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AN AI-GIS BASED SEISMIC HAZARD ASSESSMENT SYSTEM FOR URBAN AREA

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ABSTRACT

The paper presents an on-going integrated project on computer decision-making system for seismic disaster reduction in urban area with emphasis on protecting existing buildings and infrastructures. Overall scheme of this program is outlined. The paper gives a detail description on an AI-GIS (Artificial Intelligence-Geographic Information System) Based Seismic Hazard Assessment System, developed as one of the components of this program.

INTRODUCTION

Natural disasters are one of the causes of human suffering in urban areas. The need to improve human safety and protect dwindling resources is emphasized by recent disasters, particularly those happened to urban areas, such as 1994 Northridge Earthquake and 1995 Kobe Earthquake. Many have had their main impact in urban areas, where there is a large concentration of people with a strong dependency on infrastructure and services. Table 1 shows some recent disasters which had major effects on human settlements in only the past five years. The fact that so many disasters have occurred in only the past five years, highlights the importance of looking at disaster risks in the framework of urban development. Nevertheless, urban societies depend on infrastructure systems for the provision of their basic survices. In large urban agglomerations, infrastructure systems are increasingly complex, and therefore more subject to disruption, and more costly to repair or replace. In China, as one of developing countries, the rapid development of urban areas makes it difficult to keep pace with the development of infrastructure and basic survices. Systems are often poorly maintained, which further increases their vulnerability, particularly to the suddenly exposed natural disasters, like Earthquakes.

Damage to urban infrastructure by natural disasters has long-term as well as short-term impacts. Natural disasters often trigger secondary disasters caused by the failure of infrastructure. Breakage of gas lines can cause fires and collapsing infrastructures cause deaths and further damage. The long-term impact of damage to key infrastructure can be enormous in terms of disruption of the economy and difficulties in re-establishing the urban community.

Table 1 Some Major Disasters since 1990

Year	Hazard	Country	No. of Dead	Damage estimate (million US$)
1990	earthquake	Philippines	1,660	920
	tropical cyclone	South Pacific	8	119
	tropical cyclone	Philippines	503	720
1991	earthquake	Georgia	270	1,700
	volcano	Philippines	932	260
	cyclone and flash	Philippines	4,899	
	flood	Bangladesh	138,866	1,780
	tropical cyclone	China	2,470	21,000
	river flood	USA/Caribbean		20,000
	cyclone	India	2,000	
	earthquake tropical cyclone	South Pacific	12	331
1992	tsunami	Indonesia	2,080	100
	tsunami	Nicaragua	116	25
	earthquake	Turkey	547	
	mudflow	Philippines	333	320
1992-93	drought	Southern Africa		
1993	river flood	United States		20,000
	earthquake/tsunami	Japan	122	
	31 typhoons	Philippines	514	
	tropical cyclone	Fiji	21	134
	earthquake	India	10,000	
	flood	Western Europe	7	hundreds of millions
1994	earthquake	United States		20,000
	earthquake/mudslid	Colombia	271	
	e	Papua New	100,000	
	volcano	Guinea	affected	
			1,400	
	flood	China	2,001	
	flood	India		
1995	earthquake	Japan	5,500	100,000
	earthquake	Russia		

An integrated project titled Computer Decision-Making System for Seismic Disaster Reduction in Urban Area (CODE-SDR) is now being conducted under the support of the State Seismological Bureau and National Natural Science Foundation of China. This project is designed to analyze seismic risks and take action for preparedness and emergency response in urban area with emphasis on existing buildings and infrastructures.

OUTLINE OF THE CODE-SDR SYSTEM

The CODE-SDR System is designed for government to well manage earthquake disasters in an urban area. This system consists of three main parts: Seismic Risks Assessment, Seismic Preparedness and Emergency Response. The whole system is built on the platform of Geographic Information System(GIS). The general scheme of the CODE-SDR System is shown in the Figure 1.

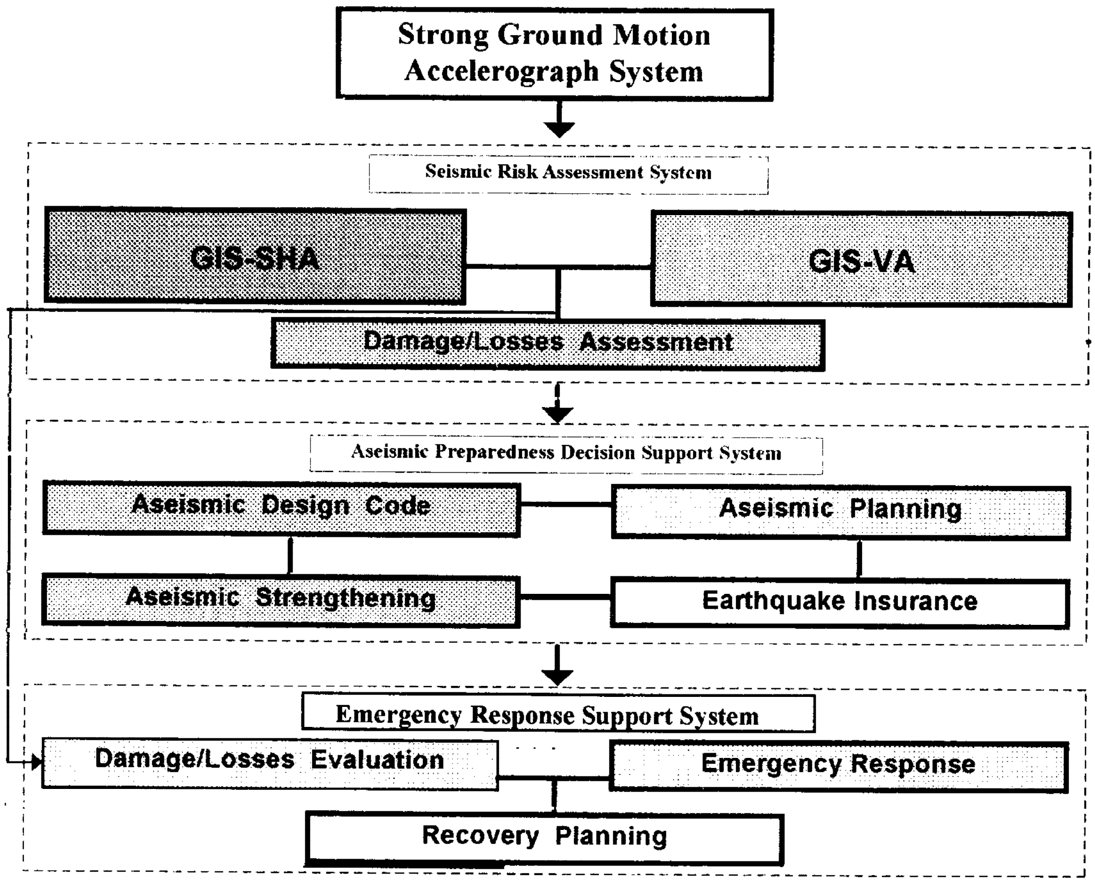

Figure 1 Scheme of the CODE-SDR System

The Subsystem of Seismic Risk Assessment provides Seismic hazard and vulnerability in-formation on both probabilistic and deterministic bases. The probabilistic hazard and vulnerability analysis works out the average risk level in terms of probabilities of exceedance according to the geographical distributions and frequencies of occurrence of the potential seismic sources and provides with engineering design parameters for new system design and strengthening of existing systems. The deterministic risks are estimated from a scenario earthquake which simulates an actual earthquake or a real earthquake recorded by an on-line strong motion accelerograph system which input the recorded ground accelerograms automatically to the system. Evaluation of the actual damage and losses during the earthquake could be automatically derived in a real-time mode by the system immediately following the earthquake. And emergency response plan corresponding to the actual damage will be given out by the system.

GIS AND AI BASED SEISMIC HAZARD ANALYSIS (GIS-SHA) SYSTEM

GIS- SHA is a seismic hazard analysis system operated in the environment of Windows and PC-ARC/INFO. It integrates Geographic Information System (GIS), Artificial Intelligence (AI), Data-Base Management System (DBMS), statistical analysis and seismic hazard analysis as a whole. By virtue of the GIS's functions on spatial information management and analysis, GIS-SHA could be used for multi-task purposes with high efficiency. Figure 2 shows the scheme of its system's frame.

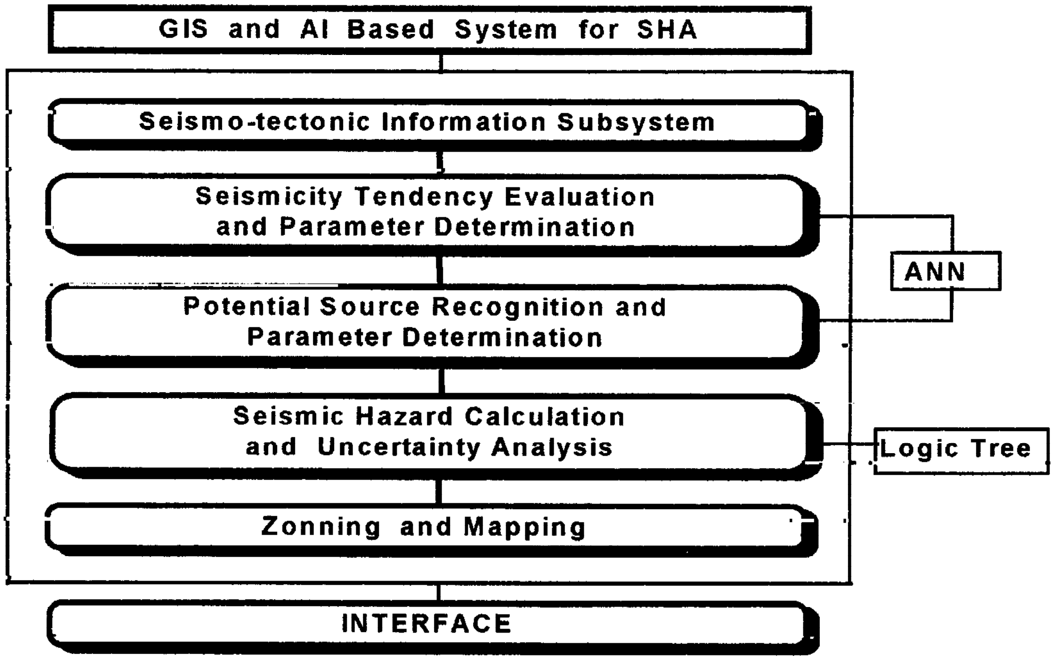

Figure 2 Scheme of GIS-SHA

<u>Seismo-Tectonic Information Subsystem (STIS)</u>
The module will be discussed in detail in next section of the paper.

<u>Estimating the Tendency of Seismicity</u>
The system could be used for displaying spatial distribution of the historical destructive earthquakes, analyzing time series, plotting M-T, E-T and N-T curves and estimating the tendency of seismicity within coming 50 years by using Artificial Neural Networks (ANN).

<u>Identification of Potential Seismic Sources</u>
The potential seismic source can be outlined directly on the screen based on the displayed active faults and distribution of past destructive earthquakes or on the identified source area given by artificial neural networks. What the users do is to adjust the weights of magnitude intervals for each source. according to seismicity and seismo-tectonic features

<u>Seismic Hazard Analysis and Determination of its Uncertainties</u>
The parameters for input to the system are: (1) selected ground motions (Aa, Av, SA0.3, SA1.0 Smax, Tg etc.), (2) site parameters, (3) probabilities of exceedance, (4)attenuation laws of selected ground motions, (5) selected algorithm models for seismic hazard analysis. Then the seismic hazard analysis (probabilistic or deterministic method) could be carried out in various plans depending on what kinds of input parameters, attenuation laws, recurrence relationships and potential sources are selected for input. The curves of probability of exceedance could be calculated and plotted by the system.

<u>Zoning and Mapping</u>
In this system the results of seismic hazard analysis could be given as the spatial attributes and zoning map for ground motion at any given probability of exceedance could be generated. The corresponding design response spectra could also be automatically produced for any interested site.

As an example, Fig.3-6 illustrates ground motion zoning maps for the area approximate 700,000km^2 in the North China

BUILDING AND MANAGING OF SEISMO-TECTONIC INFORMATION SUBSYSTEM (STIS)

STIS is a fundamental subsystem providing multi-manipulation functions and necessary tectonic related information for seismic hazard analysis. Since the seismo-tectonic information usually features qualitatively and even obscurely, management and application of such information are extremely difficult for an efficient risk management. This system was built on ARC/INFO GIS package platform and then makes easy to multi-manipulate and analyze various spatial information associated with their attributes. It consists of spatial database and various modules, such as generation of buffer for active faults, compiling of maximum intensity map, extraction of characterized parameters of grid cell and identification of potential seismic sources.

Formation of Spatial Database

The unique feature of a spatial database is that the database is composed of data with not only the attributes but also the spatial characteristics and topological relations.

The North China is one of the regions with abundant data of seismicity and geotectonics. A spatial data base has been built to cover an area of about 700,000km^2, located on about 109°-120°E and 35°-41°N. It consists of several coverages as: Active Fault, Destructive Earthquake, Instrumental Seismic Record, Historical Seismic Isoseismal, Potential Source, Seismic Zoning Map, Administrative Zoning Map etc..

Management of Seismo-Tectonic Information

The GIS based spatial database provides clients with powerful tools in storing, updating, displaying, deleting, querying and mapping the data. With the advantage of GIS in quick response, labor saving and flexible manipulating this system could be widely used to aid decision-making. Conventionally, the information presented on the map is static and limited. The usage to a great extent relies on the visual ability and experience. Therefore it is rather difficult to perform spatial analysis manually and apply complex models in analysis. However, the GIS based database supply a convenient environment for developing analytical model and speed up the transition from qualitative to quantitative study.

Generation of Buffers to Active Faults

The correlation of earthquakes with active faults can be analyzed through the overlay of destructive and/or instrumentally recorded event coverages with the coverage of buffer for active faults. There are 425 destructive events and 30472 instrumentally recorded events located in the study area. Table 2 shows the number of events at four magnitude intervals fallen in the different buffers.

Table 2 The Number of Events Fallen in Different Buffers

DISTANCE	$M_s<6$	$6\le M_s<7$	$7\le M_s<8$	$M_s\ge 8$	DEN	IEN
5	168	28	7	2	205	16520
10	265	42	12	3	322	23494
15	308	45	14	3	370	27534
20	330	49	14	3	396	28954

DEN--Destructive Event Number

IEN --Instrumentally Recorded Event Number

Compiling of Observed Maximum Intensity Map

The observed maximum intensity map was compiled with many different isoseismal maps of historical destructive events to show the exposed maximum earthquake intensity in the history at each location. This map illustrates the damage image of strong historical events. It provides important information to recognize the distribution of strong events and their effects for studying the correlation of seismicity with seismo-tectonic conditions. It is a basic map for preparing the seismic zoning map. By using of STIS, it becomes rather easy for compiling the map. The isoseismal lines were digitized and stored in database, then they were projected into a uniform coordinate system and integrated by overlay commands of GIS. Fig7-a shows the observed maximum intensity map of 41 isoseismal lines; Fig7-b shows the theoretical maximum intensity map generated with intensity attenuation law and buffer command of GIS.

Extraction of Characterized Parameters of Grid Cell

The study area was divided into a number of grids of different size (10×10 km, 20×20 km). Characterized parameters were used to describe the characteristics of grid, such as , the number of faults in grid, the intersection of faults in grid, and the maximum magnitude and the number of events in grid. The characterized parameters can be extracted automatically through the spatial manipulation of GIS in stead of conventionally manual works. The extracted results were used as the inputs for identifying upper-bound magnitude (Mu) of each grid by artificial neural network approach, or pattern recognition or fuzzy judgment. Then potential seismic sources could be outlined.

The extraction process could be carried out with ARC/INFO's commands of data conversion and manipulation. There are two kinds of methods for extracting relevant characterized parameters. One is choosing the "most dangerous attributes" of the faults. Another is to compare the attributes of the faults in grid, and select the attributes of the "most dangerous fault". The latter approach was used in this study. And active period, slip velocity, striking direction, seismicity pattern, length and depth of faults were used in selecting the "most dangerous fault" in each grid.

Identification of Potential Seismic Sources by ANN Approach

The upper-bound magnitude (Mu) assigned to each grid of study area could be identified by ANN approach with the eight characterized parameters extracted from each grid cell. A 8×7×6 layered neural network was designed to study the relationship between seismo-tectonic features and Mu. Based upon the results of ANN, the potential seismic sources were then outlined. Fig8 shows the intersection of active faults; Fig9 gives the results of Mu by ANN approach.

CONCLUSION

This paper outlines a general scheme of the on-going project titled Computer Decision-making System for Seismic Disaster Reduction in Urban Area (CODE-SDR) and describes more detail about one of its components: an AI-GIS Based Seismic Hazard Assessment System. The combination of GIS and AI technologies could greatly enhance and improve the abilities for seismic hazard analysis as well as the seismic preparedness and emergency response in urban area. We can take the advantage of powerful function of both GIS and AI technologies in data management and analysis. It is believed that the system could play an significant role in evaluating seismic vulnerability of existing buildings and infrastructures for further action in strengthening.

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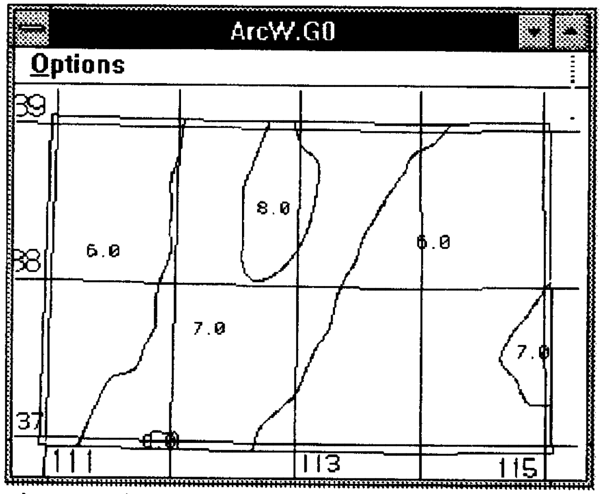

Fig3. Zoning Map of Intensity

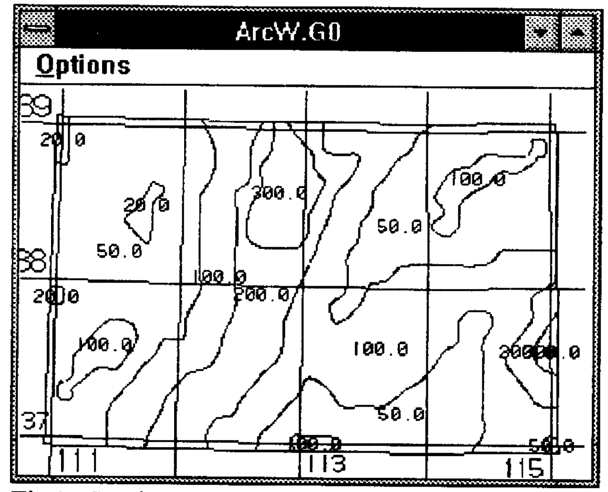

Fig4. Zoning Map of Peak Ground Acceleration

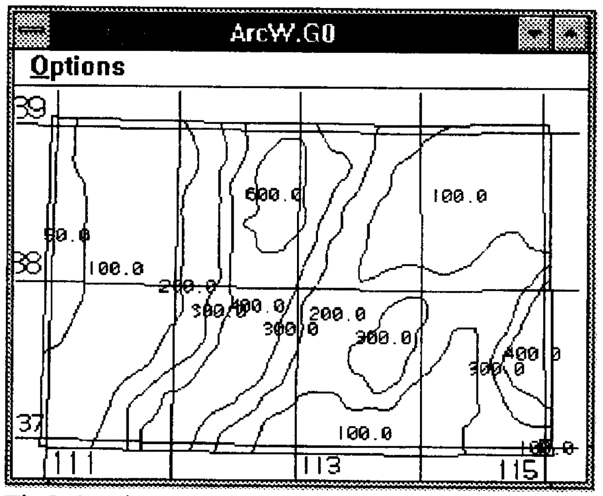

Fig5. Zoning Map of 0.3 Second Spectra(SA0.3)

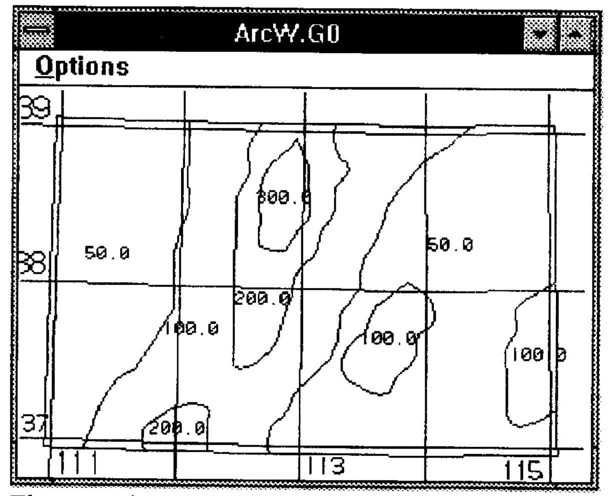

Fig6. Zoning Map of 1.0 Second Spectra(SA1.0)

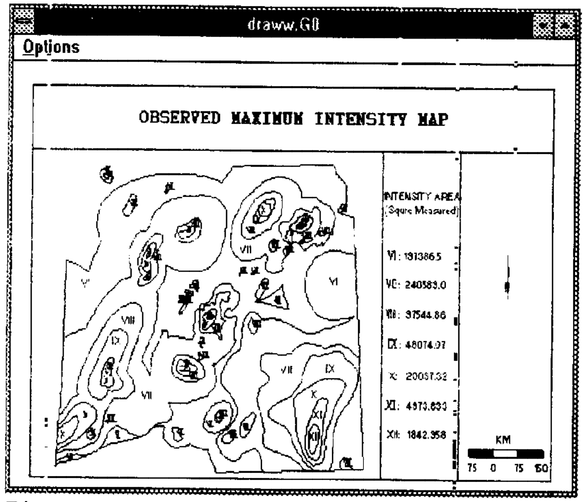

Fig7-a. Map of Observed Maximum Intensity

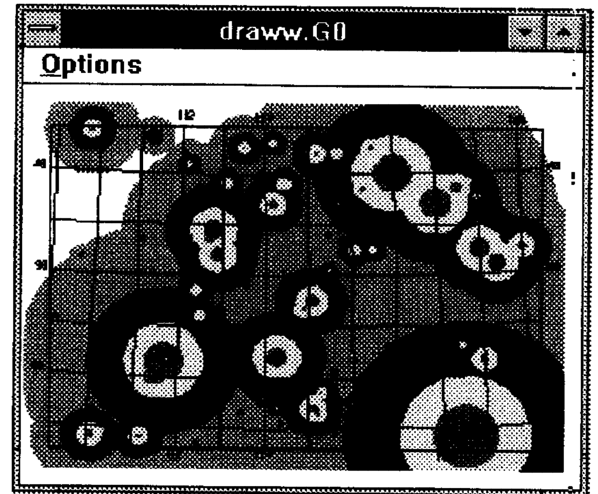

Fig7-b. Map of Maximum Intensity Generated by STIS

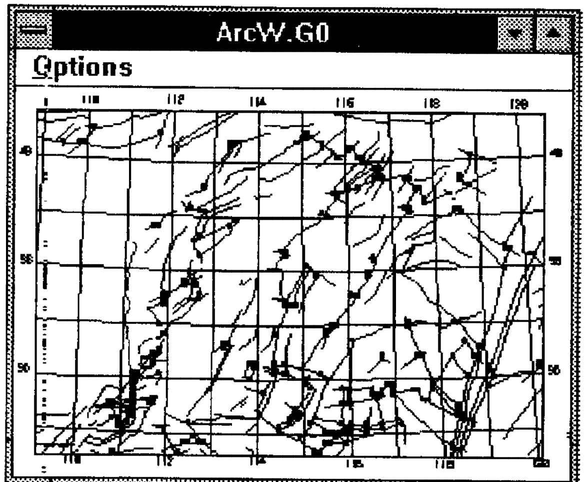

Fig8. Identification of Active Faults Intersection

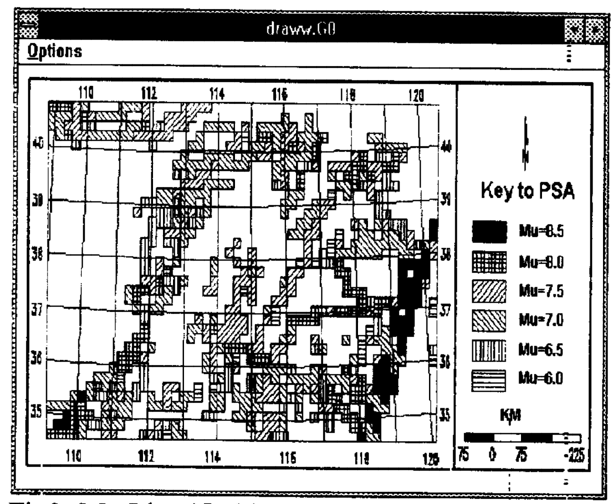

Fig9. Mu Identified by Artificial Neural Network