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LAND USE PLANNING AND SEISMIC HAZARDS OF THE PROPOSED ASWAN NEW CITY AREA, EGYPT

Raafat E. FAT-HELBARY [1], Karrar O. EL FARAGAWY [2] and Abdel-Nasser M. ABDEL MOTAAL [1]

[1] *Aswan Earthquake Research Center, P. O. Box 152, Aswan, Egypt*
[2] *Geology Dept., Aswan Faculty of Science, South Valley University, Aswan, Egypt*
**Corresponding author's e-mail*: Fat_Helbary@yahoo.com

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ABSTRACT
Land use planning has been used only recently as a method to mitigate losses due to earthquake hazard. The most fundamental approach in land use planning is to simply avoid proposing development on lands that have seismic hazard and subsurface structures. This approach is most applicable in raw land situations where land values are comparativily low. The magnetic methods are applied for detection the subsurface structutres. The seismic hazard represented by peak ground acceleration and characteristic of site period at selected 19 sites in the study area were evaluated and represented by a contour maps. The structures deduced from applying the trend analysis method to the RTP magnetic map indicate that there are two sets of fault trends. The major trends are the N-S directions and the minor trends are the E-W direction. The maximum acceleration has its minimum value of about 36 gal at the central eastern part and the maximum of about 64 gal at the southern part of the studied area. The computed natural period has its minimum value of about 0.8 sec at the southern part of the area, while the maximum value is about 4.2 sec at the northwestern part of the area. Recommendations for land-use planning policies relative to structural trend map, ground shaking and characteristic of site period were considered.

KEYWORDS: Land use, hazard, Aswan city, Faults, Ground Motion, Site period

1. INTRODUCTION

In the last few years, the Egyptian government proposed a general plan, aiming at constructing a number of new cities in desert areas to accommodate the rapid increase of population and to avoid the construction on green lands. One of those cities is Aswan New City, which is located about 12 km north of Aswan City and lies on the western bank of the Nile River. The suggested location of the Aswan New City is situated between latitudes 24° 09' 20'' & 24° 13' 07'' N and longitudes 32° 50' 18'' & 32° 52' 08'' E covering an area of about 21 Km^2 (Fig. 1). The present study aims to evaluate the subsurface structures, ground shaking and characteristic of site period at the proposed site of Aswan New city.

Land use planning has been used only recently as a method to mitigate losses due to earthquake hazards (Lennis Berlin, 1980). According to Mader (1976), urban planners in the past have generally not been sufficiently aware of seismic problems and therefore have too often simply ignored them. In USA several key pieces of legislation have been enacted to achieve seismic hazard reduction via land use planning. Nichols and Buchannan-Banks (1974) described various types of land use plans that can be implemented for developing areas, to mitigate losses arising from subsurface structures, ground shaking, ground failure, and tsunami effects. In this study the land use planning was applied to mitigate losses arising from subsurface structures, ground shaking and characteristic site period.

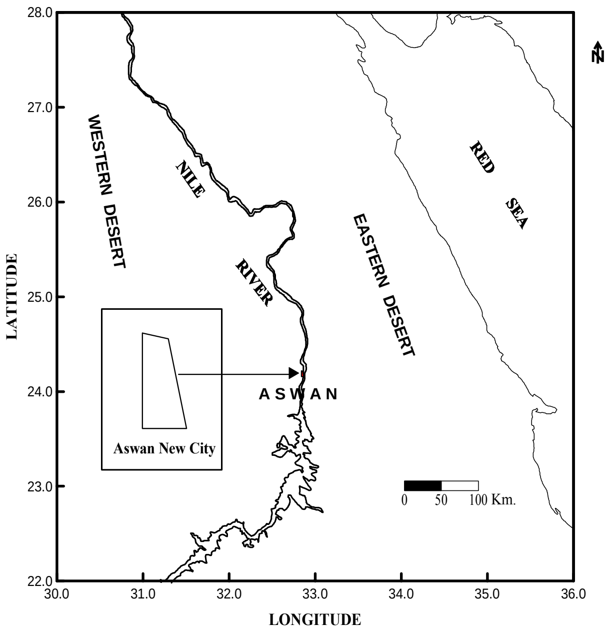

Fig. 1 Location map of the study area

The main task of this detailed study is concerned with the land-use and regional planning and development of the study area. One motive behind land-use planning is safety and how to mitigate losses.

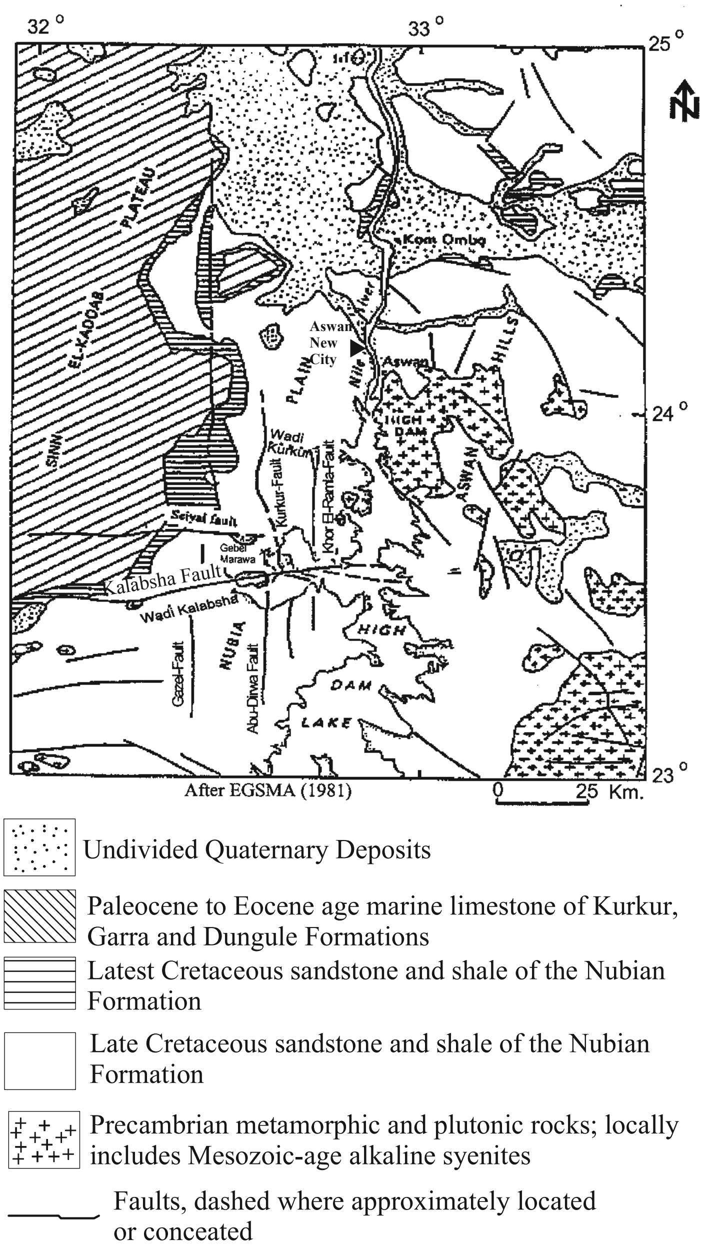

Fig. 2 Geology of Aswan area

2. GEOLOGICAL AND TECTONIC SETTING

The geological map (Fig. 2) established by the Egyptian Geological Survey and Mining Authority (EGSMA, 1981) shows rocks distribution in the study area. Rocks of this area are belonging to the Nubian Formation. Many authors (e.g., Issawi, 1968, El Shazly et al., 1974 and 1976, Van Houten & Bhattacharyya, 1979, Butzer & Hansen, 1968, Klitzch & Wycisk, 1987, Hendriks et al., 1987) have studied the geology of the study area.

These studies indicated that the study area is consist of a thick sedimentary section of Nubian Sandstone Formation of Upper Cretaceous age that overly the Precambrian basement rocks. This section is consist of ferruginous sandstone, sandstone and clays. Clays are present as beds and lenses of widely varying dimensions within the sandstone beds.

Faults crossing the study area are part of the Western Desert fault system. The Western Desert fault system consists of two sets of east-west faults that exhibit right-slip displacement, and north-south faults of left-lateral displacement. The north-south faults are predominantly located at the eastern end of the fault-set zone. Their limited distribution and low degree of activity suggest that they are secondary to the east-west set of faults (Issawi, 1968). South of the study area, many faults (Kalabsha, Seiyal, Gebel El-Barqa, Kurkur, Khour el Ramla, Abu Derwa, Spillway, and Ghazal faults) were mapped and identified in Kalabsha area. Also, other faults having generally east-west trends were mapped in this area, but they are of lesser extent and cut mainly through the sandstone beds. Moreover, many faults of small extent have trends oblique to the main two fault sets in the present area (Fig. 2).

3. LAND MAGNETIC SURVEY

The land magnetic survey has been performed using two Protons magnetometer with accuracy one nT. One of these instruments was fixed as a base station for diurnal and the other was using in the measuring of the observed magnetic field. The survey was performed along about 140 stations distributed along the studied area (Fig. 3).

The surveyed data was digitized to the computer program with respect to its coordinates. The deduced total magnetic anomaly map has been reduced to the north magnetic pole using the RTP technique of Baranov (1975) after making the diurnal variations and latitudinal corrections as shown in Fig. 4.

The RTP land magnetic map represents the distribution of the magnetic anomalies along the studied area. This map was subjected to intensive analysis to detect the subsurface structures affecting the studied area.

3.1. TREND ANALYSIS TECHNIQUE

The trend analysis technique was used to delineate the subsurface structures deduced from the RTP land magnetic map and correlate the results with the published surface geologic structures. This technique was performed using the gradient method (Nettleton, 1976) where the peaks of the gradient profiles represent the location of the fault lines. The deduced structures map, Fig. 5 indicates that there are two sets of fault trends.

The most predominant trends are the NNW-SSE and NE-SW directions, followed by two sets that trend NNE – SSW and NNW-SSE directions. The less common trends are NW-SE and NNE-SSW and ENE-WSW directions.

These trends are highly corresponding with surface fault systems in the Western Desert (Issawi, 1968).

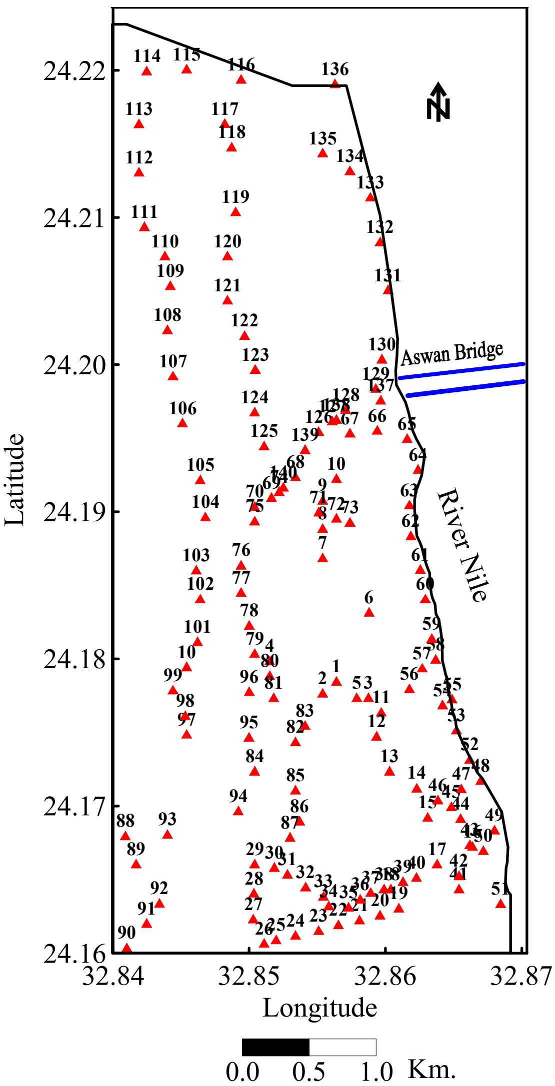

Fig. 3 Location map of the magnetic measurements stations.

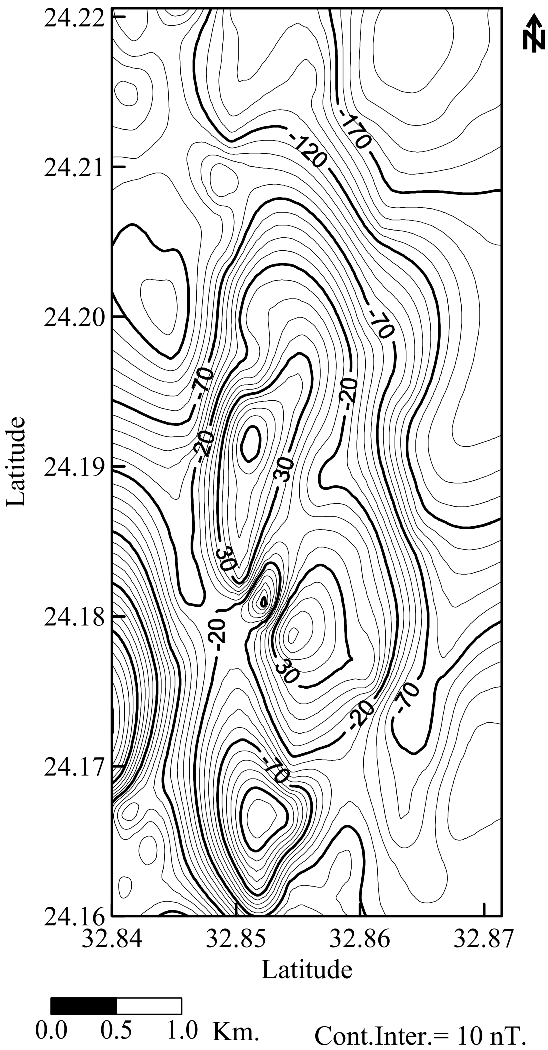

Fig. 4 RTP Magnetic anomaly map of the study area.

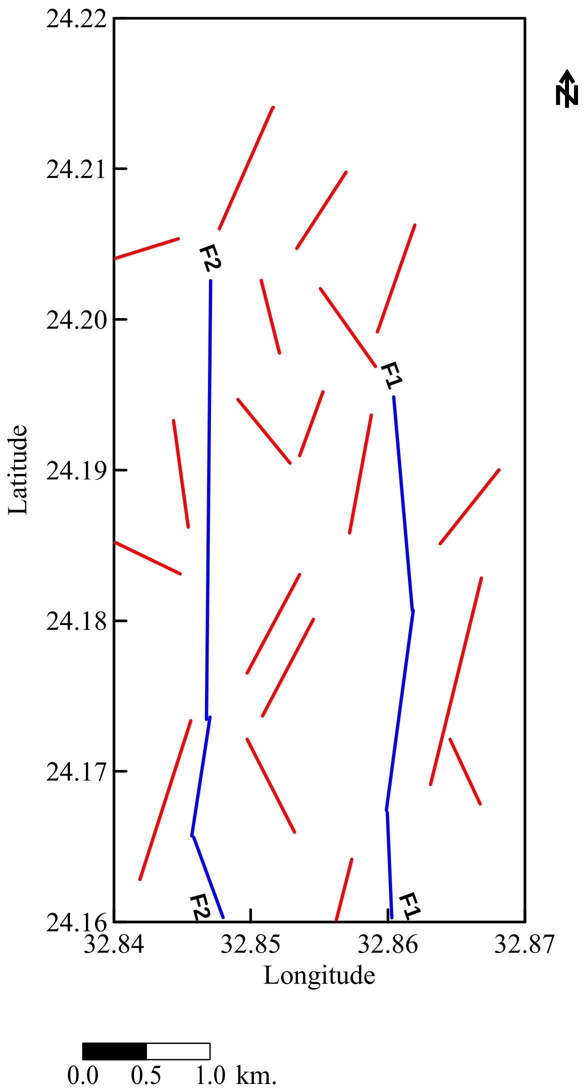

Fig. 5 Structural trends deduced from the RTP magnetic anomaly map of the study area.

4. GROUND SHAKING

Ground shaking is the motion of seismic waves felt on the earth's surface caused by an earthquake. The strength of ground shaking depends on the magnitude of the earthquake, the type of fault that is slipping, and distance from the epicenter. Ground shaking translates to structural damage as amplitude of ground motion. Generally, the process to estimate the ground motion starts with investigation of seismic motion characteristics at the base rock from the seismic source, and then to surface as a function of site effects.

4.1. SEISMICITY OF THE PROPOSED ASWAN NEW CITY AREA

Instrumental earthquakes during the period from 1900 to 1981 were collected from Maamoun et al., (1984), International Seismological Center bulletin (ISC), National Earthquake Information Center (NEIC) and Preliminary Determination of Epicenters (PDE). On November 14, 1981 an earthquake of magnitude m_b 5.3 occurred in Kalabsha area about 80 km south of the proposed Aswan New City site. Following this earthquake, Aswan telemetry seismic network is installed in the northern part of Aswan reservoir area by Helwan observatory. Before installation of Aswan seismic network, a few numbers of large earthquakes occurred in Red Sea and one in Gulf El-kebir had been reported in Upper Egypt, because the closest station to record earthquakes in Upper Egypt was Helwan station (690 km from Aswan), it wasn't possible to determine the low magnitude activity from Upper Egypt. The first seismographs installed in Upper Egypt that were capable of recording small local earthquakes were short-period instruments installed at Aswan and Abu-Simble in 1975. In 1990 a portable short period seismic station was installed in Mersa Alam along the Red Sea coast to monitor the seismic activity in Abu-Dabbab area and Red Sea. In addition to the collected earthquakes from National and International Bulletins, the regional data used in this study during the period from 1982 to 2003 mainly was located using Aswan, Abu-Simbel, Mersa Alam seismic stations and Aswan seismic network.

4.2. GROUND MOTION AT THE BASE ROCKS

A probabilistic seismic hazard analysis was conducted for assessing the ground motion at 19 selected sites in the proposed Aswan New City area as shown in Fig. 6. The objective of the analysis was to evaluate the probability of exceedance of different levels of ground motion due to earthquakes that they may occur in and around the proposed Aswan New City area.

All data relating to known earthquakes with magnitude $\geq$ 3.0 around Aswan New City site are collected and analyzed. This analysis includes:

1. All significant seismic sources in the area are identified.
2. For each seismic source, the rate of earthquakes at different magnitudes is determined by a statistical analysis on all data related to that source.

4.3. METHOD

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

4.3.1. 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 for the period from 1900 to 2003, the seismicity

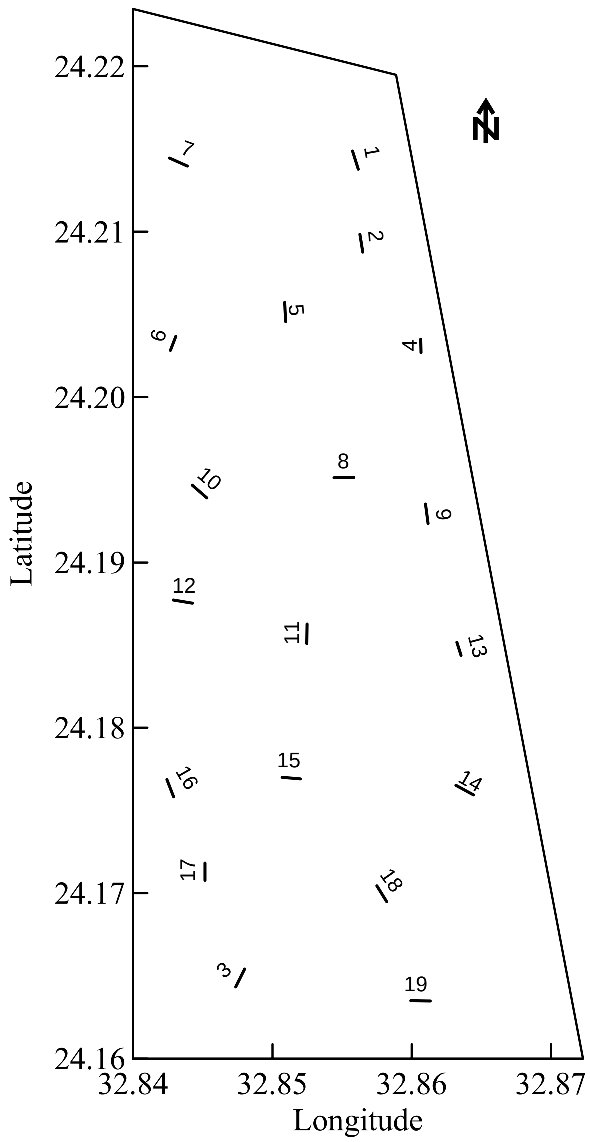

Fig. 6 Location map of the 19 selected sites.

around Aswan new city area has been modeled as 6 source zones significant to the study area as shown in Figure 7.

4.3.2. MAXIMUM EARTHQUAKE MAGNITUDES

One of the most controversial and important variables in representing a source of seismicity is the size of the maximum credible earthquake. In this study for each seismic source area, the cutoff magnitude is taken to be the observed maximum magnitude known for the source plus 0.5 (Al-Hadad et al., 1992).

4.3.3. EARTHQUAKE RECURRENCE RATES

An earthquake occurrence model describes the recurrence of events in time within each seismic source zones. A linear regression analysis was carried out to estimate the coefficients of Gutenberg-Richter's relationship between magnitudes and their cumulative frequency of occurrence, i.e.,

$$\log N_m = a - b\text{m}, \quad (1)$$

where N_m is the number of earthquakes in a given period having magnitude greater than or equal to m. The program used for this purpose is the ESA program (Ahmed, 1991). The rate of occurrence at the minimum magnitude as well as the value $\beta[\beta = b\ln(10)]$ are given in Table (1). The lower bound magnitude at m = 3.0 has been set, because smaller earthquakes are not interesting from the seismic hazard point of view.

4.3.4. GROUND MOTION ATTENUATION MODEL

Ground motion attenuation model describes mathematically the manner in which earthquake ground motions decrease with distance from an earthquake source for various magnitudes. We used attenuation model developed from peak ground acceleration for the Aswan area (Fat-Helbary, 1995).

$$\ln A = 1.895 m_b - 0.938\ln(\Delta) - 3.715$$
$$(\sigma = 0.558) \quad (2)$$

Where A represents the peak ground acceleration in cm/s^2, m_b is the body wave magnitude and Δ is the hypocenteral distance in km. The residuals of this equation are log – normally distribution with standard deviation (σ) 0.558.

4.3.5. EXPECTED MAXIMUM ACCELERATION AT SURFACE LAYERS

The maximum amplitude of ground motion expected within a given period of time and corresponding to a chosen probability level using inputs from steps (4.3.1)-(4.3.4) is calculated (Table 1). The computer program used for this purpose is EQRISK (McGuire, 1976). The program yields the expected accelerations with 90 percent probability of not being exceeded in exposure times of 100 years. The procedure of analysis is repeated systematically in the 19 selected on the proposed Aswan New City area. The results show that the expected acceleration at the 19 sites is almost the same and in range from 42 to 47 cm/sec^2. For use as input motions at the bottom of the actual soil columns, one must remove from the computed motions the effects of free-surface boundary conditions, which invoke certain components of the stress tensor to be zero. To achieve this, the free-surface motions are divided by a factor of 2 (Jacob et. al., 1995).

Local site conditions play an important role in changing the characteristics of seismic waves. It is often associated with the extent of damage and destructiveness of a site incurs due to a strong earthquake. Therefore, it is important to incorporate some type of site factor into the analysis of risk such as amplification factor. The amplification factors at

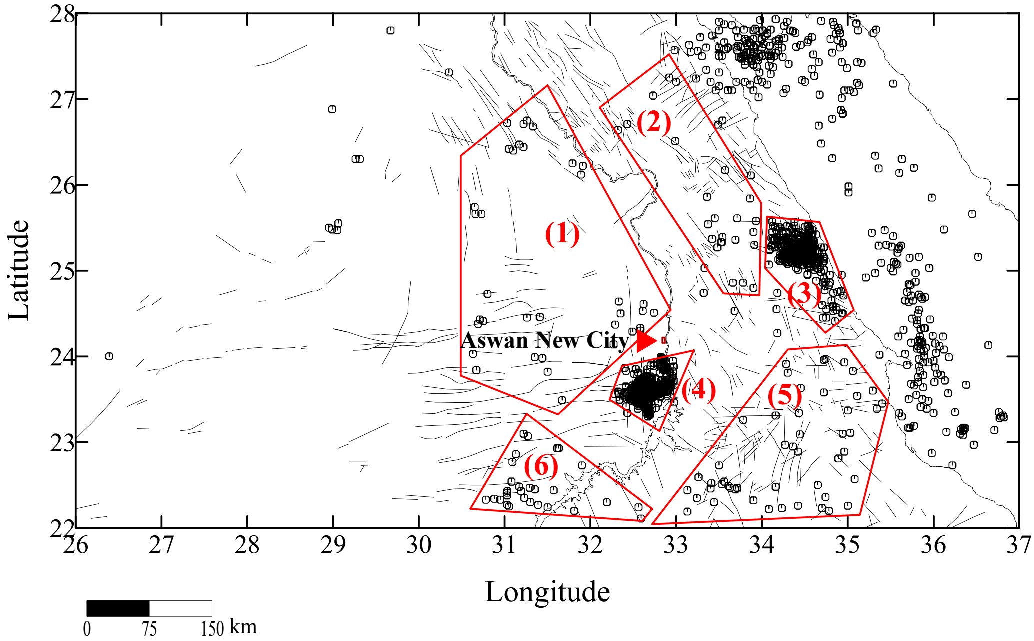

Fig. 7 Epicentral distribution of the catalogued events in the period from 1900 to 2003 and the significant earthquakes source zones to Aswan New city site.

Table 1 Parameters of seismic recurrence curve for each source

Source No.	**Mag.** (m_b)	**No. of events**	**β**	**Occurrence rate (λ)**	**Average depth**
A1	5.3	36	1.441	0.375	9.28
A2	4.7	27	2.121	0.281	10.70
A3	6.1	488	2.256	4.743	10.80
A4	5.8	294	2.120	0.677	16.31
A5	4.9	51	2.231	0.531	7.75
A6	4.2	29	2.141	0.302	6.55

the 19 selected sites are calculated by Abdel-Motaal (2003) (Fat-Helbary et al., 2004) and used in the present study. The computed amplification has its minimum value of about 1.61 at the west central part of the area, while the maximum value is about 4.46 at the southern and northwestern parts of the area where the sediments are loose and thick. Finally the maximum surface acceleration was estimated by the multiplication of peak acceleration at the base rock with the relative amplification factor for the surface layers. The maximum ground accelerations and their distributions at the ground surface in exposure time 100 years are represented by a contour map as shown in Figure 8. The calculated acceleration has its minimum value of about 36 gals at the central eastern part, while the maximum value is about 64 gals at the southern part of the studied area.

5. CHARACTERISTIC SITE PERIOD

The response of a building to shaking at its base depends on the design quality of the construction (Slob, 2002). However, what is a very important factor is the height of the building. All objects or structures have a natural to vibrate. The rate at which it wants to vibrate is its fundamental period or natural frequency. High rise building (with a low natural frequency) react totally different than smaller building (with a much higher natural frequency).

$$\omega_0 = \pi Vs / 2H, \qquad (3)$$

in which ω_0 = fundamental frequency
Vs = Shear wave velocity
H = Soil thickness

and

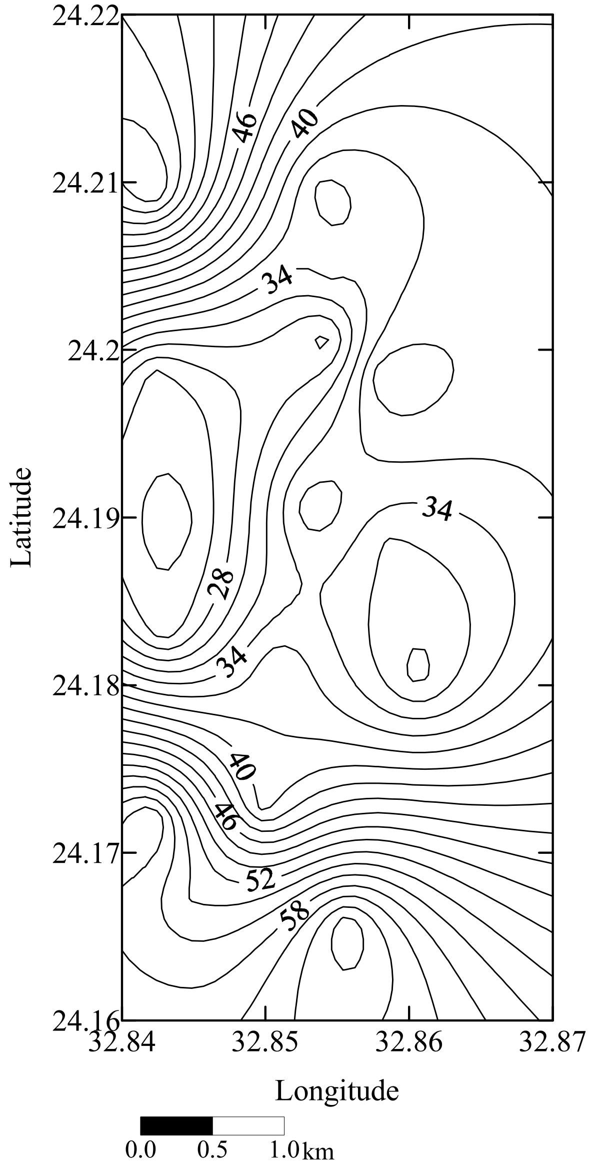

Fig. 8 Surface acceleration for expected values in 100 Years (in gals)

$$Ts = 2\,\pi / \omega_0 = 4H / Vs \qquad (4)$$

in which

Ts = Characteristic site period.

Buildings have a high probability to achieve (partial) resonance, when the natural frequency of the ground motion coincides with natural frequency of the structure. Resonance will cause increase in swing of the structure and given sufficient duration, amplification of ground motion can result in damage or destruction. Specific ground conditions may result in resonance and large amplification of the seismic signal, but if the frequencies for which this occurs lie far outside the natural frequency range of our building, this may not have significant effects. Shallow seismic refraction survey was carried out at the 19 selected sites on the proposed location of Aswan New City as shown in Figure 6, to obtain P- and S- wave velocities and the thickness of each layer (Abdel-Motaal, 2003). The calculated S-waves velocities and the thickness of each layer at each site is used in equation 4 to calculate the characteristic of site period. The calculated natural site period and their distributions at the ground surface are represented by a contour map as shown in Figure 9. The computed natural period has its minimum value of about 0.8 sec at the southern part of the area, while the maximum value is about 4.2 sec at the northwestern part of the area.

CONCLUSIONS AND RECOMMENDATIONS

The structures deduced from applying the trend analysis method to the RTP magnetic map indicate that there are two sets of fault trends The major trends are the N-S directions and the minor trends are the E-W direction. The surface peak ground acceleration

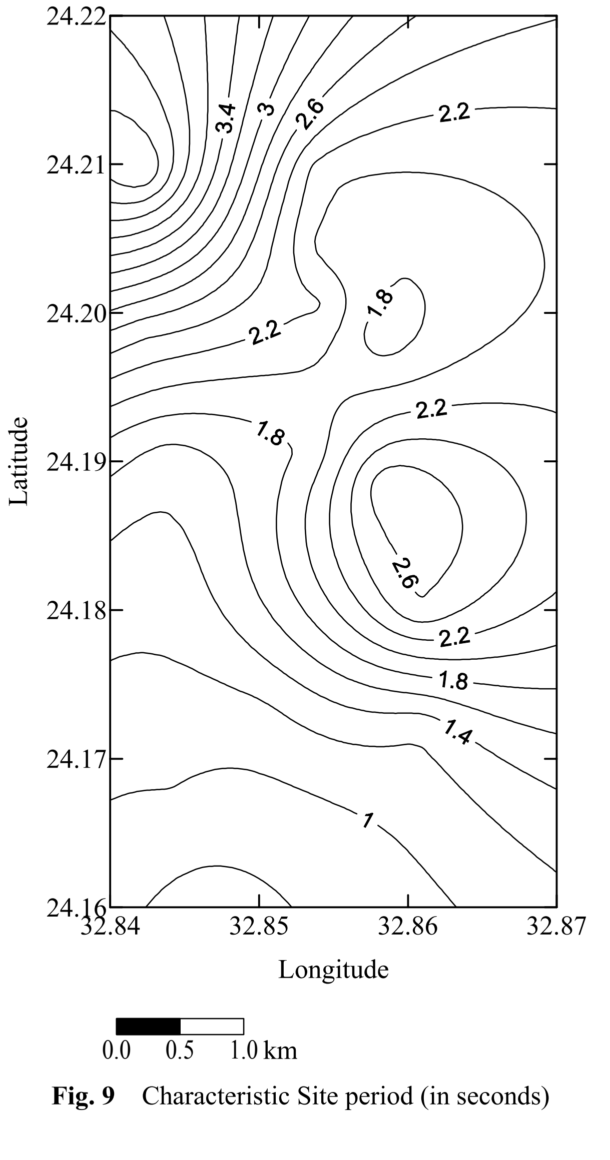

Fig. 9 Characteristic Site period (in seconds)

was estimated by multiplication of peak acceleration at the bedrock with relative amplification factor for the surface layers and represented by a contour map.

The maximum acceleration has its minimum value of about 36 gal at the central eastern part and the maximum of about 64 gal at the southern part of the studied area. While the natural sites period and it's distributions at the ground surface are represented by a contour map. The computed natural period has its minimum value of about 0.8 sec at the southern part of the area, while the maximum value is about 4.2 sec at the northwestern part of the area.

Considering land-use planning, the present study recommends that:

3. The trace of the detected faults must be left without construction and reserved as green park or open space.
4. A distance of 50 m must left astride each fault without high buildings.
5. The ground shaking at the southern and north western parts are relatively high, the development with special engineering solution may be appropriate.
6. The natural periods for bulidings should be lie far outside the natural periods range of site, this may not have significant effects.

REFERENCES

Abdel-Motaal, A. M.: 2003, Engineering seismological studies on the proposed location of Aswan New City, M.Sc. Thesis, Aswan Faculty of Science, South Valley University, Egypt.

Ahmed, K.A.: 1991, Engineering applications of the probabilistic seismic hazard analysis in Egypt Master Thesis, Cairo University.

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

Baranov, V.: 1975, Potential field and their transformation in applied Geophysics- Geo-exploration Monograph series 1-6, Gegruden Born target, Berlin- Stuttgart.

Butzer, K.W. and Hansen C.L.: 1968, Desert and Rivers in Nubia, Geomorphology and prehistoric Environment at Aswan Reservoir, University of Wisconsin presses. Madison, Milwaukee, U.S.A.

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

EGSMA: 1981, Geological map of Egypt scale 1:2,000,000, EGSMA, Ministry of Industry and Mineral Resources, Cairo.

El Shazly, E.M., Abdel Hady, M.A., El Ghawaby, M.A. and El Kassas, I.A.: 1974, Geologic interpretation of ERTS-1 satellite images for west Aswan area, Egypt. Proceedings of the ninth international symposium on remote sensing of environment, 15-19 April (1974), Arbor. Michigan, U. S. A., 119-131.

El Shazly, E.M., Abdel Hady, M.A., El Kassas, I.A., Salman, I.A., Salman, A.B., El Shazly, M.M., El Amin, H. and Abdel Megid, A.A.: 1976, Geology of Kharga-Dakhla Oasis area, Western Desert, Egypt, from NASA land sat.1 Satellite images; Remote Sensing Research project, Academy of Scientific Research and Technology, Cairo, Egypt,1p.

Fat-Helbary, R.E.:1995, Assessment of Seismic Hazard and Risk in Aswan Area, Egypt, Ph. D Thesis, Division of Engineering, The University of Tokyo, Japan.

Fat-Helbary, R.E., El-Faragawy, K.O. and Abdel Motaal, A.M.: 2004, Engineering seismological studies on the proposed location of Aswan New City, Egypt, J. of Geophysics, 1, No. 3, Helwan.

Hendriks, F., Luger, P., Bowtiz, J. and Kallenbach, H.: 1987, Evolution of the depositional environments of SE-Egypt during the Cretaceous and Lower Tertiary. - Berliner geowiss. Abh. (A), 75 (1), 49-82, Berlin.

Issawi, B.: 1968, The geology of Kurkur-Dungle area: Geol. survey, Cairo, Egypt, paper No. 46, 102.

Jacob, K., Horton, S., Barstow, N. and Armbruster, J.: 1995, Seismic Hazard Assessment, Design Ground Motions and Comments on Liquefaction Potential for the Site of the Tappan Zee Bridge, New York, Final Report, Part1, Lamont-Doherty Earth Observatory of Columbia University, F.R. Harris, Inc. 1-75.

Klitzch, E. and Wycisk, P.: 1987, Geology of the sedimentary basins of northern Sudan and bordering areas. -Berliner geowiss. Abh. (A), 75(1), 97-136, Berlin.

Lennis Berlin, G.: 1980, Earthquakes and the Urban Environment, Volume III, CRC Press, Library of Congress, US.

Maamoun, M., Megahed, A. and Allam, A.: 1984, Seismicity of Egypt, Helwan Institute of Astronomy and Geophysics Bull., Vol. IV Ser. B, 109-162.

Mader, G.G.: 1976, Land use planning, in Architects and Earthquakes: Research Needs, AIA Research Corporation, Washington, D. C., 11.

McGuire, R.K.:1976, " FORTRAN computer program for seismic risk analysis", U. S. Dept. of Interior, Geol. Surv., Open-File Rep. 76-67, 90, Denver Colorado.

Nettleton, L.L.:1976, Gravity and magnetic in oil prospecting. Mc-Graw-hill Book Co, New York, 464.

Slob, S.: 2002, Engineering Geology for Developing Countries – Proceedings of 9th Congress of the International Association for Engineering Geology and the Environment, South Africa, van Rooy and C.A. Jermy, editors.

Van Houten, F.B. and Bhattacharyya, D.P.: 1979, Late Cretaceous Nubia Formation at Aswan south Eastern Desert, Egypt. Annals of the Geological Survey of Egypt, Vol. IX, 408-431.