FLOOD HYDROGRAPH PREDICTION DUE TO GRAND ETHIOPIAN RENAISSANCE DAM BREAK

Mohammed I. Idress[1], *Fahmy S. Abdelhaleem*[2], *Bakenaz A. Zeidan*[1]

[1] *Faculty of Engineering, Tanta University, E- mail: e_m_idress@yahoo.com*
[2] *Benha Faculty of Engineering, Benha University.*

ABSTRACT

Floods due to dam break constitute a potential hazard to life and property at downstream area. During the recent decades several catastrophes have happened due to the failure of dams at various locations in the world. The actual failure modes are not well understood for either earthen or concrete dams. In previous attempts to predict the downstream flooding due to dam failures, it was usually assumed that the dam failed suddenly. The prediction of dam break flood hydrograph is very important for dam safety analysis. Controlling downstream developments, evacuation planning, assessment the damage due to dam break and the propagation of flood waves are additional benefits. The main objective of this paper is to predict the outflow hydrograph which may occur when the GERD break. The risk of the Grand Ethiopian Renaissance Dam (GERD) breaking is numerically presented. Site data, measurements and data collection are analyzed. A suitable numerical model is selected to simulate flood hydrograph after dam break. Expected impacts of the GERD break are simulated. Obtained results are analyzed and presented. Outflow hydrographs due to the failure mode are obtained and highlighted. A risk assessment to the GERD breaking is achieved and different scenarios are proposed. Results of the present paper can help decision makers to set alternative plans to cope with risks of the GERD break.

Key words: Flood Hydrograph, GERD, Dam Break, Numerical Models

1 INTRODUCTION

The length of the Nile River is about 6670 km and has a catchment drainage area of 3.2 million km^2. The Equatorial Lakes plateau in Uganda is drained by tributaries forming the White Nile, which joins the Blue Nile (Ethiopian plateau) at Khartoum, Sudan. Atbara River is another major tributary of the Nile system, which also has its headwater on the Ethiopian plateau and joins the main Nile course at Atbara, north of Khartoum. Thereafter, the main Nile flows through the Saharan Desert without any significant tributaries (El Bastawesy et al., 2014). Dams provide a wide range of benefits such as economic development, increase irrigated area, power generation and flood protected. The Grand Ethiopian Renaissance Dam (GERD) is located on the Abbay/Blue Nile, 20 Km upstream Ethiopia – Sudan border, Fig. 1. The GERD is consisting of two parts, a main dam and a saddle dam. The main dam is a roller compacted concrete dam, with a dam height of 145 m from its foundation, it has a length of 1780 m and a volume of 10.1 million cubic meters (MCM). The saddle dam is a Rock fill dam with a bituminous surface sealing, it has 45 m height, 4800 m long and 644 m+ msl (mean sea level) crest elevation. The GERD reservoir has 640 and 590 m+msl as a full and minimum supply level, respectively. The total storage of the reservoir is 74.01 billion cubic meters (BCM), which is divided into live and dead storages as 59.22 BCM and 14.79 BCM, respectively. The reservoir area will cover 1874 km^2 at full supply level and 606 km^2 at minimum level (IPoE, 2013). The main objective of this paper is to predict the outflow hydrograph which may occurred when the GERD break.

2 STATE OF ART

Ramadan et al. (2011, 2013 and 2015) used a hydrological model to quantify the shortage of water in the active storage of Nasser Lake due to impounding of GERD reservoir. Different scenarios of impounding were considered as 6, 3 and 2 years under different inflow conditions. They used a hydrological model (the river basin modeling and simulation package (MODSIM)). They conducted three scenarios of impounding of GERD and its impact on Lake Nasser storage. First scenario impounding of GERD at normal flow from the Blue Nile through 6, 3, 2 years will decrease the active storage of Nasser Lake by 13.287, 25.413, 37.263 BCM through each year. Second scenario impounding of GERD at min. of average flow from the Blue Nile through 6, 3, 2 years will decrease the active storage of Nasser Lake by 25.963, 37.814, 45.105 BCM per year. Third scenario impounding of GERD at min. flow case through 6, 3, 2 years will decrease the active storage of Nasser Lake by 44.398, 54.415, 55.138 BCM through each year. Their results indicate that the negative impacts of GERD impounding on Lake Nasser Storage will be severe especially if the filling period is shorter than 6 years. Abdelhaleem and Helal (2015) assessed the potential impact of the shortage of Egypt water resources that will reduce the discharge from AHD due to the construction of the GERD on the Nile water in Egypt. They concluded that the maximum allowable reduction in Egypt water share should not be more than 5 - 15%. They recommended the win–win strategy between Egypt and Ethiopia over the capacity of the GERD reservoir, impounding rules of the GERD reservoir and operating rules.

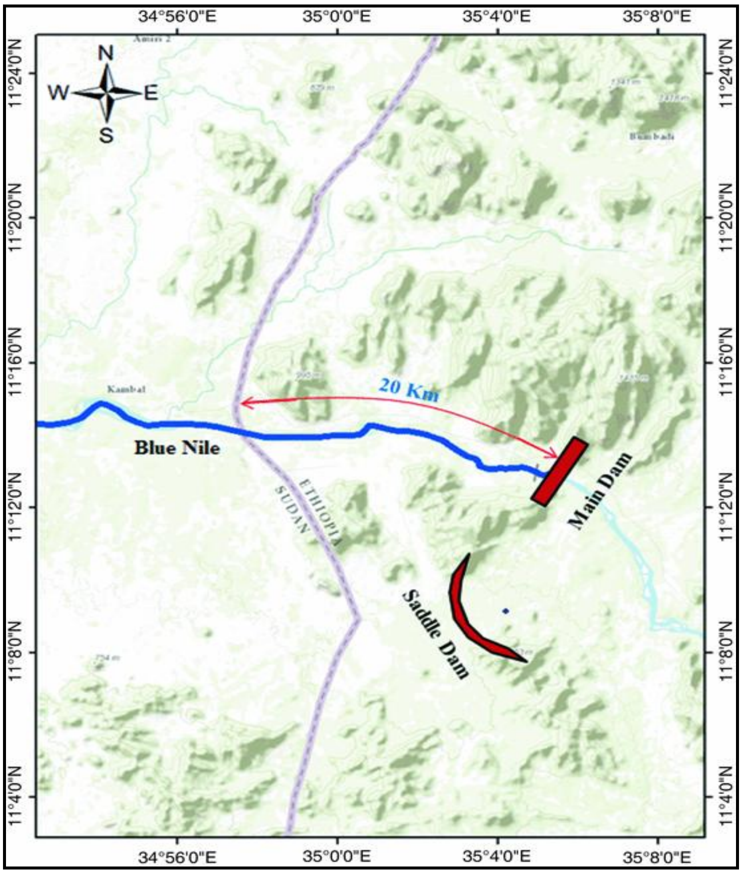

Figure1. GERD location (Soliman et al., 2017)

Failure modes of dams are overtopping, piping, seepage, land slide, foundation failure, structure failure, rapid drawdown of pool and sabotage Hydrologic Engineering Center ,HEC (2010). Floods due to dam break constitute a potential hazard to life and property at downstream area. During the recent decades several catastrophes have happened due to the failure of dams at various locations in the world. The number of significant dam failures that occurred in the period from 1900 to 1990 is

about 123. Failure of the Malpasset concrete dam in 1959 in France caused 421 killed. In Italy in 1963, a land slide fell into the Vaionet Reservoir which cause 110 m as splash wave over dam crest, and two thousand capita were lost their life. Failure at upstream deck of Gouhou Dam, In China, in 1993, leads to local instability and erosion with rapid breaching which are a main cause for 400 killed Novak et al., 2007, and Soliman et al., 2017. Abdelhaleem et al. (2011) assessed the risk of the Aswan High Dam (AHD) breaching due to overtopping and piping, numerically. They designed scenarios to represent minimum, normal and maximum flood flow due to AHD breach employing HR Breach model. Outflow hydrographs due to the failure were simulated using SOBEK 1D2D model. Abdelhaleem et al. (2011) presented flood wave propagation in terms of inundations maps, flows, water levels, flood arrival time, and flow velocities along the water course from Aswan High Dam to Delta Barrages, Egypt. The actual failure modes are not well understood for either earthen or concrete dams. In previous attempts to predict the downstream flooding due to dam failures, it was usually assumed that the dam failed completely and instantaneously, sudden collapse (Mahdi, 2007).
The Grand Ethiopian Renaissance Dam (GERD) has not gained significant interest from researchers, although the importance of the dam in the Sudanese and Egyptian lives. Therefore, this study was initiated in order to assess the GERD breaking risks. The main objective of this paper is to predict the outflow hydrograph which may occurred when the GERD break. Therefore, the area between the GERD's reservoir and the Rosaries Dam on Blue Nile is considered as the study area.

3 STUDY AREA

The Blue Nile has a total drainage area of approximately 330,000 km^2, and approximately contributes the Nile River by 62% of its flow. The Blue Nile basin is characterized by considerable variation in altitude, ranging from 367 m + msl at Khartoum to 4,256 m + msl in the Ethiopian highlands. The source of the Blue Nile is a small spring at about 100 km to the south of Tana Lake with an elevation of 2,900 m + msl. From this spring, the Little Abay River (Gilgile Abay) flows down to Tana Lake. The Tana Lake is the biggest lake in Ethiopia. It has 73 km long and 68 km wide. It is located at 1,786 m + msl and has a surface area of 3,042 km^2 and stores 29.2 BCM of water which fluctuates seasonally. The lake is shallow with a mean depth of 9.53 m, while the deepest part is 14 m. From Tana Lake, the river travels 35 km to the Tissisat Falls, where it drops by 50 m. The river then flows for about 900 km through a gorge crossing the Ethiopian Highlands, which in some places is 1,200 m deep. The Blue Nile basin is divided into 17 major sub-basins namely, Blue Nile Sudan, Dinder, Rahad, Tana, Jemma, Beles, Dabus, Didessa, Jemma, Muger, Guder, Fincha, Anger, Wonbera, South Gojam, North Gojam and Welaka. The Dinder and Rahad rise to the west of Tana Lake and flow westwards across the border joining the Blue Nile below Sennar Dam. The Blue Nile flow is reflected seasonality of rainfall over the Ethiopian highlands, where there are two separate periods. The flood period or wet season extends from July to October with maximum flow in August-September and the low flow or dry season takes place between November and June. The average annual flows of the river downstream Tana Lake (1959–2003) was estimated to be 3.9 BCM and 16.3 BCM, respectively (Ali, 2014). The Blue Nile system encounters several structures from its source to Khartoum, Fig. 2. The existing system consists of small structure such as Chara Weir and Fincha Dam and big structures such as Roseires and Sennar Dams. Available measurements data were collected from different sources. These data described the water levels and the inflows of the dam. Also, metrological data were collected. All these data were analyzed in order to perceive an insight to the physical properties of the breaching process. The analyzed data were a guide in the design of the simulated scenarios.

4 METHODOLOGY AND MODELING

A flood hydrograph due to dam breaks can be estimated based on physically, parametric; predictor and comparison method (U.S. Department of the interior bureau of reclamation, 1988). Hydrologic Engineering Center in the U.S army corps of Engineers developed (HEC-RAS) as a parametric computer models in order to estimate the peak discharge and breach hydrographs from dam break based on breach geometry and breach development time provided by the user. Furthermore, HEC-RAS is employed to estimate the flood routing of the downstream hydrograph (Hydrologic Engineering Center (HEC), 2010). A numerical model is developed to predict the outflow hydrograph, and breach characteristics due to dam failure. Numerical models could be considered as the most widely applied technique to solve mathematical expressions that describe any physical phenomena. These models are mainly classified by number of spatial dimensions over which variables are permitted to provide much more detailed results than others. However, collection of adequate and reliable data is highly required to fulfill the model calibration and verification which lead to successful application. In this study, the HEC-RAS is employed to predict the flood hydrograph due to break of the main concrete dam of the GERD. HEC-RAS can be used to rout an inflowing flood hydrograph through a reservoir with one dimensional unsteady flow routing (full Saint-Venant equation), two dimensional unsteady flow routing (full Saint-Venant equation or Diffusion wave equation) or with level pool routing. A detailed description of the model is given in Hydrologic Engineering Center HEC, (2010). In order to model the GERD; the reservoir of GERD, main dam of GERD, waterway downstream of the GERD and the reservoir of the Roseires dam were simulated. The reservoir of GERD and the Roseires dam were considered as the upstream US and downstream Ds Boundaries, respectively. Dam break scenarios were also designed.

Figure 2. Main dams on the Blue Nile (Circleofblue, 2013)

Model Schematization

To set up the HEC-RAS model, it is necessary to define the upstream boundary which is the GERD's reservoir (Inflow hydrograph), the main dam of the GERD, the cross section of the Blue Nile between GERD and the Roseires Dam, and the downstream boundary (The Roseires's reservoir) as a water levels. The schematization is depicted in Fig. 7.

Upstream Boundary Conditions

The developed model was based on the unsteady flow. The upstream boundary condition was considered in the present investigation as the incoming flow to GERD reservoir within the simulation period which tabulated in Table 1.

Table 1. Inflow discharge to the GERD (ENTRO, 2011a)

Day	Inflow (m^3/s)	Day	Inflow (m^3/s)	Day	Inflow (m^3/s)	Day	Inflow (m^3/s)
1	5817.4	9	7487.8	17	7663.5	25	6596.8
2	7487.8	10	7487.8	18	7663.5	26	6596.8
3	7487.8	11	7487.8	19	7663.5	27	6596.8
4	7487.8	12	7663.5	20	7663.5	28	6596.8
5	7487.8	13	7663.5	21	7663.5	29	6596.8
6	7487.8	14	7663.5	22	7663.5	30	6596.8
7	7487.8	15	7663.5	23	6596.8		
8	7487.8	16	7663.5	24	6596.8		

Reservoir of the GERD

Topography upstream of the GERD area varied from 506 to 1777 m + msl. The construction site of the main dam was in a narrow floodplain area, which is bounded by two high shoulders 1222 and 945 m +msl. This location can only support a lake with a maximum depth of 100 m. This is because the lake at 606 m + msl level will spill over its shore line into the Roseries downstream through a southwestern tributary wadi apart from the main course of the Blue Nile. This is why the saddle dam is being constructed to the west of the main dam. The estimated storage capacity and surface extent of GERD reservoir at a various level is proposed by EL Bastawesy et al. (2014) as presented in Table 2.

GERD's reservoir was modeled using water level by the routing method of HEC-RAS. This technique requires the coordinate of the storage area which was defined by the analysis the satellite images and the geographic information system (GIS). The coordinate of the area of the GERD's reservoir changed with pool level. To propose the worst case, the GERD break considered at the maximum operating level (640 m + msl) with 74 Km^3 as a storage volume. The GERD's reservoir at level of 640 m + msl is depicted in Fig 3. Table 2 is applied to describe the elevation–storage curve for GERD's reservoir model, Fig 4. The reservoir of GERD is input to the model as the US boundary condition.

Table 2. capacity and surface area of the GERD's reservoir (El Bastawesy, et al., 2014)

Water level (m + msl)	Water depth (m)	Surface area (Km^2)	Storage (Km^3)
586	80	442	9.6
606	100	745	17.5
636	130	1560	56
646	146	1954	80.5
686	180	3130	173

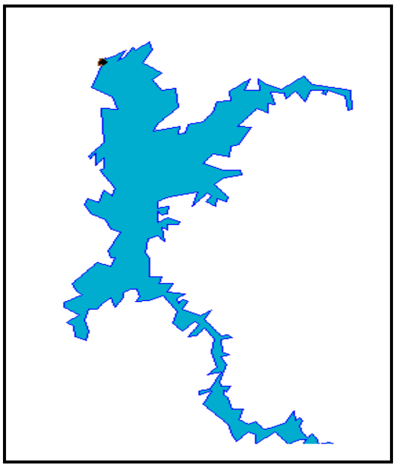

Figure 3.The modeled reservoir of the GERD

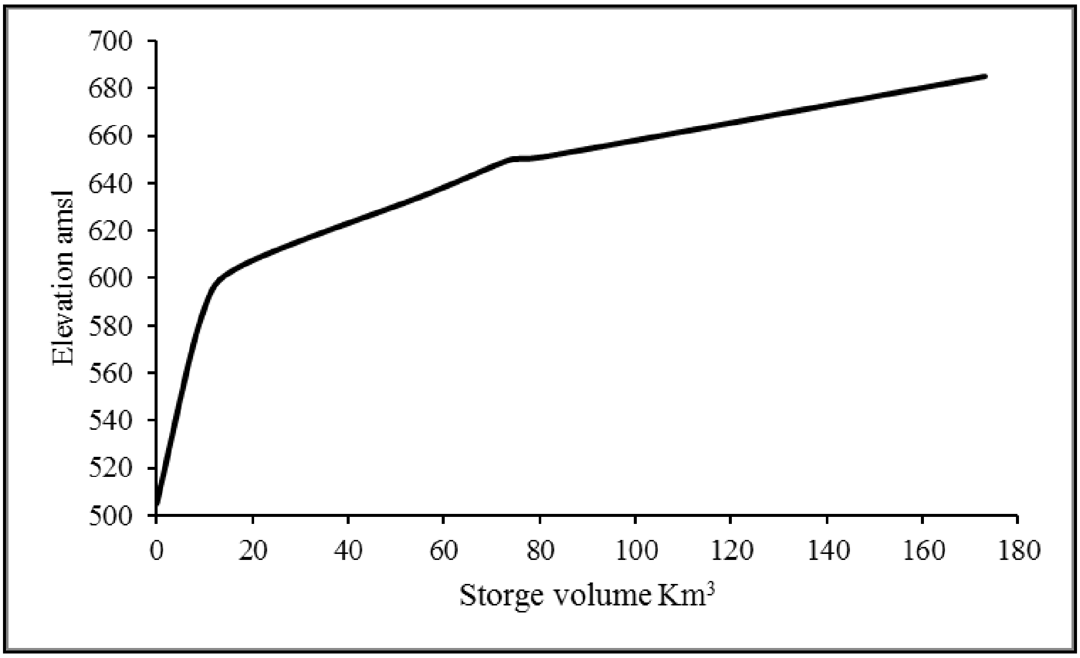

Figure 4. Elevation-Storage curve of the GERD's reservoir

Main Dam of the GERD

The main dam of the GERD was modeled as an inline structure. Inline structure is a barrier through channel connected with channel and reservoir. Main data for model for this case are bottom width which input as 1390 m, bottom elevation of 505 m+ msl, side slope which considered as 1, stating breaching level assumed as 640 m+ msl, pilot flow estimated as 3700 m^3/s and full formation time which varied from 1 to 24 hours to design 15 scenarios.

Modeled Reach

The study flood area was bounded from the GERD as US boundary to the Roseires's reservoir as DS boundary, with approximately 115 Km length. In the way of model this reach in HEC-RAS, the bathymetric data of the reach were collected from available measured data, analysis satellite images, and the GIS. Fig. 7 shows the modeled reach. A digital elevation model (DEM) was employed to predict 28 cross sections through this reach, Fig 5 and 6 show a sample of the considered cross sections.

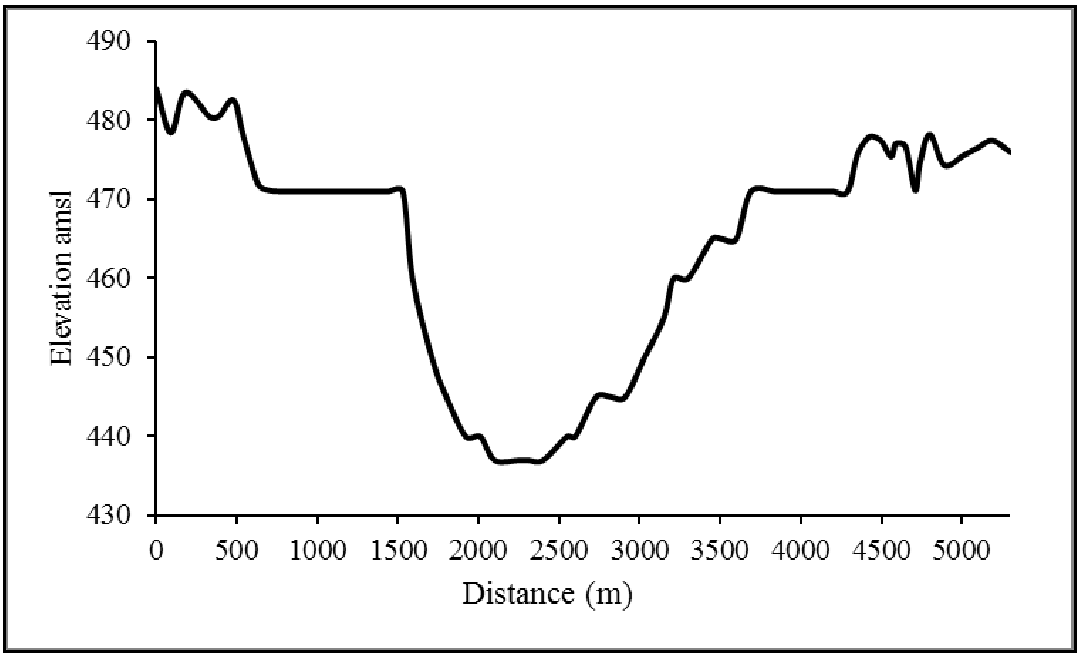

Figure 5. Cross section no. 9

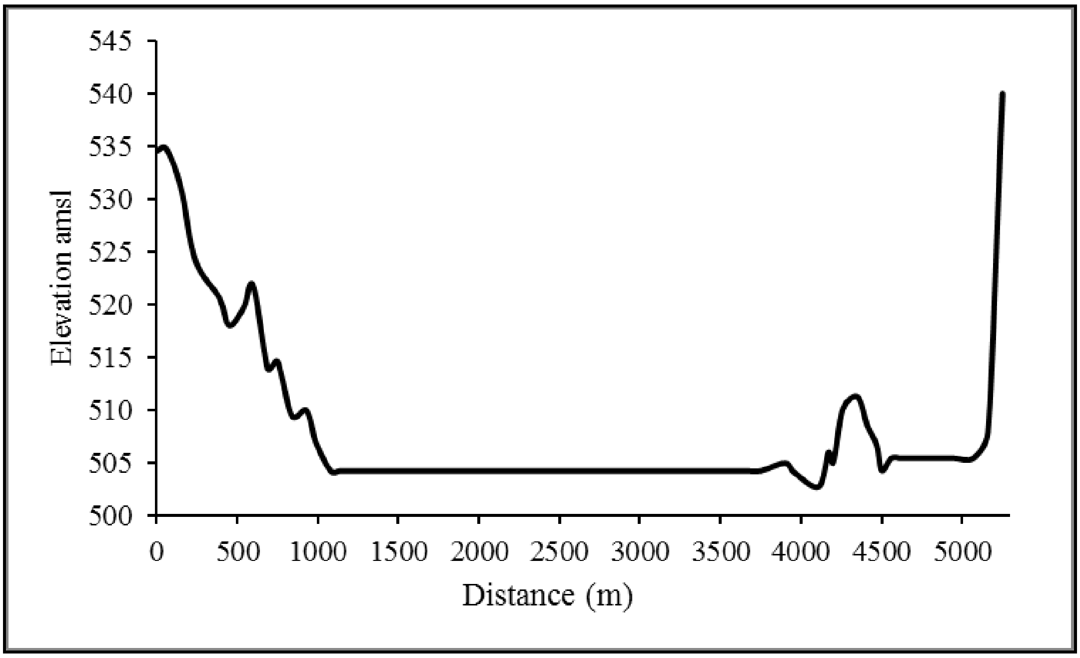

Figure 6. Cross section no. 21

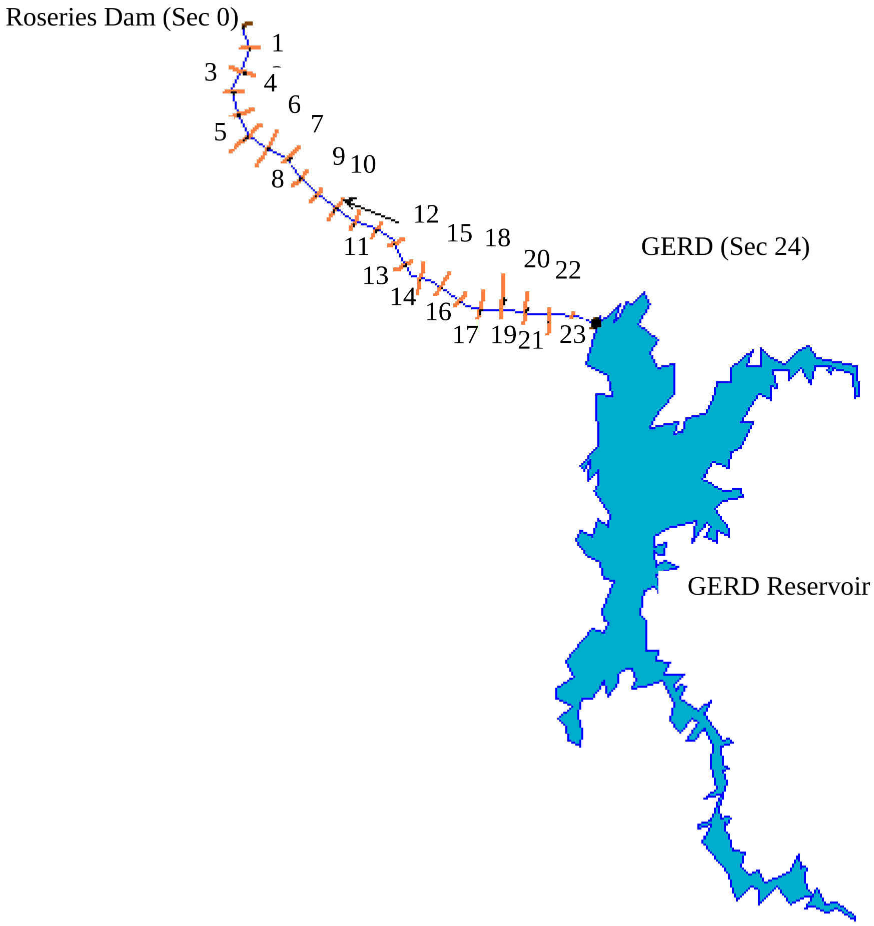

Figure 7. Schematization of the study area

Downstream Boundary

The downstream boundary condition was considered in the present investigation as the water level upstream the Roeires Dam.

Simulation Period

The model was run to estimate the outflow hydrograph due dam break require a setup data, such as, the inflow discharge in 30 days for the GERD's reservoir. 30 days was considered as a simulation period during each failure scenario. It was selected by trial and error to be suitable to the inflow of reservoir.

5 RESULTS AND DISCUSSIONS

The mode of the Main Dam break was considered as overtopping failure starting at water level 640 m+msl. The full formation time was changed from 1 hr to 24 hrs. It was employed to design the break scenarios. 15 scenarios of full formation time of the main dam were considered using 1, 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20, 22 and 24 hrs as the full formation time.

Regarding the overtopping failure mode considered a break, it had a formation time between 1 to 24 hrs. For the first scenario, the formation time was an hour. The reached flow peak was 4563234 m^3/s after 2 hrs from the breaking, Fig. (11). The maximum water stage of flood wave was 645 m+ msl after 3 hrs, Fig (8). For the second scenario, the formation time was 2 hrs. The reached flow peak was 3707612 m^3/s after 3 hrs, Fig. (11). The maximum water stage of flood wave was 639 m+msl after 3 hrs from start the break, Fig (8). For the third scenario, the formation time was 3 hrs. The reached flow peak was 2942611 m^3/s after 7 hrs from start the breaking, Fig. (11). The maximum water stage of flood wave was 640 m+msl after 4 hrs from the start of breaking, Fig (8). For the fourth scenario, the formation time was 4 hrs. The peak flow was 2383245 m^3/s after 7 hrs, Fig. (11). The maximum water stage of flood wave was 637 m + msl after 5 hrs, Fig (8). For the fifth scenario, the formation time was 5 hrs. The reached flow peak was 2382912 m^3/s after 8 hrs, Fig. (11). The maximum water stage of flood wave was 639 m + msl after 5 hrs, Fig (8). For the sixth scenario, the formation time was 6 hrs. The reached flow peak was 2371625 m^3/s after 9 hrs, Fig. (12). The maximum water stage of flood wave was 637 m + msl after 6 hrs from the start of break, Fig (9). For the seventh scenario, the formation time was 8 hrs. The reached flow peak was 2367545 m^3/s after 10 hrs, Fig. (12). The maximum water stage of flood wave was 634 m + msl after 7 hrs, Fig (9). For the eighth scenario, the formation time was 10 hrs. The reached flow peak was 2350758 m^3/s after 11 hrs, Fig. (12). The maximum water stage of flood wave was 632 m + msl after 9 hrs from the start of break, Fig (9). For the ninth scenario, the formation time was 12 hrs. The reached flow peak was 2319606 m^3/s after 12 hrs, Fig. (12). The maximum water stage of flood wave was 630 m + msl after 10 hrs from the start of break, Fig (9). For the tenth scenario, the formation time was 14 hrs. The reached flow peak was 2297598 m^3/s after 14 hrs from start the break, Fig. (12). The maximum water stage of flood wave was 628 m + msl after 12 hrs from the start of break, Fig (9). For the eleventh scenario, the formation time was 16 hrs. The reached flow peak was 2269893 m^3/s after 15 hrs from start the break, Fig. (13). The maximum water stage of flood wave was 624 m+msl after 14 hrs from the start of break, Fig (10). For the twelfth scenario, the formation time was 18 hrs. The reached flow peak was 2264992 m^3/s after 17 hrs from start the break, Fig. (13). The maximum water stage of flood wave was 623 m + msl after 15 hrs from the start of break, Fig (10). For the thirteenth scenario, the formation time was 20 hrs. The reached flow peak was 2260478 m^3/s after 18 hrs, Fig. (13). The maximum water stage of flood wave was 620 m + msl after 17 hrs, Fig (10). For the fourteenth scenario, the formation time was 22 hrs. The reached flow peak was 2162607 m^3/s after 20 hrs, Fig. (13). The maximum water stage of flood wave was 618 m + msl after 18 hrs, Fig (10). For the fifteenth scenario, the formation time was 24 hrs. The reached flow peak was 2130869 m^3/s after 21 hrs, Fig. (13). The maximum water stage of flood wave was 616 m + msl after 20 hrs, Fig (10). The Peak discharge and stage due to the considered break of the GERD is tabulated in Table 3 and 4.

Data obtained from modeled different scenarios revealed that the worst full formation time is 1, 2 and 3 hrs. The peak discharge from full formation time was 4 to 24 hr is between 2 $x10^6$ to $2.5x10^6$ m^3/s. There were lag time from full break to peak discharge is between 1 to 4 hrs, and from high water level and full formation time. Flood hydrograph due to the GERD break and stage hydrograph for the different scenarios are shown in Figs 8 through 13. The time between the start and the end of the hydrograph wave was two days.

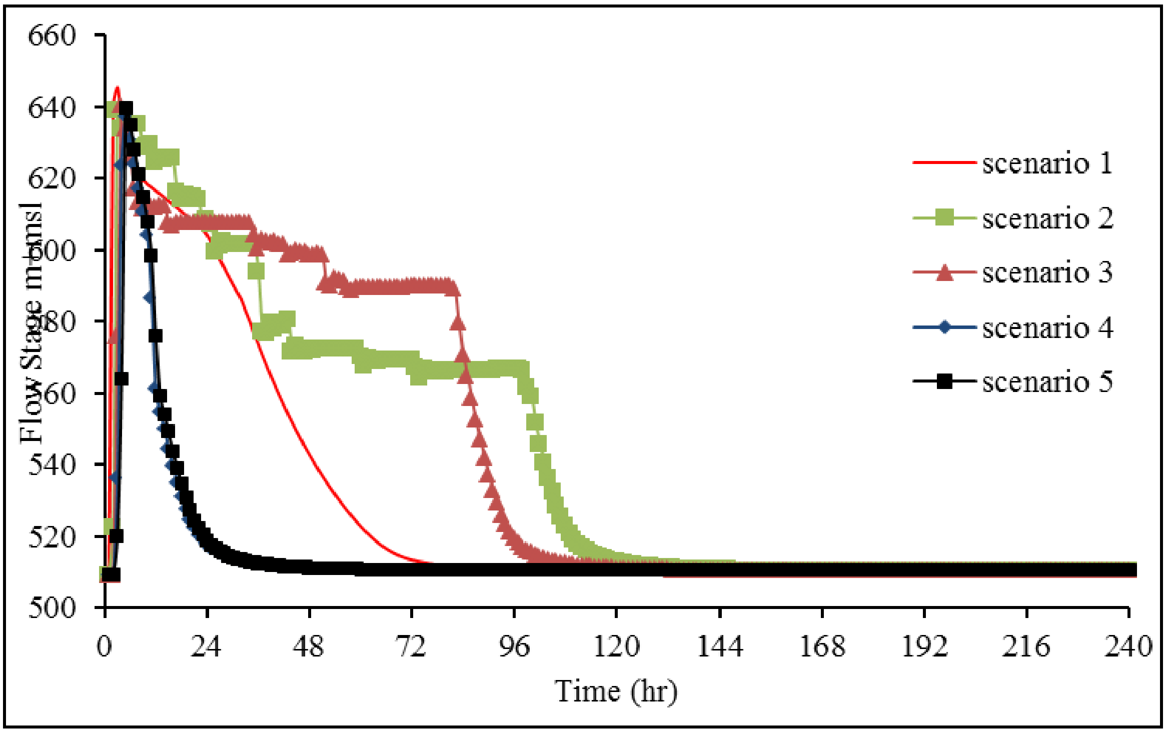

Figure 8. Stage curves of scenarios 1, 2, 3, 4 and 5

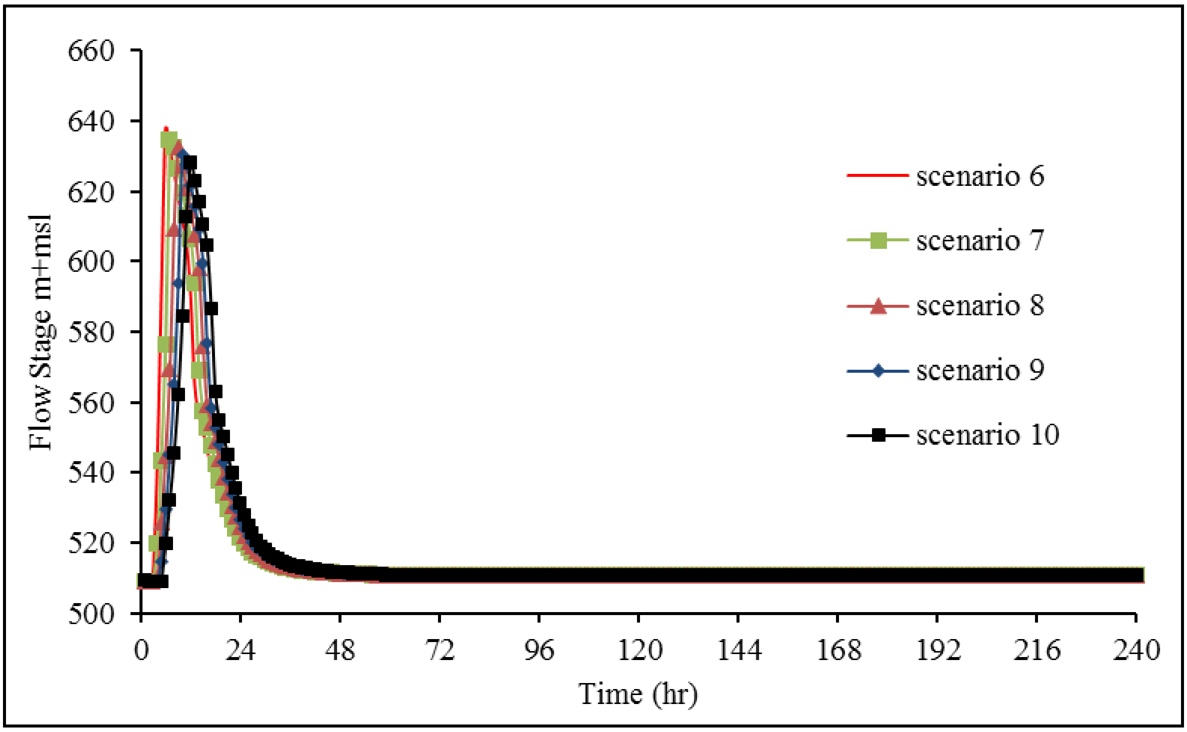

Figure 9. Stage curves of scenarios 6, 7, 8, 9 and 10

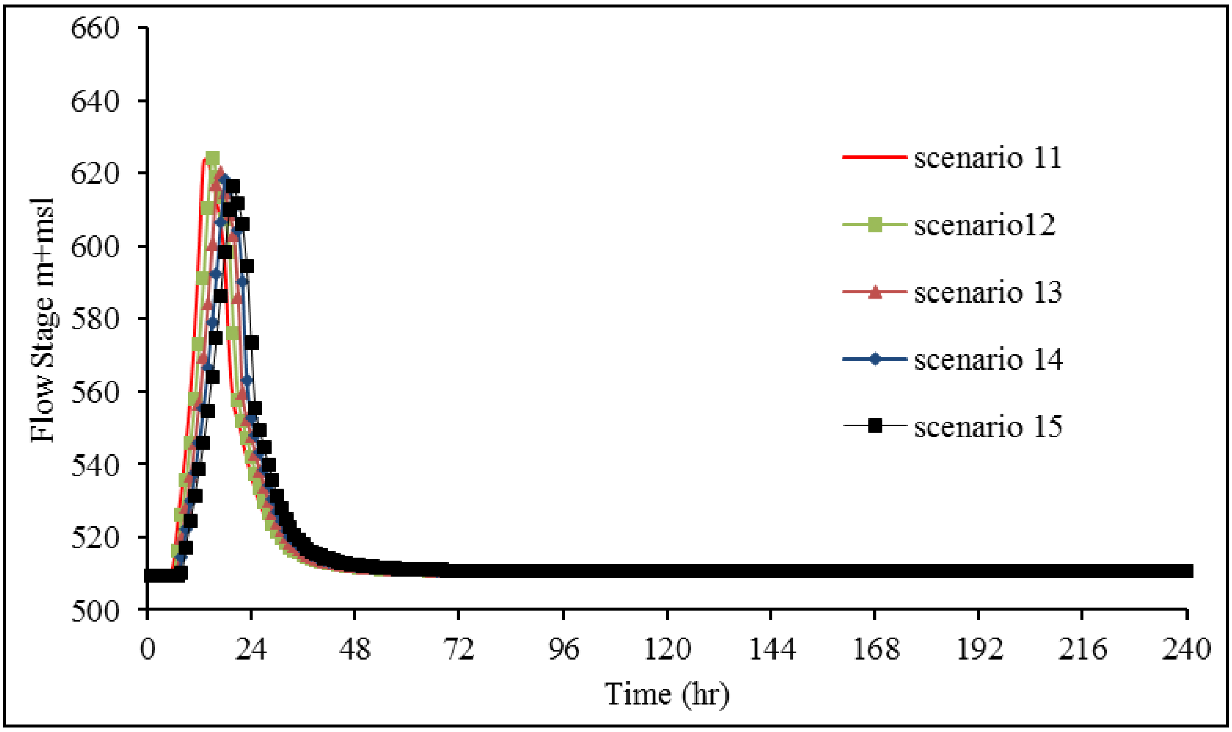

Figure 10. Stage curves of scenarios 11, 12, 13, 14 and 15

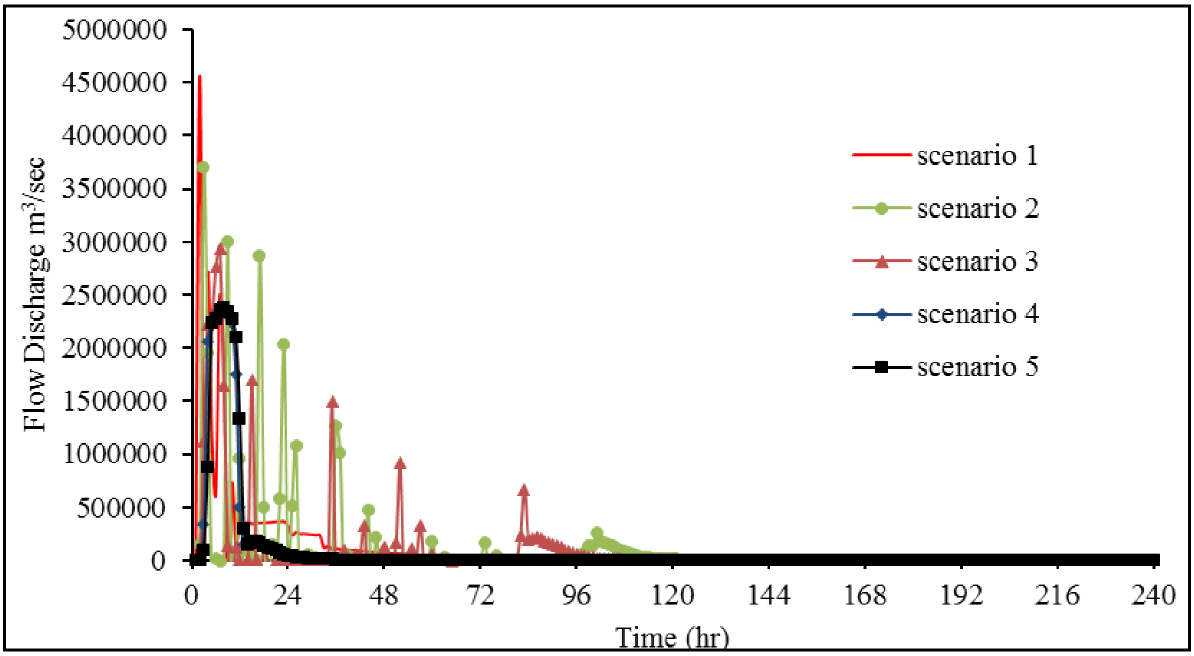

Figure 11. Flood hydrographs of scenarios 1, 2, 3, 4 and 5

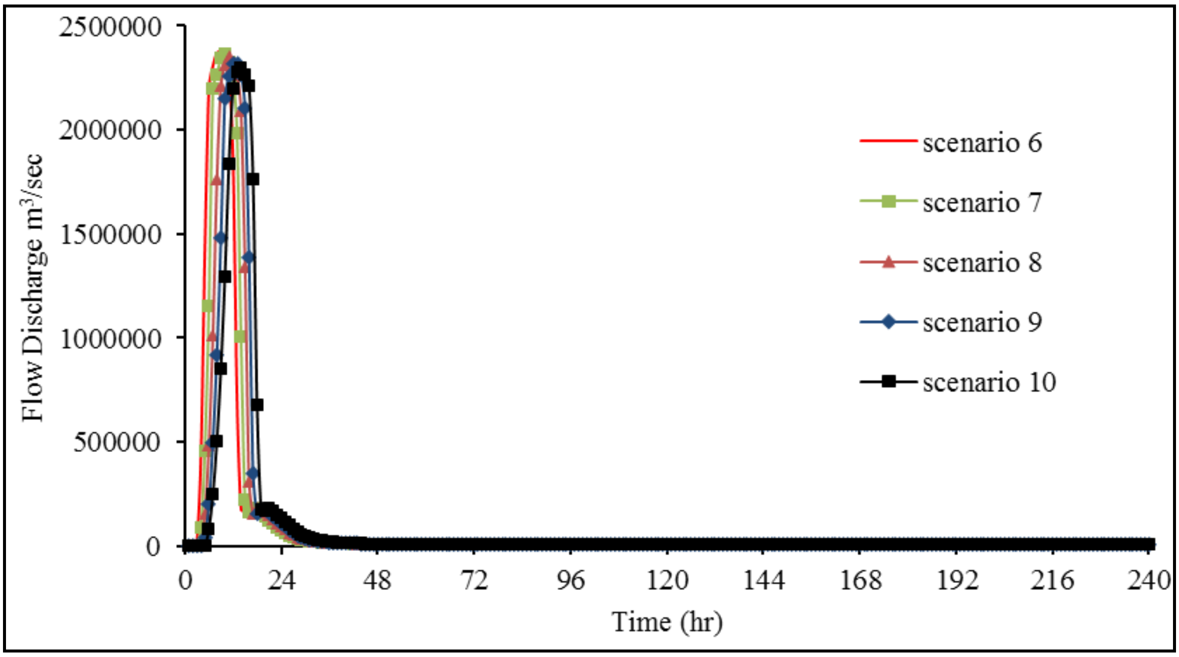

Figure 12. Flood hydrographs of scenarios 6, 7, 8, 9 and 10

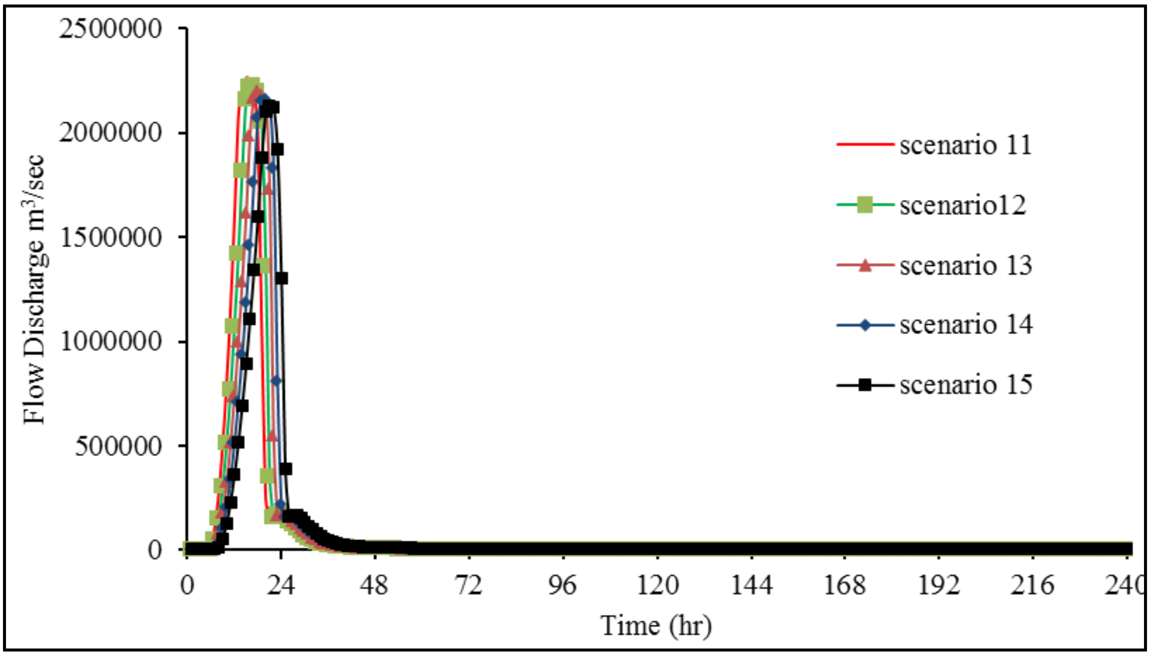

Figure 13. Flood hydrographs of scenarios 11, 12, 13, 14 and 15

Table 3. Peak stage due to the GERD break

Scenario no.	Full formation time (hr.)	Stage (m + msl)	Time from start break (hr.)	Scenario no.	Full formation time (hr.)	Stage (m + msl)	Time from start break (hr.)
1	1	645	3	9	12	630	10
2	2	639	3	10	14	628	12
3	3	640	4	11	16	624	14
4	4	637	5	12	18	623	15

5	5	639	5	13	20	620	17
6	6	637	6	14	22	618	18
7	8	634	7	15	24	616	20
8	10	632	9				

Table 4. Peak discharge due to the GERD break

Scenario no.	Full formation time (hr.)	Discharge (m^3/s)	Time from start break (hr.)	Scenario no.	Full formation time (hr.)	Discharge (Q) m^3/s	Time from start break (hr.)
1	1	4563234	2	9	12	2319606	12
2	2	3707612	3	10	14	2297598	14
3	3	2942611	7	11	16	2269893	15
4	4	2383245	7	12	18	2264992	17
5	5	2382912	8	13	20	2260478	18
6	6	2371625	9	14	22	2162607	20
7	8	2367545	10	15	24	2130869	21
8	10	2350758	11				

6 CONCLUSIONS

GERD break modeling reveals that the peak outflow ranges from two to 4.5 MCM per second and occurs within 48 hours from the beginning of GERD break. Wave estimated from the GERD break could be have a stage between 615 to 645 m+msl. A Flood Model will employ these outflow hydrographs to simulate the Blue and the Main Nile downstream the GERD. Inundations hazards and risk analysis will be assessed. The impacts of such a catastrophic event on the inhabited areas or any urban which might be in the path of the flood surge waves will be evaluated. Flooding studies might assist engineers in designing protective and measures to assure the safety of the affected areas, and to develop emergency evacuation procedures.

REFERENCES

Abdelhaleem, Fahmy S, Helal Y. E, (2015). Impacts of Grand Ethiopian Renaissance Dam on Different Water Usages in Upper Egypt. British Journal of Applied Science & Technology, 8(5): pp. 461-483, 2015.

Abdelhaleem, Fahmy S, Helal Y. E, El-Belasy A., Ibrahim S.A, and Sobeih M.F. (2011). Assessing the risk of the Aswan High Dam Breaching. Engineering Research Journal, ERJ, Faculty of Engineering, Minoufiya University Vol. No.933, January 2011

Abdelhaleem, Fahmy S., Ibrahim SA, El-Belasy AM (2011). Prediction of breach formation through the Aswan High Dam and subsequent flooding downstream. *Nile Water Science and Engineering Journal. 2011:4(1):99-111. ISSN: 2090-0953.*

Ali, Y.S.A. (2014). the impact of soil erosion in the upper Blue Nile on downstream reservoir sedimentation. *PhD. thesis, the UNESCO-IHE Institute for Water Education*.

Circleofblue (2013). http://www.circleofblue.org/2013/world/infographic-wealth-of-the-nile-basins-countries-dams-gdp-per-capita/ 7/4/201

El Bastawesy, M., Gabrac **S.**, Mohamed, I. (2014). Assessment of hydrological changes in the Nile River due to the construction of Renaissance Dam in Ethiopia, The Egyptian Journal of Remote Sensing and Space Sciences, Vol. 18, No. 1, June 2015, pp. 65-75.

ENTRO (2011a). Eastern Nile Irrigation & Drainage (ENID) Knowledge Base Development, Final Report, Eastern Nile Technical Regional Office (ENTRO), Ethiopia, 2011.

Hydrologic Engineering Center (HEC), (2010) Hydrologic Engineering center-river analysis system (HEC-RAS): Hydraulic Reference Manual, version 4.1 HEC, U.S. army corps of engineering center.

International Panel of experts (IPoE) on Grand Ethiopian Renaissance Dam Project (GERDP). (2013) Final Report, Addis Ababa, Ethiopia, May, 31st; 2013. Available:http://www.internationalrivers.org

Mahdi, Rana S. (2007), Dam Break Modelling and Flood Wave Propagation in Urban Area: The Bovilla Dam, *MSc Thesis April 2007, UNESCO-IHE INSTITUTE FOR WATER EDUCATION*

Novak, P., Moffat, A.I.B., Nalluri, C., Narayanan, R. (2007). Hydraulic Structures.Taylor& Francis, Fourth edition.

Ramadan SM, Negm AM, Owais TM. (2011). Effect of new upper Nile Project on the integrated Management of The Basin, *Proc of fifteenth int. water technology conf. (IWTC 15), Alexandria, EGYPT, 2011*

Ramadan SM, Negm AM, Samany M, Helmy AHM (2013). Environmental Impact of Great Ethiopian Renaissance Dam on the Egyptian water resources management and security, *the 23th international conference on: Environmental protection is a must, 11-13 May, Alexandria, Egypt, 2013*

Ramadan SM, Negm AM, Smanny M, Helmy AHM. (2015), Quantifying the impacts of impounding Grand Ethiopian Renaissance Dam Reservoir on Nasser Lake active storage, *Proc. of eighteenth Int. Water Technology Conf. (IWTC 18), Sharm ElSheikh, 12-14, Egypt, March; 2015.*

Soliman, Ahmed H., El Zawahry Alaa , Bekhit Hesham (2017). GERD Failure Analysis and the Impacts on Downstream Countries, the Handbook of Environmental Chemistry. Springer, pp. 1-23.

U.S. Department of the interior bureau of reclamation (1998), downstream hazard classification guidelines,https://www.arcc.osmre.gov/resources/impoundments/USBR-TechMemo11-DownstreamHazardClassificationGuidelines1988.pdf.