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Seismic Hazard Assessment for Azerbaijan

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Seismic Hazard Assessment for Azerbaijan is studied in the frame of a NATO SFP project "Seismic Hazard RiskAssessment for Southern Caucasus – Eastern Turkey Energy Corridors".

The territory of Azerbaijan which is included into the Alpine folded system is characterized by a high seismic activity. In the territory fault zones with different direction create a very complex geological structure. Such heterogeneity of distribution of seismicity is connected with a various level of activity of separate parts of fault zones.

Probabilistic seismic hazards of the territory were calculated by defining source zones at high seismicity areas.Hazard maps were prepared, in terms of intensity, spectral accelerations at 0.2, 1.2, 2.0 , 4.0 sec periods, PGA, PGV and PGD for 10% probability and 2% probability in 50 years. Max PGA and PGV for 10% probability in 50 years reach up to 0,216 g and 31.3 sm/s at Sanqachal, Shamakhy-Ismailly regions respectively.

Maps of maximum earthquake intensities for Azerbaijan and adjacent Caspian Sea territory have been plotted and analyzed.

The analysis of these maps show high level of hazard are observed in Vandam fault zone, in the regions Shamakhy, Ismailly.

The background level of seismic hazard in terms of intensity is equal to 8 (MSK - 64). High seismic hazard 9 (MSK - 64) is expected in a zone of the Great Caucasus which covers territory from the city of Shamakhy up to border of Georgia. Other zones with the same potential danger are allocated within the limits of Small Caucasus.

This information about seismic hazard will be used at seismic risk assessment of the pipelines.

As a part of the Alpine folded system Azerbaijan territory characterized as very high seismic activity. Strong and catastrophic earthquakes which happened several times in this area from ancient times till now caused large number of human loses and destructions (Figure 1).

The strongest earthquakes mainly have been registered in Shamakhi and Ganja regions. The earthquake happened in Shamakhi in 1668 (M≈ 7.0; İ0 = 9 -10 points) can be considered as one of the strongest earthquakes happened in the Caucasus up to now.

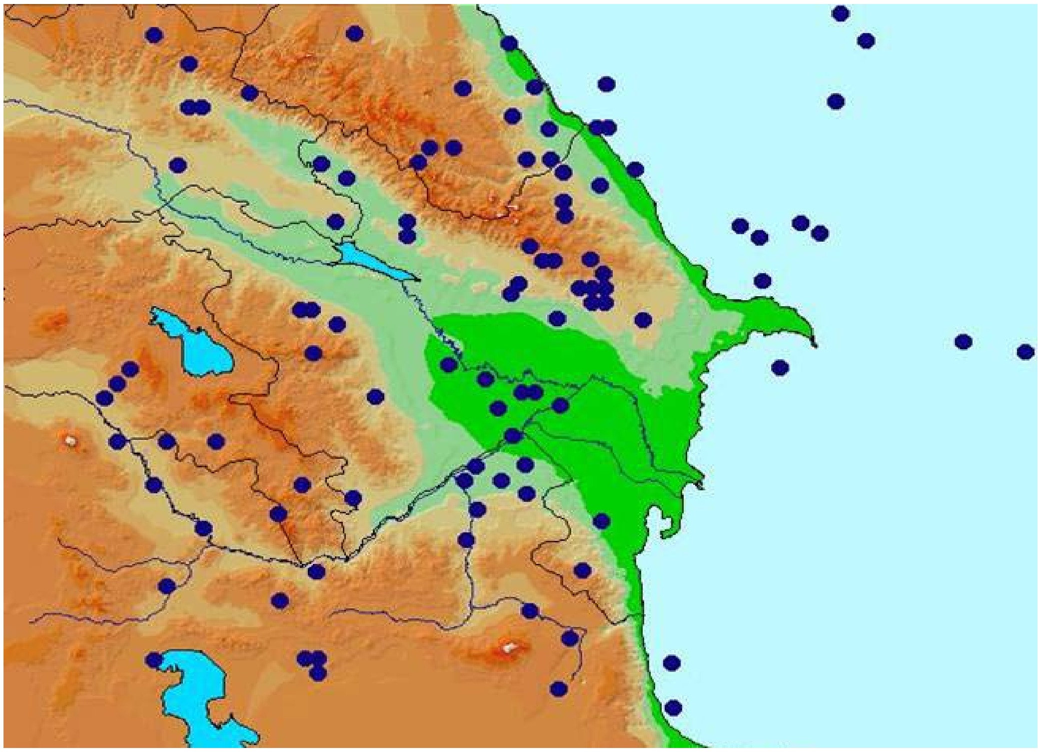


Figure 1. Epicenters map of earthquakes (M≥5,0) happened in Azerbaijan territory in 427-1930.

According to historical information this earthquake resulted with landslides and more than 80000 people died [10].

In Shamakhi region registered seismic shocks with intensity up to 8 according MSK-64 in 1828, 1859, 1869 and 1872 years. In this area the last catastrophic earthquake (M = 6.9; İ0 = 9 points) happened in 1902.

Other area where happened destructive earthquakes is Ganja region. In this area happened strong earthquakes in 427 (M ≈ 6.7; İ0 = 9 points), in 1139 (M ≈ 6.8; İ0 = 9 points), in 1235 (M ≈ 5.7; İ0 = 8 points). After earthquake happened in 1139 because of landslide created Goy-gol Lake. In another regions of republic also were registered a number of strong earthquakes. Intensity of these earthquakes was not more than $İ_0$= 6-7 points, but in many cases resulted with many destructions.

Last years new seismic stations with higher sensitivity seismographs added to Republican seismic stations network and after this it become possible to register lower intensity (magnitude) earthquakes in republican territory [7, 9].

Since 2003 in the Azerbaijan territory installed 30 telemetry seismic stations production of “Kinemetrics”. Up to now in republican territory working analogue seismic stations also. During installation of these stations it was taking into account the level of the seismicity of selected territory (figure 2).

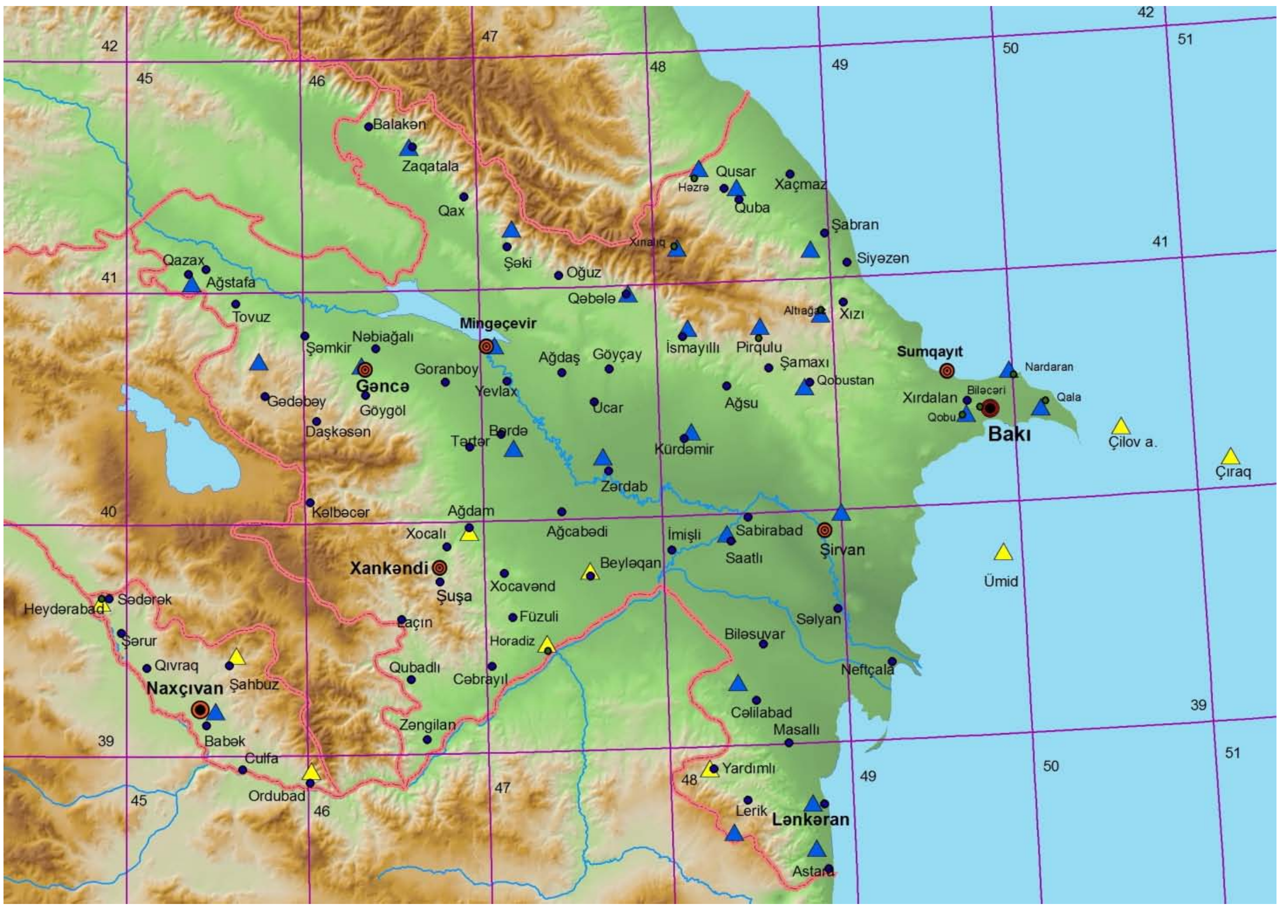


Figure 2. The map of “Kinemetrics” telemetric seismic stations.

At present, in the Azerbaijan territory recording all earthquakes with M ≥ 0.5 and increased accuracy of location of earthquakes. Digital "Kinemetrics" seismic monitoring system allowed to increase efficiency of registration of seismological registration works in the territory of the Republic (during a few minutes determining main parameters of happened earthquake) and also to improve the quality of the results. The possibility of enlarging and zooming in of earthquake records increases the accuracy of registration and measurement of seismic waves (figure 3). This allows determining earthquake source coordinates, magnitude and carrying out spectrum analysis of this seismic waves and defining of source mechanisms and other parameters with high accuracy.

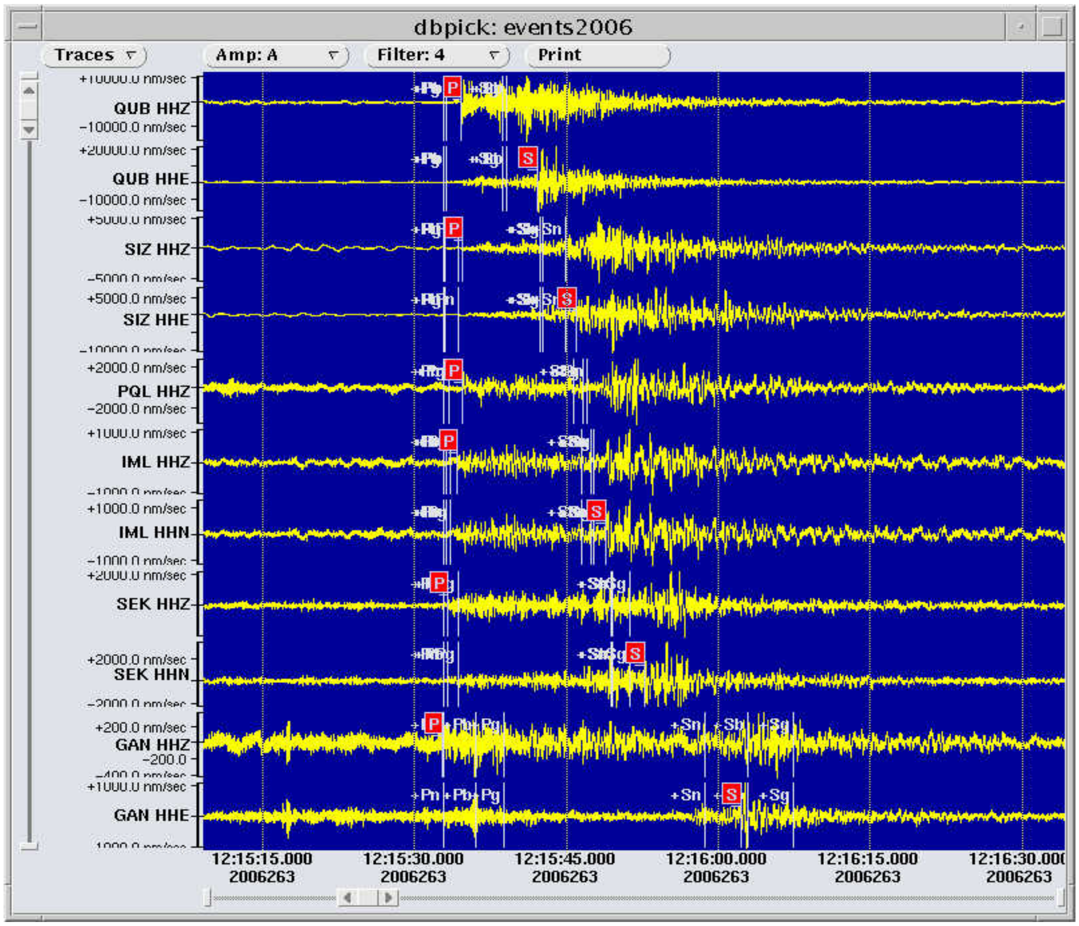


Figure 3. Digital seismogram of earthquake.

Registration of low intensity earthquakes giving large opportunity deeply investigation of seismicity of territory. Seismic regime of the Azerbaijan territory analyzing each year, defining areas characterized with high activity (Fund of RSSC of ANAS from 1980 to 2011).

Despite the regularity of distribution of seismic impacts in the Earth crust on depth has been specified based on data of 482 earthquakes with the magnitude M≥3,5

(K≥10) determined by depth in the territory of the republic within the period before 1980 [2], presently information concerning the depth of earthquakes, which were both small (M≥2,0) and multitudinous (more than three thousand) enable us to speak out thorough and exactly as regards depth encompassed by the seismogenic areas [8].

As a result of researches there was revealed that the earthquakes in the territory of Azerbaijan (especially multitudinous minor earthquakes) were distributed irregularly on the space. The high seismic activity is peculiar to the separate regions of the republic, including the local zones of earthquakes noted beforehand [5] (figure 4).

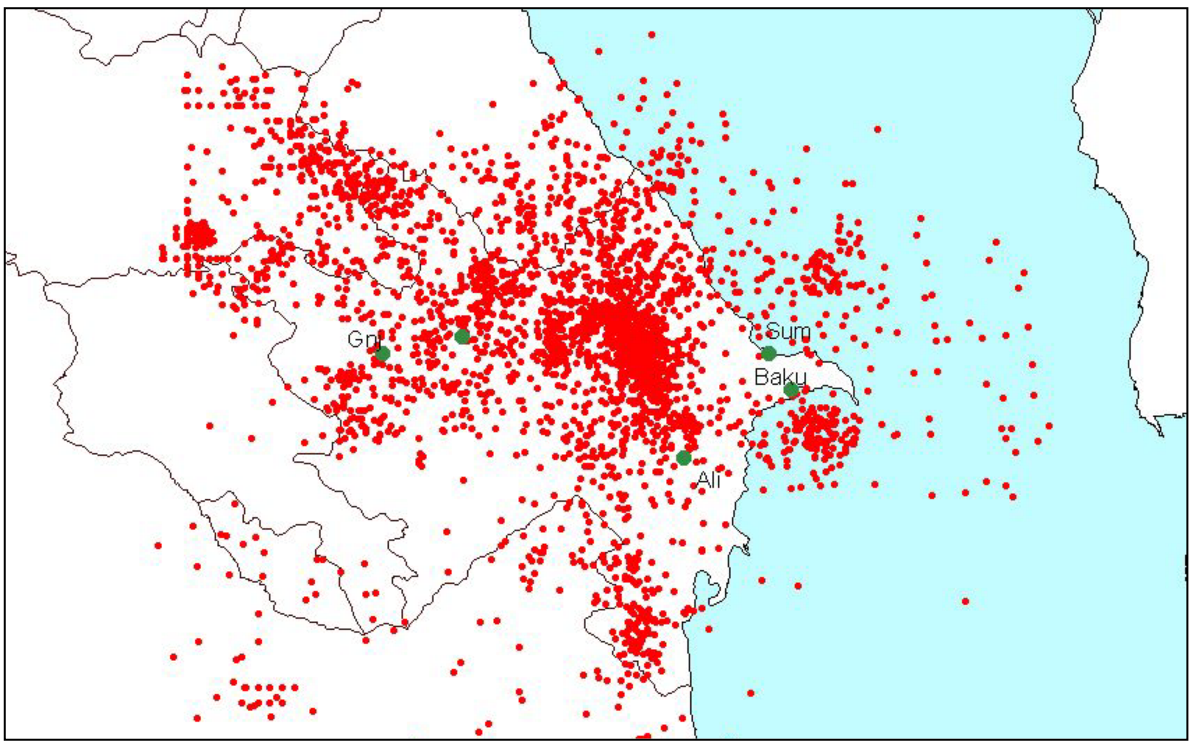


Figure 4. Map of epicentres of earthquakes with K≥9 (M ≥ 2,8) arisen in the territory of Azerbaijan within 1980-2005.

In Azerbaijan, the regions of Zagatala-Balakan, Ganja, Shamakhi-Ismayilli, Guba, Northern Absehron, Imishli-Sabirabad and Talish are defined by higher seismic activity. The epicentral and seismic activity maps drawn up in Republican Seismic Survey Center of Azerbaijan National Academy of Sciences each year (A_{10}) displayed that the mentioned territory was evaluated always by the higher seismic activity.

There analyzed the distribution of earthquake hypocenters in Azerbaijan according to their depth. It is determined that most of focuses in this region have been allocated within interval of 25-30 km. The analysis indicates, that strong earthquakes in Caspian sea have rather greater depths (H~35 km) and consequently are felt in large territory. Earthquakes on a inshore are had on depth H =10-15 km. Deep earthquake focuses are observed in a Caspian Sea (up to 60-70 km) (figure 5).

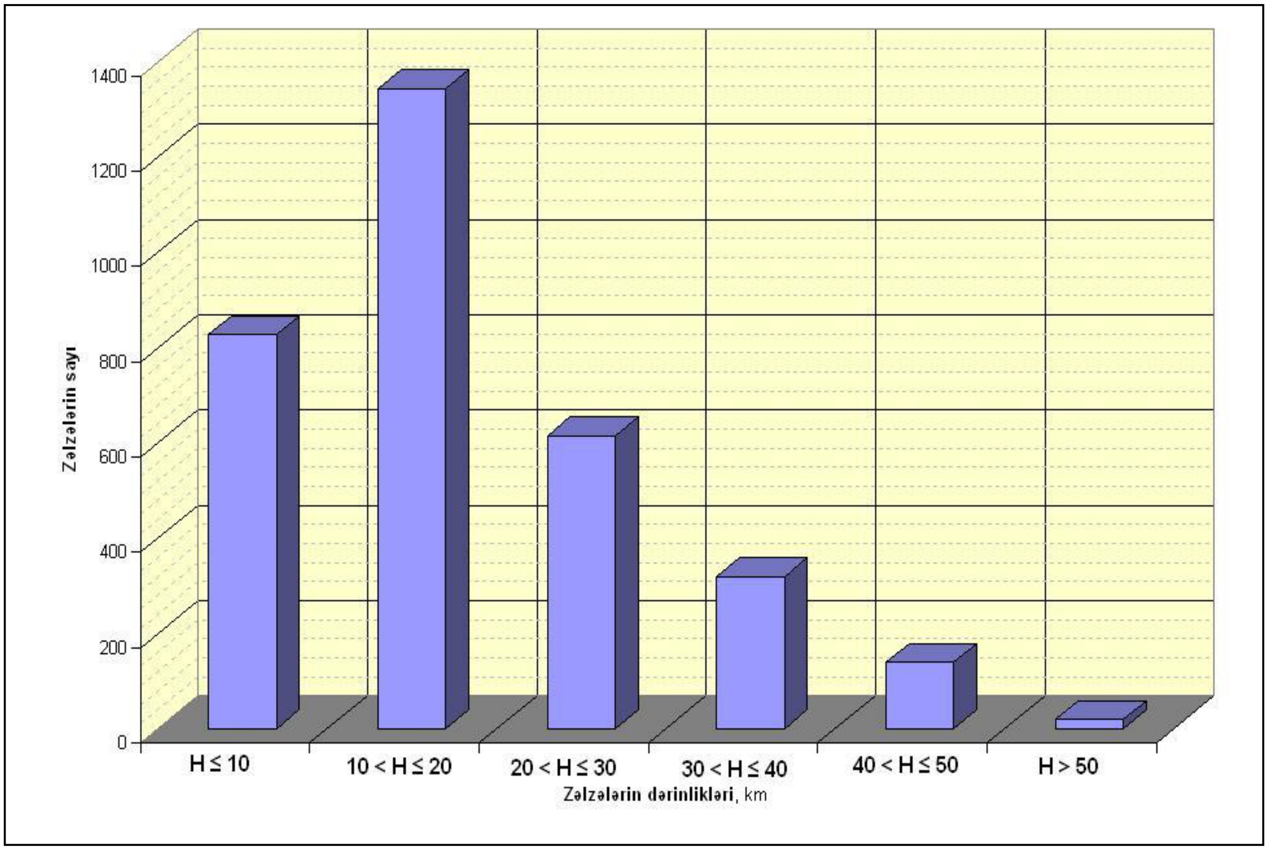


Figure 5. Distribution of earthquake focuses according to their depths, since 1980-2005 years.

There were drawn up several times the seismic zoning maps of Azerbaijan territory based on the analysis of seismological and seismotectonic data. Each time, new information obtained in the field of regional seismology, seismotectonic and geophysics enabling raising the reliability of initial information for evaluating the seismic danger made conditional on necessity of drawing up of seismic zoning maps of the former USSR, including Azerbaijan once again. The last seismic zoning map was drawn up in 1989 [1] and presently is effective (figure 6).

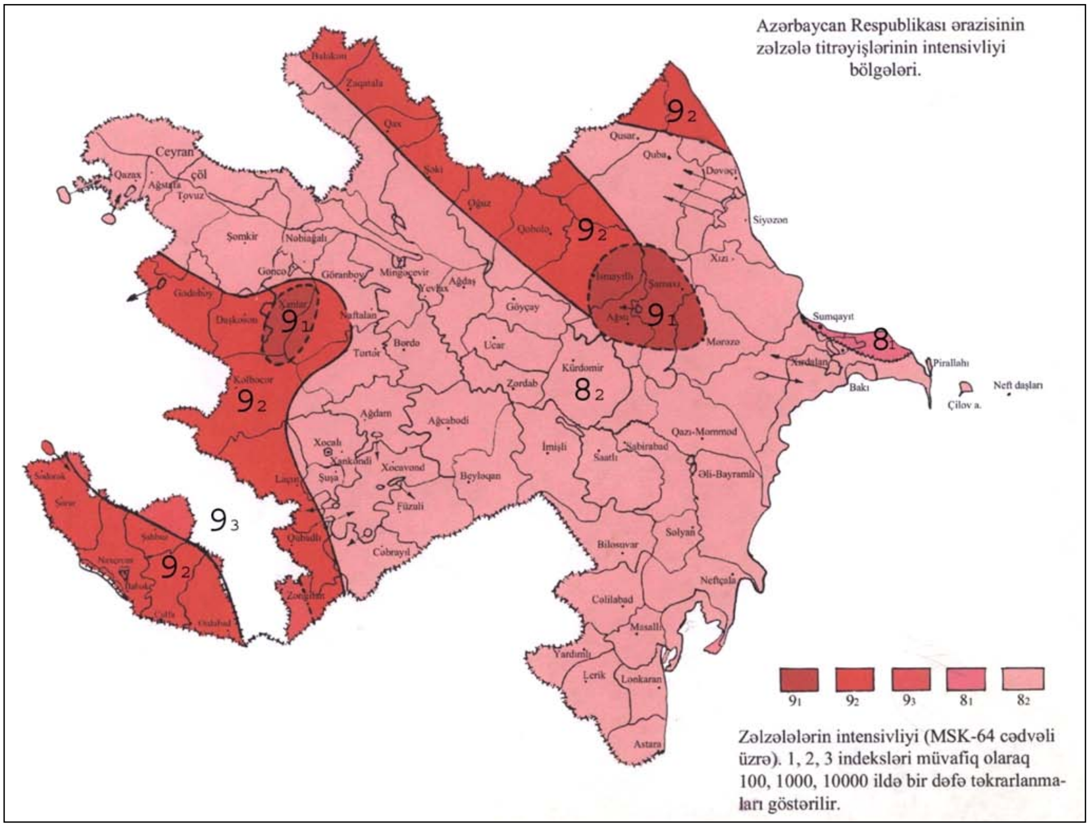
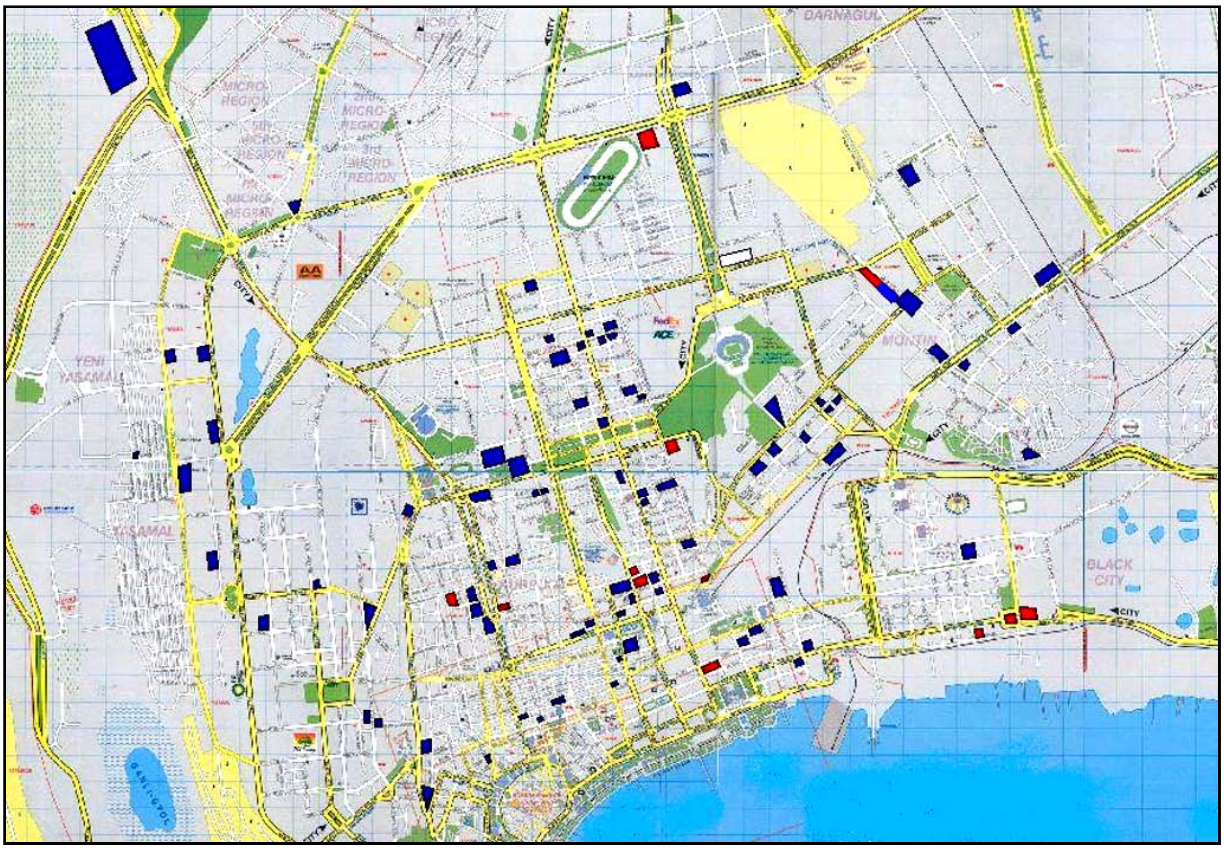


Figure 6. Seismic zonation map-scheme of Azerbaijan territory (1989)

The seismic danger resources for all territory of the republic, as well as for the territory of Baku city have been taken into account while drawing up of this map. It was defined that the highest seismic hazard is expecting from the earthquake focus in Caspian Sea located in 50-60 km of Absheron towards South. The possible massive earthquakes in this focus can shake Baku city by the intensity up to 8 points on the scale MSK-64. As to the seismic hazard to be expected from Caspian Sea, Shamakhi and other focuses located in 100 km from Absheron, it cannot exceed 6-7 grades in the city. But we know that the level of seismic hazards is affected the local engineering geological conditions and the factors of this impact have to be taken into account by all means (figure 7.).

Within the last year we are witness to the wide constructions of multi-storeyed building (skyscraper) in Baku city. The territory's seismic hazard level was determined as per the information of engineering-geological works carried out in these construction fields.

To specify the level of earth tremors of the possible maximum earthquake in the construction field we have to conduct all-inclusive engineering-geological works, i.e. to determine the depth of grounds and underground waters and physical-mechanical and other features of grounds. The results of the seismic zoning works organized in the numerous construction areas of Baku city prove that the potential level of seismic danger in the separate fields of the city varies depending on location [4] (figure 7.).



- 7; - 8 bal; - 9 bal

Figure 7. Scheme of location of seismic zoning areas in Baku city (by MSK-64 scale).

One of the methods of evaluating the territories' seismic hazard level is computing of acceleration peaks (PGA) of the Earth surface arisen by impact of seismic motion while major earthquakes. For this purpose we use the spectral attenuation law of the ground acceleration formed by the impact of seismic motion.

The other factors characterizing the seismic risk include the seismic sustainability of physical objects and the population density. Taking into account these factors, there was drawn up a seismic risk map for Baku city. According to this map-schedule, the coastal territories characterized by fields with unfavourable engineering-geological conditions (watery and loose) are potentially zones of higher seismic hazard (9 points on the MSK-64 scale).

The prediction of the dangerous seismic and other geological processes within the last years based on probability and deterministic idea proves out more dynamically in seismology and construction.

Several methods are employed in estimating of seismic hazard. These procedures are based on theories such as: deterministic, probability, deterministic-probability and other theories.

The researches carried out by us on estimating the seismic hazard of the territory of Azerbaijan are based on computing the seismic hazard in terms of probability theory.

The procedures of estimating the seismic hazard based on theory of probability include first of all the determination of the aforementioned region's seismic centres and the level of seismicity suggested in connection with these.

The procedures of estimating of seismic hazard based on probability include 4 steps:

1. Characteristic of the earthquake source. These sources may be considered spatial, linear and as point depending on their geological nature and generally on the completeness of information.

2. Estimating the source seismic parameters (recurrence) and probability models.
This step arranges the seismic magnitude's recurrence behaviour for each source. The recurrence models are made traditionally based on the Gutenberg-Richter dependence.

3. Selection of ground vibrations' extinction models.

This step includes the extinction coequalities reflecting the ground vibrations alteration depending on the distance from the centre and value of magnitude.

4. The quantitative estimation of the seismic hazard.

This step consists of estimating based on influence of the above mentioned three steps.

Our research accepts the seismic centre zones in the form of range having the known depth on the horizontal surface. It is recognized that earthquakes are distributed inside the range equally and any point thereof contains the probability of motion. There were prepared 10 models of earthquake creating centre zones on the territory of Azerbaijan based on the distribution characteristic of hypocentres on the surface and their near-extreme errors. There was arranged Gutenberg-Richter dependence for each zone of seismic centre and there were computed the values of **a** and **b** coefficients and the activity parameters.

The surges of soil in the analyzed area depending on the distance of the earthquake with known magnitude and the known ground conditions are modelled through seismic vibration's extinction dependence that is one of the key parameters for each seismic hazard model. Therefore we have used the Boore and Atkinson (Boore, Aktinson (2008)) and Campell and Bozorgnia (Campell, Bozorgnia (2008)) extinction dependence formula. The calculations were made for the rock ground conditions and there were accepted that the speed of the transverse earth waves was 760 m/second and the ground's seismic efficiency was equal to the value of acceleration.

The below specified sequence is observed in implementation of the research work:

1. There was drawn up a catalogue encompassing earthquakes of the years of 427-2008 ($M_w \geq 4$); (RSSC of ANAS);

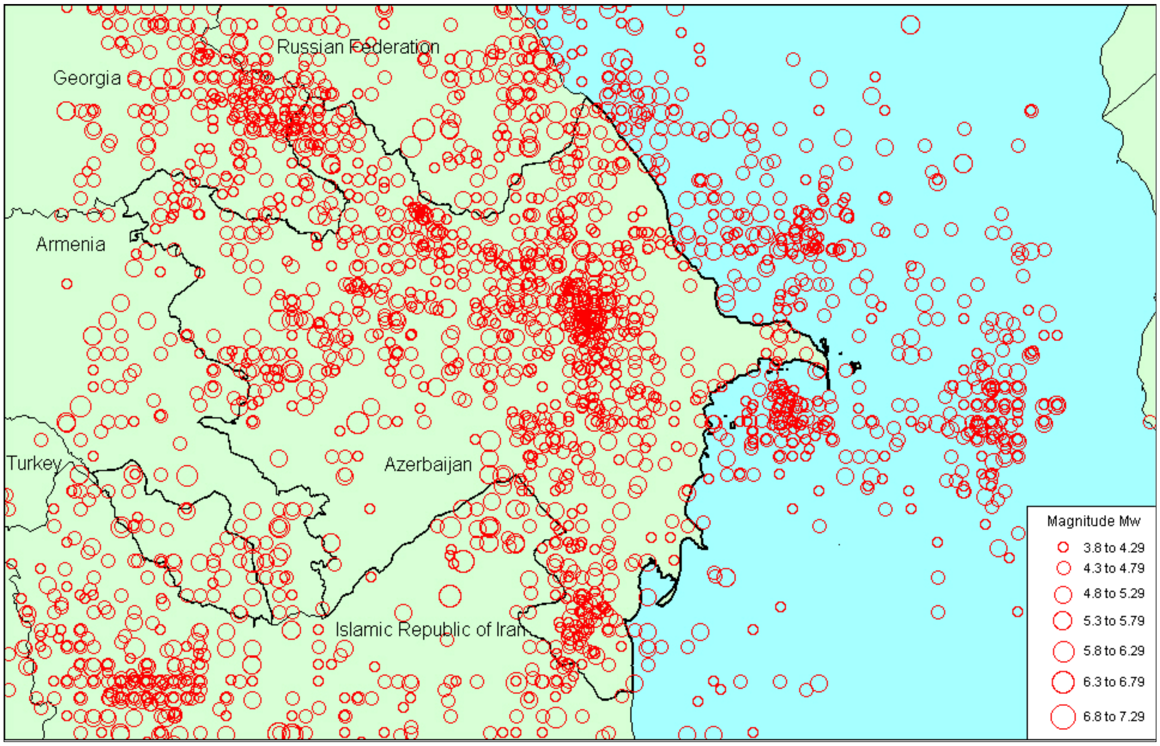


Figure 8. Map of epicentres of earthquakes (with Mw≥4) arisen in the territory of Azerbaijan within 427-2008.

2. Have selected active tectonic faults of Azerbaijan territory which will be used;

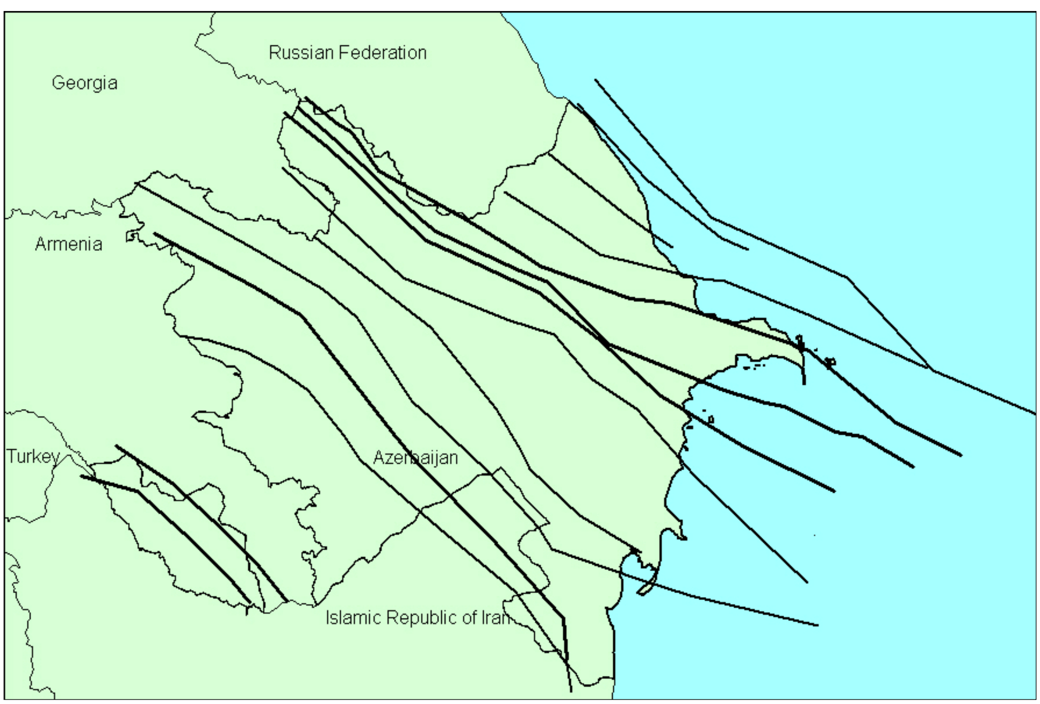


Figure 9. The map of active tectonic faults of Azerbaijan (A.Akhundov)

3. Have created seismic source zone modells (SSZ);

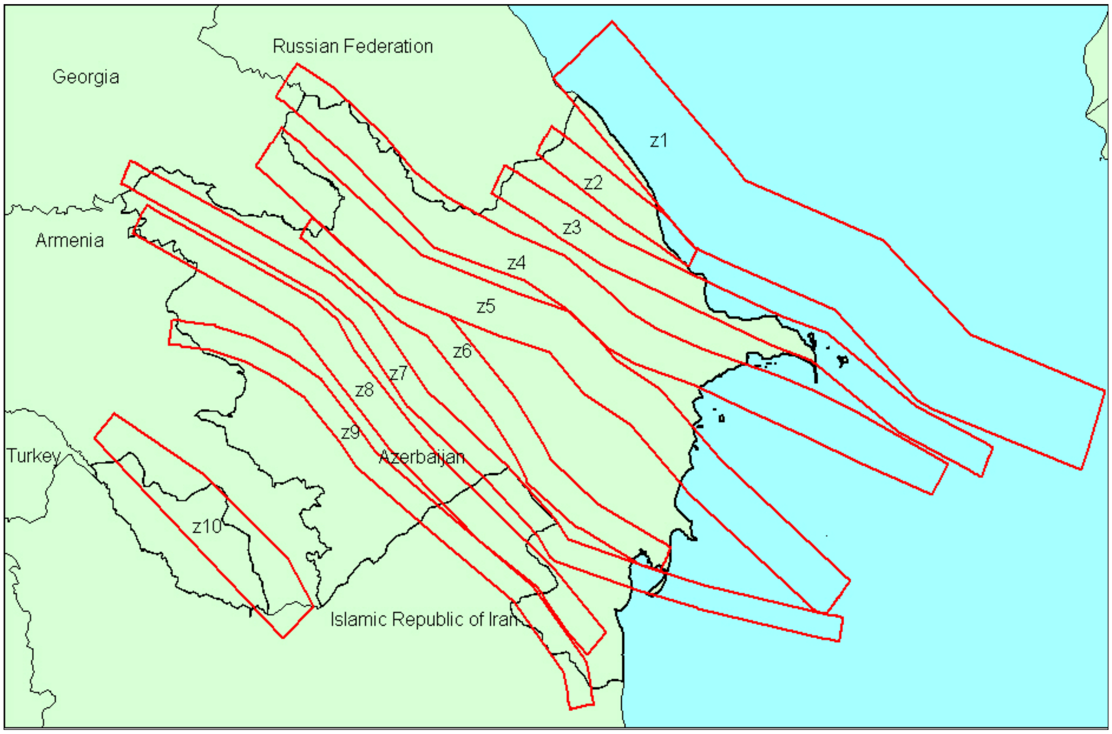


Figure 10. Seismic source zone modells of Azerbaijan territoty (SSZ)

4. The seismic activity for each EOZ zone and values of a and b parameters were calculated;

The seismic characteristics of the earthquake centres originating zones used in estimating the seismic hazards are indicated in the schedule 1.

Schedule 1

SSZ	Mmax	Mmin	Depth		b coefficient	Activity for Mmin
			hmin	hmax		
Zone1	6.6	4.0	10	90	-1.334	2.8
Zone 2	6.0	4.0	9	75	-0.956	0.187
Zone 3	5.7	4.0	3	68	-0.765	0.709
Zone 4	7.0	4.0	2.5	70	-1.215	2.77
Zone 5	6.0	4.0	3	49	-1.449	2.22
Zone 6	5.5	4.0	5	53	-0.93	0.525

Zone 7	6.0	4.0	5	39	-1.13	0.623
Zone 8	6.7	4.0	6	60	-1.296	1.763
Zone 9	6.5	4.0	3	42	-0.937	0.42
Zone 10	6.3	4.0	5	41	-1.051	0.64

5. The seismic hazard of the research area has been estimated using the EZ-FRISK program packet and entered on the map through the MapInfo program. The seismic hazard maps were prepared according to the recurrence interval of 475 (exceeding 10% within 50 years) and 2475 years (with the probability - exceeding 2% within 50 years) of ground's maximal acceleration (pga) and pseudo-acceleration (sa(0.2, 1.0, 2.0, 4.0 second) parameters. The received conclusions were reflected in the form of a map in the figures 11-24.

As the carried out seismic hazardous calculations prove, the seismic hard of the Azerbaijani territory is characterized mainly by the source zones of z4, z8 and z10. And the most powerful earthquakes arisen in the territory of Azerbaijan (in Ganja in 1139, in Shamakhi in 1902, in Caspian Sea in 2000) were related namely to these source zones.

The values of the ground's maximal acceleration in the territory of Azerbaijan in connection with aforementioned factors for 475 recurrence period are equal to 0.22 g (Io=VIII points by MSK-64 scale) and for the recurrence period of 2475 years 0.39 g (Io=IX points), the maximal acceleration in the acceleration spectre correspond to 0.2 second for 475 years recurrence period and their values equal to 0.5 g and 0.88 g for 2475 years recurrence period.

The peak ground displacement (PGD) was accordingly equal to 3.65 cm for 475 year's recurrence period and 9.0 cm for 2475 year's recurrence period.

The peak ground velocity (PGV) were accordingly 9.7 cm/sec for 475 year's recurrence period and 19.5 cm/sec for 2475 year's recurrence period.

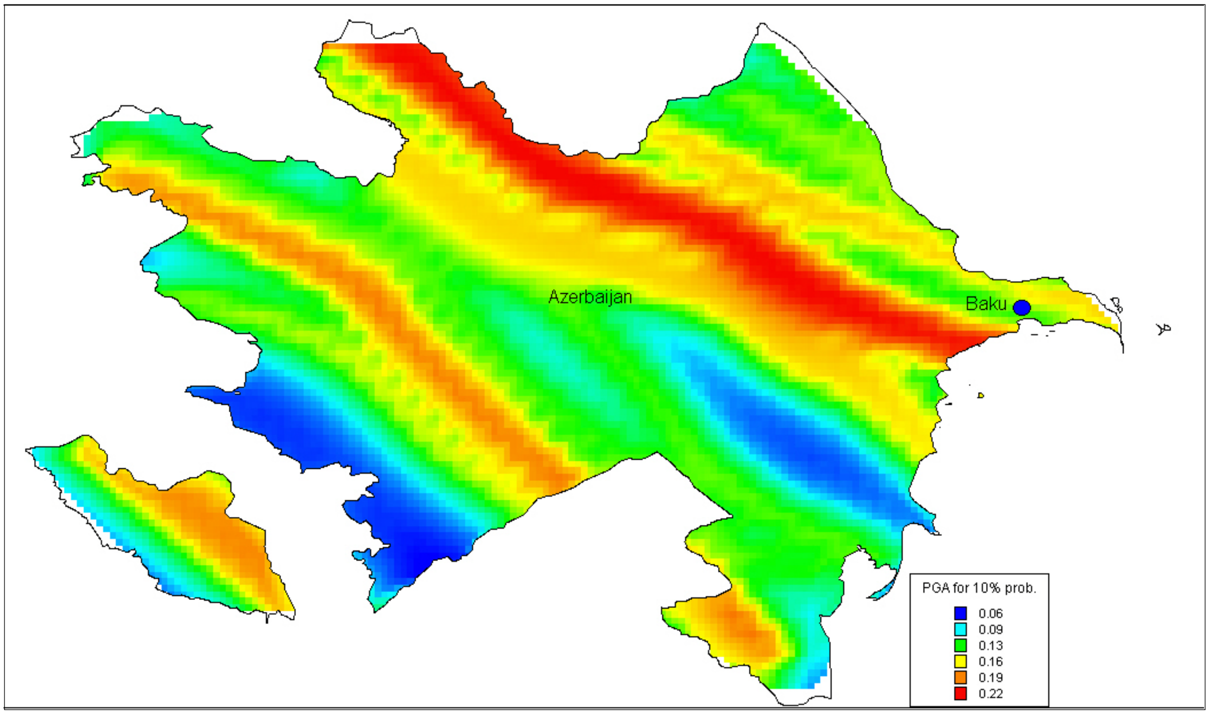


Figure 11. PGA for 475 return period (10% probability)

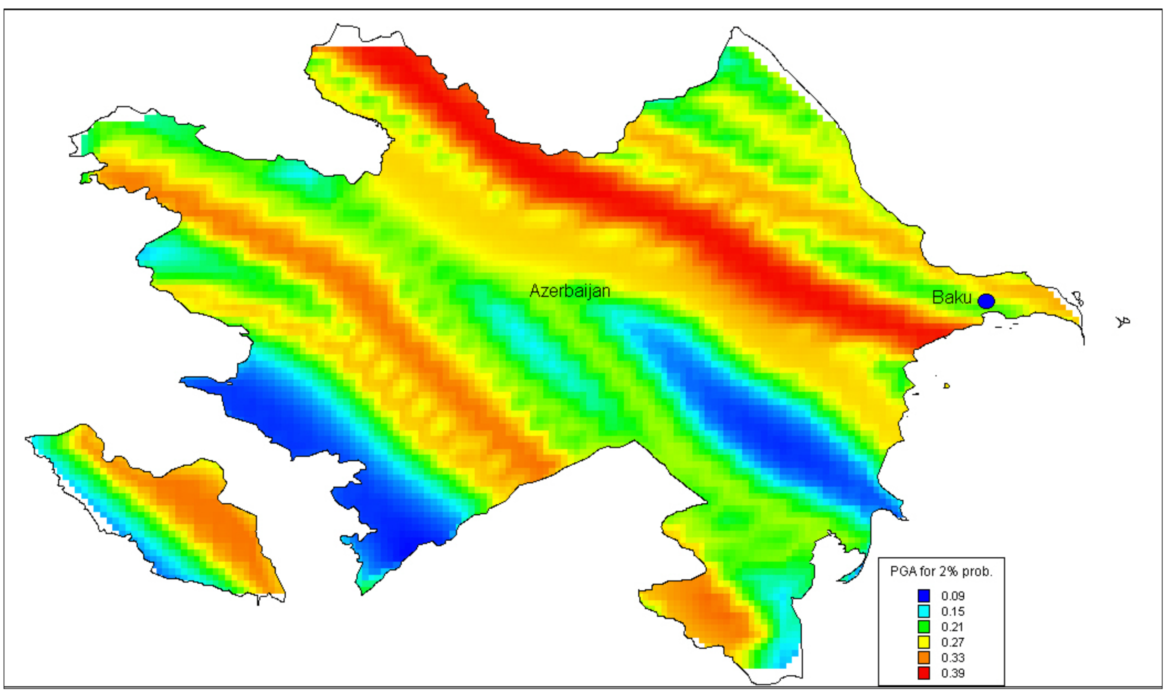


Figure 12. PGA for 2475 return period (2% probability)

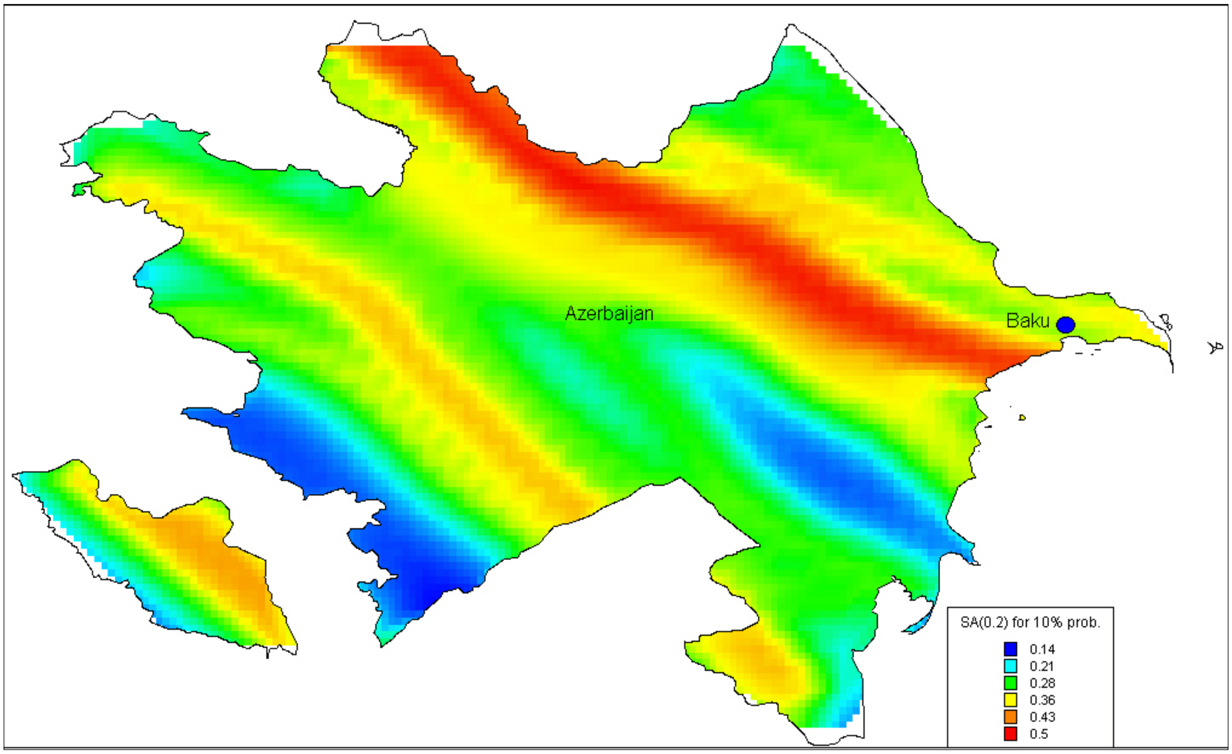


Figure 13. SA (0.2) for 475 return period (10% probability)

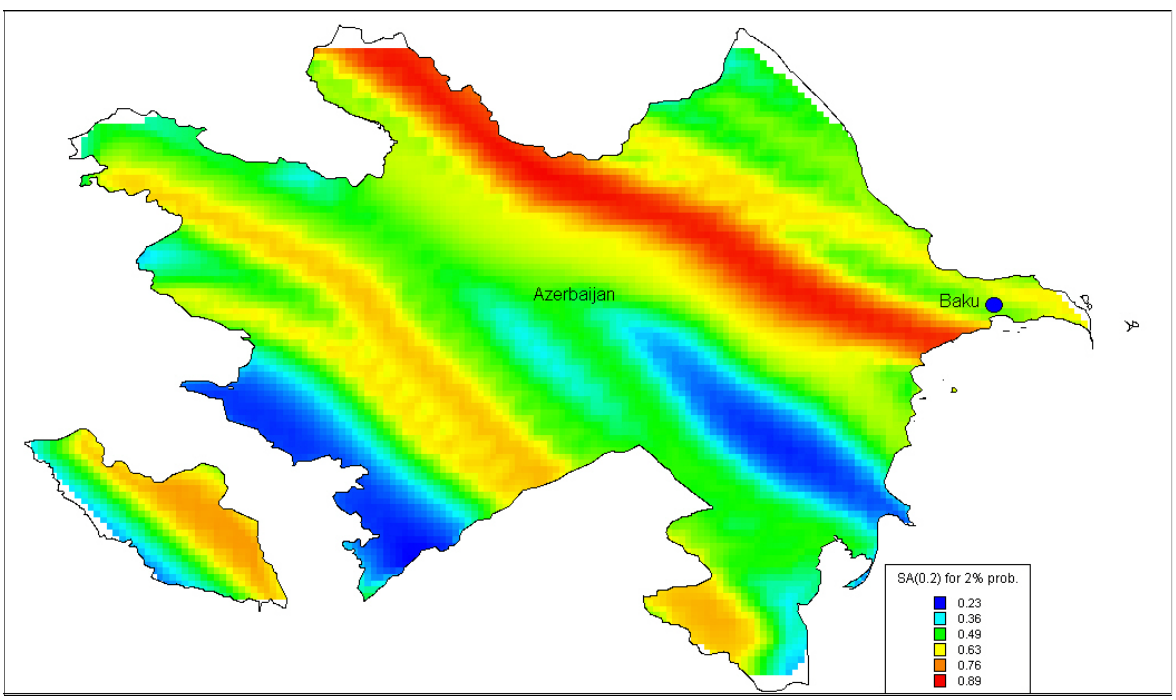


Figure 14. SA (0.2) for 2475 return period (2% probability)

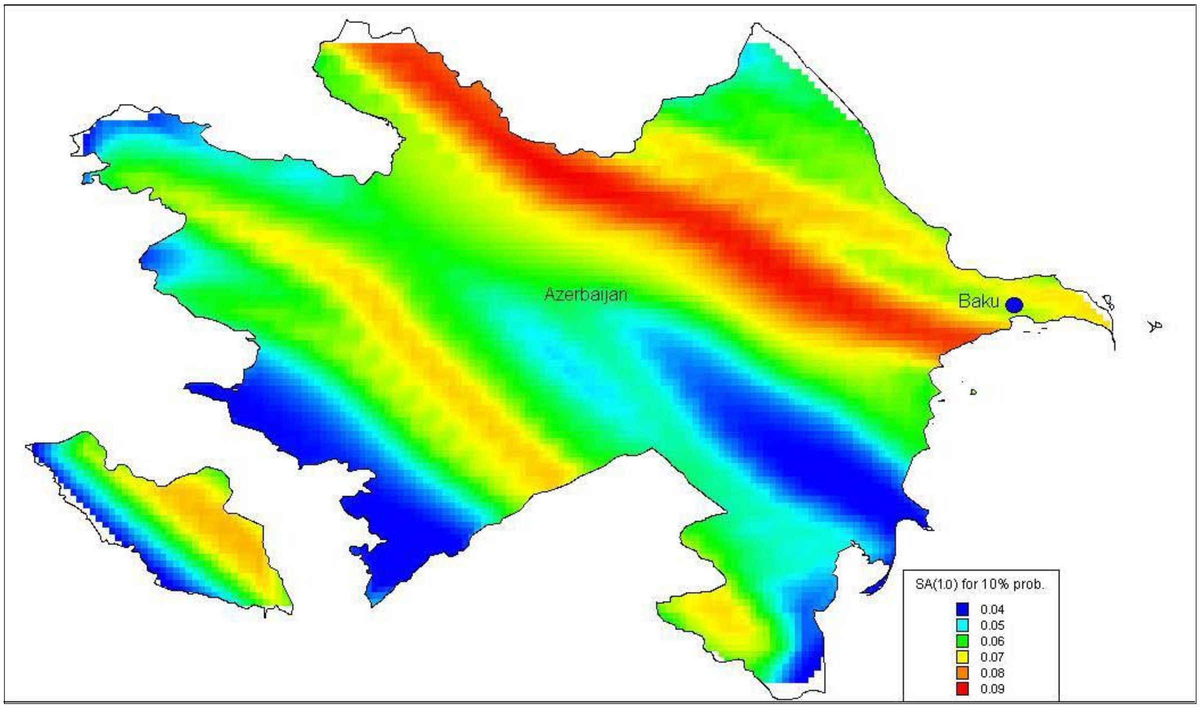


Figure 15. SA (1.0) for 475 return period (10% probability)

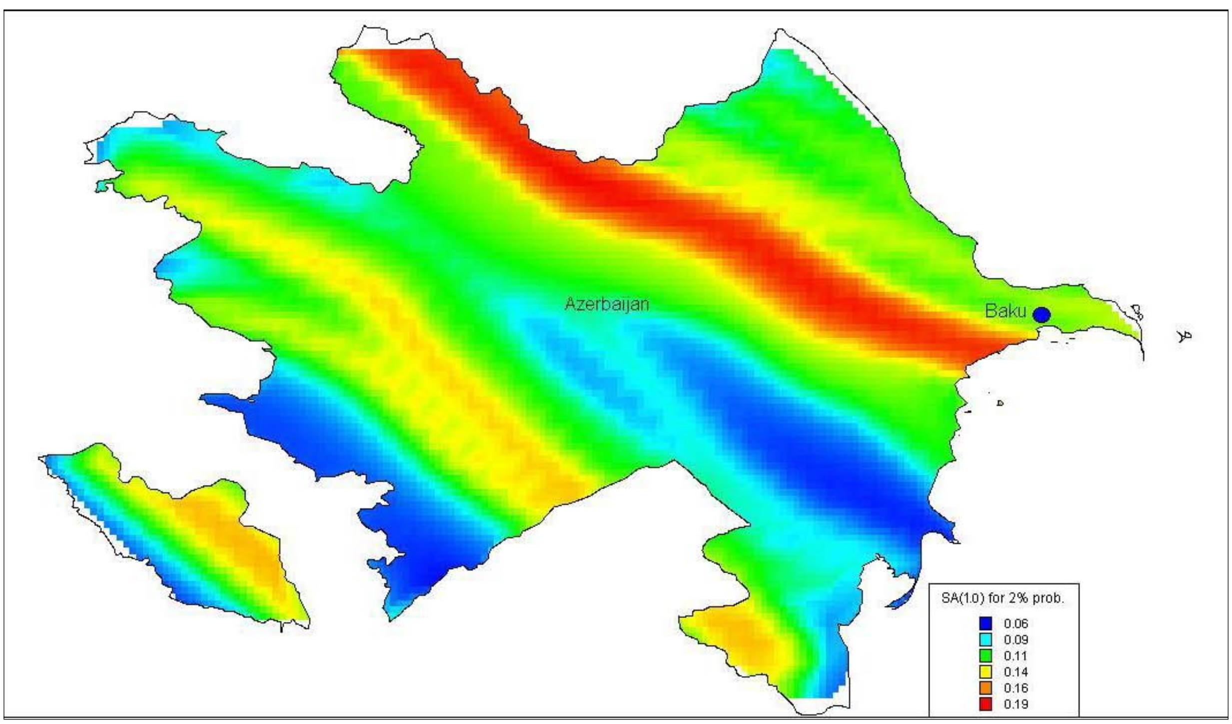


Figure 16. SA (1.0) for 2475 return period (2% probability)

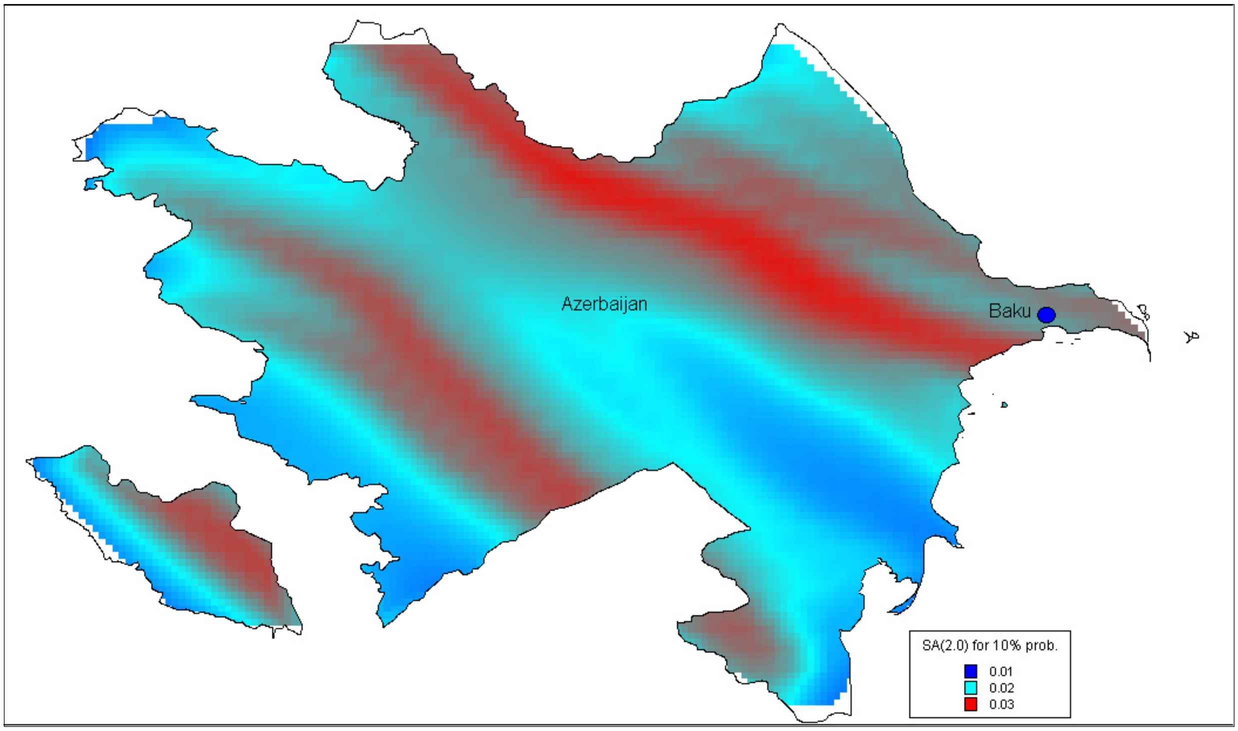


Figure 17. SA (2.0) for 475 return period (10% probability)

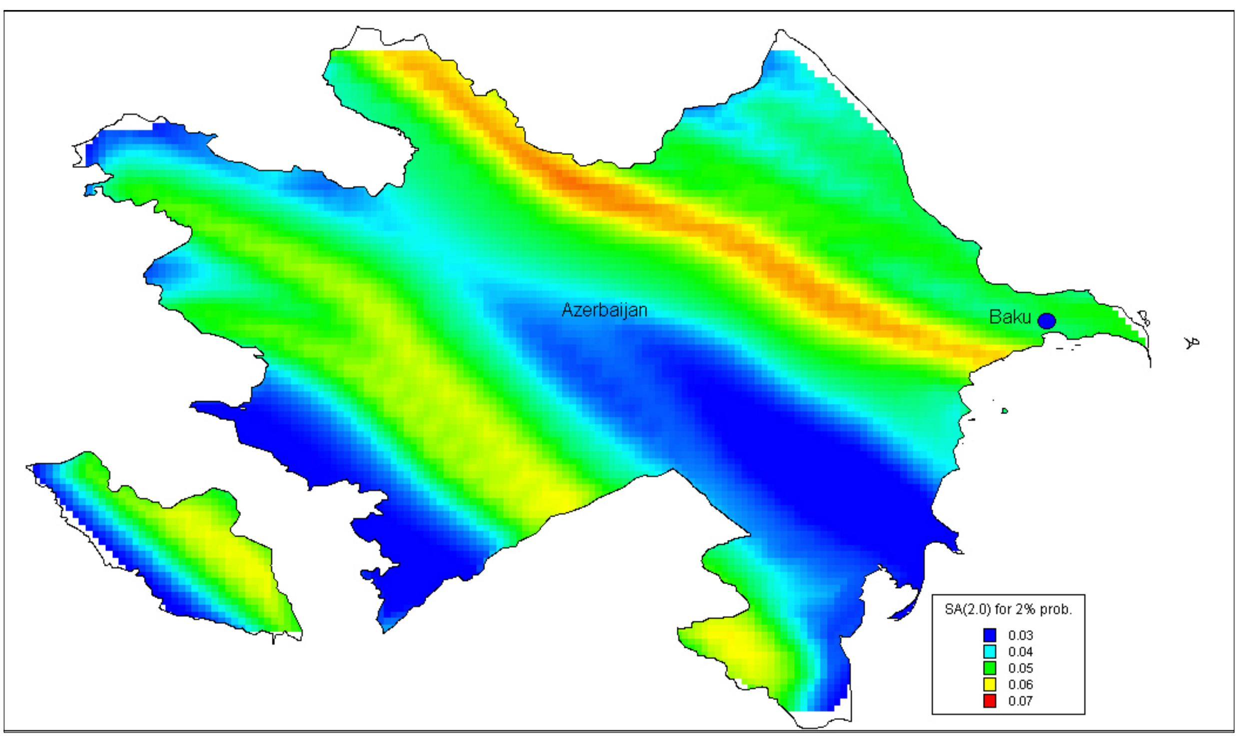


Figure 18. SA (2.0) for 2475 return period (2% probability)

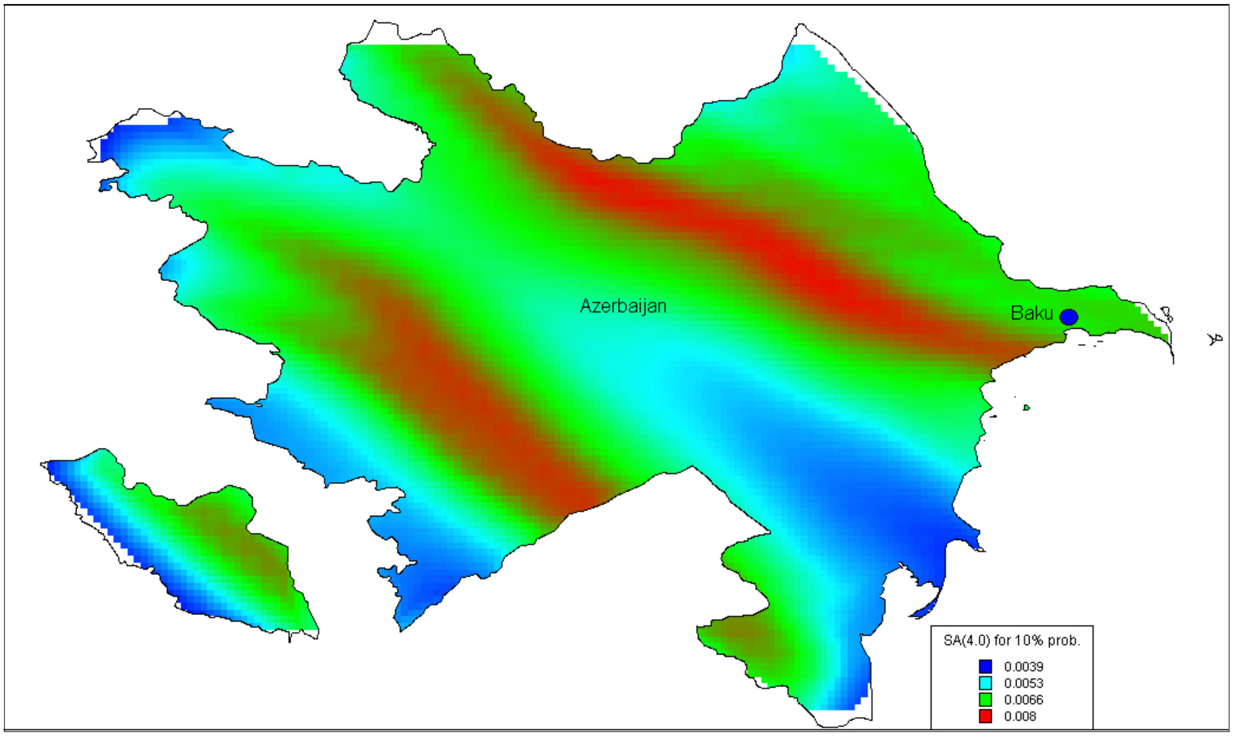


Figure 19. SA (4.0) for 475 return period (10% probability)

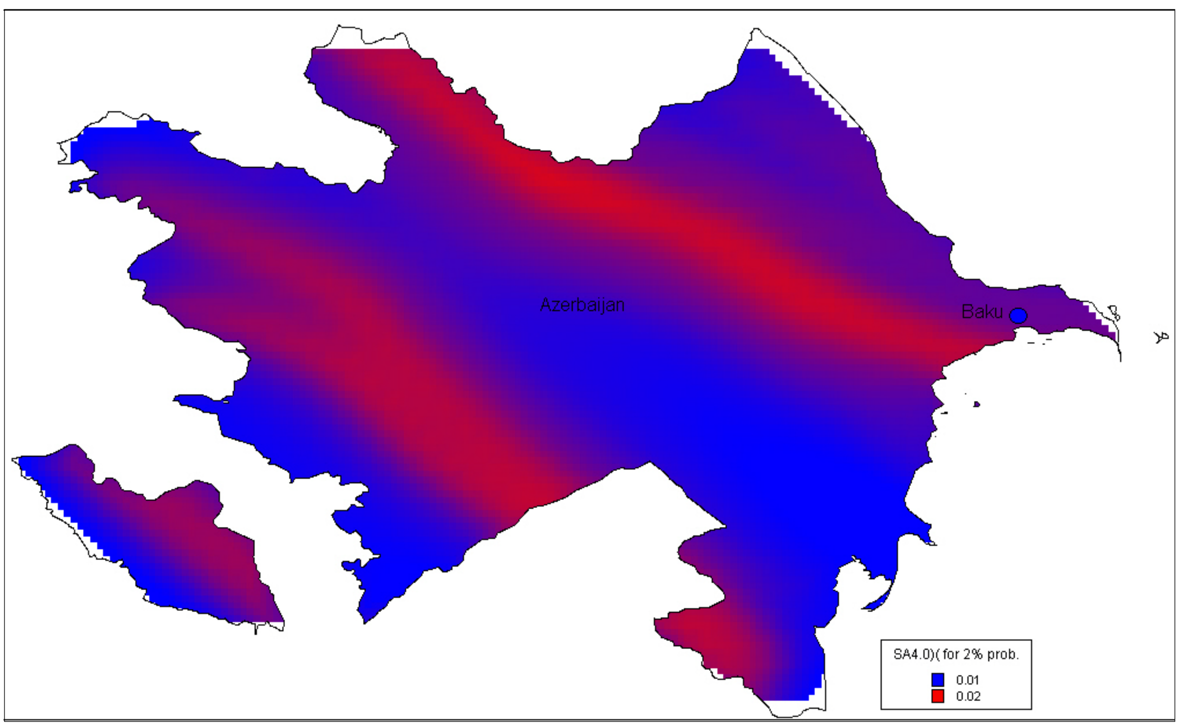


Figure 20. SA (4.0) for 2475 return period (2% probability)

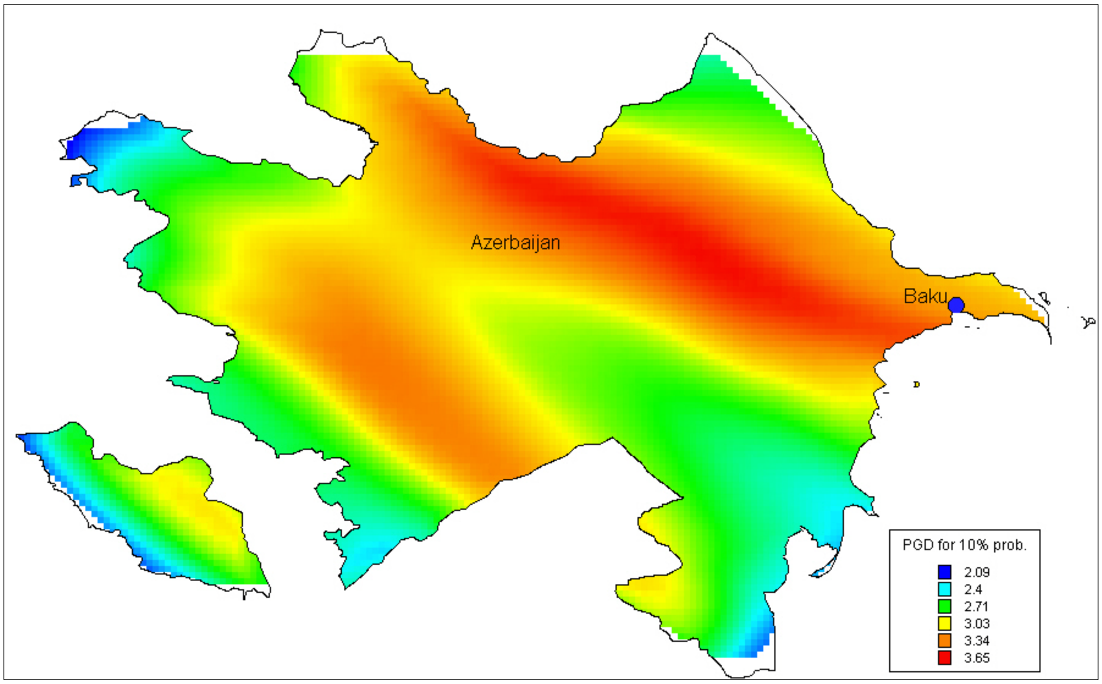


Figure 21. PGD for 475 return period (10% probability)

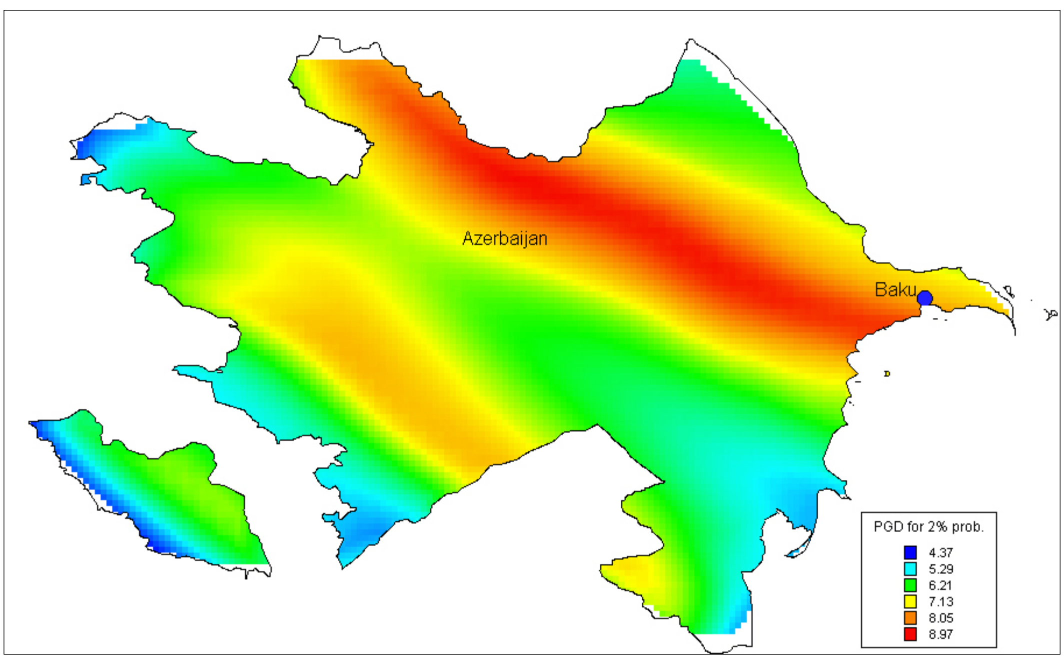


Figure 22. PGD for 2475 return period (2% probability)

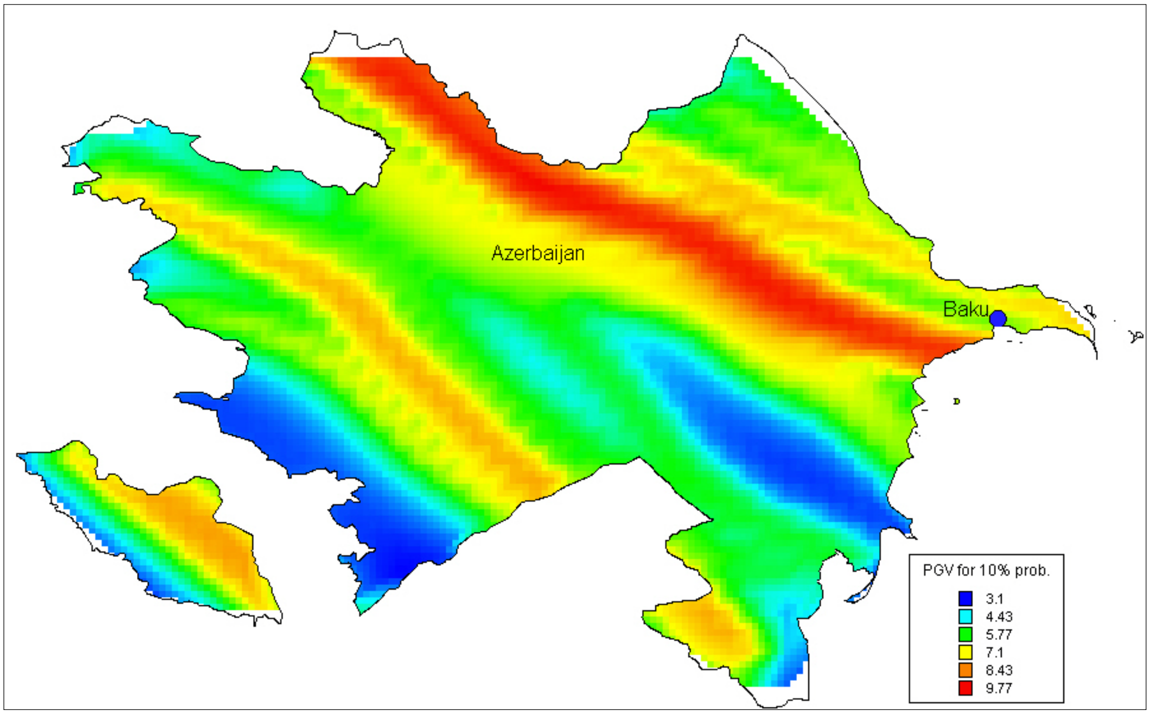


Figure 23. PGV for 475 return period (10% probability)

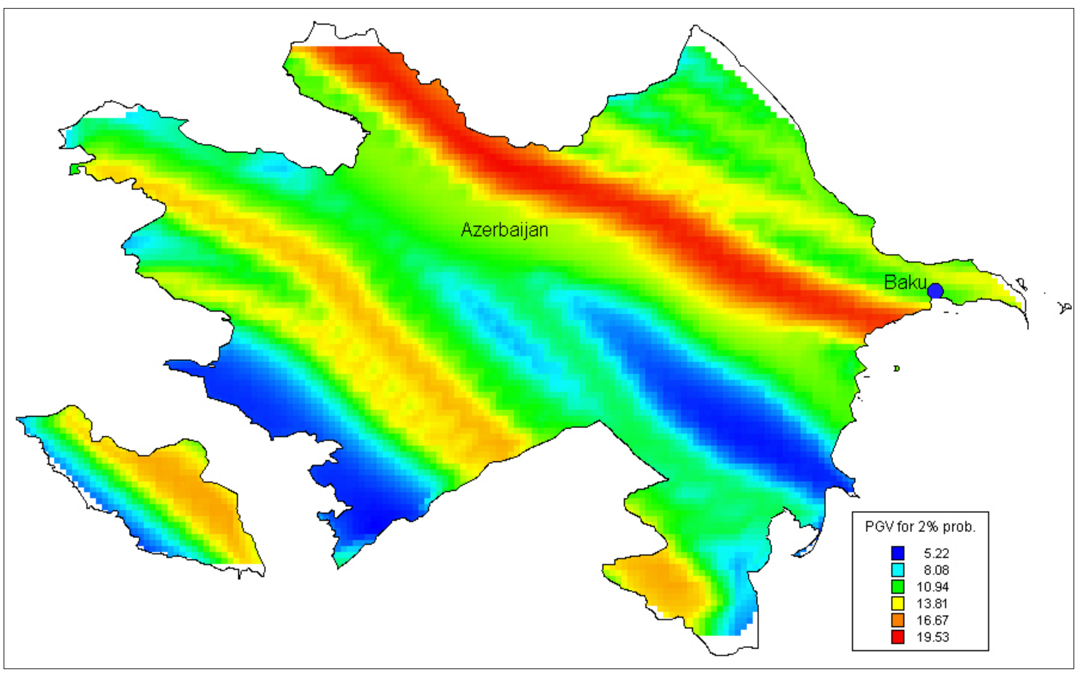


Figure 24. PGV for 2475 return period (2% probability)

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