changes for each year. Table 2 illustrates the changes occurred in water level compared with year 1995. Figure 4 shows the water level changes for each year and for different discharges. It can be concluded that no significant change in water levels during the period 1995-2001. On the other hand, a drop in the water levels occurred during the period 2002-2009. The water drop ranged from 4 cm to 23 cm. The water level drop starts to decrease from 2008, while in 2009 the water drop has decreased significantly. However, a rise in water levels at low discharge (50 to 100 m.m$^3$/day) were observed at year 2009 compared with those at year 2005. Meanwhile, the water levels were also dropped in higher discharges.

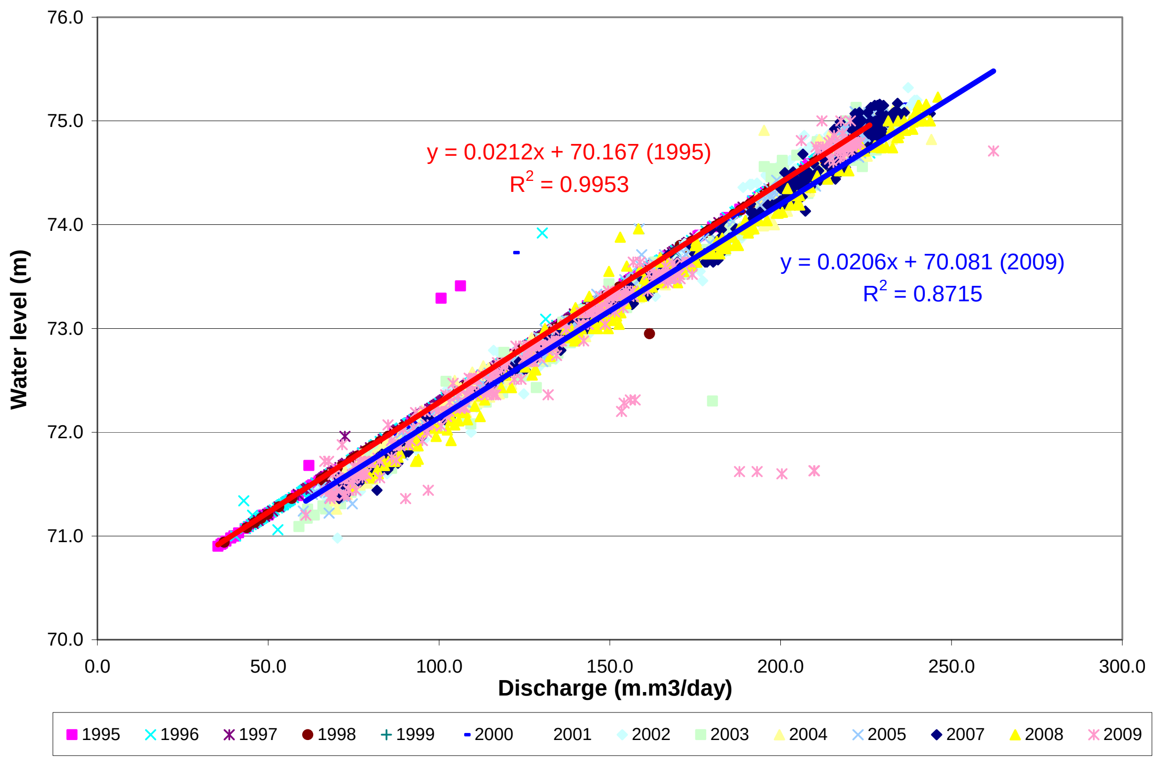


**Fig. 4 Down stream Esna Barrage rating curve**

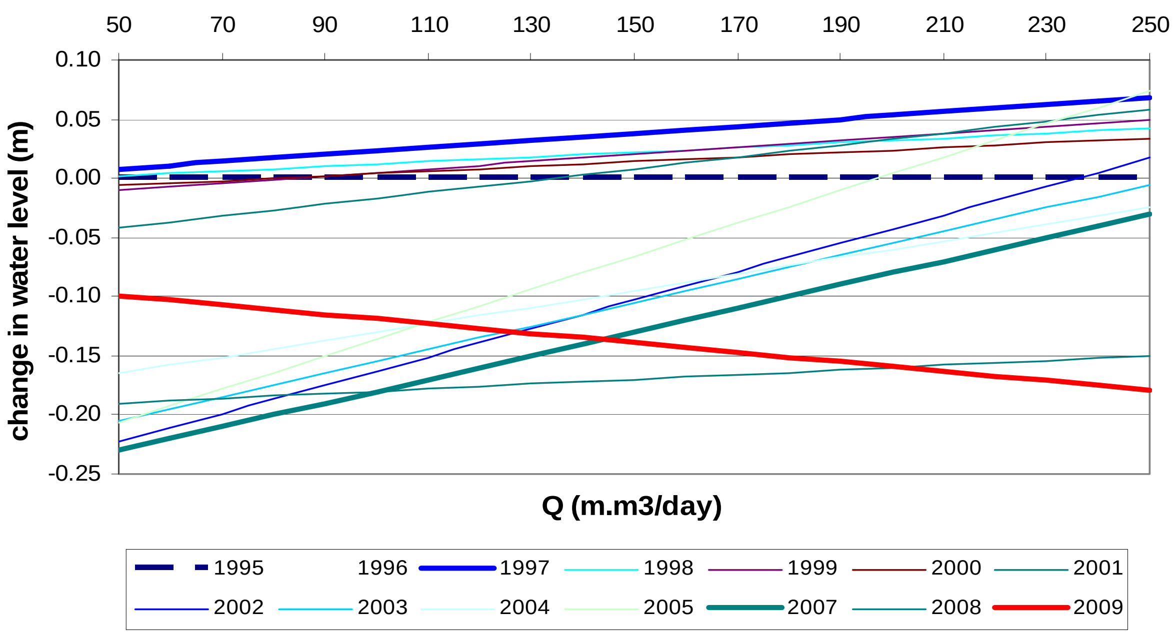


**Fig. 5 Water level changes down stream Esna Barrage**

**Table 2 Water level changes downstream Esna Barrage**

| Q | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **50** | 0.01 | 0.01 | 0.00 | -0.01 | -0.01 | -0.04 | -0.22 | -0.20 | -0.17 | -0.21 | -0.23 | -0.19 | -0.10 |
| **60** | 0.01 | 0.01 | 0.00 | -0.01 | 0.00 | -0.04 | -0.21 | -0.20 | -0.16 | -0.19 | -0.22 | -0.19 | -0.10 |
| **70** | 0.01 | 0.01 | 0.01 | 0.00 | 0.00 | -0.03 | -0.20 | -0.18 | -0.15 | -0.18 | -0.21 | -0.19 | -0.11 |
| **80** | 0.01 | 0.02 | 0.01 | 0.00 | 0.00 | -0.03 | -0.19 | -0.17 | -0.14 | -0.16 | -0.20 | -0.18 | -0.11 |
| **90** | 0.02 | 0.02 | 0.01 | 0.00 | 0.00 | -0.02 | -0.17 | -0.16 | -0.14 | -0.15 | -0.19 | -0.18 | -0.11 |
| **100** | 0.02 | 0.02 | 0.01 | 0.01 | 0.00 | -0.02 | -0.16 | -0.15 | -0.13 | -0.14 | -0.18 | -0.18 | -0.12 |
| **110** | 0.02 | 0.03 | 0.01 | 0.01 | 0.01 | -0.01 | -0.15 | -0.14 | -0.12 | -0.12 | -0.17 | -0.18 | -0.12 |
| **120** | 0.02 | 0.03 | 0.02 | 0.01 | 0.01 | -0.01 | -0.14 | -0.13 | -0.12 | -0.11 | -0.16 | -0.18 | -0.13 |
| **130** | 0.02 | 0.03 | 0.02 | 0.01 | 0.01 | 0.00 | -0.13 | -0.13 | -0.11 | -0.09 | -0.15 | -0.17 | -0.13 |
| **140** | 0.03 | 0.04 | 0.02 | 0.02 | 0.01 | 0.00 | -0.11 | -0.11 | -0.10 | -0.08 | -0.14 | -0.17 | -0.13 |
| **150** | 0.03 | 0.04 | 0.02 | 0.02 | 0.01 | 0.01 | -0.10 | -0.11 | -0.10 | -0.07 | -0.13 | -0.17 | -0.14 |
| **160** | 0.03 | 0.04 | 0.02 | 0.02 | 0.02 | 0.01 | -0.09 | -0.09 | -0.09 | -0.05 | -0.12 | -0.17 | -0.14 |
| **170** | 0.03 | 0.04 | 0.03 | 0.03 | 0.02 | 0.02 | -0.08 | -0.08 | -0.08 | -0.04 | -0.11 | -0.17 | -0.15 |
| **180** | 0.03 | 0.05 | 0.03 | 0.03 | 0.02 | 0.02 | -0.07 | -0.08 | -0.07 | -0.02 | -0.10 | -0.16 | -0.15 |
| **190** | 0.04 | 0.05 | 0.03 | 0.03 | 0.02 | 0.03 | -0.05 | -0.06 | -0.07 | -0.01 | -0.09 | -0.16 | -0.15 |
| **200** | 0.04 | 0.05 | 0.03 | 0.04 | 0.02 | 0.03 | -0.04 | -0.05 | -0.06 | 0.00 | -0.08 | -0.16 | -0.16 |
| **210** | 0.04 | 0.06 | 0.03 | 0.04 | 0.03 | 0.04 | -0.03 | -0.04 | -0.05 | 0.02 | -0.07 | -0.16 | -0.16 |
| **220** | 0.04 | 0.06 | 0.04 | 0.04 | 0.03 | 0.04 | -0.02 | -0.03 | -0.05 | 0.03 | -0.06 | -0.16 | -0.17 |
| **230** | 0.04 | 0.06 | 0.04 | 0.04 | 0.03 | 0.05 | -0.01 | -0.02 | -0.04 | 0.05 | -0.05 | -0.15 | -0.17 |
| **240** | 0.05 | 0.06 | 0.04 | 0.05 | 0.03 | 0.05 | 0.00 | -0.02 | -0.03 | 0.06 | -0.04 | -0.15 | -0.17 |
| **250** | 0.05 | 0.07 | 0.04 | 0.05 | 0.03 | 0.06 | 0.02 | 0.00 | -0.03 | 0.07 | -0.03 | -0.15 | -0.18 |

## 3.3 Third Reach

Figure 6 shows the rating curves for downstream Naga Hammadi Barrage during the period 1995 to 2007, the dredging amount for this reach is about 2,000,000 cubic meters. (NRI [9]). Figure 7 shows the water level changes for each year considering the different discharges. Table 3 illustrates the observed changes in water level. It can be concluded that no significant change in the water levels from 1995 to 2006. However, the water level dropped slightly in 2007. The water drop ranged from 8 cm to 11 cm. The drop was higher in high flow discharges and it was not observed for low discharges. This water drop might be attributed to morphological changes downstream Naga Hammadi Barrage. After 2007, the water level has major change since the down stream water level was measured at the new Naga Hammadi Barrage which is located downstream the old barrage and the water level of 2008 and 2009 could not be compared with the water levels for previous years. Generally, it can be concluded that effect of dredging works on the water levels downstream Naga Hammadi Barrage was not clearly detected.

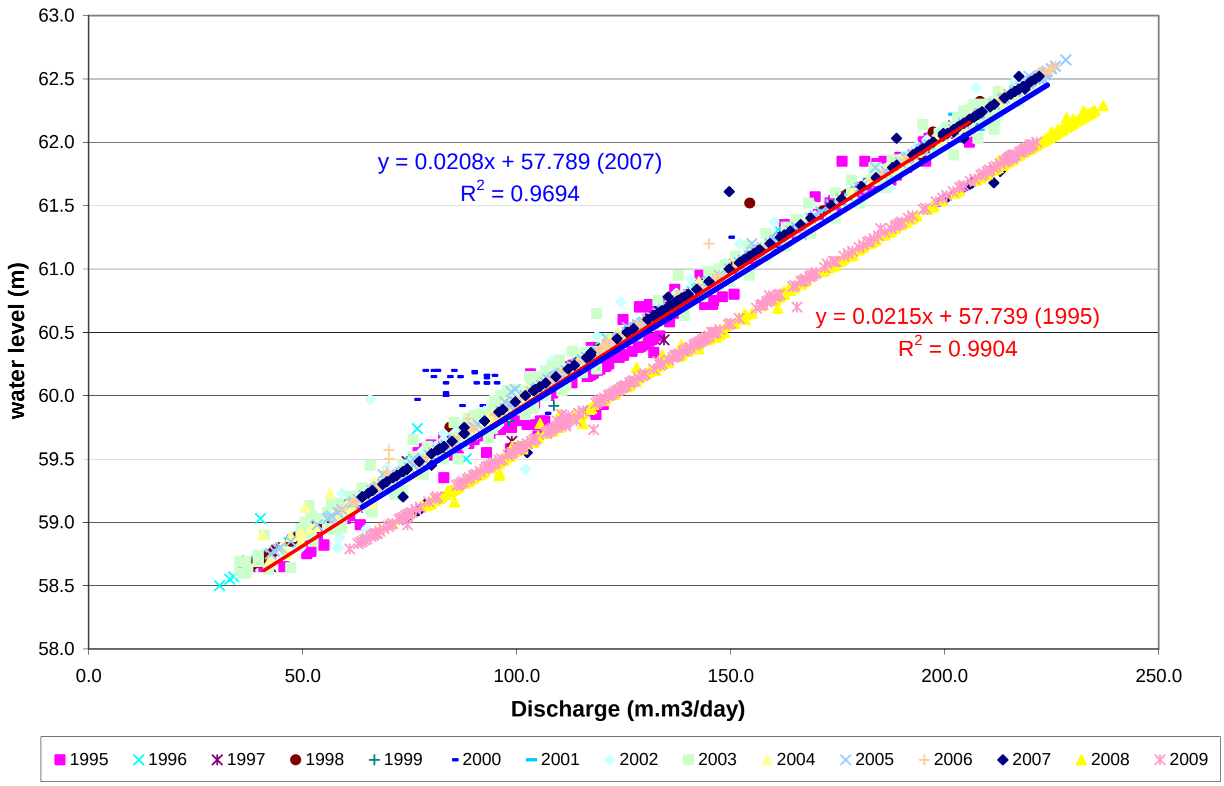


**Fig. 6 Down stream Naga Hammadi Barrage rating curve**

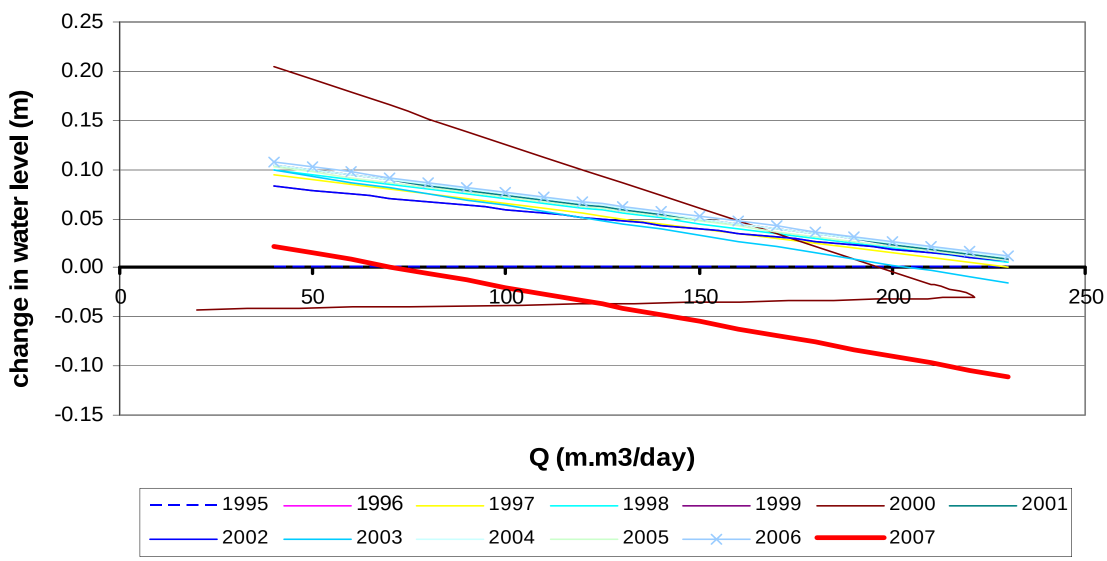


**Fig. 7 Water level changes down stream Naga Hammadi Barrage**

**Table 3 Water level changes down stream Naga Hammadi Barrage**

| Q | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **40** | 0.10 | 0.10 | 0.10 | 0.08 | 0.20 | 0.10 | 0.08 | 0.10 | 0.11 | 0.10 | 0.11 | 0.02 |
| **50** | 0.10 | 0.09 | 0.09 | 0.08 | 0.19 | 0.10 | 0.08 | 0.09 | 0.10 | 0.10 | 0.10 | 0.02 |
| **60** | 0.09 | 0.09 | 0.09 | 0.08 | 0.18 | 0.09 | 0.08 | 0.09 | 0.09 | 0.09 | 0.10 | 0.01 |
| **70** | 0.09 | 0.08 | 0.09 | 0.07 | 0.16 | 0.09 | 0.07 | 0.08 | 0.09 | 0.09 | 0.09 | 0.00 |
| **80** | 0.08 | 0.08 | 0.08 | 0.07 | 0.15 | 0.08 | 0.07 | 0.08 | 0.09 | 0.08 | 0.09 | -0.01 |
| **90** | 0.08 | 0.07 | 0.08 | 0.06 | 0.14 | 0.08 | 0.06 | 0.07 | 0.08 | 0.08 | 0.08 | -0.01 |
| **100** | 0.07 | 0.07 | 0.07 | 0.06 | 0.13 | 0.07 | 0.06 | 0.06 | 0.08 | 0.07 | 0.08 | -0.02 |
| **110** | 0.07 | 0.06 | 0.07 | 0.05 | 0.11 | 0.07 | 0.05 | 0.06 | 0.07 | 0.07 | 0.07 | -0.03 |
| **120** | 0.06 | 0.06 | 0.06 | 0.05 | 0.10 | 0.06 | 0.05 | 0.05 | 0.07 | 0.06 | 0.07 | -0.03 |
| **130** | 0.06 | 0.05 | 0.05 | 0.05 | 0.09 | 0.06 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | -0.04 |
| **140** | 0.05 | 0.05 | 0.05 | 0.04 | 0.07 | 0.05 | 0.04 | 0.04 | 0.05 | 0.05 | 0.06 | -0.05 |
| **150** | 0.05 | 0.04 | 0.05 | 0.04 | 0.06 | 0.05 | 0.04 | 0.03 | 0.05 | 0.05 | 0.05 | -0.05 |
| **160** | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.04 | 0.04 | 0.03 | 0.05 | 0.04 | 0.05 | -0.06 |
| **170** | 0.04 | 0.03 | 0.04 | 0.03 | 0.03 | 0.04 | 0.03 | 0.02 | 0.04 | 0.04 | 0.04 | -0.07 |
| **180** | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 | 0.04 | 0.03 | 0.04 | -0.08 |
| **190** | 0.03 | 0.02 | 0.03 | 0.02 | 0.01 | 0.03 | 0.02 | 0.01 | 0.03 | 0.03 | 0.03 | -0.08 |
| **200** | 0.02 | 0.02 | 0.02 | 0.02 | 0.00 | 0.02 | 0.02 | 0.00 | 0.03 | 0.02 | 0.03 | -0.09 |
| **210** | 0.02 | 0.01 | 0.02 | 0.02 | -0.02 | 0.02 | 0.02 | 0.00 | 0.02 | 0.02 | 0.02 | -0.10 |
| **220** | 0.01 | 0.01 | 0.01 | 0.01 | -0.03 | 0.01 | 0.01 | -0.01 | 0.02 | 0.01 | 0.02 | -0.10 |
| **230** | 0.01 | 0.00 | 0.01 | 0.01 | -0.04 | 0.01 | 0.01 | -0.01 | 0.01 | 0.01 | 0.01 | -0.11 |

## 3.4 Fourth Reach

Figure 8 shows the rating curves for downstream Assiut Barrage during the period 1995 to 2009, the dredging amount for this reach is about 5,000,000 cubic meters. (NRI [9]). Figure 9 shows the water level changes for each year. Table 4 illustrates the changes occurred in water level compared with 1995. It indicates that a water level rise was occurred in the period 2001-2009 compared with the period 1995-2000. This phenomenon might be attributed to some morphological changes and man-made activities. However, it can be concluded that effect of dredging works on the water levels at this reach was not clearly detected.

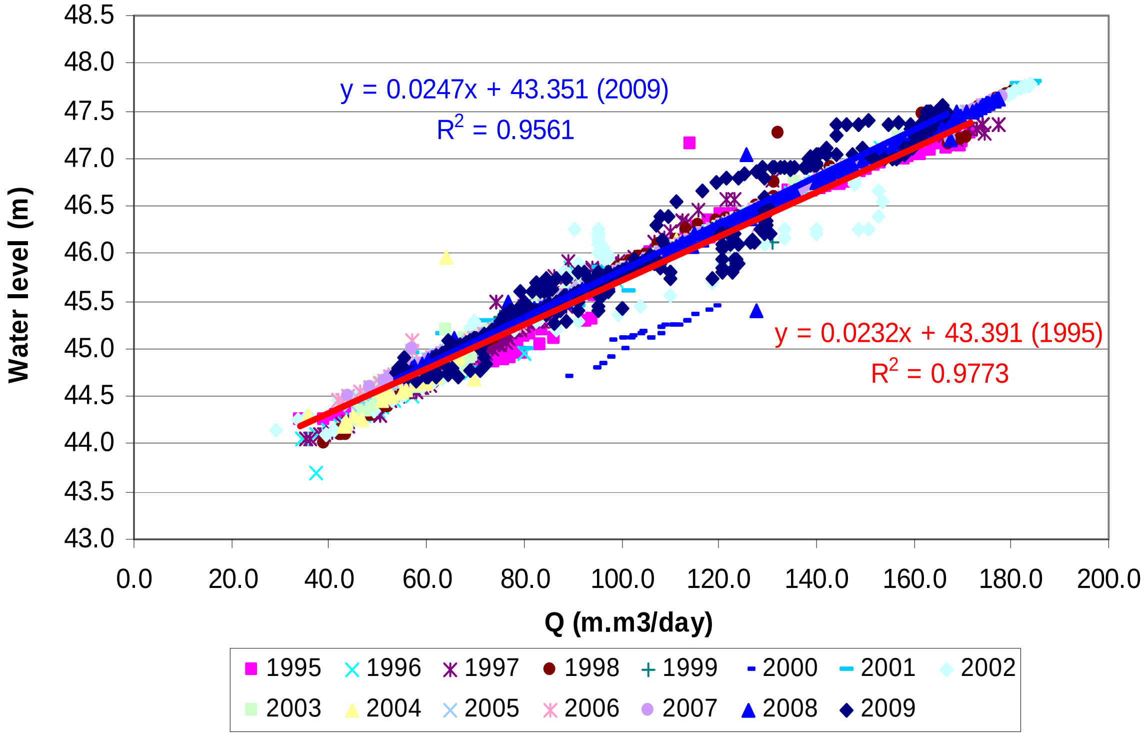


**Fig. 8 Down stream Assiut Barrage rating curve**

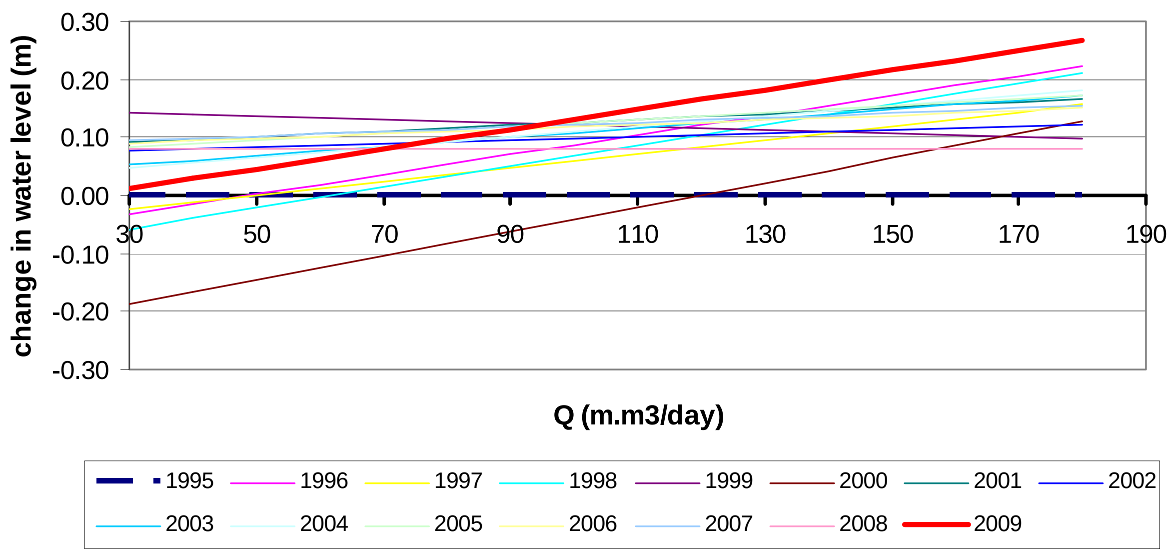


**Fig. 9 Water level changes down stream Assiut Barrage**

**Table 4 Water level changes down stream Assiut Barrage**

| Q | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 30 | -0.03 | -0.02 | -0.06 | 0.14 | -0.19 | 0.09 | 0.08 | 0.05 | 0.05 | 0.08 | 0.09 | 0.09 | 0.08 | 0.01 |
| 40 | -0.02 | -0.01 | -0.04 | 0.14 | -0.17 | 0.10 | 0.08 | 0.06 | 0.06 | 0.09 | 0.09 | 0.10 | 0.08 | 0.03 |
| 50 | 0.00 | 0.00 | -0.02 | 0.14 | -0.15 | 0.10 | 0.08 | 0.07 | 0.06 | 0.09 | 0.10 | 0.10 | 0.08 | 0.05 |
| 60 | 0.02 | 0.01 | 0.00 | 0.13 | -0.13 | 0.11 | 0.09 | 0.08 | 0.07 | 0.10 | 0.10 | 0.11 | 0.08 | 0.06 |
| 70 | 0.04 | 0.02 | 0.01 | 0.13 | -0.10 | 0.11 | 0.09 | 0.08 | 0.08 | 0.11 | 0.11 | 0.11 | 0.08 | 0.08 |
| 80 | 0.05 | 0.04 | 0.03 | 0.13 | -0.08 | 0.12 | 0.09 | 0.09 | 0.09 | 0.11 | 0.11 | 0.11 | 0.08 | 0.10 |
| 90 | 0.07 | 0.05 | 0.05 | 0.13 | -0.06 | 0.12 | 0.10 | 0.10 | 0.10 | 0.12 | 0.11 | 0.12 | 0.08 | 0.11 |
| 100 | 0.09 | 0.06 | 0.07 | 0.12 | -0.04 | 0.13 | 0.10 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.08 | 0.13 |
| 110 | 0.10 | 0.07 | 0.09 | 0.12 | -0.02 | 0.13 | 0.10 | 0.12 | 0.12 | 0.13 | 0.12 | 0.13 | 0.08 | 0.15 |
| 120 | 0.12 | 0.08 | 0.10 | 0.12 | 0.00 | 0.14 | 0.11 | 0.12 | 0.13 | 0.14 | 0.13 | 0.13 | 0.08 | 0.16 |
| 130 | 0.14 | 0.10 | 0.12 | 0.11 | 0.02 | 0.14 | 0.11 | 0.13 | 0.14 | 0.14 | 0.13 | 0.13 | 0.08 | 0.18 |
| 140 | 0.16 | 0.11 | 0.14 | 0.11 | 0.04 | 0.15 | 0.11 | 0.14 | 0.15 | 0.15 | 0.13 | 0.14 | 0.08 | 0.20 |
| 150 | 0.17 | 0.12 | 0.16 | 0.11 | 0.06 | 0.15 | 0.11 | 0.15 | 0.15 | 0.15 | 0.14 | 0.14 | 0.08 | 0.22 |
| 160 | 0.19 | 0.13 | 0.18 | 0.10 | 0.09 | 0.16 | 0.12 | 0.16 | 0.16 | 0.16 | 0.14 | 0.15 | 0.08 | 0.23 |
| 170 | 0.21 | 0.14 | 0.19 | 0.10 | 0.11 | 0.16 | 0.12 | 0.16 | 0.17 | 0.17 | 0.15 | 0.15 | 0.08 | 0.25 |
| 180 | 0.22 | 0.16 | 0.21 | 0.10 | 0.13 | 0.17 | 0.12 | 0.17 | 0.18 | 0.17 | 0.15 | 0.15 | 0.08 | 0.27 |

# 4. NUMERICAL ANALYSIS

A numerical analysis was used to estimate the effect of dredging works on water levels along the second reach of the River Nile. The water surface profile was computed along the River reach before and after dredging. Different flow scenarios were considered and consequently effects of dredging works were evaluated.

## 4.1 Computer Model

HEC-RAS computer model (US Army Corps of Engineers [10]) was used for water level computations. This model is developed by the US Army Corps of Engineers. It is a one-dimensional model able to simulate steady, unsteady and sediment transport for movable boundary conditions. The model is first calibrated using the actual available data, and then it is used to simulate flow conditions and compute water levels.

## 4.2 Second Reach Discharges

Figure 10 shows the discharges frequency percentage down stream Esna Barrage for the period 1995-2009. The study discharges were considered as follows:

- The minimum discharge was considered to be the minimum discharge has a frequency of more than 1%, q=60 million cubic meters per day.

- The maximum discharge was considered to be the maximum discharge has a frequency of more than 1%, q=230 million cubic meters per day.
- The average discharge was considered as the discharge has an accumulated frequency of about 50 %., q=130 million cubic meters per day.

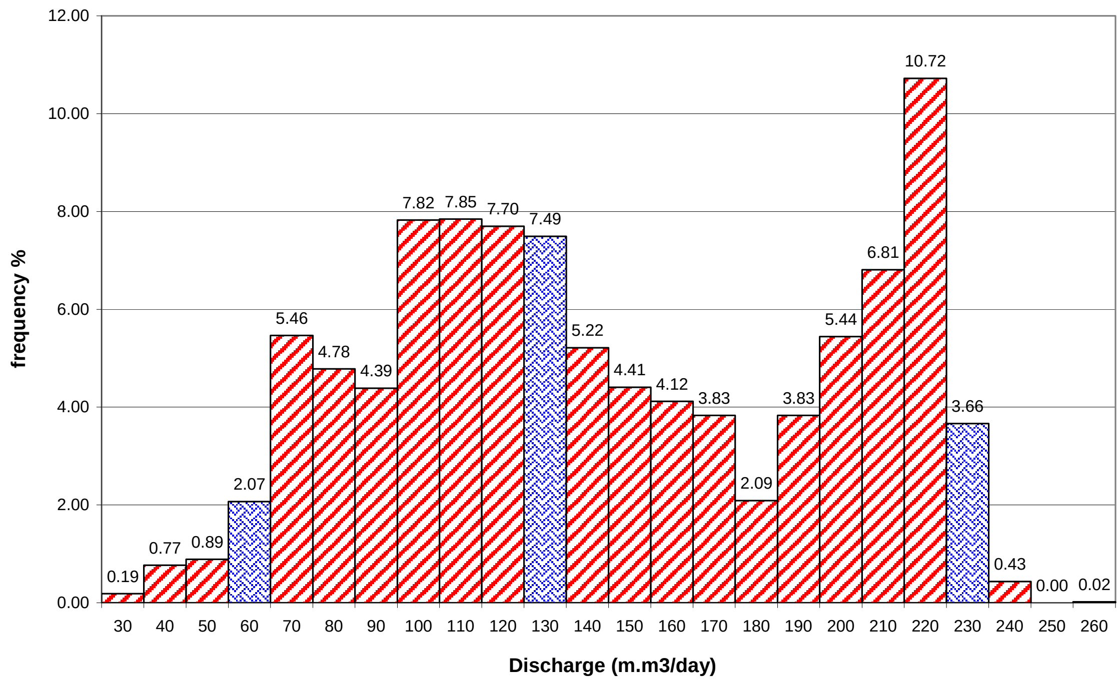


**Fig. 10 Water discharges down stream Esna Barrage**

## 4.3 Model Calibration

The model was calibrated to obtain the required coefficient for model simulation, roughness Manning's "n". Several cross sections along the second reach were used for this analysis considering the three studied discharges; 60, 130, 230 million cubic meters per day. The calibration was done for both cases; before and after dredging (NRI [9]), (NRI [11]).

### 4.3.1 Cross Sections

Figure 11 shows three cross sections for the study reach before and after the dredging as an example for the considered cross sections along the study reach. The first cross section is located downstream Esna Barrage at kilometers 168.50 from Old Aswan Dam (OAD). Second cross section is located in the middle of the reach at kilometers 264.00 from OAD. The third cross section is located upstream Naga Hammadi Barrage at kilometers 358.00 from Old Aswan Dam (OAD). These three cross sections illustrate the dredging and the cross section changes during this period.

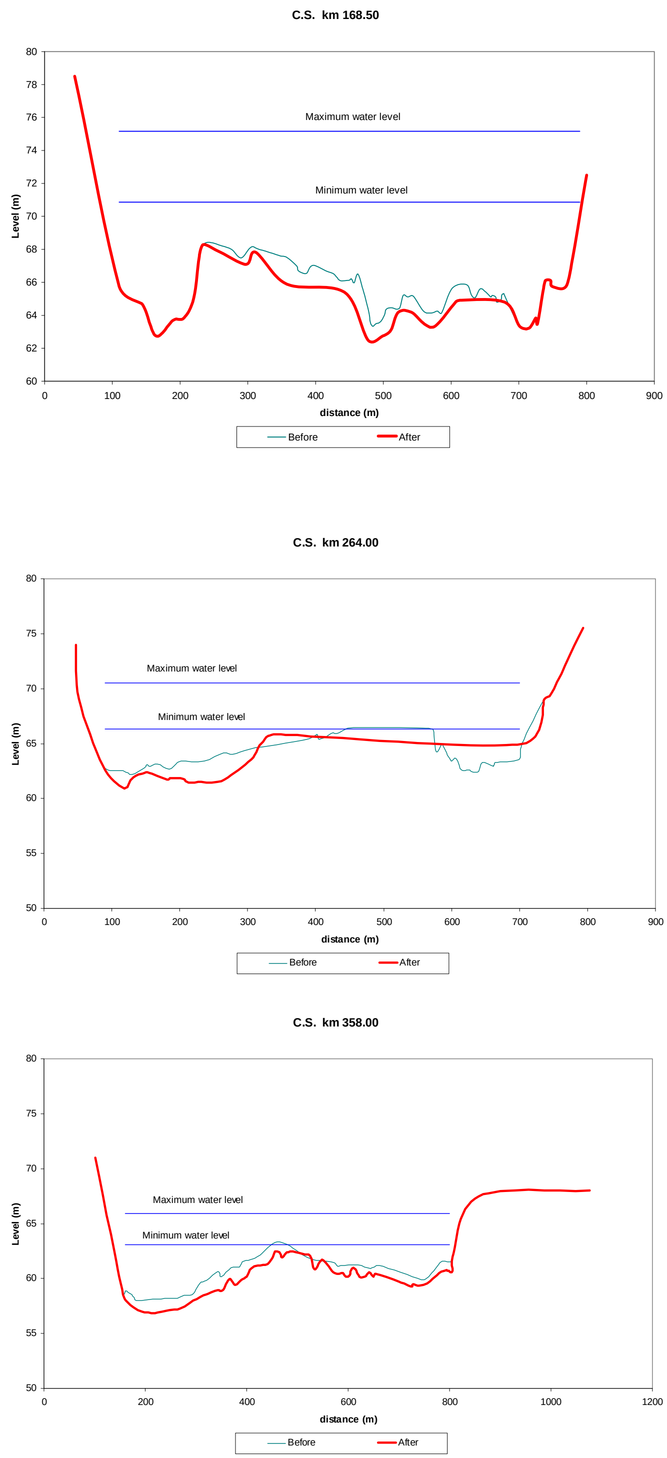


**Fig. 11 Three cross sections, before and after dredging**

***Before dredging condition:***

Figure 12 shows the calibration results for this case. The used cross sections for this case are the pre-dredging cross sections. This figure illustrates the computed water levels along the whole reach in case of the three studied discharges; 60, 130, 230 million cubic meters per day. The calibration figure illustrates the actual water level values for the period of time from 2000 to 2004 (before dredging period). It can be observed that the computed values are close to the actual values for this period especially for low flow case.

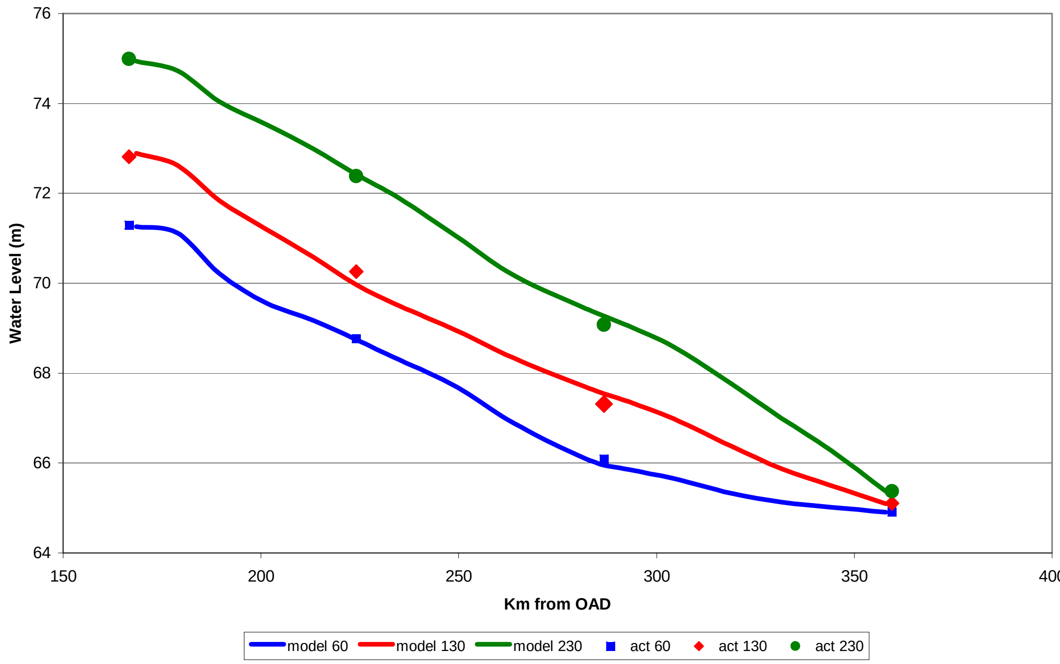


**Fig. 12 Model calibration before the dredging**

***After dredging condition:***

Figure 13 shows the calibration results for this case. The used cross sections for this case are the post dredging cross sections. This figure illustrates the computed water levels along the whole reach related to the studied three discharges; 60, 130, 230 million cubic meters per day. This figure, also, illustrates the actual water level values for the year of 2009 (after dredging period). The calibration results show that the computed values are close from the actual values for this period especially for low flow case.

## 4.4 Simulation

Figure 14 shows the simulation results for both cases; before and after dredging. This figure illustrates that the water level profile for the whole reach in both years 2005 and 2009. It can be concluded that the numerical model results were alike with the analysis of the actual rating curve downstream Esna Barrage. The model results indicated that the water levels along the second reach were higher at year 2009 compared with year 2005, in both cases of minimum and average discharges. Meanwhile the water levels were lower in 2009 in case of maximum discharge.

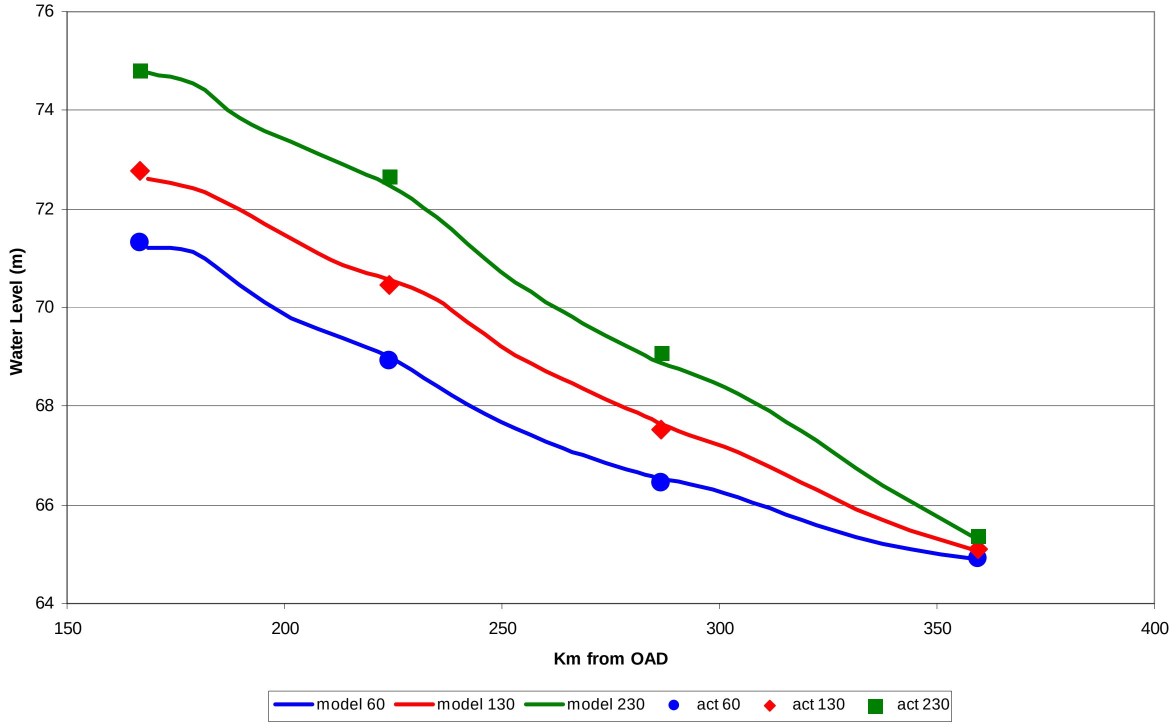


**Fig. 13 Model calibration after the dredging**

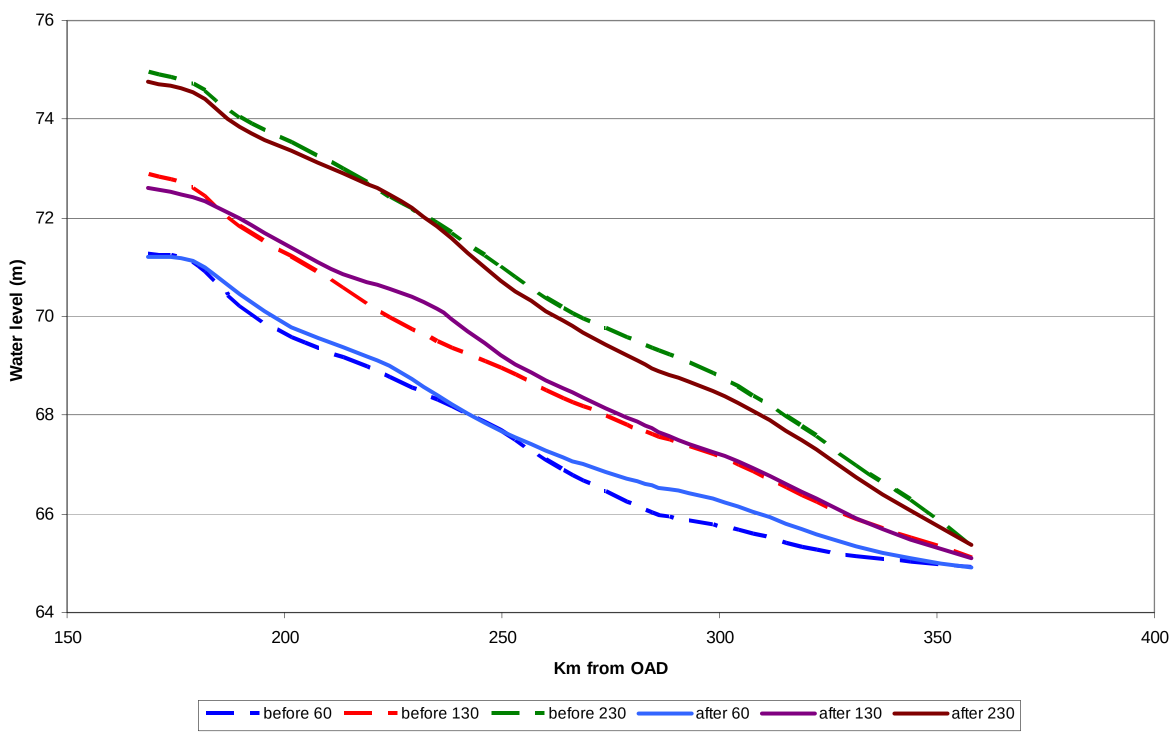


**Fig. 14 Water levels before and after the dredging**

## 5. SUMMARY AND CONCLUSIONS

Several dredging works took place in many locations along the River Nile to achieve an acceptable water depth for navigation. This study investigated the effect of this dredging works on the River Nile water levels. The water levels changes were studied and analyzed for the River Nile from Old Aswan Dam to Delta barrages along the years 1995-2009. The study is conducted by comparing the rating curves downstream the main barrages along the River Nile throughout the study period. The actual water levels and discharges were considered to monitor the changes of water level. Moreover, a numerical model was used to predict the water level along the River. The model was calibrated using actual observations. Actual cross sections before and after dredging were used to estimate the water level change along the second reach of the River Nile. The study concluded the following:

- There was no significant drop in water levels downstream Aswan Dam during the study period.
- The study shows that the second reach was subjected to some water drop during the study period. However, the water level drop for the study period (1995 to 2009) was not noticed for the dredging period (2005-2009) for low flows.
- The study shows that the third reach has not suffered from significant water level drop due to dredging.
- For the fourth reach, there was no drop in water levels.
- The mathematical modeling simulation results for the second reach shows that the drop in water levels does not exceed few centimeters for the “after dredging case “compared with the “before dredging case”.
- The dredging in this case study has not impacted the water level significantly. However, the dredging should be the only applicable solution that used for all cases.

## 6. RECOMMENDATIONS

It is strongly recommended to study the application of other alternatives for solving navigation problems other than dredging. On the other hand, it is very important to study other dredging negative impacts such as morphological and environmental impacts.

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