Impacts of Reduced Released Flow From High Aswan Dam on The River Course in Egypt

Hany G. Radwan, and Abu-Bakr T. Hussin

Abstract**—**The main objectives of this paper are to discuss the effects of reduced water discharge from High Aswan Dam on the hydraulics of the River Nile in Egypt. The reach from High Aswan Dam to new Esna Barrage was studied as case study in this paper. Three scenarios are developed using three percentage of flow reduction with 10%, 20%, and 30%. The effect of flow reduction was appeared in four impacts. First impact was reduction in the water surface varies from 0.22m to 1.1 m as minimum and maximum drop. This reduction in the water level lead to the second impact which is the safety of the intake level of existing water supply's pump stations along the studied reach. Number of existing pump stations become out of service. This number of broken pumps varies from zero pumps for 10% flow reduction to 4 , and 8 pumps for 20% and 30% flow reduction, respectively. The third impact was the appearance of new islands along the studied reach through low flow condition. The final studied impact was the effect of flow reduction on river navigation. This impact was studied by detecting the sections along the studied reach that need dredging for successful navigation process.

Index Terms**—** Flow reduction, High Aswan Dam, Islands, Navigation**.**

I. Introduction

Surface water resources are limited to Egypt's share of the Nile River, together with minor amounts of rainfall and flash floods. The average annual natural flow of the Nile estimated at Aswan is about 84 billion m^3, of which 55.5 billion m^3 represents Egypt's share, 18.5 billion m^3 Sudan's share, and the remainder is allowed for evaporation. High Aswan Dam provides storage to guarantee regulated water supplies inside Egypt as shown in Fig.1. [1].

The main water resources in Egypt at year 2025 will be 74.3 BCM, and water demand the same year will be 81.9 BCM [1]. That means, in the near future there will be a shortage in water in case of everything remains as it is. But, there are other challenges which can increase the water shortage in the future, such as climate change, and the change in the Egyptian Nile water share. The Nile River is standing less than two meters above sea level; however, it is also extremely vulnerable to the effects of climate change [2].

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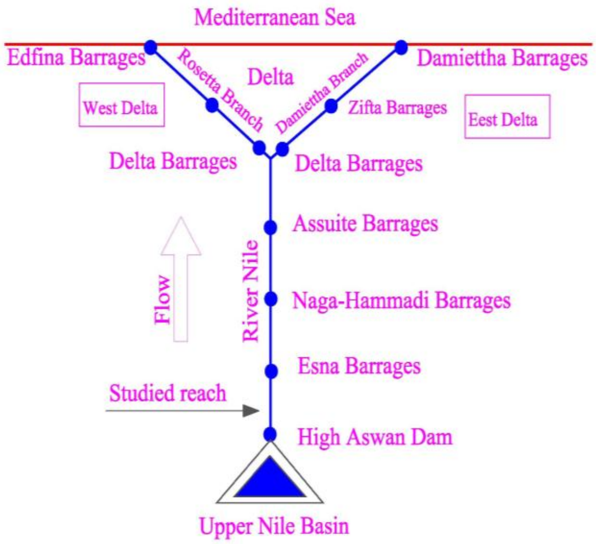

Fig. 1. Nile Valley and Barrages in Egypt

Impacts on the supply side are likely to arise from possible changes of precipitation patterns over the Ethiopian hills (which accounts for around 85% of water flow into the River Nile), and equatorial lakes such as Lake Victoria (15%) [3]. Due to the importance of predicting environmental impacts which could result from climate changes affecting the Nile basin, several models have been advanced. These models are still incapable of predicting, with some certainty, what would happen if climate change occurs. Some of these models predict an increase in Nile water budget with about 30%, and other models predict decrease in Nile water budget with about 77% [3]. Another challenge which will increase the water shortage in the future is by changing the Egyptian Nile water share by constructing Great Ethiopia Renaissance Dam (GERD) without consultation with the downstream countries; Egypt and Sudan. Many studies discussed the effect of GERD on Egypt through three impacts; decreasing Egyptian Nile water share, decreasing water level at Lake Nasser at High Aswan Dam, and decreasing the generated hydroelectric power [4], [5], and [6].

This paper will study the effect of the reduction in the Nile water budget on the hydraulics of the River Nile for the first reach from HAD to new Esna Barrage with total length of 166.5 km as shown in Fig.1.

II. Literature Review

River navigation is considered one of the important activities for tourism and transportation purposes. It is also important to secure a safe navigation depth during low flow periods. Therefore, it was decided to dredge many locations along the River Nile to achieve the required water depth in the low flow condition. However, the dredging in some cases may have some negative impacts on river water levels. So, Ismail, and Samuel at 2011 studied the impact of dredging on River Nile water levels from Old Aswan Dam to Delta barrages along the study period 1995-2009 using HEC-RAS computer model [7]. It is concluded from this study that, there was no significant drop in water levels downstream High Aswan Dam till new Esna Barrage.

The side effects of low flows at Nile River are many, some examples of these side effects are the water supply un-sufficiency, navigation problems, and some local sedimentation problems. So, Aziz, and Ismail at 2003 studied the effect of Nile low flows on the pump stations for water supply from Old Aswan Dam to Delta barrages using HEC-RAS computer model [8]. The computed water levels were compared to the design and critical pump station water level to determine the adequacy of the water level for pump station supply. The model was run to pass 60 million cubic meter from HAD as the low flow condition. The results showed that about 15% of the existing pump stations for water supply form HAD to new Esna Barrage will be out of service in case of low flow condition.

III. METHODOLOGY

The methodology used to study the research objectives is as shown in Fig.2. The methodology starts with data collection about available cross section data, available data of existing water supply's pump stations in the studied area, and available observed data. The second step in the methodology is to setup and calibrate one dimensional HEC-RAS model to simulate the changes in water level in the studied area. Then the third step is develop different scenarios and discuss their results.

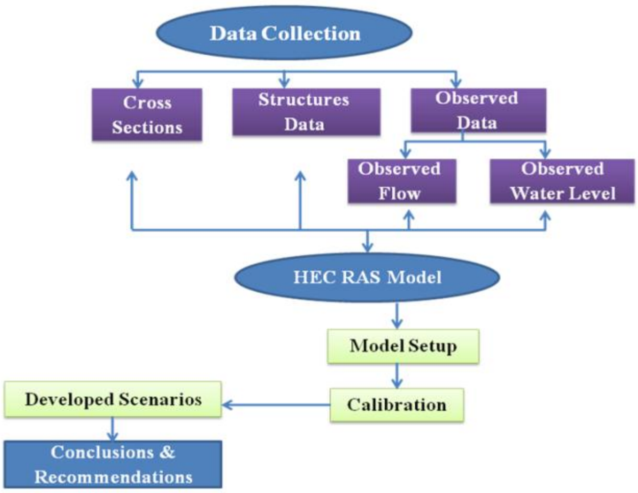

Fig.2. Applied Methodology Steps

A. Data Collection

Through the studied reach from HAD to new Esna Barrage, the data are collected for year 2011. First collected data is fourteen cross section as shown in Fig.3, and Table I. Second data is critical water level data for fifty five pump stations used for water supply. Final data is observed water level data for three stations along the studied reach as shown in Fig.3, and Table II (source: Nile Research institute). Fig.4. illustrates the observed water level data for the available three stations. Fig.5, and 6. illustrate the released discharge from HAD and observed water level upstream new Esna Barrage respectively. It is clear that the minimum released discharge from HAD is at December month (low flow), and the maximum released discharge is at June month (high flow).

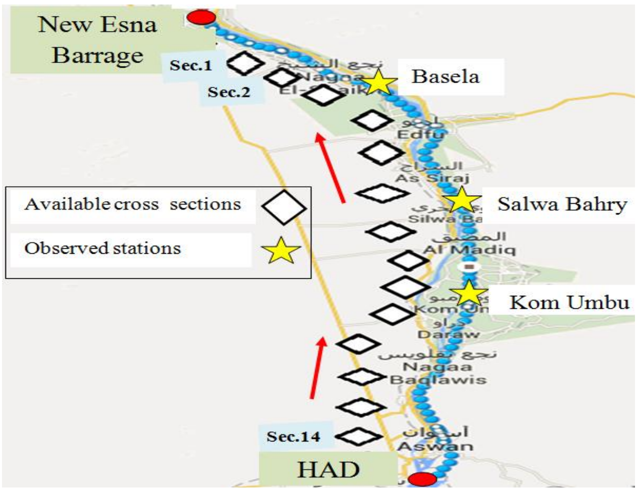

Fig.3. Studied Reach And Available Data

TABLE I
LOCATIONS OF AVAILABLE CROSS SECTIONS

Section number	Distance from HAD (Km)	Section number	Distance from HAD (Km)
1	165.44	8	78.55
2	154.98	9	58.3
3	143.03	10	46.57
4	135.9	11	37.25
5	123.5	12	28.45
6	105.2	13	17.9
7	98	14	8.45

TABLE II
LOCATIONS OF AVAILABLE OBSERVED STATIONS.

Station	Distance from HAD (km)
Kom Umbu	49.65
Salwa Bahry	85.45
Basela	131
Esna barrage	166.5

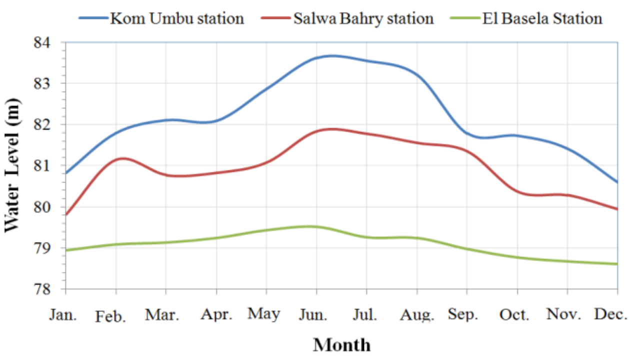

Fig.4. Observed Water Level Data At Available Stations.

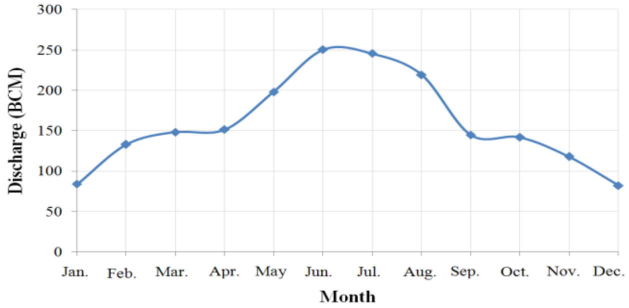

Fig.5. Observed Water Discharge Hydrograph From HAD Towards New Esna Barrage

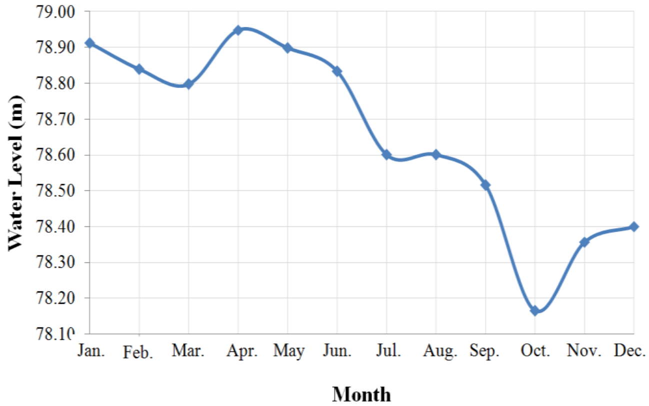

Fig.6. Observed Water Level Upstream New Esna Barrage.

B. Model setup and calibration

One dimensional hydraulic model HEC-RAS was used to simulate the current situation as the base case. The boundary conditions for the model were the released water flow hydrograph from HAD , and observed water level at Esna at downstream part. The three available water level stations were used to calibrate the model to be able to develop the future scenarios. Fig.7 illustrates the calibration results for the three available stations. It is clear from this figure that the model was calibrated effectively.

C. Scenarios

Three scenarios were developed after the successful process of model calibration. The three scenarios are based on developing reduction percentage for the released flow from HAD with three percentages 10%, 20% , and 30% . The expected effects on three parameters were detected as follows:-

- ✓ The expected reduction in water level, and
- ✓ Effect on the critical intake level for the existing pump stations, and
- ✓ Effect on the appearance of new island (if any), and
- ✓ Effect on the available navigation in the River Nile by assuming a minimum required water depth of 2.5 m for navigation process.

To discuss the effect of flow reduction from HAD on the previous parameters, the low flow at December month will be used as the critical case for the three scenarios.

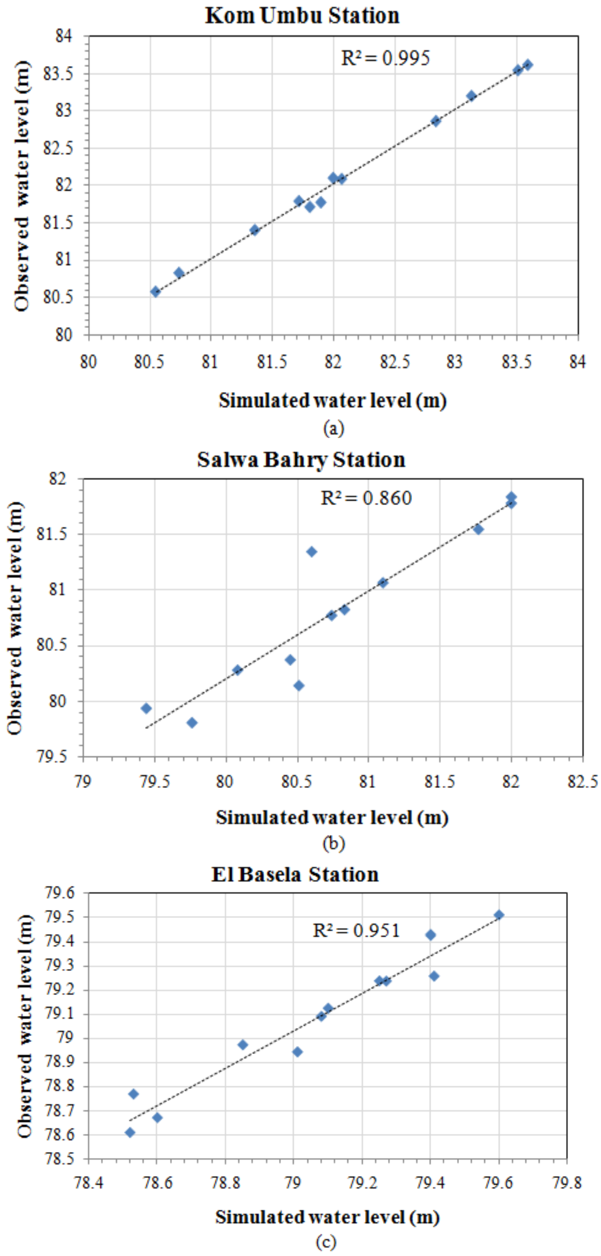

Fig.7. Results Of Model Calibration (a) Kom Umbu Station, (b) Salwa Bahery Station, (c) El Basela Station.

D. Scenarios Results

1) Base case scenario (no flow reduction)

The results of this scenario can be summarized as follows:-

- ➢ All intakes of the existing pump stations are safe and covered by a minimum water depth of 1.5 m. Fig.8 illustrated the longitudinal profile for the studied reach showing the intakes locations of the existing pump stations for December month (low flow).
- ➢ For the base case and for low flow condition at December month, there is one island is appeared at section 14 with width of 51 m and long of 2 km as shown in Fig.9. In some other sections, the right river bank or left river bank become uncovered with water. For example at section 11, the left river bank is uncovered by a width of 132 m and length 3.7 km as shown in Fig.10. At section 8, the right and left river banks are uncovered for average width of 20m and length of 2.8 km as shown in Fig.11.

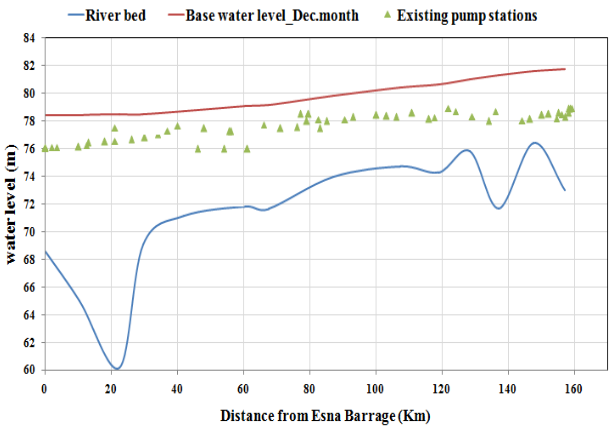

Fig.8. Water Level And Pump Stations For The Longitudinal Profile For Base Case.

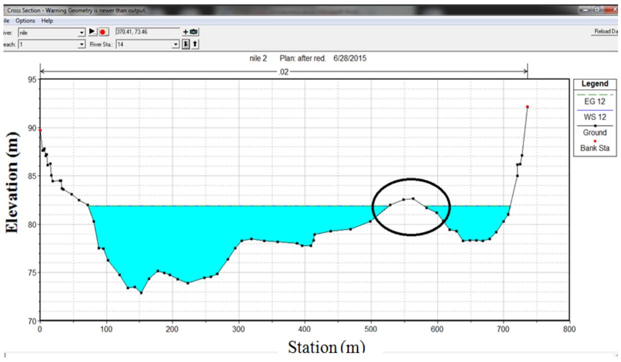

Fig.9. Water Level For Base Case In December (2011) At Section (14).

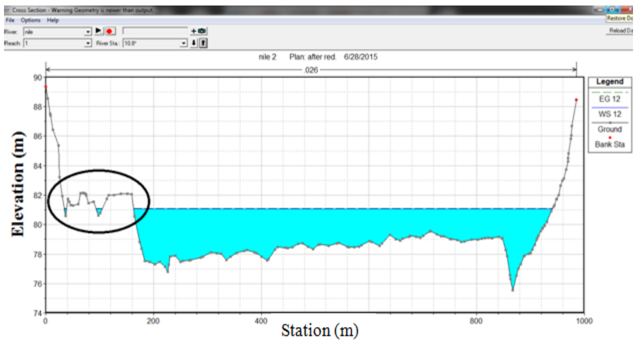

Fig.10. Water Level For Base Case In December (2011) At Section (11).

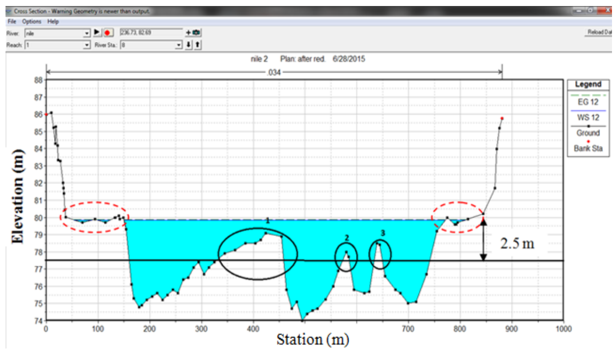

Fig.11. Water Level For Base Case In December (2011) At Section (8).

- For navigation process, there are three sections that need dredging for successful navigation in the river. The first section is section 8 as shown in Fig.11 with maximum width of 133m. The second section need dredging is section 5 with width of 145 m as shown in Fig.12. Finally section 14 also need dredging with width of 51m.

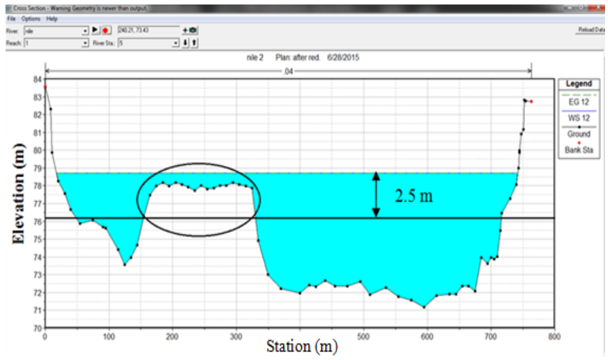

Fig.12. Water Level For Base Case In December (2011) At Section (5).

2) Scenario (1) : 10% Flow reduction

The results of this scenario can be summarized as follows:-

- All intakes of the existing pump stations are safe and covered by a minimum water depth of 0.5 m. Fig.13 illustrated the longitudinal profile for the studied reach showing the intakes locations of the existing pump stations for December month (low flow).

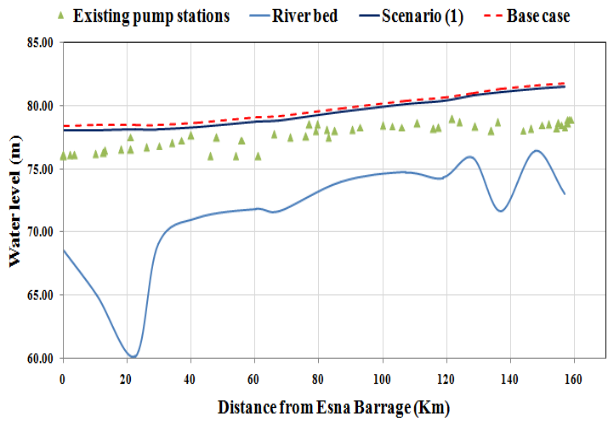

Fig.13. Water Level And Pump Stations For The Longitudinal Profile For Scenario (1).

- The same islands and uncovered areas in this scenario are the same as in the base case except one additional island at section 2 will be appeared.
- For base case there were three sections that needed dredging at sections 5, 8, and 14. For scenario (1), there are three additional sections that need dredging at sections 10, 11, and 13.

3) Scenario (2) : 20% Flow reduction

The results of this scenario can be summarized as follows:-

- All intakes of the existing pump stations are safe and covered except four pump stations that will be affected and can't take their water easily. Fig.14 illustrated the longitudinal profile for the studied reach showing the intakes locations of the existing pump stations for December month (low flow) and scenario (2).
- The same islands and uncovered areas in this scenario are the same as in scenario (1) in addition to the following

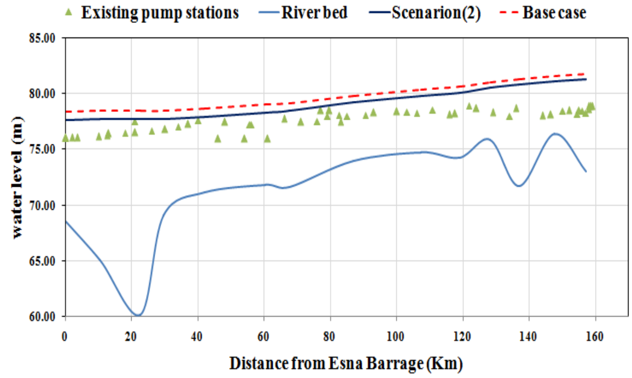

Fig.14. Water Level And Pump Stations For The Longitudinal Profile For Scenario (2).

new areas. At section 5, a new island will be appeared with width of 145 m and length of 2 km as shown in Fig.15. An additional uncovered area at left river bank will be appeared at section 2 with width of 20 m and length of 800 m.

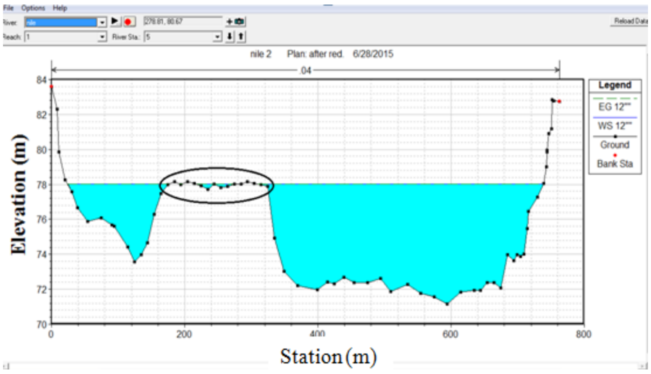

Fig.15. New Island For Scenario (2) In December (2011) At Section (5).

- For scenario (2), the sections that need dredging are the same previous sections for scenario (1) and base case in addition to a required new dredging at section 12.

4) Scenario (3) : 30% Flow reduction

The results of this scenario can be summarized as follows:-

- All intakes of the existing pump stations are safe and covered except eight pump stations that will be affected and can't take their water easily. Fig.16 illustrated the longitudinal profile for the studied reach showing the intakes locations of the existing pump stations for December month (low flow) and scenario (3).

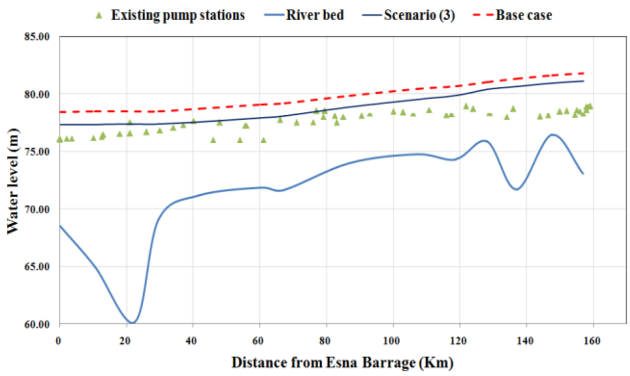

Fig.16. Water Level And Pump Stations For The Longitudinal Profile For Scenario (3).

- The same islands and uncovered areas in this scenario are the same as in scenario (2) with increase in the island width. At section 8, new island will be appeared with width of 31 m and length of 832 m as shown in Fig.17. An uncovered area at the right bank of the river will be appeared at section 12, and section 4.

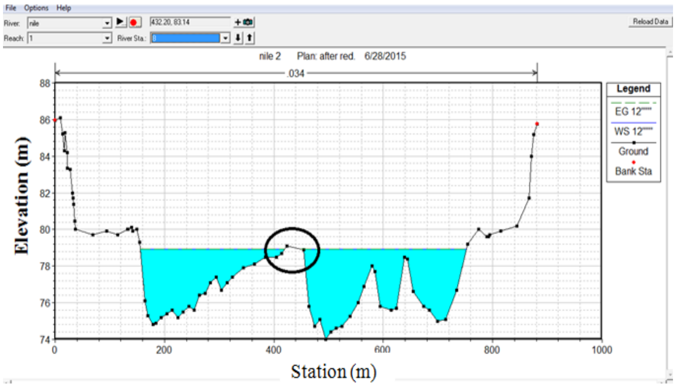

Fig.17. New Island At Section (8) For Scenario (3).

- The required sections to be dredged are the same sections for the base case and the previous two scenarios except the dredging depth will be increased. There is no additional sections that need dredging in this scenario than the previous mentioned ones.

IV. Conclusions

The main conclusion in this paper is studying the effect of flow reduction from HAD on the reduction of water levels and the impact of that on the intakes of the existing pump stations. In addition to studying the effect of that on the appearance of new island , beside the impact on the navigation process in the Nile river. The conclusions can be summarized as follows for low flow condition:-

- The flow reduction from HAD with 10%, 20%, and 30% will affect on expected reduction in the water level along the studied reach as shown in Fig.18. These reductions in water level is maximum at Esna Barrage with about 1.1 m for scenario (3) and the minimum drop of about 0.22m is happened at HAD at first scenario.

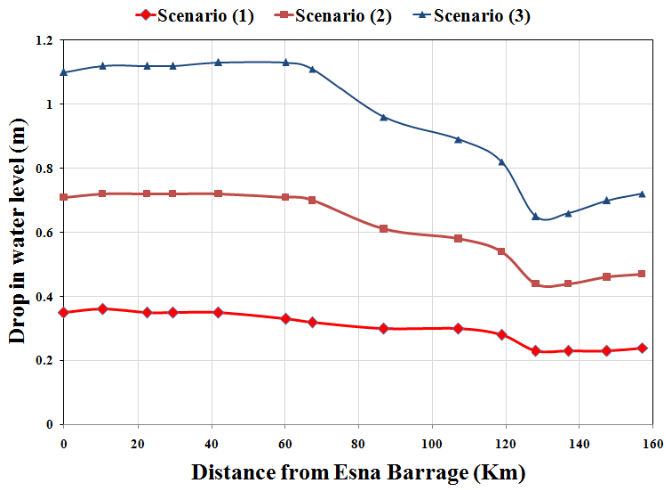

Fig.18. Reduction In Water Level From The Base Case For The Three Scenarios.

- For the intakes of the existing pump stations, the number of pumps that becomes out of services increased with increasing the percentage of flow reduction. For 10% flow reduction, there are no pumps out of services, but for

20% , and 30% flow reduction there are four and eight pumps respectively became out of services.

- For base case, there is already an appearance of one island at section 14, and uncovered areas for the right and left river bank at sections 8,and 11. As the water level decreased along the studied reach, more islands become to be appeared with variable width and length. For more flow reduction with10%, 20%, and 30 % new island will be appeared at section 2, 5, and section 8 respectively. For successful navigation process, it is assumed a minimum required water depth with 2.5m unless there is a need for dredging process. For base case, there are three sections at 8, 5, and 14 that need dredging in the current condition. These sections increased as the reduction in water levels increased. For the three scenarios , there are four additional sections; section 10, 11,12, and 13 need dredging.

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