EFFECT OF HYDROGRAPHIC DATA QUALITY ON WATER SURFACE PROFILE AND NAVIGATIONAL DREDGING COMPUTATIONS

Nasr Hekal

Dr., Nile Research Institute (NRI), National Water Research Center (NWRC), Ministry of Water Resources and Irrigation, NWRC Building, El-Qanater, Egypt
Post Code: 13621. E-mail: Nhekal@yahoo.com.

ABSTRACT

It is known that the accuracy of field data acquisition plays an important role in making the final results of the concerned studies always more reliable and nature representative. Collection of proper hydrographic data usually contributes effectively to the accuracy of the final results of some studies, such as the Water Surface Profile (WSP) computations. This, in turn, affects other related works such as river navigational dredging. To prove this fact, the paper discusses how much the WSP computations are significantly affected by the reduction in the geometric data (such as the number of cross sections representing the study reach and the number of points representing each cross section) of the river reach under study. It also discusses how this affects the computations of the dredging volume. The research concludes that intensive hydrographic field data collection is always justified and recommended when the WSP along any river reach is to be computed and determined as it eventually affects other dependent river works and studies.

INTRODUCTION

Water Surface Profile computation along a river reach is governed by different parameters. Such parameters include the water level at the control structure at the beginning or end of the reach, the released discharges, the flow velocities, the bed roughness, and the geometric properties of the cross sections representing the reach configuration. The more accurate these parameters are measured, the more accurate are the results obtained. These results directly affect other interdependent studies such as water distribution through distributaries (canals) and navigational dredging computations. As for water distribution through canals, the water levels computed along the river reach have to be accurate since the water is supplied to the users according to certain levels through such canals. In this way, their actual needs could be satisfied without waste or shortage and the water could be rationalized. On the other hand, the dredging works necessary in constructing navigational channels depend basically on the minimum water levels computed or recorded along the river reach under study. This is because the depth of the trapezoidal navigational channel is always taken as 2.30 m below the minimum water level according to navigational laws. If the minimum water level is miscalculated, the consequent computation of the required dredging volume will be far from reality. This, in turn, misleads the estimation of the budget required for the implementation of the proposed navigational channel.

OBJECTIVE

The paper aims the following:

1- To prove that *Water Surface Profile* (*WSP*) computation along a river reach needs high quality hydrographic data to represent the reach under study more closely to reality and give reliable and actual results.

2- To search how much the dredging volume computations could be affected by the miscalculated *WSP* in case the number of cross sections representing the study reach is reduced.

To achieve these objectives, two practical case studies were selected for examination; the first for the WSP computations and the second for dredging volume computations depending on the results of the first one.

FIRST CASE STUDY DEFINTION

Reach (4) of the River Nile was chosen for WSP computations. It is about 408.720 km long. It extends from just downstream Assyut Barrages at km (544.780) from Old Aswan Dam (OAD) far up in the south down to just upstream Delta Barrages at km (953.500) in the North as shown in Figure (1). This reach was specifically chosen for the availability of the two sets of data required for model calibration purposes (hydrographic and hydrologic data). It is worth mentioning that the 1-D model used in computations was developed by the author during his PhD study (2003).

MODEL CALIBRATION

In order to calibrate the model, two sets of data were obtained; the hydrographic and hydrologic data of the selected reach. The geometry of the reach was represented by 200 cross sections surveyed in 2003 (the most recent hydrographic survey that was done by the Nile Research Institute where the author works) spaced at an in-between distance of 2 kilometers. As for the hydrologic data, the water levels recorded at twelve gauging stations spread along the reach for discharges of 30, 70, 100, 140, and 170 $M.m^3$/day were obtained. These discharges were chosen to represent the different conditions of the reach round the year and to ensure a good quality of the deduced roughness coefficients at each cross section.

The water surface elevations corresponding to each discharge at the locations of the 200 cross sections were deduced by linear interpolation using the water levels recorded at the 12 staff gauge stations. These surface elevations were considered as measured values. Then, the model was run for each discharge to give the roughness coefficients “n” at the different cross sections by automatically adjusting the computed water surface elevations with the measured ones.

Finally, the values of the roughness coefficients computed by the model at the 200 cross sections for each discharge were obtained as shown in Figure (2). Now, 5 values of the roughness coefficient became available at each kilometer. They were used to deduce the value of the roughness coefficient corresponding to any other suggested discharge at that kilometer.

Having the model calibrated and verified, it was run for three cases where the hydrographic (geometric) data representing the reach were as follows:

1. The reach was first represented hydrographically by 200 cross sections. This case was considered the reference in comparison as this is the maximum number of cross sections available for the author and the model used can process any number of cross sections. No other 1-D models such as ***HEC2, HEC6, HECRAS,*** and ***GSTARS*** can deal with more than 100 cross sections (NRI Reports);
2. The reach was, then, represented by 100 cross sections; and
3. Finally, only 50 cross sections were chosen to represent the reach.

In addition, the hydrologic data was such that the discharge released was taken as 25 $M.m^3$ /day (the minimum discharge ever released through the reach over the last 15 years). Also, the downstream boundary condition which was the detention level at Delta Barrages was taken as 14.00 m (a.m.s.l). The minimum discharge was particularly used in this case study to compute the minimum water surface elevations resulting from the 3 cases especially at the location of the second case study (where a navigational channel was to be constructed) that will follow below so as to help prove how much the differences in the minimum water levels could affect the dredging volume computations.

RESULTS AND ANALYSIS

Table (1) and Figure (3) show the differences in water surface profiles computed for the two cases of 100 and 50 x-sections compared with the case of 200 x-sections which was considered as a datum. From the figure, it could be noticed that the values of the water levels in both cases are randomly staggered up and down the datum (reference case). This is due to the decrease in the number of the cross sections representing the reach. Such a decrease increases the distances between the cross sections which, together with the different roughness and the change in the geometric properties (such as water area, wetted perimeter, top width, and hydraulic depth) and current velocities at each cross section, affect the computation of the water surface slope between sections, a matter which, eventually, affects the vertical change in water levels when applying the *Standard Step Method* used in the model.

Also, it could be noticed that the fewer the number of the cross sections used, the bigger the deviation the water levels undergo away from the datum. It was found that the biggest deviation values whether positive or negative were found in the second case where 50 cross sections were used. These values were (-70) and (+62) cm far away from the datum values, whereas the biggest deviation values computed in the first case where 100 cross sections were used, were (-24) and (+39) cm.

This indicates that the fewer the hydrographic cross sections used in representing a river reach, the bigger the deviation from the correct results when computing the *WSP*. This entails that no effort or investment should be spared in hydrographic survey as the accuracy of the final results gets influenced significantly.

This leads us to evaluate the effect of the errors (though in centimeters) that could be resulted from computing the water surface levels inaccurately on other river studies. The following case study examines such an effect on the dredging volume computations of a proposed navigational channel.

SECOND CASE STUDY DEFINTION

A navigational bottleneck that had taken place over a distance of about 2 km downstream the BaniSwafe Nile-crossing Bridge at km 808 from OAD as shown in Figure (4) was to be studied. The problem used to be pressing especially during the low water levels as the transport vessels traveling along the Nile at this part of the river started to collide with the riverbed and get aground, a matter that hindered or paralyzed the traffic movement completely. It was asked to plan and design the best quality navigational channel with the minimum cost of dredging possible.

To carry out the study, hydrographic data had to be acquired from the field to represent the problem area very closely. Based on field experience, 44 cross sections in the form of XYZ points with an in-between spacing of about 50 m or less were surveyed to cover the area and reflect the riverbed morphology there. From these sections, the thalweg path (the line connecting the deepest points at the different cross sections) was determined to help guide the planning and design of the most suitable navigational route throughout the river reach under study.

A suitable and smooth centerline of the navigational route was eventually planned as shown in Figure (5). Also, a trapezoidal shape was suggested to represent the navigational channel throughout the study reach. The bottom base of the trapezoid was 100 m wide and 2.3 m deep under the minimum water level of the River Nile in that area. Both side slopes of the channel were taken as 5 to 1 (5 H : 1 V).

ANALYSIS AND DISCUSSION OF RESULTS

In order to see how much the dredging volume computations are affected by the minimum water surface elevations computed in the 3 cases used in the first case study at the site, different scenarios have been tried as follows:

SCENARIO (1)

The minimum water surface elevations computed in the first case study above for the three cases of 200, 100, and 50 x-sections were used in computations. For the case of 200 x-sections (the reference case), the minimum water surface elevation was found to be 22.49 m (a.m.s.l) at km 808 from OAD as shown in Table (2).

The cross section of the proposed navigational channel was used at every original cross section to compute the required dredging area. Then, the total dredging volume was computed using these dredging areas and the spacing (L) between the cross sections.

$$\textit{\textbf{Total dredging volume}} = \sum_{i=1}^{i=n} \frac{(A_i + A_{i+1})}{2} * (L_i)$$

in which:

i indicates the number of the cross section;
n = the total number of the cross sections covering the study reach;
$\boldsymbol{A_i}$ = the dredging area computed at cross section number ***(i)***;
$\boldsymbol{A_{i+1}}$ = the dredging area computed at cross section number ***(i+1)***; and
$\boldsymbol{L_i}$ = the spacing between cross sections number ***(i and i+1)*** along the centerline of the dredging channel suggested.

The resulting dredging volume was = ***332773.58 m^3***.

For the case of 100 and 50 x-sections, the minimum water surface elevations happened to be equal to 22.78 m and 22.91 m (a.m.s.l) at the same location respectively i.e. 29 and 43 cm bigger than that in the reference case. The computed corresponding dredging volumes were then = ***260422.91 m^3*** and ***229206.07 m^3*** respectively.

In other words, the dredging volume computed in the case of 100 x-sections is 22 % less than that computed in the reference case. Also, the dredging volume in the case of using 50 x-sections is 31 % less than the reference case. This means that the reduction in the number of cross sections used in computing the WSP resulted in inaccurate water surface elevations that affected the dredging volume computations. This, in turn, can mislead the preparation of the budget to be earmarked for such a navigational dredging project.

On the other hand, suppose that the position of the second case study were at another kilometer along the study reach. The difference between the minimum water surface elevations would be different and the dredging volumes computed in the two cases of 100 and 50 x-sections might be bigger or less than that computed in the reference case. This means that the values of the water surface elevations are randomly distributed and get more deformed depending on the number of the cross sections used and the distances between them. This assures that it is important to survey the necessary number of cross sections to represent the reach under study more closely so that the best result of the WSP is obtained. In other words, the values of the water surface elevations should undergo less and less deviation from the actual situation in practice.

SCENARIO (2)

In this scenario, the reduction of the number of x-sections representing the study area was examined. As mentioned above, 44 x-sections were used to cover the study area. Now, the number was reduced to 22 x-sections only to see the effect of data reduction on the dredging volume computations. X-sections with both even (2,4,…,44) and odd (1,3,…,43) numbers were used in computations, each set apart. The minimum water surface elevation was taken = 22.49 m (a.m.s.l), which was computed in the reference case.

The resulting dredging volume for the x-sections with even numbers was = ***343460.17 m***^{3}, while it was = ***330169.12 m***^{3} for the sections with odd numbers. It is found that the difference between the results = ***13291.05 m***^{3} which is a significant value. Also, the difference between the dredging volume computed using the 44 x-sections and that of the even number x-sections was found to be = ***-10686.60 m***^{3} and the difference with the odd number sections was = ***2604.46 m***^{3}.

From the above results, it can be concluded that the less the collected hydrographic data representing the river study area (number of cross sections), the more the inaccurate results and vice versa. This means that accurate and intensive hydrographic data always represent the river morphology quite well and contribute much to the accuracy of dependent studies and computations.

SCENARIO (3)

In this scenario, the number of points representing each cross section of the above 44 was reduced in a percentage ranging from 10 to 60 so as to study the reduction effect on the dredging volume computations.

It is worth mentioning here that the reduction process was done as follows:

Each cross section hydrographically surveyed in the field is composed of a certain number of (XYZ) points representing the river morphology at that location with a certain top width. In order to reduce the number of points with 10 % for instance, 90 % of the total number of points is computed (NP). Then, the top width of the section is divided into equal distances. The total number of these distances = NP – 1. Then, at the start and end of each distance, the new depths (Z coordinate) are computed by interpolation using the original cross section points and configuration. In this way, the number of points representing the cross section is reduced and hence the accuracy, giving new points with new depths as if the original section were surveyed in the field collecting these points only.

Then, for a minimum water surface elevation of 22.49 m (a.m.s.l) at the location of the case study, the dredging volume was computed for the different cases of reduction. All the results were compared to the case where the original cross sections had undergone no point reduction. The results obtained are shown in Figure (6). It could be noticed that the resulting dredging volumes became less due to the inaccuracy coming from the reduction in the number of points representing each cross section. This means that intensifying the number of points of the cross section during field survey always represents and describes the riverbed configuration almost exactly and contributes much to the accuracy of computations.

CONCLUSIONS

From the above analyses and results of the two case studies and the different scenarios attempted, it can be concluded that:

1. The accuracy of *Water Surface Profile* computations of any river reach depends basically on the collection accuracy of both hydrologic and hydrographic datasets. The lack of the hydrographic data always leads to the misrepresentation of the river reach under study, a matter which results in incorrect values of the water levels computed. This, in turn, affects other related studies such as the dredging volume computation which is a prerequisite for navigational projects.

2. Since the reduction of the number of points of the cross sections misleads the dredging volume computations, the adopted concept of approximating the natural cross sections to representative rectangular cross sections for the purpose of easing or simplifying the computations is not always correct or precise and should not be blindly generalized.

3. The economics of the related navigational projects is very sensitive to field data collection. The budget estimated and earmarked for such projects is always governed by the accuracy of data acquisition which affects the dredging volume computations.

4. In order to obtain credible and precise results and come up with sound and reliable decisions from river studies based on Water Surface Profile computations, intensive field hydrographic data collection should never be denied. They should always be justified and highly recommended.

REFERENCE

Hekal, N.T.H., 2003. Evaluation of Nile Flood Effects Downstream Flood Control Structures in Egypt, Ph.D. Thesis, Ain Shams University, Egypt.

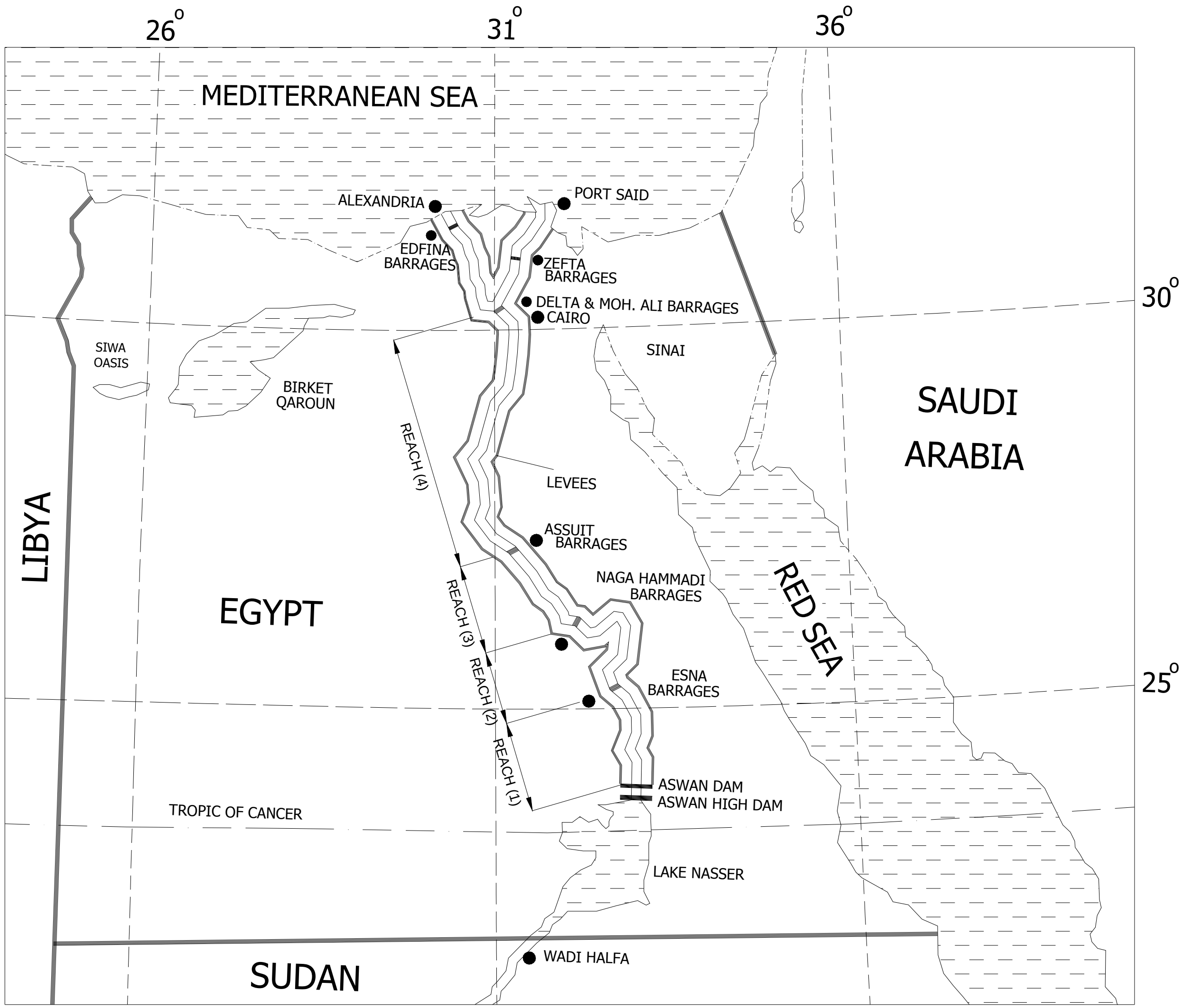

Figure-1: A map showing the River Nile through Egypt and its four Reaches

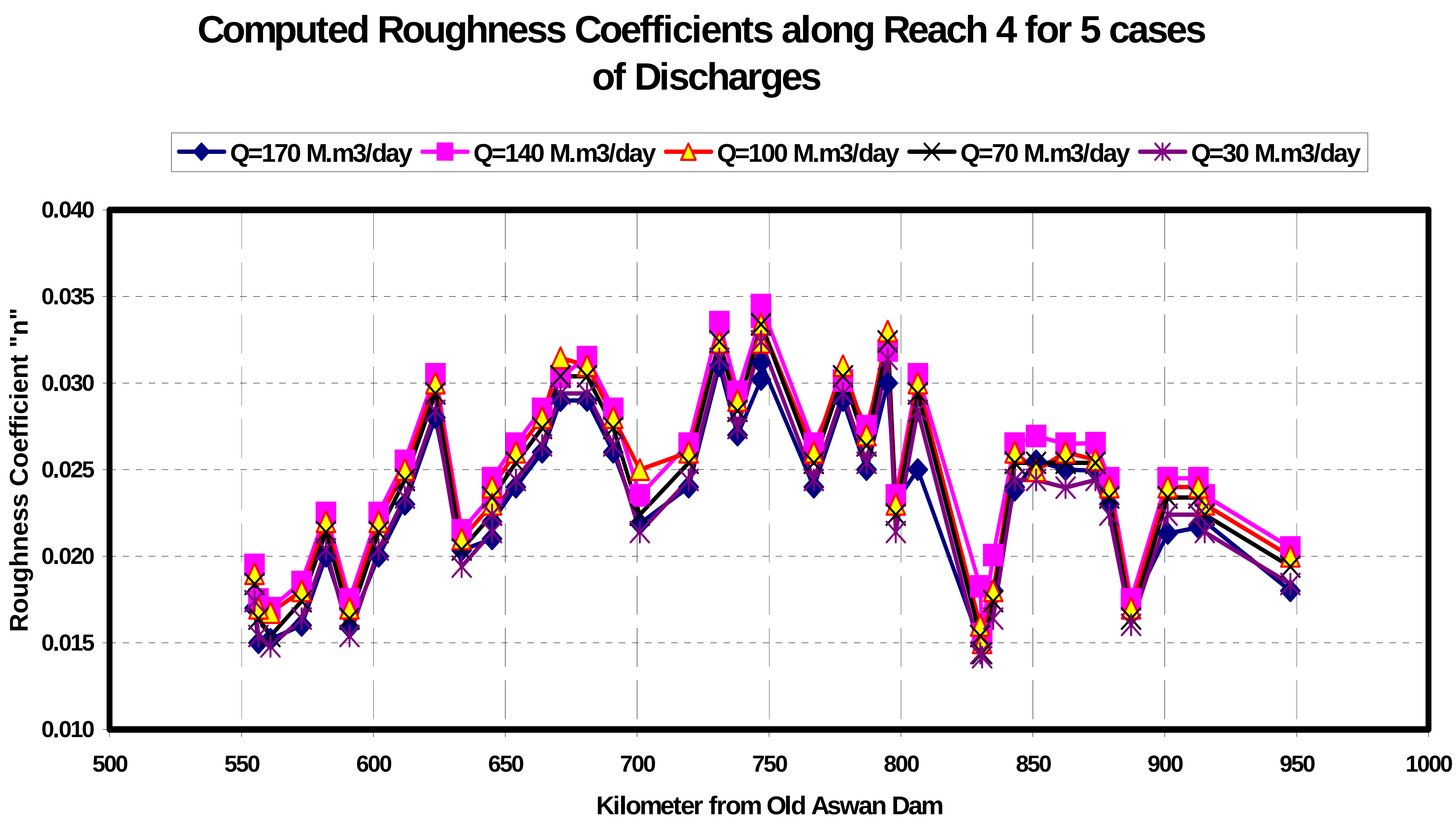

Figure 2: Roughness coefficients due to calibration along reach 4 of the Nile

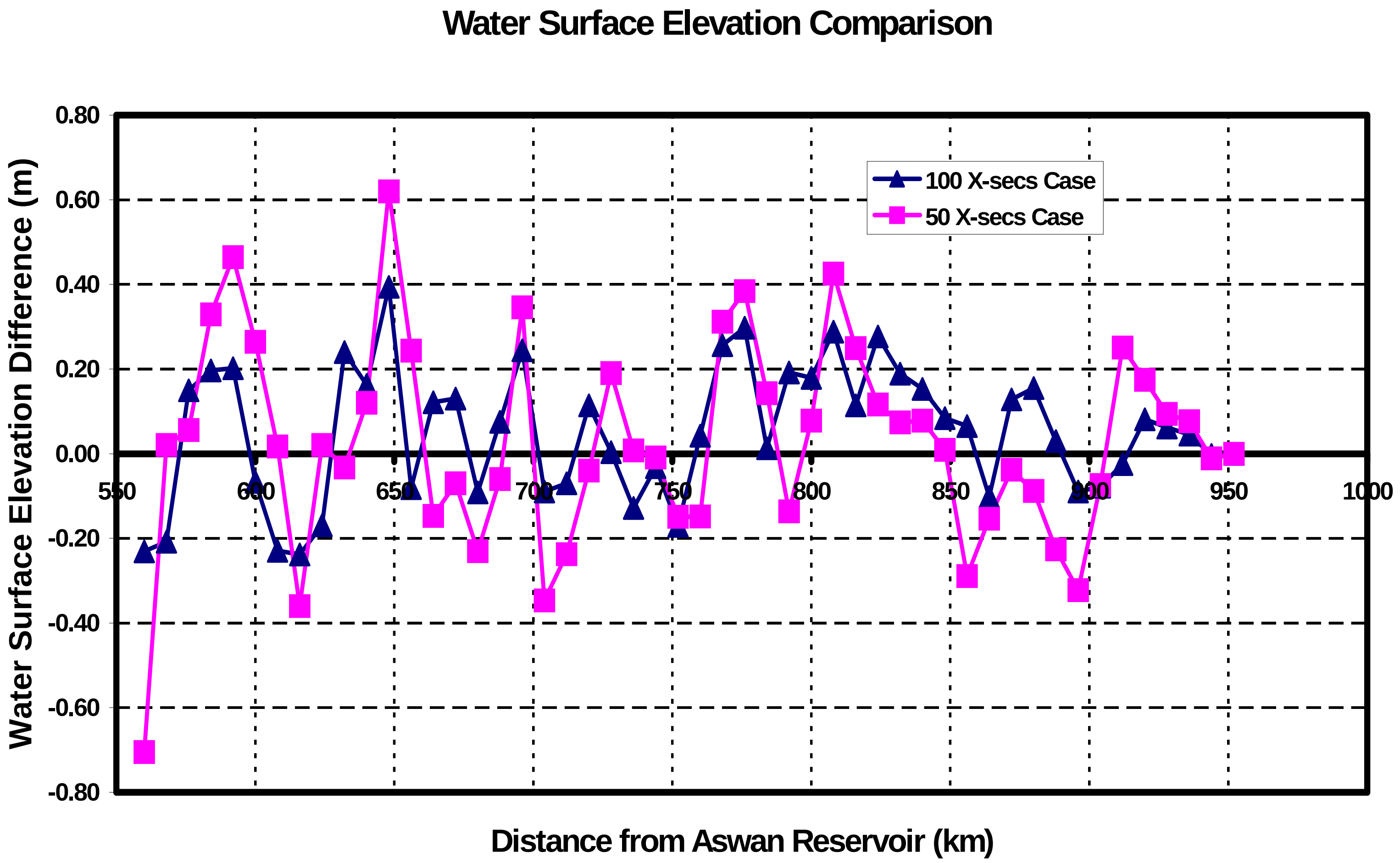

Figure 3: Differences in Minimum Water Surface Elevation in case of using 100 & 50 X-sections compared with the case where 200 X-sections are used

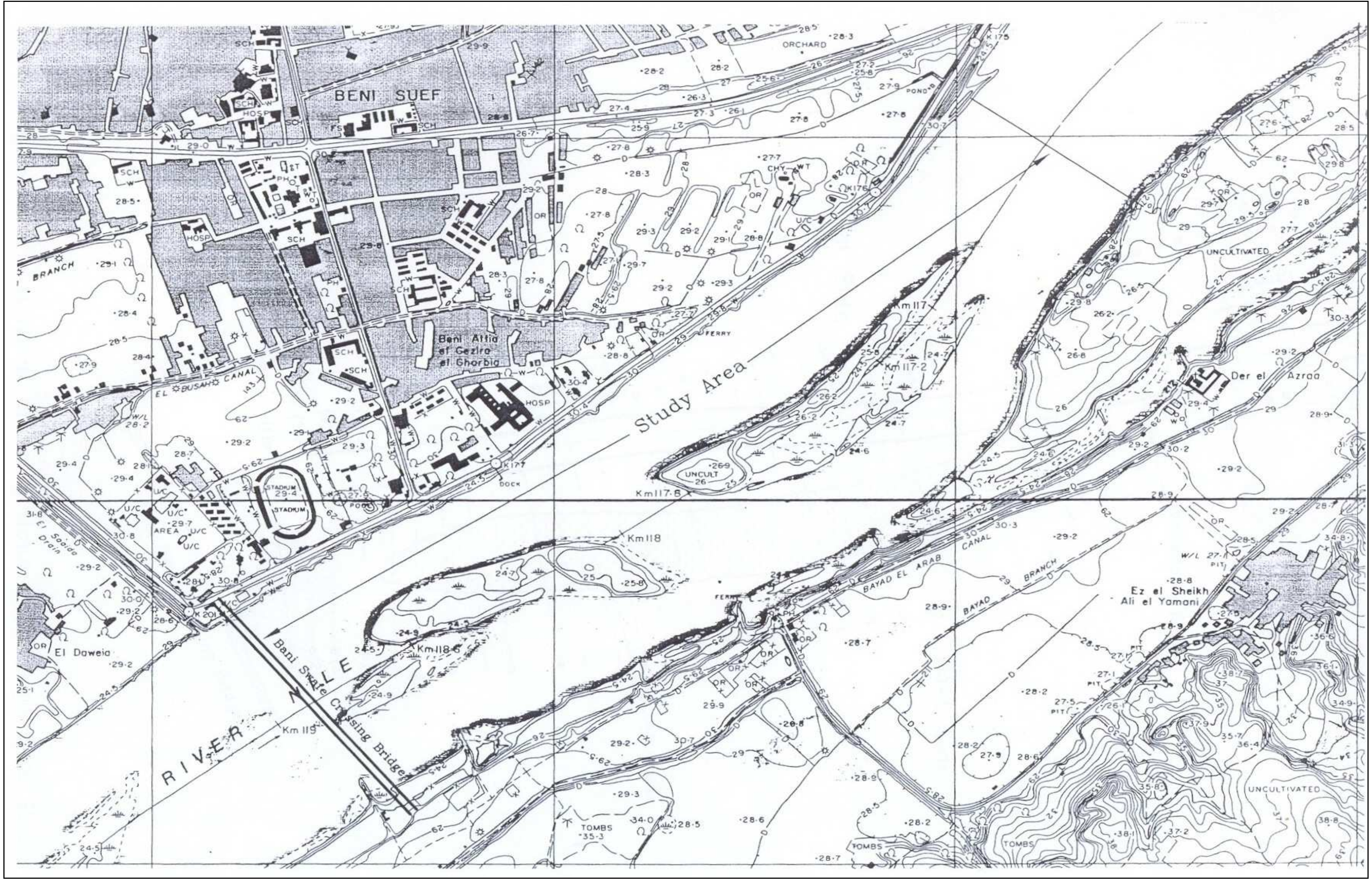

Figure 4: A map showing the study area where the navigational channel was to be constructed

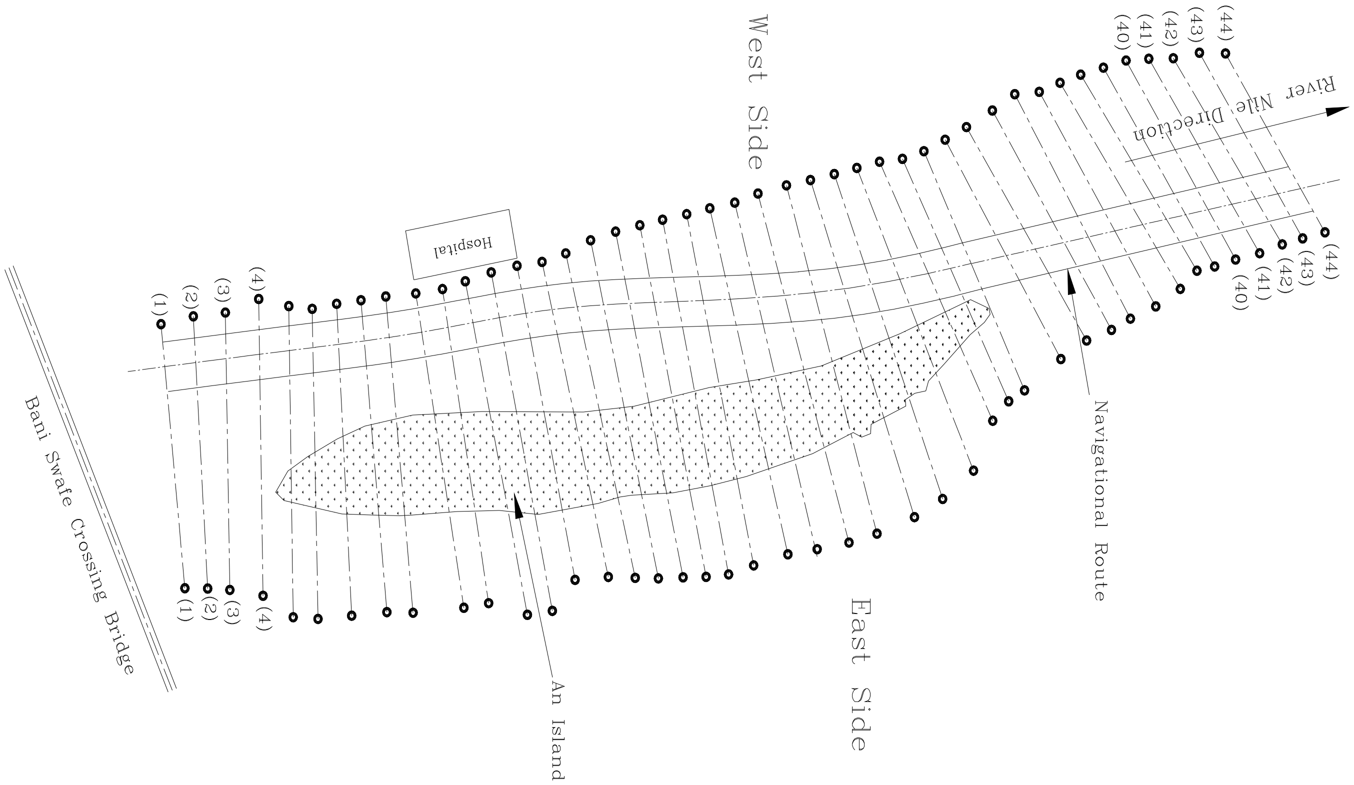

Figure 5: Positions of cross sections and Navigational Route

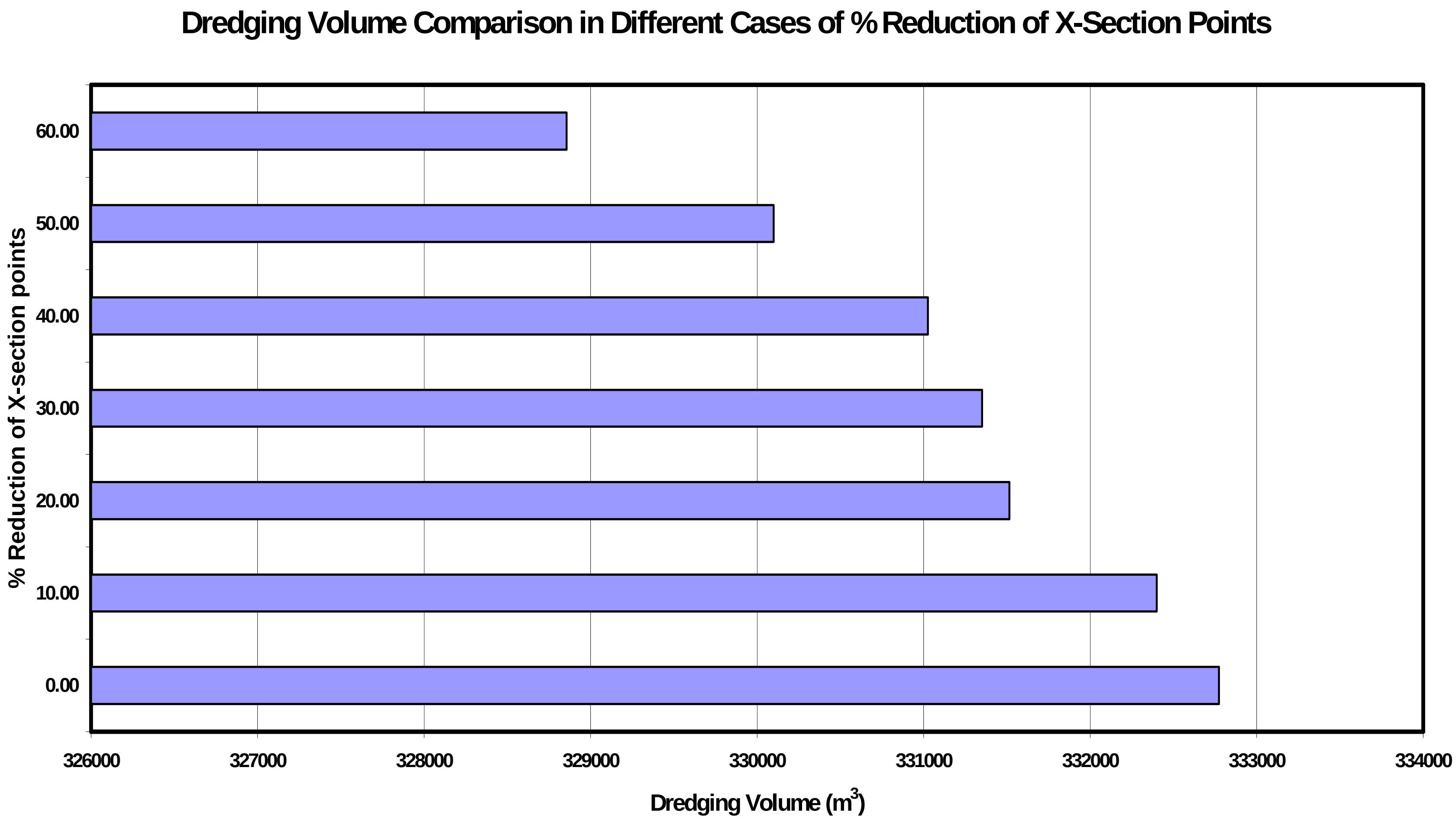

Figure 6: Dredging Volume Comparison in Different Cases of % Reduction of X-Section Points

Table 1: Differences in Minimum Water Surface Elevation in case of using 100 & 50 X-sections compared with the case where 200 X-sections are used

Table (1)		
WSP Differences compared with the Case of 200 x-secs		
km from OAD	Case of 100 x-secs	Case of 50 x-secs
952	0.00	0.00
944	0.00	-0.01
936	0.05	0.08
928	0.06	0.09
920	0.08	0.17
912	-0.02	0.25
904	-0.08	-0.07
896	-0.09	-0.32
888	0.03	-0.23
880	0.15	-0.09
872	0.13	-0.04
864	-0.10	-0.15
856	0.07	-0.29
848	0.08	0.01
840	0.15	0.08
832	0.19	0.07
824	0.28	0.12
816	0.11	0.25
808	0.29	0.43
800	0.18	0.08
792	0.19	-0.14
784	0.01	0.14
776	0.30	0.38
768	0.26	0.31
760	0.04	-0.15
752	-0.17	-0.15
744	-0.03	-0.01
736	-0.13	0.01
728	0.00	0.19
720	0.11	-0.04
712	-0.07	-0.24
704	-0.09	-0.35
696	0.24	0.35
688	0.08	-0.06
680	-0.09	-0.23
672	0.13	-0.07
664	0.12	-0.15
656	-0.08	0.24
648	0.39	0.62
640	0.16	0.12
632	0.24	-0.03

Table 2: The minimum water surface elevation at km 808 from OAD for the 3 cases

Table (2)			
km from Old Aswan Dam	Case of 200 x-secs Water Surface Elevation	Case of 100 x-secs Water Surface Elevation	Case of 50 x-secs Water Surface Elevation
952	14.00	14.00	14.00
944	14.01	14.01	14.00
936	14.14	14.18	14.21
928	14.18	14.24	14.27
920	14.38	14.47	14.56
912	14.66	14.64	14.91
904	14.94	14.87	14.87
896	15.29	15.20	14.96
888	15.48	15.51	15.25
880	15.81	15.97	15.73
872	16.25	16.37	16.21
864	17.33	17.22	17.17
856	18.26	18.32	17.97
848	18.88	18.96	18.89
840	19.37	19.52	19.45
832	19.84	20.03	19.92
824	20.39	20.66	20.50
816	21.45	21.57	21.70
808	22.49	22.78	22.91
800	23.04	23.22	23.12
792	23.94	24.13	23.81
784	24.70	24.71	24.84
776	25.13	25.43	25.52
768	25.42	25.68	25.74
760	26.02	26.06	25.87
752	26.99	26.82	26.84
744	27.71	27.68	27.70
736	28.10	27.97	28.11
728	28.93	28.93	29.12
720	29.51	29.63	29.47
712	29.93	29.86	29.70
704	30.37	30.28	30.02
696	31.99	32.24	32.34
688	32.56	32.63	32.50
680	33.34	33.25	33.11
672	34.44	34.57	34.37
664	34.69	34.82	34.55
656	35.25	35.17	35.49
648	36.19	36.59	36.81
640	36.51	36.67	36.63
632	36.99	37.23	36.96