Urban geology of Gumushane

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Abstract: For urban planning, it is necessary to investigate the engineering geological properties of foundation rock units and also understand behavior of these rock masses. The bearing capacity of the foundation material, strength of rock mass, slope trends, settlement properties and the determination of horizontal ground acceleration during earthquakes are the main data required for determining the structure type and number of building floors. In this study, earthquake, hydrogeological and hydrological, rock mass rippability, topographical, geotechnical, geophysical and geological features beneath the developing city of Gümü hane to define suitable land units for suture development. For assessing the excavatability of the rock the degree of rippability was obtained using both seismic refraction methods and geomechanical parameters. The fequency of flooding of Har it River, which passes through the city, was calculated using the Gumbel probability distribution. Maximum flood discharge rates of 10, 30, 50 and 100 year return periods were investigated and the probability of flooding over the next 10, 20 and 50 year periods calculated. Potential earthquake risks around the city were studied and a magnitude-frequency relationship established. Seismic risk values and return periods of earthquakes between the years 1900 to 2000 were also calculated. Earthquake simulation models were produced using field derived S-Wave velocities, from which horizontal ground acceleration and soil expansion coefficients were calculated. The strength of the fractured rock masses were determined using the emprical Hoek-Brown approach. The bearing capacity of the rock mass was determined using seismic reflection methods. The results obtained in this study were analyzed and evaluated in a computer environment using a Geographic Information System. Finally, maps of engineering geology, slope zonation and flooding were produced. In addition, an urban stability map and a 3-D topographic map of the city were overlayed onto the hazard maps.

Résumé: Dans la sélection du habitat, tout d'abord, il est nécessaire que la récherche des spécialites de l'ingénierie géologie sur des unités composées de la terre de la ville et que la détermination des comportements des roches .Le pouvoir du rèlevement du fondement de la terre, la force de la masse, la condition de la pente, les spécialites du habitat et la détermination des accélerations de la terre ont été réalisées par les vagues du sèisme composent les rénseignements fondementals sur le choix de la structure, du nombre de l'étage. Dans ce travail, on a déterminé la terre convenable pour les habitats et on a pris les rénseignement sur le plan de la consruction en faisant les récherches,sur le sèisme,la géologie, le géopyhisique, la géotécnique, la topographique, la hydrogéologique avec les éxperiances laboratoire et la champ des unités qui se composent l'habitat de la ville de Gümü hane. Le dégre de l'excavation des rouches du habitat a déterminé à avec les paramètres géomecanique et aussi avec la méthode de la cassé du sysmique pour faire bien déscription de la contition de l'excavation et pour faire le correct choix des machines convenables. La rivière Har it où se déroule au milieu de la ville l'analyse de la frequance de la débordé de la rivière Har it où se déroule au milieu de la ville a fait avec la distrubution de la probabilité de Gumbel. On a calcuté la débordé de la courant de l'avoir lieu de la rivière Har it la période 10, 30, 50, 100 années et la probabilité de la répetion dans les périodes du futur, 10, 30, 50, 100 années.

En considerant le sèisme de la ville, on a trouve la rélation magnitude-frequance, à l'aide de la modèle Poisson , on a calcuté la période de la rendre et la value de la risque de la sysmique des sèismes qui ont eu lieu entre les annés 1900-2000.En composant le modèle de la production du scénario du sèisme, en mesurant la vague de la vitesse s des unités composant la champ étudiée a calcuté la maxsimum value d'accélaration horizantal de la terre et la coefficient qui est grandir la terre. On a déterminé la force de la fracture des roches masses avec l'approche ampirique de Hoek-Brown. On a utilisé la mèthode de la fracture sysmique pour la détermination le pouvoir du rèlevement des unités du habitat. Les résultas de la récherche en portant le miliue ortinateur à l'aide de la Système de l' nformation Geographique de hardware et de software a fait analyse et interrogation. Finalement, la Géologie d'Enginière, la focus de la perve et la carte de la débordé et et avec accrocher de ces cartes, à l'inténtion de réaliser la topographie de la ville justement et la carte de la conformité du habitat est composé la modèle de la champ de la nominale ave trois diméntion.

Keywords: Urban geology, weathering, mass strength, bearing capacity, earthquake study, flood, rippability.

INTRODUCTION

Urban planning is key to providing the necessary social and physical infrastructure to accommodate urban migration. An appraisal of the geological and geotechnical properties of the ground must be undertaken to identify restrictions to urban expansion. The issues are generally addressed through environmental geology and generally comprise the identification of the environmental geology, geotechnical appraisal and investigation of geological structure. Geological factors of which urban planners should take account include earthquakes, flooding, landslides and erosion. Therefore, the availability of a reliable geological and geotechnical hazard map for the urban planner is of prime importance. The map should include geological and geotechnical features which are both advantageous and disadvantageous to urban development. While the basic parameters affecting land use in urban planning are topography, geological structure, hydrogeological conditions, climate, rock mass rippability and geotechnical properties of underlying materials, the range and complexity of these parameters increases with respect to engineering in the urban environment. In accordance with these concepts, engineering geological mapping was carried at a scale of 1:5000 out in Gumushane City, northheastern Turkey, in order to characterize the basic engineering geological units. For each urban area, the foundation materials, excavatabiltiy, earthquake hazard, degree of weathering, and suceptibility to flooding were assessed according to specific attribute checklists (Tudes, 2001).

Of the many reasons for undertaking a study of the urban geology in this city, the following are the most important:

- The need for engineering geological information for land use planning;
- That response of the the city to earthquakes has never been observed despite being 80km from the North Anatolia fault line;
- Inadequately scaled geological maps currently in existance for planning purposes;
- The Har it River, which divides the poses a major flood risk.

LOCATION

Gümüşhane, is located at an altitude of 1150 m above sea level off the southern coast of the black sea. The topographical situation of the area is the main obstruction to the development of the city.

The Harşit River, which flows SE-NE through a narrow V-shaped valley, dividing the city in two is the main obstruction to urban development. As a consequence, much of the recent settlement has taken place along the length of the Harşit River.

METHODOLOGY

Paleozoic granitic rocks and Eocene volcanic rocks, which represent the two basic rock types in the study area have been described taking into account the Anon. (1995) classification both in the laboratory and field. Subsequently, the rocks were classified according to the weathering grade of the rock masses throughout the weathering profiles identified at 87 scan line locations. Zones of weathering identified during the engineering geological mapping exercise, were undertaken according to the definitions contained in Anon. (1995) and Ceryan (1999). The areas of weathering identified have been included on the engineering geological map.

In the identification of the engineering features of rock mass, the Hoek-Brown Empirical Approach (Hoek *et al*. 2002) has been utilized along with the modifications for natural slopes proposed by Sönmez and Ulusay (1999). In determining the rippability of the rock masses, a combination of geophysical (Seismic Refraction) and geomechanical parameters have been employed.

For the identification of flooding area, the flood volume and return periods have been calculated using historic flood data. In determining the flooding area a 26 year return period and a 629m^3/sn flooding area for the Har it River have been used in this research.

All earthquakes that occurred between 1900 and 2000 with a magnitude M>4,5 were used in the earthquake hazard analysis.

For the GIS analysis, the ArcInfo 7.0 and ArcView 3.2 software suites have been used.

WEATHERING OF THE ROCKS

The Eocene age volcanics, the Paleozoic Gümüşhane granites and Alibaba formations have been classified according to the degree of weathering (slightly weathered, moderately weathered, highly weathered, completely weathered). These weathering zones have been incorporated in the engineering geological map (Figures 1 and 2). In these maps, the area has been characterised in terms of the geological features, degree of weathering of the rocks and the presence of residual soils.

The classification of the weathered rock materials in the Gümüşhane Granite and Eocene volcanics is based on the preservation of the original rock structure and susceptibility of strength changes upon saturation.

STRENGTH OF THE ROCK MASSES

The degree of weathering for each rock type can be assessed in terms of the Unconfined Compressive Strength (UCS), tensile strength, elastic modulus, cohesion and the angle of internal friction (Tables 1 and 2). The data indicate that as the degree of weathering increases, the strength of the rock mass reduces. For example, the average strength of a rock mass comprising of slightly weathered granite is 116 kg/cm^2, whereas for completely weathered granite the strength decreases to an average value of 10 kg/cm^2.

Table 1. The engineering characteristics determined in the weathering profiles of rock masses.

Rock Type	Weathering grade of rock mass	Statistical values	GSI point	Unconfined compressive sterength, σc (kg/cm^2)	Tensile strength, σtm (kg/cm^2)	Rock mass strength, σcm (kg/cm^2)	Cohesion,C (kg/cm^2)	Internal friction angle, Ø	Modulus Elasticity, E (kg/cm^2)
Granite	Slightly weathered	max	60.00	598	-1.170	168.70	37.20	42	17783
		min	47.00	472	-0.350	97.40	23.30	39	8414
		average	52.00	499	-0.530	115.60	26.80	40	11220
	Moderately weathered	max	51.00	496	-0.005	91.60	22.60	40	10593
		min	23.00	226	-0.310	29.90	8.20	30	1728
		average	35.10	329	-0.110	52.70	13.50	35	4564
	Highly weathered	max	49.00	444	-0.003	73.20	17.60	40	9441
		min	18.00	151	-0.290	16.10	4.50	30	1778
		ortalama	29.90	267	-0.060	38.00	10.00	34	3415
	Completely weathered	max	19.00	158	-0.002	17.00	4.70	32	2239
		min	17.00	58	-0.005	5.00	1.50	30	1242
		Average	17.90	108	-0.004	10.20	2.90	31	1664
Aglomerate	Slightly weathered	max	54.00	447	-0.280	87.30	21.38	38	12589
		min	41.00	272	-0.710	48.71	12.44	34	5957
		average	47.33	377	-0.427	68.60	17.43	36	8987
	Moderately weathered	max	49.00	437	-0.005	59.34	14.98	36	9441
		min	24.00	233	-0.380	22.06	6.46	29	2239
		average	35.25	296	-0.137	40.82	11.13	33	4591
	Highly weathered	max	36.00	326	-0.005	40.17	11.35	33	4467
		min	21.00	129	-0.090	11.03	3.27	28	1884
		average	28.87	218	-0.051	25.18	7.13	31	3060
Limestone	-	max	63.00	702	-0.960	122.11	33.59	34	21135
		min	46.00	291	-3.410	60.54	16.69	30	7943
		average	55.00	528	-2.080	89.27	24.84	32	14028

Table 2. The engineering characteristics determined by the weathering areas defined in the engineering geology maps of the granitic rock masses.

Rock Type	Area Microarea	Statistical values	GSI point	Unconfined compressive strength, σc (kg/cm^2)	Tensile strength, σtm (kg/cm^2)	Rock mass strength, σcm (kg/cm^2)	Cohesion,C (kg/cm^2)	nternal friction angle, Ø	Elasticity module, E (kg/cm^2)
Granite	1	max	60.00	598	-1.170	168.70	37.20	42.39	17783
		min	34.00	256	-1.990	42.50	10.80	35.10	3981
		average	45.20	392	-0.478	86.90	20.30	38.20	9641
	2	max	49,00	444	-0.004	73.20	18.00	39.90	9441
		min	21.00	158	-0.290	16.10	4.50	30.50	1728
		average	32.20	313	-0.083	47,00	12.30	34.70	3857
	3	max	38.00	272	-0.003	28.80	8.00	36.20	5012
		min	17.00	107	-0.060	9.00	2.60	29.50	1496
		average	24.50	170	-0.017	20.00	5.50	32.40	2558
	4	max	26.00	183	-0.005	21.60	6.20	30.10	2512
		min	18.50	58	-0.040	5.10	1.50	30.10	1242
		average	22.30	121	-0.023	13.30	3.80	30.10	1877
Aglomerate	5	max	54.00	447	-0.005	87.30	21.38	37.80	12589
		min	21.00	163	-0.710	14.72	4.34	28.10	1884
		average	35.20	296	-0.161	41.64	11.22	32.50	4869
	6	max	36.00	326	-0.005	40.17	11.35	32.20	3981
		min	24.00	129	-0.100	11.03	3.27	28.70	2054
		average	32.70	250	-0.123	33.64	9.14	31.80	4283
	7	max	34.00	214	-0.005	27.21	7.62	32.80	4467
		min	22.50	152	-0.070	17.07	5.00	29.30	2239
		average	30.50	185	-0.048	21.85	6.14	31.20	3384

THE ENGINEERING GEOLOGICAL MAPPING

The engineering geological units have been delineated according to the strength of the rock masses, bearing capacity (for alluvial soil) and weathering grade (Figure1).

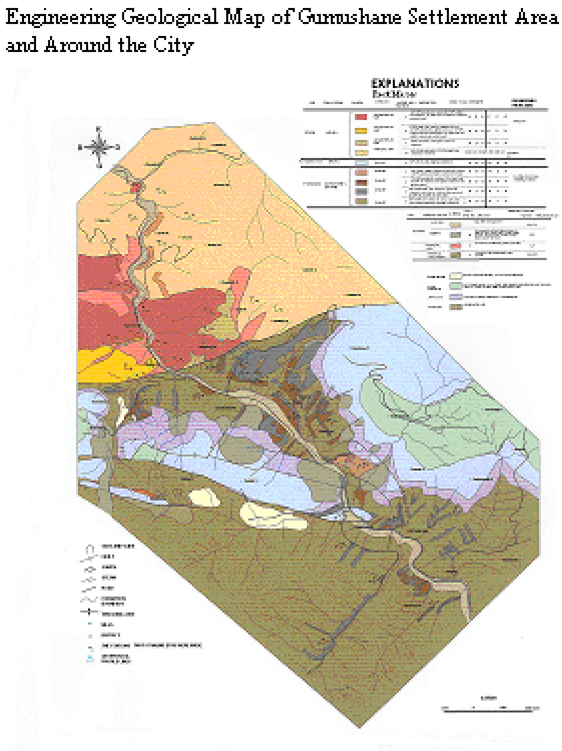

Figure 1. Engineering geological map of Gumushane city and surrounding area.

THE RIPPABILITY OF THE ROCK MASSES

In areas of slightly weathered granite rock masses, it has been concluded that very hard ripping conditions prevail requiring a combination of bulldozers and explosives for excavation. Moderately weathered granitic rocks are characterized by relatively hard ripping using mechanical excavators. Regions of highly weathered granite, the excavation of the rock mass may be achieved by using the middle to heavy functioning bulldozers. Where the rocks are completely weathered, easy ripping conditions prevail with excavation achievable using light bulldozers.

Where slightly weathered agglomerates are present, the rock masses excavation may be achieved using a combination of heavy excavation equipment and blasting. In areas of moderately weathered agglomerate excavation can be carried out by using heavy to very heavy functioning excavators under hard ripping conditions. Where the highly weathered agglmerates occur, excavations can be undertaken using middle and heavy functioning excavators and can be classified as moderate to hard ripping.

Generally, limestone rock masses are characterised by hard ripping and can be excavated by very heavy functioning excavators or blasting.

HYDROGEOLOGY

Water springs

The discharge rate of the River Harşit, the largest river of the region, fluctuates between 3.20 and 192 m3/sn. The streams connected to Harşit river from Gümüşhane city center to the springs are Işık, Pirahmet, Kabaköy, Akgedik, Arzular, to Mansaba are Nivena,Körüm, Gümüştuğ, Budak, Manastır, Kürtün, Hain, Göçük, and Gavraz springs.

There are many desalinated and mineral water sources within the city of Gümüşhane. However, the discharge rate of most of the springs is too low for exploitation .

The water sources of Budak, Tekkeköy, Akgedik, Yıldız, İnkılap, Yeşildere, Güvercinlik have been analyzed for temperature, physical, chemical, bacteriologic, radioactivity, and concentration of trace elements (Gültekin,1988). The discharge rates of the springs vary between 0.011 and 1.5 lt/sn and the temperatures range between 9 and 17 degree Celcius. From these measurements, it can be concluded that the water does not meet the criteria given in TS 9130 drinking water standards (Gültekin,1988).

In areas of limestone, granite and volanic rocks very few aquifers exist which can be expoloited for drinking water. This is because of the highly fractured and broken structure of the rock masses in repsonse to tectonic movements.

The only aquifer present is found within the alluvium deposited by the Gümüşhane river. The thickness of alluvium has been proven to be in excess of 24 m by DSI during well drilling. The source of the water supporting the aquifer withing the alluvium has been found to be the Harşit river.

Flood discharge, flood frequency analysis and identification of the flood area boundary of the Harsit River

Around Gümüşhane city center there are numerous high-rise developments constructed on the Harşit river alluvium. This necessitates the need for identifying the area at risk from flooding. The flood risk area was defined using the 26-year peak discharge rate of the Harşit River, with return periods and flood discharge rates being calculated by fitting a Gumbel distribution to the data. A conservative estimate of flooding was achieved using a flood volume of 629m^3/mn, which has a calculated return period of 150 years (Table 3).

Table 3. Annual maximum flood discharge rates of Harsit River.

Observation years	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1994	1998	1999
Max. discharge rate (m^3/sn)	125	320	145	81	120	96	49	79	61	100	56	240	130	200	96	140	120	110	120	110	200	180	125	629	105	136	165

Flood Frequency Analysis of Harşit River

The annual flood discharge rates of the Harşit River for 10, 30, 50 and 100 year return periods have been calculated using a Gumbel distribution and the probability of a flood event within 10, 20 and 50 years estimated. (Table 4).

Table 4. Annual flood discharge rates in 10, 30, 50 and 100 years and flooding probability in next 10, 20 and 50 years.

T (year)	10	30	50	100
Flood discharge rate (m^3/year)	355	465	510	582
Flooding probability, minumum once, in next 10 years	0.65	0.29	0.18	0.095
Flooding probability, minumum once, in next 20 years	0.88	0.49	0.33	0.18
Flooding probability, minumum once, in next 50 years	0.99	0.81	0.64	0.39

Identification of flooding area boundary for the Harsit River

The boundary of flooding area for the Harşit river at 10, 30, 50 and 100 years is 582 m3/sn as shown in Table 4. However, Table 3 indicates that the greatest volume of the river is 629m3/mn, which has a return period of 150 years.

Earthquake Features of the Gümüşhane City Surrounding Area

Many different types of passive faults occur in the area surrounding Gümüşhane. However, no seismic activity related to these faults has occurred during the historical and instrumental period. The largest earthquakes which have historically occurred within the study area are: the M>7.8 1939 Erzincan earthquake; M>6.8 Karlıova EQ and the >M6.8 Erzincan EQ, which occurred in 1992. The most important tectonic structure which affects the region is the North Anatolian Fault (NAF), 80km away from the city centre of Gümüşhane. Consequently, the earthquake hazards have been analyzed in terms of the activity of the NAF fault zone and the effect this has on Gümüşhane.

Magnitude frequency correlation

The magnitude-frequency relationship for earthquakes M>4.5, occurring between the years 1900 and 2000 in the NAF zone have been analyzed. Parameters A and B, which identify the strength of the magnitude-relationship correlation, have been computed as A=4.86, B=0.68 and the magnitude-frequency relationship may be expressed as LogN=4.86-0.68M.

Throughout the study area the percentage of a/b is identified as=7.14, while for the NAF line the magnitude frequency correlation is LogN=5.47-0.6M, and percentage of a/b is 9.2 (Bayrak, 2000). That the percentage of a/b on NAF is stronger than the chosen region indicates that the seismic activity on NAF is much more intense.

Through these approaches, with the goal of identifying the changes according to the seismic regions, calculated for a grid spacing of 0.25x 0.25, a contour map showing the distribution of a/b values has been produced. This map indicates that the highest a/b ratios are found in the region surrounding Erzincan, where the NAF zone passes through but declines towards Gümüşhane as the distance from the fault zone increases.

The NAF zone is subject to high strain accumulations, which produce large magnitude earthquakes as this strain is released. Away from the fault, as a/b ratios decline, seismic activity is much reduced. In the area surrounding Gümüşhane City, the earthquake risk and possible return periods have been calculated using a Poisson probability model. By using the magnitude-frequency relationship and the a/b parameters the siesmic risk and return period was calculated for the earthquakes which ocurred between 1900 and 2000. A relationship has been established between the magnitude of the earthquake and the return period. It was established that as the earthquake magnitude increases, the return period increases exponentially. In addition, the probability of an earthquake occurring decreases as the magnitude increases.

In order to determine the earthquake activity in the region, the distribution of earthquakes was investigated according to date of occurance and magnitude. This data was then included in the seismic hazard map.

STUDY OF GEOPHYSICS

Using the shear wave velocity and density of the rock massses, the shear modulus, Young's modulus, ground-vibration period and bearing capacity of the rock masses has been calculated using a number of techniques.

Peak ground accelerations were calculated for the area surrounding Gümüşhane and these accelerations were then converted into obersvational intensities using the Mercalli intensity scale (Pinter, 1996), (Tables 5, 6, 7, 8, 9, 10, 11 and 12).

Table 5. The depth distribution of engineering parameter from ground surface determined by seismic refraction methods at No 1. profile line (measuring location: Fındıklı Hill, Figure 1).

Height (meter)	Litology	Elastic parameters and bearing capacity				Soil vibration period, (Tsn) H=height, m	Max. horizantal acceleration, a, cm/sn^2	Earhquake intensity, I(MSK)
1. 35	Debris	Vp=261 m/sn Vs=146 m/sn	ρ =1.65 (gr/cm^3)	q_u=0.18 (kg/cm²)	μ =352 (kg/cm²) E=896 (kg/cm²)	H=10, T=0.17sn H=25, T=0.42	94.29	7
4.69	Lias old Volcano-sedimantere seri	Vp=1084 m/sn Vs=413 m/sn	ρ =1.82 (gr/cm^3)	q_u=12.74 (kg/cm²)	μ =3098 (kg/cm²) E=8770 (kg/cm²)	-	-	-
4.69	Slightly weathered granitic rock	Vp=2400 m/sn Vs=1200 m/sn	ρ =2.08 (gr/cm^3)	q_u=138 (kg/cm²)	μ =29952 (kg/cm²) E=79872 (kg/cm²)	H=10, T=0.03 H=25, T=0.08sn	68.2	4

Table 6. The depth distribution of engineering parameter from ground surface determined by seismic refraction methods at No 2. profile line (measuring location: Fındıklı Hill, Figure 1).

Height (meter)	Litology	Elastic parameters and bearing capacity				Soil dominate vibration period, (Tsn) H=height,m	Max. horizantal acceleration, a, cm/sn^2	Earhquake intensity, I (MSK)
0.78	Debris	Vp=292.5m/sn Vs=146 m/sn	ρ =1.66 (gr/cm^3)	q_u=0.25 (kg/cm²)	μ =354 (kg/cm²) E=943 (kg/cm²)	H=10, T=0.27sn H=25, T=0.69	101.8	7
7.40	Lias old Volcano-sedimantere seri	Vp=814 m/sn Vs=413 m/sn	ρ =1.76 (gr/cm^3)	q_u=5.40 (kg/cm²)	μ =3006 (kg/cm²) E=7978(kg/cm²)	-	-	-
7.40	Slightly weathered granitic rock	Vp=2150 m/sn Vs=1200 m/sn	ρ =2.03(gr/cm^3)	q_u=99.4 (kg/cm²)	μ =29232 (kg/cm²) E=74469 (kg/cm²)	H=10, T=0.04 H=25, T=0.10sn	70.4	4

Table 7. The depth distribution of engineering parameter from ground surface determined by seismic refraction methods at No 3. profile line (measuring location: Eskiba lar Valley, Figure 1).

Height (meter)	Litology	Elastic parameters and bearing capacity				Soil dominate vibration period, (Tsn) H=height, m	Max. horizantal acceleration, a, cm/sn^2	Earhquake intensity, I (MSK)
1.40	Arena	Vp=700 m/sn Vs=240m/sn	ρ =1.74 (gr/cm^3)	q_u=3.43 (kg/cm²)	μ =1002 (kg/cm²) E=2873 (kg/cm²)	H=10, T=0.23sn H=25, T=0.57	<86.7	>5
↓	Highly weathered granitic rock	Vp=1286 m/sn Vs=770 m/sn	ρ =1.86 (gr/cm^3)	q_u=21.27 (kg/cm²)	μ =1101 1 (kg/cm²) E=26800 (kg/cm²)	H=10, T=0.05 H=25, T=0.13sn	78.2	4-5

Table 8. The depth distribution of engineering parameter from ground surface determined by seismic refraction methods at No 4. profile line (measuring location: Inonu District, Figure 1).

Height (meter)	**Litology**	**Elastic parameters and bearing capacity**				**Soil dominate vibration period, (Tsn) H=height, m**	**Max. horizantal acceleration, a, cm/sn²**	**Earhquake intensity, I (MSK)**
1.07	Arena	Vp=390 m/sn Vs=176 m/sn	ρ =1.68 (gr/cm³)	q_u=0.60 (kg/cm²)	μ =519 (kg/cm²) E=1426 (kg/cm²)	H=10, T=0.32sn H=25, T=0.80sn	>86.7	>5
↓	completely weathered granitic rock	Vp=954 m/sn Vs=554 m/sn	ρ =1.80 (gr/cm³)	q_u=8.68 (kg/cm²)	μ =5496 (kg/cm²) E=13692(kg/cm²)	H=10, T=0.07sn H=25, T=0.18sn	78.2	5

Table 9. The changing of engineering parameter from surface to deep determined by seismic reflaction methods at the 5. profile line (measuring location: Emirler District, Figure 1).

Height (meter)	**Litology**	**Elastic parameters and bearing capacity Vp (m/sn), Vs (m/sn)**				**Soil dominate vibration period, (Tsn) H=height, m**	**Max. horizantal acceleration, a, cm/sn²**	**Earhquake intensity, I (MSK)**
0.56	road fill	Vp=686 m/sn Vs=364m/sn	ρ =1.74 (gr/cm³)	q_u=3.24 (kg/cm²)	μ =2301 (kg/cm²) E=6005 (kg/cm²)	-	-	-
5.68	moderately weathered granitic rock	Vp=1858 m/sn Vs=1034 m/sn	ρ =1.97 (gr/cm³)	q_u=64 (kg/cm²)	μ =21029 (kg/cm²) E=53780 (kg/cm²)	H=10, T=0.04sn H=25, T=0.10sn	72	4
↓	Slightly weathered granitic rock	Vp=2824 m/sn Vs=1700 m/sn	ρ =2.16 (gr/cm³)	q_u=225 (kg/cm²)	μ =62563 (kg/cm²) E=152131 (kg/cm²	H=10, T=0.02 H=25, T=0.07sn	67.3	4

Table 10. The depth distribution of engineering parameter from ground surface determined by seismic refraction methods at No 6. profile line (measuring location: Topal District, Figure 1).

Height (meter)	**Litology**	**Elastic parameters and bearing capacity**				**Soil dominate vibration period, (Tsn) H=height, m**	**Max. horizantal acceleration, a, cm/sn²**	**Earhquake intensity, I (MSK)**
1.09	Residual soil	Vp=481 m/sn Vs=167m/sn	ρ =1.7 (gr/cm³)	q_u=1.13 kg/cm²	μ =473 (kg/cm²) E=1354 (kg/cm²)	H=10, T=0.32sn H=25, T=0.79sn	99.25	6
3.25	completely weathered aglomerate mass	Vp=1006 m/sn Vs=452 m/sn	ρ =1.8 (gr/cm³)	q_u=10.2 kg/cm²	μ =3680 (kg/cm²) E=10109 (kg/cm²)	H=10, T=0.18 H=25, T=0.44sn	88.9	5-6
↓	Fresh and slightly weathered aglomerate	Vp=2182 m/sn Vs=1200 m/sn	ρ =2.04 (gr/cm³)	q_u=109 kg/cm²	μ =29324 (kg/cm²) E=75258 (kg/cm²)	H=10, T=0.03sn H=25, T=0.09sn	70.9	4

Table 11. The depth distribution of engineering parameter from ground surface determined by seismic refraction methods at No 7. profile line (measuring location: Topal District, Figure 1).

Height (meter)	**Litology**	**Elastic parameters and bearing capacity**				**Soil dominate vibration period, (Tsn) H=height, m**	**Max. horizantal acceleration, a, cm/sn²**	**Earhquake intensity, I (MSK)**
7.44	completely weathered aglomerate mass	Vp=1050 m/sn Vs=350 m/sn	ρ =1.81 (gr/cm³)	q_u=11.6 (kg/cm²)	μ =636 (kg/cm²) E=1888 (kg/cm²)	H=10, T=0.17 H=25, T=0.43sn	87.9	5-6
↓	Slightly weathered aglomerate mass	Vp=2250 m/sn Vs=1190 m/sn	ρ =2.05 (gr/cm³)	q_u=114 (kg/cm²)	μ =29030 (kg/cm²) E=75816 (kg/cm²)	H=10, T=0.03sn H=25, T=0.09sn	70.8	4

Table 12. The depth distribution of engineering parameter from ground surface determined by seismic refraction methods at No 8. profile line (measuring location: Camlıkoy Road, Figure 1)

Height (meter)	**Litology**	**Elastic parameters and bearing capacity**				**Soil dominate vibration period, (Tsn) H=height,m**	**Max. horizantal acceleration, a, cm/sn^2**	**Earhquake intensity, I (MSK)**
0.71	Arena	Vp=402 m/sn Vs=125 m/sn	ρ =1.68 (gr/cm^3)	q_u=0.64 (kg/cm²)	μ =262 (kg/cm²) E=759 (kg/cm²)	H=10, T=0.32sn H=25, T=0.9sn	<86.7	>5
2.87	completely weathered granitic rock	Vp=769 m/sn Vs=350 m/sn	ρ =1.75 (gr/cm^3)	q_u=4.55 (kg/cm²)	μ =2148 (kg/cm²) E=5883 (kg/cm²)	H=10için, T=0.11 H=25, T=0.29sn	86,7	5
↓	Highly weathered granitic rock	Vp=1371 m/sn Vs=888 m/sn	ρ =1.87 (gr/cm^3)	q_u=25.77 (kg/cm²)	μ =14779 (kg/cm²) E=33656 (kg/cm²)	H=10, T=0.045sn H=25, T=0.12sn	73.6	4-5

USING GIS FOR URVAN DEVELOPMENT ANALYSIS

Linch's (1974) slope classification approach was used to evaulate the settlement areas. This approach was devoloped using special morphological considerations. Using this classification, slope zonation maps were produced using GIS. In order to determine the microclimatic characteristics of the area surrounding Gumushane, maps of equal height zonation and exposure were identified using the GIS analysis. Topographical considerations are important in planning and for this reason a 3-dimensional digital terrain model (DTM) was produced. Maps of engineering geology, slope zonation and flooding were overlayed onto the DTM by using the GIS software. Finally and urban suitability map of Gumushane and surrounding area were produced. (Figure 2).

CONCLUSIONS

To make the maximum benefical use of the available land, a planner should take into consideration the geological factors, which may pose a hazard to future delvelopment. This will allow the accuracy and implementation of basic information to be improved and then applied in the planning process. An important goal for urban geology is to provide assistance to planners in determining the optimal areas for development.

The evaulation of results can assist planners in making decisions on land use alternatives. The results of the study described in this manuscript gives information relating to the distribution of soils and rocks and their associated geotechnical characteristics, flooding and earthquake hazards in Gumushane City. The engineering geological units provide a general assesment of rock mass strength, bearing capacity (for alluvial soil) and weathering for each area.

In the last phase of the engineering geology assessment, a map showing the suitability for settlement of Gümüşhane city and its surrounding area is designed by analyzing the flooding and slope maps overlayed in GIS. Five classes of settlement criteria are identified. These classes are: A: Suitable for settlement in an excellent degree, B class: Suitable for settlement in a good degree, C class: Suitable for settlement in middle degree, D class: Suitable for settlement in low degree (settlement under geotechnical precautions), F class: not Suitable for settlement at all. (Flooding area, stream beds and being greater than the slope of 60%, and not appropriate for settlement in terms of planning, economy and engineering.).

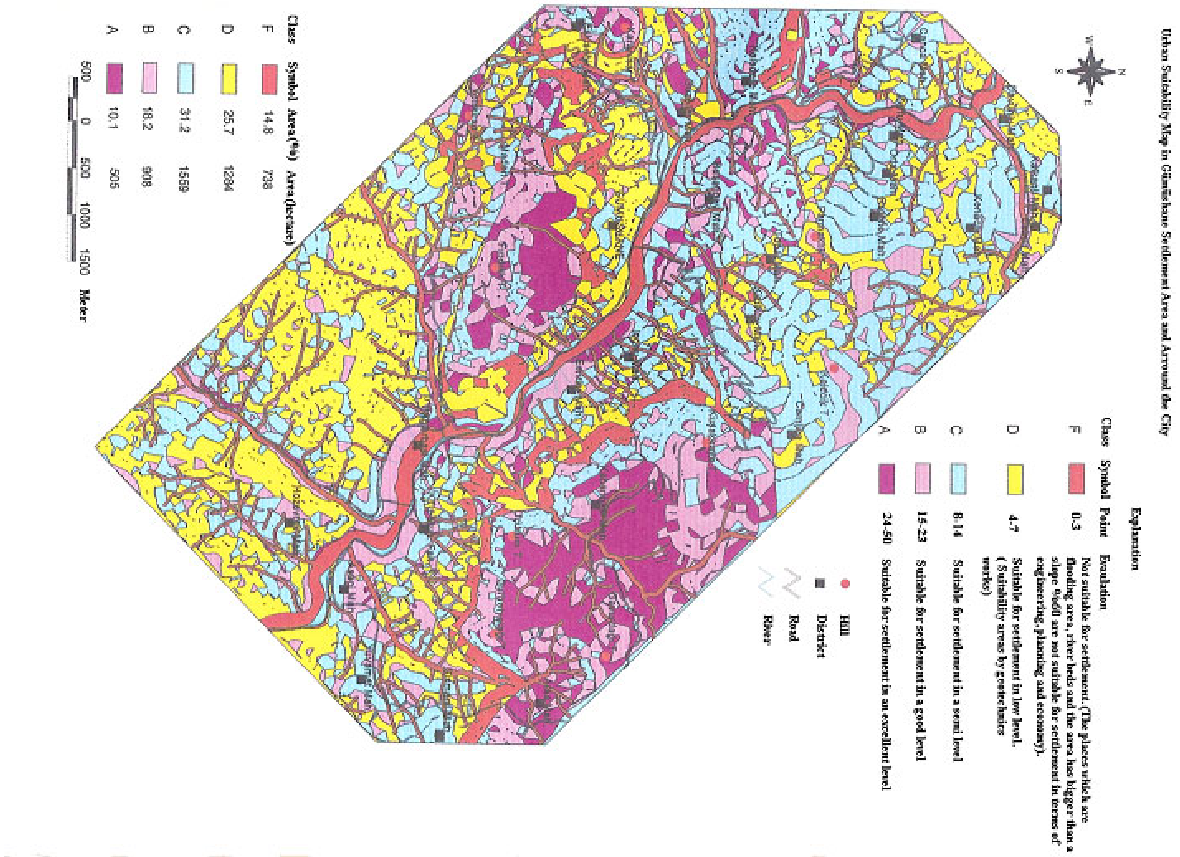

Figure 2. Urban suitability map in Gumushane settlement area and surrounding area.

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