A STUDY OF SEISMICITY AND EARTHQUAKE LOADING AT THE PROPOSED KALABSHA DAM SITE, ASWAN, EGYPT

Raafat E FAT-HELBARY[1] And Aly A TEALB[2]

SUMMARY

High and Aswan Dams Authority (HADA) proposed a plan aiming at constructing a rockfill dam in the Kalabsha area, about 60 km south of Aswan High Dam. The aim of this dam is to restrain the overflow of water to the Kalabsha Valley for keeping one billion cubic meters from being lost due to seepage and evaporation. The safety of dams during earthquakes is extremely important because failure of such a structure may have disastrous consequences on life and property. Therefore, different factors were considered as part of a site assessment. Five seismic source zones close enough to the site to give rise to potentially damaging earthquake ground motions were identified. Seven significant active faults that have the potential for producing significant earthquakes and that pass through or near the dam site were also identified. The earthquake loading represented by ground motions at the site was evaluated. Probabilistic seismic hazard procedures were conducted in detail in assessing the earthquake loading at six individual sites using Area and Line Source Models. The output represents the expected acceleration amplitude with 90 percent probability of not being exceeded in exposure times of 20, 50, and 100 years. The results from the two models appear to be different, in that for the area source model (ASM) the expected ground motions were found to be about twice as high as expected from the Line Source Model (LSM). This difference is due to the activity induced from the load of the Nasser Lake activating those parts of the faults that lie under the lake at Kalabsha area. The hazard curve that is represented by the relationship between the peak ground acceleration and its annual exceedance probability at the selected sites is given. By comparing the curves for the six individual sites for the same source model, it can be concluded that the potential ground acceleration level for the all sites is almost the same. Considering the mean results from the two models, the annual exceedance probability of the expected ground acceleration from ASM appears to be approximately ten times higher than the annual exceedance probability from LSM.

Accordingly, since the expected earthquake loading from ASM is more threating to the dam site than the earthquake loading from LSM, the earthquake loading from ASM should be taken in consideration for the design of Kalabsha Dam

INTRODUCTION

Lake Nasser expands approximately 350 km in the southern part of the Egyptian territory along the main course of the River Nile, and 150 km in the Sudan. The average flow of the Nile is 84 billion cubic meters per year, 55.5 billion cubic meters are allocated to Egypt, 18.5 billion cubic meters are allocated to Sudan and 10 billion cubic meters lost as seepage and evaporation. Kalabsha valley spreads from Nasser Lake and represents 1/10 of the total lake area. Aswan High Dam Authority proposed a plan aiming at constructing a rockfill dam in Kalabsha area (about 60 km south of Aswan High Dam). The aim of this dam is to restrain the overflow of water to the Kalabsha valley for keeping 1 billion cubic meters from being lost.Seismic hazard can be defined as the probability of occurrence of an earthquake or earthquake effects of a certain severity, within a specific period of time, in a given area (Coburn and Spence, 1992). According to the type of analysis that is being made, the earthquake may be specified in terms either of its source characteristics or its effect at a particular site. The source characteristics of earthquakes are most commonly specified in terms of the magnitude. The site characteristics of earthquake are expressed in terms of an intensity of parameter of severity of ground motion

[1] *Aswan Seismological Center P. O. Box, 152, Aswan, Egypt*
[2] *National Research Institute of Astronomy and Geophysics, Helwan, Cairo, Egypt*

vibration such as MSK or Modified Mercalli intensity scale, or in terms of peak ground acceleration or some other parameter derived from measured characteristics of the motion. Seismic hazard may be expressed in terms of average expected rate of occurrence of the specified type of event, or on a probabilistic basis. In either case, annual recurrence rates are usually used. The engineers and urban planners in different countries have used two main approaches to seismic hazard analysis. The first approach is the

deterministic one, which does not take into account the uncertainties in the size, location, occurrences and times of seismic events and other characteristics of future earthquakes (Shah and Dong, 1984). Instead, it adopts for these factors that entails extremely large design requirements. The second approach is a probabilistic one, which is based on the assumption that seismicity is equal a Poisson process, with event magnitude exponentially distributed, and equal probability of occurrence over a seismogenic zone. Cornell (1968) first introduced the theoretical assumption of the second approach and it has been computerized by various authors (Algermissen and Perkins, 1976; McGuire, 1976) by considering the seismic sources as wide areas or as linear faults. For each seismic source, the geometry, recurrence relationship and attenuation relation are needed. The output of a seismic hazard analysis using this approach is expressed by the probability distribution of a maximum specified acceleration or intensity levels corresponding to a given return period at the individual site. The investigated site in this study is the Kalabsha Dam site in Kalabsha area, southern Egypt as shown in Fig. (1).

The site of proposed Kalabsha Dam is represented by three segments AB, CD, and EF. Different factors were considered as a part of a site assessment, including identification of the seismic source zones that are close enough to the site to give rise to potentially damaging earthquake ground motions. Similarly identification of significant active faults that have potential for producing significant earthquake and which pass through or near the dam site. The probabilistic seismic hazard analysis will assess the earthquake loading at six individual sites (A, B, C, D, E, and F) along the proposed Kalabsha Dam. A probabilistic seismic hazard assessed by implementing the Cornell-McGuire probabilistic method (Cornell, 1968, McGuire; 1976, 1978) will apply for two cases, the area-source model and the line source model. In the first case we will use the catalogue of the instrumentally recorded earthquakes that may have been triggered by the Aswan reservoir. For the second case the sources of naturally occurring earthquakes identified as by five significant active faults in the region will be used.

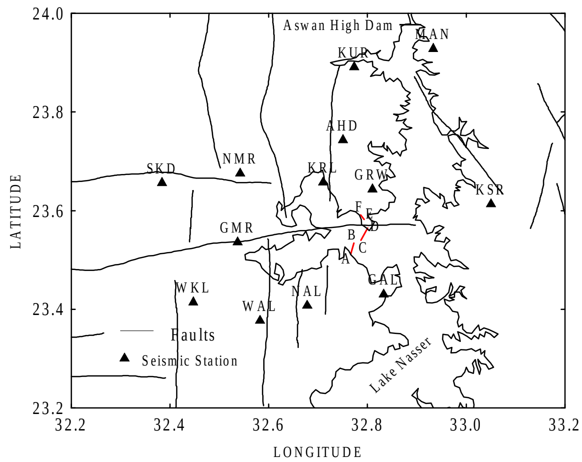


Fig. (1) Proposed Kalabsha Dam as represented by three segments AB, CD, and EF (solid Lines denote the faults around the dam and solid triangles represent the telemetry seismic stations)

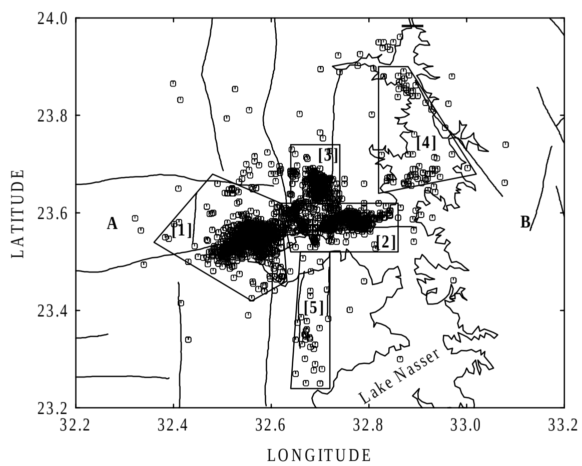


Fig. (2) Epicentral distribution of the catalogued events in the Kalabsha area in the period from 1976 to 1997 as recorded by telemetered seismic stations.
The seismicity is concentrated in five main cluster zones: [1] Gabel Marawa, [2] East of Gabel Marawa, [3] Khor el Ramla, [4] Old stream and [5] Abu Dirwa.

SEISMICITY AND SEISMIC ZONES CLOSE TO THE PROPOSED DAM SITE

The largest of the Aswan earthquakes was of magnitude 5.6 m_b and occurred on 14 November 1981, about 20 Km east of the proposed Kalabsha Dam site.

Prior to 14 November 1981, no earthquakes had been reported from the Aswan area in the catalogue of the International Seismological Center (ISC) since its inception in 1920. Because of the lack of continuous and reliable data during the early stages of filling of the reservoir, it is not possible to determine exactly when low-magnitude activity may have started. The first seismographs installed in the Aswan area that were capable of recording small local earthquakes were Soviet short-period (SMK) instruments installed at Aswan and Abu Simble in 1975. Although the operation of the stations was irregular prior to 1981, 20 events of magnitude greater than 2.5 have been identified by National Research Institute of Astronomy and Geophysics (NRIAG) as possibly occurring in the Wadi Kalabsha area. Thirteen of these took place during approximately 200 days of station operation between August 1980 and August 1981. A long sequence of aftershocks followed the 14 November 1981 earthquake including the immediate aftershocks and the continuation of Aswan activity until the present in the area of the main shock and other locations around the northern part of the Aswan reservoir. A telemetered seismic network of 13 short-period seismograph stations was installed by NRIAG at Aswan Reservoir in July 1982 to monitor induced seismicity near the site of magnitude 5.5 earthquake which occurred in November 1981 as shown in Fig. (1). The equipment of Aswan telemetered seismograph network are described in details by Simpson et al, (1987). Data are telemetered to the main center to record the output signals coming from the field stations. All the data are recorded in analogue and digital form. The computer program HYPOINVERSE (Kelin, 1978) was used for computing hypocenteral parameters for earthquakes around Kalabsha fault system. Using as input stations, arrival times at each station of P-and /or S-waves and a measure of seismic signals duration in seconds for each station.

The computer output is provided in the form of latitude, longitude, focal depth, origin time, epicentral distance for each station, azimuth for each station from epicenter and various measures of the accuracy of the location. The output data is used for constructing the seismicity map of the Kalabsha area as shown in Fig. (2). The seismicity map of the Kalabsha area shows that the seismicity is concentrated in five main cluster zones close to the proposed dam site, these zones are:

(1)Gabel Marawa Zone. This is the most active zone and located around the place of the November 1981 main shock on the Kalabsha fault. The seismicity in this zone is almost all between depths of 15 and 26 km. The composite fault plane solution of the earthquakes indicates pure strike slip faulting with a normal-fault component. The fault plain strikes 78^o and dipping 70°, (Fat-Helbary, 1989).

(2) East of Gabel Marawa Zone. This zone, northeast of Gabel Marawa zone, is located along Kalabsha fault and the focal depth of the events is shallow (between 0 and 10 km). The composite fault plane solution indicates strike-slip faulting with a normal fault component. The fault plane striking 70^o and dipping 70^o (Fat-Helbary, 1989).

(3)Khor el Ramla Zone. It is the second most active zone after Marawa zone, and includes all the shallow activity (between 0 to 10 km) located north east of Gabel Marawa and west the surface trace of the Khor El-Ramla Fault. The composite fault plane solution indicates a strike-slip fault. The fault plane that strikes 155^o and dipping 65^o (Fat-Helbary, 1989).

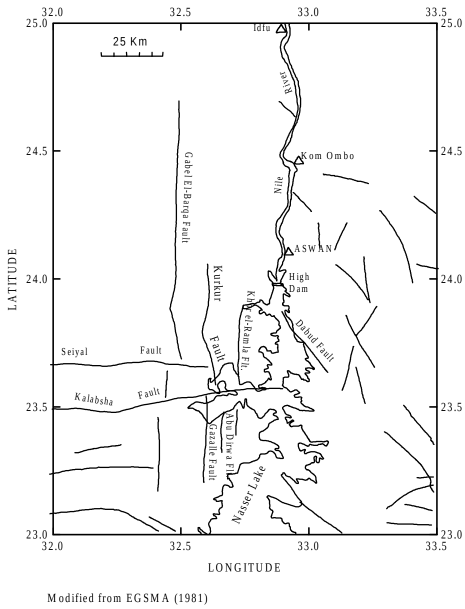
(4) Old Stream Zone. All the epicenters which have been located in the Nile River channel are located along one segment (40 km) that extends from Khor Kalabsha in the south to Khor Kurkur in the north. The fault plane solution indicates strike slip faulting. The fault plane strikes 161^o and dipping 77° (Ali, 1992).

(5) Abu Dirwa Zone. This is the only north south trend of activity recorded south of Kalabsha fault and it associated with the Abu Dirwa fault. Compared with the other Kalabsha activity zones, this is the only active zone located away from the reservoir, in an area that has not been covered with the reservoir water. The focal mechanism of this zone is strike slip fault with normal component. The fault plane strikes 177^o from the north and dipping 61° (Ali, 1992).

IDENTIFICATION OF FAULTING SYSTEM

The tectonic history of the area is complex and mainly determined by faulting system. The faults to the west of the Lake Nasser form the Western Desert fault system, which includes two major fault trends, N-S and E-W, (Issawi, 1969, 1978). The two sets of fault trends in the vicinity of the reservoir are post Upper Cretaceous (Nubian Sandstone) faults. It could be judged from their trends and positions that they are associated with the uplift of the Eastern Desert basement known to be Post Lower Pre-Middle Eocene age (Said, 1962). These faults are the Kalabsha, Seiyal, Gebel El-Barqa, Kurkur, Khour el Ramla, Abu Derwia and Gazal faults. Several other faults having generally East-West trend were mapped from this area (Issawi, 1969) but they are of lesser extent, cutting mainly through sandstone beds. Many small faults were mapped from the area, such as those having trends oblique to the two fault systems in the area as in Fig. (3)

Woodward-Clyde Consultants (WCC, 1985) evaluated the fault system in the Kalabsha area and reported that the Western Desert fault system consists of a set of east-west



Modified from EGSMA (1981)

Fig. (3) Location of fault system distributed around proposed Kalabsha Dam Site in Kalabsha area

faults that exhibit right-slip displacement, and a set of north-south faults that exhibit left-slip displacement. The east-west faults are longer, have had greater degree of activity in the Quaternary, and have larger total displacements (about 0.03 mm per year) than the north south faults (0.01 to 0.02 mm per year). The main faults were identified as active faults that have the potential for producing significant earthquake and pass through or near the dam site are:

(1) Kalabsha Fault: Is a prominent west-trending fault that is considered to have been the source of the November 1981 earthquake. The Kalabsha fault has continuous, closely related traces that extend 185 Km. This is considered to be the length of the fault. Geologic , geomorphic, and seismologic evidence indicate that the Kalabsha fault is a right-slip fault. Several locations along the Kalabsha fault have geologic evidence of multiple surface fault displacements during the Quaternary Period. The geomorphic expression, stratigraphic evidence of Quaternary displacement and earthquake associated with the fault clearly indicate that the Kalabsha fault is an active fault.

(2) Seiyal Fault: It is subparallel to and approximately 12 km North of the Kalabsha fault. The length of the fault is about 90 km. Based on the right-stepping en echelon folds commonly associated with the Seiyal fault. The fault is interpreted to have a right-slip sense of displacement. The prominent geomorphic expression of the Seiyal fault, combined with the stratigraphic evidence of Quaternary fault displacement observed at Seiyal exploration locality, indicate that the fault is active.

(3) Gabel el-Barqa Fault: It is a north-trending fault approximately 40 km west of the Nile River. The length of the fault is about 110 km. It is interpreted to be a left-slip fault. Displaced or warped Quaternary deposits were identified at four locations along the Gebel el-Barqa fault. The degree of activity of the Gebel el-Barqa fault is estimated to be low compared with other faults worldwide.

(4) Kurkur Fault: It is a north-trending fault 28 km from the High Dam at its closest approach. The length of the fault is about 44 km. It is interpreted to be a left-slip fault, the small, left-stepping en echelon folds that are common along the fault trace indicating this sense of displacement. The degree of activity of the Kurkur fault is estimated to be very low when compared with other faults in the Aswan study region and with active faults worldwide.

(5) Khor el-Ramla Fault: It is a north-trending fault with length about 36 km. A cluster of microearthquake that trends approximately north has been recorded around the southern end of the fault. The degree of activity of the Khor el-Ramla fault is estimated to be very low.

(6) Gazelle Fault: It is a north-trending structure situated south of the Kalabsha fault. At its closest approach, the fault is approximately 55 km. southwest of the High Dam. The fault has a length of about 35 km, and an inferred left-slip sense of displacement. The fault is located entirely through rocks of the Nubia Formation.

(7) Abu Dirwa Fault: It is a north-trending structure that is a few kilometers to the east of the Gazelle fault. At its closest approach, the fault is 50 km south of the High Dam. The fault has a length of 15 km, and is inferred to have a left-slip sense of displacement.

ASSESSMENT OF EARTHQUAKE LOADING FROM AREA SOURCE MODEL (ASM)

The probabilistic seismic hazard analysis was conducted in detail in assessing the earthquake loading at six individual sites (A, B, C, D, E and F) along the proposed Kalabsha Dam site. The objective of analysis was to evaluate the probability of exceedance for different levels of ground shaking due to earthquake that occurred in and around the site of the proposed Kalabsha dam.

All data and relating to seismic activity with magnitude ≥ 3.0 in Kalabsha area are collected and analyzed. The purpose of analysis:

(a) Identification of all seismic sources in the area

(b) For each seismic source, a statistical analysis is carried out on all data concerning that source in order to derive the rate, at which earthquakes of different magnitudes will occur, the relationship between frequency and the maximum expected magnitude.

Applied Method: For this work the Cornell approach (Cornell, 1968) was applied. The fundamental elements enter into a seismic hazard analysis following this approach: the geometrical definition of the earthquake source, the parameters of its seismicity, and the choice of attenuation relationship.

1- Earthquake source geometry

The Cornell method requires the seismicity of the region under consideration to be divided into spatially distinct earthquake source zones. Based on the spatial distribution of the catalogue of earthquake data, the seismicity of Kalabsha area has been modeled as 5 source zones. For the period from 1976 to 1997, a total of 594 events with magnitude 3.0 and larger were selected and the subjected source area was defined by five main seismic area sources as shown in Fig. (4) and defined as follows:

SOURCE 1 (Kalabsha Fault Area): This area lies along the Kalabsha fault, in which the November, 1981 earthquake occurred. The seismicity of this area is seen mostly between depths of 15 and 26 km.
SOURCE 2 (East Gabel Marawa area): This area represents the activity aligned with the Kalabsha fault trend.
SOURCE 3 (Khor El-Ramla Fault Area): This area includes all the shallow activity (foci less than 7 km) and follows the existing Khor El-Ramla fault trends
SOURCE 4 (Old Stream Channel Area): In this area all the epicenters have been located in the Nile River channel .
SOURCE 5 (Abu-Dirwa Fault area): This area lies south of Kalabsha fault, the activity in this area is associated with the Abu-Dirwa fault in a north south direction.

2- Assessment of maximum earthquake magnitudes

One of the most controversial and important variables of interest in representing source seismicity is the size of the maximum credible earthquake to be used as the upper cut off magnitude in the linear recurrence relationship (Al-Haddad et al., 1992). In this work for each area seismic source, the cut-off magnitude is taken to be the observed maximum magnitude developed by the source plus 0.5.

3- Define recurrence rate for earthquakes

Assessment of earthquake occurrence model describes the recurrence of events in time within the seismic source zones. According to the proposed source area pattern, a linear regression analysis was carried out to estimate the coefficients of Gutenberg-Richter's relationship between magnitudes and their cumulative normalized frequency.

$$\text{Log } N_m = a - b\ m$$

where N_m is the number of earthquakes in a given period having magnitude greater than or equal to m. The computer programs used for this purpose is ESA program (Ahmed, 1991), is used to evaluate the cumulative normalized frequency-magnitude fitting coefficients needed to define the magnitude density function and to evaluate many other results which is used in hazard calculation. The slope of the line (b) and vertical axis intersection (a) are calculated and given in the output. The rate of occurrence at the minimum magnitude as well as the value [β = bLn (10)] are then calculated and given as in Table 1.

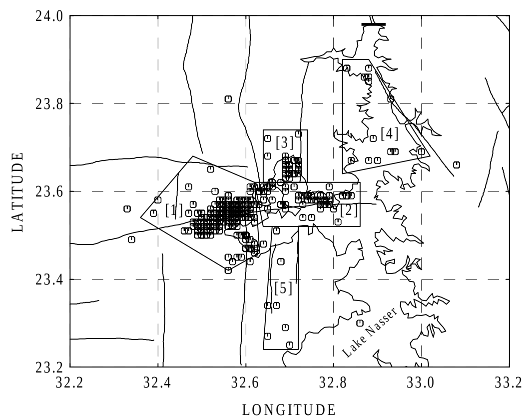


Fig. (4) Proposed area source model (ASM). Closed circles represent seismic activity with magnitude $\geq$ 3.0 in the period from 1976 to 1997.

4-Ground motion attenuation model

Ground motion attenuation model describes mathematically the way in which earthquake ground motions decreases with distance from an earthquake source for various magnitude levels. The attenuation model developed from peak ground acceleration for Aswan area by Fat-Helbary; Ohta (1994) is used:

$$\text{Ln } A = 1.895\ m_b - 0.938\ \text{Ln } (\Delta) - 3.715$$

where A represents the peak ground acceleration in cm / s^2, m_b is body wave magnitude and hypocenteral distance Δ is in km. The residuals of this equation are log - normally distributed with standard deviation 0.56.

5-Expected maximum acceleration at the selected sites

The probability of the expected maximum amplitude of ground motion within a given period of time corresponding to a chosen probability level for six individual sites along the Kalabsha Dam using inputs from steps (1), (2), (3) and (4) that were calculated in previous section.

Table 1. Parameters of seismic recurrence curve for each source

Source No.	Max Mag. (m_b)	No. of events	b Value	Occurrence rate (λ)	Average Depth (km)
1	6.1	435	1.14	18.929	17.15
2	4.3	85	0.87	1.428	7.68
3	4.2	47	1.14	3.744	5.47
4	4	13	1.14	0.72	3.54
5	3.7	7	1.14	2.375	3.29

The computer program used for this purpose is EQRISK program. This program, coded by McGuire (1978), was used to evaluate the site-by-site hazard associated with acceleration levels in an adoption of the area source model. The output of EQRISK program represents the expected acceleration amplitude with 90 percent probability of not being exceeded in exposure times of 20, 50 and 100 years as in Table 2. It can be concluded that the expected acceleration amplitude is found at all sites almost the same with relatively small different.

Table (2): Maximum ground acceleration at individual selected sites (in cm/s^2)

selected sites	Exposure period		
	20 years	50 years	100 years
A	110	162	205
B	111	163	206
C	106	155	196
D	103	152	190
E	106	154	195
F	105	154	194

ASSESSMENT OF EARTHQUAKE LOADING FROM LINE SOURCE MODEL (LSM)

1-Source Characteristics parameters:

The fault-rupture model (McGuire, 1978) is based on the assumption that the earthquake originates at the focus and propagates symmetrically on each side of the focus along the fault. Where the maximum intensity of the ground motions at a site is determined by the rupture closest to the site. The fault-rupture length is accounted for as a function of earthquake magnitude, and ground-motion estimates are made using the earthquake magnitude and closest distance from the studied site to the rupture zone. The FRISK code (McGuire, 1978) was used in this method, taking into account the fault-rupture model. The seismogenic model for all the sources was materialized as line sources located at the ground surface. FRISK requires the maximum expected magnitudes and their associated probability, the annual seismic rate λ (number of earthquakes per year), and the slope of the frequency/magnitude (β=b Ln (10)) for each fault as input seismicity parameters.

2-Source location and geometry.

A detailed field study performed by the working group from WCC, HADA and EGSMA disclosed the nature and characteristics of significant earthquake sources that have a potential for future earthquakes attacking the study area. For each of these sources, maximum earthquake magnitude and the frequency of occurrence of potentially damaging earthquakes have been estimated.

Five faults were identified as active faults that have the potential for producing significant earthquakes. These Faults are Kalabsha, Seiyal, Gebel el-Barqa Kurkur and Khor el-Ramla and shown in Fig. (5). These faults were defined by digitizing a number of points as a series of straight-line segments in Cartesian coordinate. In addition to these faults, a random area source has been included in the seismicity model to account for the occurrence of smaller-magnitude earthquakes on faults and near by areas extending for 50-km radius of octagonal shape in the site region. Due to the absence of seismic parameters of Abu dirwa fault, the data of this fault take in consideration as a seismically as in previous section.

Table (3) Parameters of line source model

Fault Name	Fault Length (km)	Max. Magnitude (M_s)
Kalabsha	185	6.7
Seiyal	90	6.7
Gabel el-Barqa	110	6.4
Kurkur	44	6.2
Khor el-Ramla	36	6.0
Random area source	50-km radius	5.3

3-Maximum earthquake magnitude.

Empirical and analytical relationships have been developed to relate maximum earthquake magnitude on a fault to fault parameters such as total fault, seismogenic rupture length and rupture area, and amount of fault displacement per event. These relationships are based on both theoretical analysis (Kanamori and Anderson, 1975) and on observations of worldwide historical earthquakes of moderate to large magnitude (Slemmons, 1977; Bonilla et al., 1984). The maximum earthquake magnitude of the significant earthquake sources in the study region was evaluated from empirical relationship of maximum earthquake magnitude on a fault to the amount of fault displacement by WCC, (1985). These values are presented in Table (3).

4- Annual mean number of events and recurrence rates.

The recurrence model for the five significant faults and the random area source designed by Woodward-Clyde Consultants (WCC, 1985) are used. The occurrence of earthquakes on these sources is assumed to be a Poisson process. Due to the lack of historical seismicity data for the region, the b-value determined from Gutenberg-Richter relationship for the induced activity was used.

5- Magnitude/ Rupture length relationship

The magnitude / rupture length relationship in hazard analysis was developed from a relationship between rupture area and magnitude (Idriss et al., 1985), as rupture area has a higher correlation with magnitude than does surface rupture length. The resulting relation was modified in normal logarithm as follows (WCC, 1985):

$$\text{Log } L = 0.547\, M_s - 2.137$$

where L is the rupture length (km). The definition of distance used in the attenuation relationship is closest distance to the surface projection of the center of energy release.

6- Ground motion attenuation relationship

The attenuation model developed from peak ground acceleration for Aswan area by Fat-Helbary and Ohta (1994) is used:

$$\text{Ln } A = 1.895\, m_b - 0.938\, \text{Ln}\,(\Delta) - 3.715$$

where A represents the peak ground acceleration in cm / s^2, m_b is body wave magnitude and hypocentral distance Δ is in km. The residuals of this equation are log - normally distributed with standard deviation 0.56.

7- Expected Maximum Acceleration at the Selected Sites

Based on the above input data, the computation is carried out using the computer program FRISK. The peak ground acceleration in 20, 50 and 100 years of exposure period and 90% of non-exceedance probability for the selected sites are calculated and presented as in Table (4).

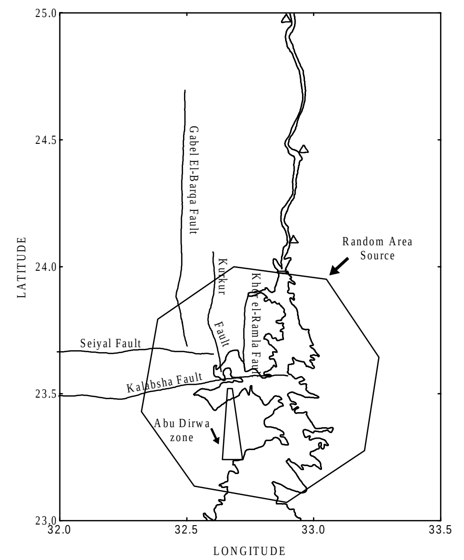


Fig. (5) Proposed line source model (LSM)

ESTIMATION OF HAZARD CURVE

The hazard curve represented by the relationship between the peak ground acceleration and its annual exceedance probability at a certain site. Employing the same parameters and principles as used for both ASM and LSM in the previous sections, the resulting hazard curves for the selected six individual sites from ASM and LSM are plotted as in Fig. (6). By comparing the curves for the six individual sites for the same source model as in the figure, it can be concluded that the potential ground acceleration levels for all sites are almost the same. Considering the mean results from the two models, the annual exceedance probability of the expected ground acceleration from ASM appears to be approximately ten times higher than the annual exceedance probability from LSM.

Table (4): Maximum ground acceleration at individual selected sites (cm/sec^2)

selected sites	Exposure period		
	20 years	50 years	100 years
A	39	73	108
B	39	74	110
C	38	72	107
D	38	72	105
E	38	73	107
F	38	73	108

RESULTS AND CONCLUSION

The main conclusions and results may be formulated as follows:

1-The seismic source zones that are close enough to the site to give rise to potentially damaging earthquake ground motions and the significant active faults that have potential for producing earthquake and which pass through and near the dam site were identified.

2-The earthquake loading represented by ground motions is these likely to cause at the six individual sites was evaluated, using Area and Line Source Models for earthquake sources. The potential ground acceleration level from the same source model for all sites is almost the same. The results from two models appear different, where in area source model (ASM) the expected ground motions are about twice that expected from line source model (LSM).

3-The annual exceedance probability of the expected ground acceleration from ASM appears to be approximately ten

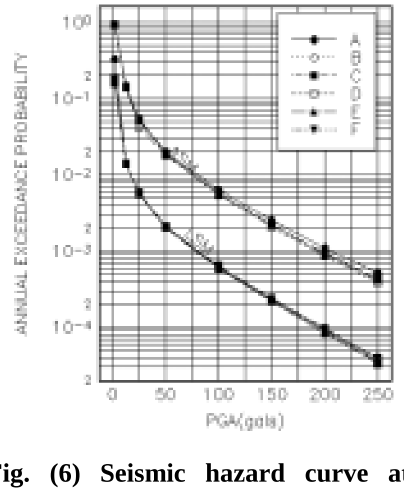


Fig. (6) Seismic hazard curve at the selected sites along the proposed Kalabsha Dam resulting from ASM and LSM.

times higher than the annual exceedance probability from LSM.

Accordingly since the expected earthquake loading from ASM is more threatening to the dam site than the earthquake loading from LSM. Consequently, the earthquake loading from ASM should be taken in consideration for the design of Kalabsha Dam.

REFERENCES

Ahmed, K. A. (1991). Computer program for earthquake statistical analysis (ESA), Cairo University, Faculty of Engineering.

Algermissen, S. T. and Perkins, D. M. L. (1976). A probabilistic estimate of maximum acceleration in rock in the contiguous United States, U. S. Surv. Open-File Rep. 76-416, p. 45.

Al-Hadad M., G. H. Siddiqi, R. Al-Zaid, A. Arafah, A. Neciogh and N. Turkelli (1992). Seismic hazard and design criteria for Saudi Arabia, Procc. of 10th WCEE, 449-454.

Ali, A. G. (1992). The Crust and the Upper mantle Structure in the Lake Nasser Area from Seismic Waves Generated by Earthquakes and Explosions: Ph.D. Dissertation, Fac. Sci., Cairo Univ., Egypt.

Bonilla, M. G., R. K. Mark, and J. J. Lienkaemper (1984). Statistical relations among earthquake magnitude, surface rupture length, and surface fault displacement, Bull. Seis. Soc. Am., v. 74, pp. 2379-2411.

Coburn, A. W. and R. J. S. Spence (1992). Earthquake Protection, Library of Congress Cataloging-in-Publication data.

Cornell, C. A. (1968). Engineering seismic risk analysis, Bull. Seism. Soc. Am., 58,1583-1606.

Egyptian Geological Survey and Mining Authority (1981). Geological map of Egypt, Ministry of Industrial and Mineral Resources.

Fat-Helbary R. E. (1989). A study of the local earthquake magnitude determination recorded by Aswan Seismic Network, Master Thesis, Assiute University, Sohag Faculty, Egypt.

Fat-Helbary R. E. and Y. Ohta (1994). Attenuation models of seismic intensity and peak ground acceleration in Egypt, First Cairo Earthquake Engineering Symposium on Seismic Risk Assessment, Cairo, Egypt.

Idriss, I., M., Arango, W. Savage, R. Youngs and K. W. Lee (1985). Probabilistic analysis of potential ground motion levels, Internal Report, High and Aswan Dams Authority, Egypt.

Issawi, B. (1969). The geology of Kurkur-Dungul area, General Egyptian Organization for Geological Research and Mining Geol. Surv., Paper No. 46, P. 102, Cairo.

Issawi, B. (1978). Geology of Nubia west area, Western Desert, Egypt. Annals of the Geol. Surv. of Egypt, Vol. 8, 237-253

Kanamori, H., and D. L. Andrson (1975). Theoretical basis of some empirical relations in seismology, Bull. Seism. Am. V. 65, no. 5, pp. 1073-1095.

Kebeasy, R. M., Maamoun, M., Ibrahim, E., Megahed, A., Simposn, D. W., and Leith, W. S. (1987). Earthquake studies at Aswan Reservoir, J. Geodynamics, 7, 173-193.

Kelein, F.W., (1978). Hypocentre Location program. HYPOINVERSE: Users guide to versions 1, 2, 3 and 4. Geolo. Surv., open-File Rep. (USA) 78-679, 1 – 119.

McGuire, R. K.(1976). FORTRAN computer program for seismic risk analysis, U. S. Dept. of Interior, Geological Survey, Open-File report 76-67, 90 pp., Denver, Colorado.

McGuire, R. K. (1978). Computer program for seismic risk analysis using faults as earthquake sources (FRISK). U. S. Dept. of Interior Geological Survey, Open-File report 78-1007, 71 pp., Denever, Colorado.

Said, R. (1962). The geology of Egypt, Elsevier publisher, Amstrdam, New York.

Shah, H. C. and Dong, W. M., (1984). A re-evaluation of the current seismic hazard assessment methodologies, Proc. 8th Int. WCEE, San Francisco, Vol. 1 pp. 247-254.

Simpson, D. W., R. M. Kebeasy, C. Nicholson, M. Maamoun, R. N. H. Albert, E. M. Ibrahim, A. Megahed, A. Gharib and A. Hussain (1987). Aswan Telemetered Seismograph Network, Jurnal of Geodynamics 7, 195-203.

Simpson, D. W., Gharib, A. A., and Kebeasy, R. M. (1992). Induced Seismicity and changes in water level at Aswan reservoir, Egypt: Gerlands Beitr. Geophysik. Leipzig, vol. 99(3), pp. 191-204.

Slemmons, D. B. (1977). State-of-the-art for assessing earthquake hazards in the United States Report 6: faults and earthquake magnitude: U. S. Army Corps of Engineers, Waterways Experiment station, Vicksburg, Mississippi, Miscellaneous Paper S-73-1.

WCC (Woodward-Clyde Consultants), (1985). Identification of earthquake sources and estimation of magnitudes and recurrence intervals, Internal Report, High and Aswan Dams Authority, Egypt.