JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
CENTRE FOR EARTHQUAKE AND ENVIRONMENTAL STUDIES OF TEHRAN (CEST)
TEHRAN MUNICIPALITY

THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

MICROZONING MAPS

November 2000

PACIFIC CONSULTANTS INTERNATIONAL
OYO CORPORATION

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
CENTRE FOR EARTHQUAKE AND ENVIRONMENTAL STUDIES OF TEHRAN (CEST)
TEHRAN MUNICIPALITY

THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

MICROZONING MAPS

November 2000

PACIFIC CONSULTANTS INTERNATIONAL
OYO CORPORATION

PREFACE

In response to a request from the Government of the Islamic Republic of Iran, the Government of Japan decided to conduct " The Study on Seismic Microzoning of the Greater Tehran Area in the Islamic Republic of Iran" and entrusted the Study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Itaru Mae of Pacific Consultants International, and composed of members of Pacific Consultants International, and OYO Corporation, four times between April 1999 and September 2000 to the Islamic Republic of Iran.

The team held discussions with the officials concerned of the Government of the Islamic Republic of Iran and conducted field surveys at the study area. Upon returning to Japan, further studies and analysis were made and the present report was prepared.

I hope that this report will contribute to the promotion of the seismic disaster management of Iran and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of the Islamic Republic of Iran for their close cooperation extended to the team.

November 2000

Kunihiko SAITO
President
Japan International Cooperation Agency

Mr. Kunihiko SAITO
President
Japan International Cooperation Agency
Tokyo, Japan

November 2000

Letter of Transmittal

Dear Mr. SAITO,

We are pleased to formally submit herewith the final report of "The Study on Seismic Microzoning of the Greater Tehran Area in the Islamic Republic of Iran".

This report compiles the result of the study which was undertaken in the Islamic Republic of Iran from March 1999 through September 2000 by the Study Team organized jointly by Pacific Consultants International and OYO Corporation under the contract with the JICA.

The Final Report is composed of the two volumes, "Main Report" and attached "Microzoning Maps".

In the main report, existing social and physical conditions of the study area are described and seismic damage analysis was carried out based on the potential big earthquakes. Necessary recommendations for the seismic disaster management and mitigation were also made. The Study Team developed a comprehensive geographic database (GIS) to support data analysis and presentation of the study results. "Microzoning Maps" were compiled out of this GIS data base in such a way that those who are interested in urban analyses, detailed disaster management, studies and planning for Tehran area may easily make use of the data base.

Finally, we would like to express our sincere gratitude and appreciation to all the officials of your agency, the JICA advisory Committee, the Embassy of Japan in Islamic Republic of Iran, and Ministry of Foreign Affairs. We also would like to send our great appreciation to all those extended their kind assistance and cooperation to the Study Team, in particular, relevant officials of Centre for Earthquake and Environment Studies of Tehran (CEST), the Iranian counterpart agency.

Very truly yours,

Itaru MAE
Team Leader,
The Study on Seismic Microzoning
of the Greater Tehran Area
in the Islamic Republic of Iran

An Outline of the Seismic Microzoning Maps

Introduction

Based on a number of map data collected through the project, JICA Study Team developed a GIS data base to support an analysis work for seismic microzoning. Through the GIS-technique, the collected basic data maps were fully processed and analysed to understand spatial distribution of both socio-economical and physical constraints of the study area against potential seismic disaster. Results of those data analysis were displayed in forms of maps and tables.
This 'Seismic Microzoning Maps' compiles a number of selected outputs out of the results of this study. The existing urban condition, topographical and geological background of the study area and the results of seismic damage analysis according to the earthquake scenario were visually compiled.
These Seismic Microzoning Maps were prepared as an additional material to supplement the main report of this study. These will contribute to those who are concerned with research and planning works of urban environment or solution of urban land use problems of Tehran area.

Outline of the Microzoning Maps

Input Data Items
In order to develop the GIS data base for this study, many kinds of both graphical and statistical data/information have been collected with cooperation of relevant agencies. All collected map data were digitised and filed in the computer after necessary modification, adjustment and updating. A total of sets of original map data were stored into the Microzoning Maps, which are demonstrated in this map atlas.

Data Processing by GIS
Data processing by GIS consists of three hierarchical stages, namely, primary, secondary and tertiary process, according to the degree of the spatial data manipulation.

The primary data analyses:
Simple overlay analyses of basic maps were conducted to identify spatial distribution patterns and characteristics in relation with regional factors. Cross tabulation in terms of area, length, density, average and/or frequency calculation were made to identify specific geographic features by district or census survey unit in this stage. Statistical data such as population and building were compiled into the corresponding statistical maps. Results of the primary data analysis may not only show existing urban conditions of Tehran, but also bear planning indicators for seismic disaster management.

The secondary data analyses:
In this stage, seismic disaster related data were combined and analysed to understand spatial distribution of damage potential and constraints of the study area. For the model building, a number of evaluation criteria affecting seismic disaster such as conditions of natural/environmental constraints, and urban infrastructures were selected from the urban seismic disaster analyses point of view. The results of this data processing are the basis for the next data analysis.

The tertiary data analysis:
Simulation analyses for potential earthquake in the study area were conducted according to the earthquake scenario as the tertiary data analysis. Comprehensive damage analysis for buildings and human casualty of the study area was the most important results of this study. Details of damage analysis were explained in the main report.

GIS system for this study
For the development and operation of GIS of this study, study team applied ARC/INFO NT and Arc View 3.1 software as a GIS. These are the most standard GIS software package in the world. Appropriate PC systems were used for data processing and compilation of output mapping. Large scaled inkjet plotter and A3 size colour printer were used for final map production. A0 size digitizer and scanner were used for digitisation. Functions on 'local database development' were fully employed for this study.

Contents of Maps

A. Existing Conditions

B. Earthquake Analysis

C. Seismic Damage Analysis

D. Overall Vulnerability Evaluation

E. Pilot Study

Explanation of Maps

A. Existing Conditions

Base Map
A-1 Study Area

Topographical map can provide the most basic and general information of the study area. In Tehran, 1:25,000 and 1:2,000 scale topographical maps were compiled by Tehran GIS center. These maps were used as a base map of this study. Twenty two districts boundary data were overlaid on 1:25,000 topographic map to show the study area clearly.

Census Zone as an analysis unit
A-2 Census Zone

Census zone covers the whole Tehran area. Statistical Center of Iran conducted comprehensive census survey in 1996 based on 3176 zones.
Each zone are divided into smaller survey unit of census block. Detailed population, building statistics and related data were collected according to these blocks and aggregated into zone data. Boundary data of census zone were digitised by detailed census zone maps, which were prepared by Statistical Center of Iran as scale at 1:2000 compiled. These census boundary data were overlaid on topographic map, however, minor discrepancies of coordinates can be seen due to the difference of mapping system. Census zone was used as a basic analysis unit of this study.

Topographic Condition
A-3 Topography
A-4 Slope Gradient

Slope analysis map was generated by contour data processing. Originally, this map was provided to the study team by the project office of Beautification Organisation, Tehran Municipality. Detailed slope analysis based on 50m X 50m grid was conducted and each slope gradient was classified into ten categories as shown in the map legend. Grid data covers only northern half of the City of Tehran. Southern part of the city is rather gentle sloped area less than 2 % in gradient.

Geology
A-5 Geology

Geological map was compiled by Geological Survey of Iran for this study. Several geological formations were classified according to the type of sediments, landform and location. Main geological formation of this area is composed of alluvial fan deposits such as sand and gravels which had been deposited since Pliocene Pleistocene period. These fan deposits are providing relatively hard and stable foundation to buildings.
The main active faults in and around Tehran are Mosha Fault, North Tehran Fault, South and North Ray Faults.

Ground Water table
A-6 Groundwater Table

Ground water table, together with the geology, is one of the essential factors for liquefaction of the ground. Almost all of urbanised area is locating on alluvial fan, ground water table of this area can be found rather deeper level. Ground water table in the southern part of Tehran city, especially in district 20 is showing rather shallow level such as 5 to 10 meters beneath the ground surface. Basic data of ground water table is prepared by CEST and this data were overlaid on geological map.

Earthquake Catalogue and Seismic Data
A-7 Epicentral Distribution (Historical Earthquake [734-1994])
A-8 Epicentral Distribution (1996-1999)

The Study Team compiled epicentral distribution maps in the Tehran vicinity. Two earthquake catalogues are used in the Study. Moinfar et al.(1994) collected many world-wide references and compiled an earthquake catalogue for Iran. This catalogue covers activity from the 7th Century through 1992 and includes almost 5,000 events. Major historical earthquakes with a magnitude above seven, which damaged Tehran area, occurred in 855, 958, 1177 and 1830. IGTU (Division of Seismology, Institute of Geophysics, Tehran University) has a seismic network around Tehran. Two stations (Tehran, Shahran) are located within the City. Seismic observations with a digital recorder were started in 1996. Over 1000 earthquakes occurred within a 100 km radius from the centre of Tehran between 1996 to 1999. Most of the earthquakes had magnitudes less than 3.5. Micro-earthquake activity is observed in the following areas: Southeast Tehran, South Tehran, near the North and South Ray faults, Far eastward of Tehran, alongside the Mosha Fault

Land Use
A-9 Land Use

General land use pattern can be interpreted by observation of the topographic map. Urbanised/built-up area is extending to the west and the south part of the city. There is still enough open space, which is utilised as an agricultural land in the south-western part of the city. Main transportation network, which can direct the future urbanisation, is also interpreted in this map.

Population (1996 Census)
A-10 Population
A-11 Population Density

According to the Census data of 1996, a series of maps from map number 7 to 9 are showing the distribution of population, population density and under age of five (5) based on each census zone. Total population of the City of Tehran is calculated at 6.7million in 1996. Fast growing of urban population is generating many densely populated zones. Especially in the southern part of the city, densely populated zones, which have more than 600 persons per hectare, are located in district 10, 15, 17 and 19.

Residential Buildings
A-12 Building Distribution (Dwelling Unit)
A-13 Building Distribution by Structure (Steel) [Dwelling Unit]
A-14 Building Distribution by Structure (Reinforced Concrete) [Dwelling Unit]
A-15 Building Distribution by Structure (Others) [Dwelling Unit]

Building statistics was also compiled by Statistics Center of Iran in 1996. Total number of buildings in 1996 was counted at 1.44 million, however, this number is indicating a number of dwelling unit or household in the study area. Distribution maps for building structures were compiled. Steel structure buildings are distributing relatively higher percentage in outer area of old Tehran. Reinforced concrete buildings are distributing still rather limited numbers and this structure can be seen in newly developed area. The category 'Others' is classified into nine (9) structural types combining steel, brick, wood and masonry. Building structure of this type is well representing a traditional type of buildings in Tehran and distributing mainly in southern part of the city.

Building Age
A-16 Building Distribution by Construction Year (Before 1966) [Dwelling Unit]
A-17 Building Distribution by Construction Year (1966-1975) [Dwelling Unit]
A-18 Building Distribution by Construction Year (1976-1988) [Dwelling Unit]
A-19 Building Distribution by Construction Year (After 1988) [Dwelling Unit]

Distribution maps of building age were compiled. These maps represent the characteristics of urban growth of the city. Before 1965, urbanised area is limited in old Tehran area. Many buildings of old Tehran area had constructed since late 19th century by adobe. Population of Tehran in 1966 was only 2.7 million. Between 1965 and 1975, urbanisation occurred neighbourhood area of old Tehran and extension of urbanisation can be seen toward north of Tehran. This tendency became much clear between 1976 and 1988. Urbanisation of the city expands toward all directions. Large size housing were developed, and open spaces had been changed to residential area in the northern part of the city. After 1988, urbanisation extended even to a smaller open space within the city and district 21 and 22 were established in late 1990's due to the extension of urbanisation.

Public Facilities Distribution

A-20 Public Facility (Fire Fighting Stations)
A-21 Facility Accessibility (Fire Fighting Stations)
A-22 Public Facility (Police Stations)
A-23 Public Facility (Traffic Police Stations)
A-24 Public Facility (Hospitals)
A-25 Facility Accessibility (Hospitals)
A-26 Public Facility (Governmental Facilities)
A-27 Public Facility (Elementary Schools)
A-28 Public Facility (Intermediate Schools)
A-29 Public Facility (High Schools)
A-30 Public Facility (Higher Education Centers)
A-31 Public Facility (Park)

Distribution maps of public facilities such as higher education centers, schools, hospitals, fire-fighting offices, police stations, parks, bridges and road networks are compiled. Originally, these data were collected and provided to the Study Team by relevant organisations.

Lifeline

A-32 Lifeline (Water)
A-33 Lifeline (Gas)
A-34 Lifeline (Electricity)
A-35 Lifeline (Telecommunication)

Wide range of data has been collected from lifeline related companies such as water, gas, electricity and telecommunications. Since comprehensive database set-up is the first time, lack of quality and data missing are observed. Only basic data including main network were set up. Distribution maps for those main networks of lifeline data were compiled.

Road and Bridges

A-36 Road Length by Population (3m, 6m Width Road)
A-37 Bridge Location

With cooperation of Tehran GIS Center, line file with road width has been prepared. The road width is classified into fourteen (14) categories from minimum 3 meters up to 120 meters. For the rescue operation at a time of strong earthquake, 3 and 6 meters width roads, which are relatively narrow streets, are considered as one of the big constraints. Distribution map of these narrow streets ratio was compiled.
Bridge distribution data was provided by TETCO. The Study Team conducted additional site survey and identified 79 bridges and flyovers. These bridge data is analysed for vulnerability against strong earthquake.

Hazardous Facilities

A-38 Hazardous Facility

Hazardous Facilities deal with hazardous and dangerous substances. Those facilities may cause secondary disaster such as fire outbreak, explosion, etc. For the seismic disaster management planning, listing and knowing location of those facilities can provide a basic information to minimise a secondary disaster. Database for these facilities were set up with cooperation of Fire Fighting Department of Tehran Municipality. Distribution map was compiled. Those data are still containing partly an old data and data updating is required.

B. Earthquake Analysis

Ground Classification

B-1 Location Map of Boreholes
B-2 Model Ground for Seismic Analysis

The ground condition of the Study Area was analysed and classified to construct the ground model for seismic analysis.
About 400 borehole data were used to analyse the ground condition of the Study Area. The location map of these boreholes was compiled. Fifty boreholes, which include three of 200 m depth, were drilled in the Study. Shear wave velocities of ground were measured. Suspension PS logging method and downhole PS logging method were introduced.
Engineering seismic bedrock is defined as 1) The layer at which the shear wave velocity Vs exceeds 600m/sec or the SPT N value (equivalent to 30 cm penetration) exceeds 100, and 2) The continuity and thickness of the engineering seismic bedrock is adequate for wave propagation. In the eastern alluvial plain, the engineering seismic bedrock is situated at a depth of around GL-150m. From this area, the depth of the bedrock becomes shallower until ground surface towards the north and east. Based on the depth of the seismic bedrock and the soil condition, the ground is classified into 41 types. The distribution map of model ground was compiled.

Scenario Earthquakes and Earthquake Analysis

B-3 Source Fault Model for Scenario Earthquake

Applying a scenario earthquake can be very useful to a city for emergency response and seismic disaster prevention planning. The earthquake that would affect Tehran would occur on an active fault near the city. Among the many active faults in the area, the most probable hazardous faults model were defined as following: 1) Mosha Fault Model, 2) North Tehran Fault Model, 3) Ray Fault Model.
It should be noted that 'hidden' faults might exist underneath sediment layers of the city of Tehran. If such were the case, it would be difficult to determine their location, and the probability of occurrence would be the same anywhere in the city. To take into account this situation, the Floating Model concept is introduced.
The amplification of the subsurface was analysed using a one-dimensional response analysis. The non-linearity effect was not considered because the soil is stiff enough to neglect the non-linearity.

Peak Ground Acceleration and Seismic Intensity

B-4 Peak Ground Acceleration Distribution Map (Ray Fault model)
B-5 Peak Ground Acceleration Distribution Map (NTF model)
B-6 Peak Ground Acceleration Distribution Map (Mosha Fault model)
B-7 Peak Ground Acceleration Distribution Map (Floating model)
B-8 Seismic Intensity Distribution Map (Ray Fault model)
B-9 Seismic Intensity Distribution Map (NTF model)
B-10 Seismic Intensity Distribution Map (Mosha Fault model)
B-11 Seismic Intensity Distribution Map (Floating model)

Peak ground acceleration and seismic intensity were calculated and those distribution maps were compiled. Characteristics are as follows:

		Ray Fault model	NTF (North Tehran Fault) model	Mosha Fault model	Floating model
Length (km)		26	58	68	13
Width (km)		16	27	30	10
Moment Magnitude (Mw)		6.7	7.2	7.2	6.4
PGA (gal)	Northern area	500 and over	200 and less	200 and less	300 to 400
	Southern area	200 and less	400 and over	200 and less	300 to 400
Seismic Intensity (MMI)	Northern area	8	8 to 9	7	8 to 9
	Southern area	9	7 to 8	7	8 to 9

PGA: Peak Ground Acceleration

C. Seismic Damage Analysis

Building distribution, damage functions for residential buildings and human casualties

C-1 Building Distribution by Structure (Total)
C-2 Building Distribution by Structure (Steel)
C-3 Building Distribution by Structure (Steel and Brick)
C-4 Building Distribution by Structure (RC-0)
C-5 Weak Building Distribution

Residential building database was established based on the 1996 Housing Census data. Available information is structural type, construction year and the number of stories. Based on these, the buildings were categorised into nine types, especially from the viewpoint of resistance of buildings.
The census data provides information by dwelling unit. Therefore, dwelling units data were converted to buildings data. Distribution maps of the total number of buildings, each structural type (steel, steel and brick and RC-0) and the ratio of low seismic resistance buildings in each census zone were compiled. The steel and RC-0 buildings, which have high seismic resistance, are mainly distributed in the northern part of the city. The steel and brick buildings, which have low seismic resistance, are mainly distributed in the southern part of the city.
Damage function is relationship between seismic intensity and damage ratio. The functions for building were constructed for each types of structure. The functions for human casualties were also constructed. The definition of dead people is those people killed only because of building collapse.

Damage to Residential Buildings and Human Casualties

C-6 Heavily Damaged or Collapsed Buildings Ratio Distribution (Ray Fault model)
C-7 Heavily Damaged or Collapsed Buildings Ratio Distribution (NTF model)
C-8 Causality Ratio Distribution - Night, No Rescue Work (Ray Fault model)
C-9 Causality Ratio Distribution - Night, No Rescue Work (NTF model)

Damage to residential building and human casualties were estimated and damage distribution maps were compiled. The emergency rescue operations are the basic factor in determining the death. The effects were also examined as type of operation and occurrence time. The followings are damages for case of night-time and no rescue operation.

	Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model	Current Condition
Building Damage	483,000	313,000	113,000	446,000	Number of Buildings 876,000
Building Damage Ratio	55%	36%	13%	51%	
Damage Cost (% of GDP) (Reconstruction cost of residential buildings)	22.7%	14.30%	5.16%	20.38%	Gross GDP (1998) 109 Billion US$
Number of Dead People	383,000	126,000	20,000	302,000	Population 6,360,000
Death Ratio	6%	2%	0.3%	5%	

Note: Damage cost is calculated by using published GDP(1998) at price of US$50,000 per building (government official exchange rate 1US$=Rls.3,000)

In case for Ray Fault Model, seismic intensity is high in the southern area, where vulnerable building are prevailing. The number of damaged buildings in District 15 is the largest. The building damage ratio in Districts 11, 12, 16 to 20 show a very high value of around 80%. The casualties in District 15 will be vast because of the large number of its inhabitants. The death ratio in the northern part of the City will be about 2%.
In case of NTF Model, seismic intensity is high in the northern area, where vulnerable buildings are not prevailing. In northern part of the city, the building damage ratio in District 1 to 5 will be around 50%. The building damage ratio in southern part of the city will be less than 30%. The death ratio in the northern part of the City, in Districts 1 to 5 will be high, around 3%.
In case of the Mosha Fault Model, the building ratio for most of the district is almost 10% except case for District 12, where many vulnerable Adobe or Wood and Brick structures are prevailing. The death ratio does not exceed 0.3% of the total population of the city.
In case of Floating Model, the results indicate a relative vulnerability in the entire Study Area. The damage ratio of Districts 12 and 3 is relatively high. The major reason for the high damage ratio in these districts is that relatively soft soil is deposited in these areas and the seismic motion is amplified by this soil.

Damage to bridges

C-10 Damages of Bridges (Ray Fault model)

The damage of bridges was analysed by the multidimensional quantification theory one proposed by Tsuneo Katayama. The method (Disaster Prevention Council of the Tokyo Metropolitan Area (1978)) is widely used in Japan for practical purpose. Result of analysis is expressed as a total score. Judgement of stability of bridges is defined as follows:
- Total score 26 and over: 'collapsed'
- Total score 20 to 26: 'unstable'
- Total score below 20: 'stable'

Distribution maps of collapsed and unstable bridges were compiled. Details are as follows:

	Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model
Collapsed	6	0	0	0
Unstable	5	7	0	10

The bridges judged as 'collapsed' are almost all limited to temporary purposes. Their piers are made with weak steel. Compared to residential building damage, the number and damage ratio of bridges is low. Bridges are made for public purposes; therefore, detailed designs are usually applied and the construction quality is relatively high. However, the social influence is very high.

Damages to public facilities

C-11 Damage Ratio of Governmental Facilities (Ray Fault Model)
C-12 Damage Ratio of Police Stations (Ray Fault model)
C-13 Damage Ratio of Traffic Police Stations (Ray Fault Model)
C-14 Damage Ratio of Fire Fighting Office (Ray Fault model)
C-15 Damage Ratio of Hospitals (Ray Fault model)
C-16 Damage Ratio of Schools (Ray Fault model)

Information on seismic damage to major public facilities is very important for the preparation of a seismic disaster mitigation and management plan. The method of damage estimation for major public facilities is the same as that of residential buildings. Distribution maps of damage ratio for district were compiled. Details as follows:

	Number of Damage and Damage Ratio			
	Ray Fault Model	NTF Model	Mosha Fault Model	Floating Model
Govemmental Facility	18	11	4	16
	40%	25%	8%	36%
Police	27	18	7	26
	43%	28%	11%	41%
Traffic Police	7	5	2	6
	52%	35%	16%	48%
Fire Fighting	28	21	7	28
	52%	38%	12%	53%
Hospital	56	33	11	50
	50%	29%	9%	44%
Elementary School	623	376	133	558
	57%	35%	12%	51%
Intermediate school	369	250	81	350
	54%	36%	12%	51%
High School	340	242	75	331
	52%	37%	12%	51%
Higher Education Center (University)	66	61	18	76
	42%	39%	12%	48%

The damage ratio in the southern Districts is relatively high. The results of the damage analysis show that all public facilities will suffer damages to the same extent as residential buildings. The results suggest that those facilities will be difficult to use for disaster management in case of an earthquake.

Damages to lifelines

C-17 Damage of Water Supply Pipeline (Ray Fault model)
C-18 Damage of Gas Pipeline (Ray Fault model)
C-19 Damage of Electric Power Supply Cable (Ray Fault model)
C-20 Damage of Telecommunications Cable (Ray Fault model)

Information on seismic damage to lifelines is very important for the preparation of a seismic disaster management plan. The following 4 types of lifelines are considered: 1) Water supply pipelines, 2) Gas pipelines, 3) Electric power supply cables, 4) Telecommunications cables.
The damage distribution maps for the Ray Fault Model were compiled for each type of lifeline. In general, the damages are huge in the southern districts in response to the seismic intensity. The damage figures are conservative, considering the limitations of the damage estimation procedure and quality of available data.

Damages to hazardous facilities

C-21 Fire Outbreak Rank from Hazardous Facilities (Ray Fault model)

A possibility of fire outbreaks from facilities where inflammable liquids or gases materials are handled was estimated. The leaking liquids or gases ignite to fire are estimated based on Japanese experience. No case information on fire occurrences in Iran was available. The distribution for the hazardous facilities is not uniform. It is considered that the database was not prepared based upon a uniform criterion. Therefore, fire outbreak was calculated for the municipal districts in which more than 5 hazardous facilities were located within the district. Consequently, the results show only a relative possibility of fire occurrence. The number of fire outbreaks is summed up in each district and then expressed as rating of fire hazard. Distribution map of the vulnerability rating for districts under the Ray Fault Model was compiled.

Liquefaction

C-22 Liquefaction Potential (Ray Fault model)

A combination of the F_L method and the P_L method was used for liquefaction analysis. This method is commonly used in Japan for practical purposes. The result of the analysis was expressed as a point base. In the calculations, the groundwater level was modelled as the actual groundwater level minus 5 m considering fluctuation of level. The Ray Fault Model presented the biggest peak ground acceleration value in the selected area. Therefore, The acceleration value for the model at each borehole location was used. Distribution map of liquefaction potential was compiled. Almost the entire area is rated as having 'very low' or 'relatively low' liquefaction potential. Stiff cohesive clayey soil is predominantly deposited in the analysed area. Only one borehole location was judged as having 'relatively high' liquefaction potential.

Slope Stability

C-23 Slope Stability (NTF model)

Stability of large-scale natural slopes was examined. Stability was judged using slope stability chart by Panah et al. (1992). This chart indicates the relationship between stable slope gradient and peak ground acceleration. The current condition of the slopes and the result of the slope stability estimation were expressed in maps.
In case for Ray Fault Model, Mosha Fault Model and Floating Model, most of the meshes are judged as stable. In case for NTF Model, many meshes at the edge of the Alborz Mountains are judged as unstable. Most of these unstable meshes are not in residential areas. Slopes located at planning raw water transmission tunnels and behind the oil tank are judged as high-risk.

D. Overall Vulnerability Evaluation

D-1 Evaluation of Seismic Hazard Risks (Ray Fault model)
D-2 Evaluation of Seismic Hazard Risks (NTF model)
D-3 Evaluation of Seismic Hazard Risks (Floating model)

Each seismic hazard and damage item indicates direct damage caused by earthquakes. Each social condition item indicates difficulty of rescue operations, evacuation, recovery operations and living conditions after an earthquake disaster. Evaluation criteria of risk items were considered. The ranking of each item was depicted by radar charts for each district and seismic hazard risk maps were compiled. In the radar chart, the more area of red part expressed, the higher the risk is. Since the Mosha Fault Model produced only minimal seismic hazard, it was not included.

Ray Fault Model

As a whole, the southern area of the city has relatively high disaster risk. District 17 has the highest disaster risk, not only for the Ray Fault Model, but also for every other model. The district experiences a high seismic intensity, a high ratio of building damage and a high death ratio. Evacuation will prove difficult because the district has narrow roads. The death ratio of District 10 is relatively low but each item of social condition has a rank of 5. This shows there may be great difficulty in the evacuation and restoration efforts carried out in District 10.

NTF Model

The northern part of the city recorded higher seismic hazard and damage risk. Overall, the disaster is considered lesser than that attributed to the Ray Fault Model, because ground conditions and social conditions of the northern areas are better than those of the southern areas. In this model, seismic hazard and damage risk is high in the northern areas and social condition risk is high in the southern areas, but no district is extremely vulnerable.

Floating Model

Relative seismic damage risk that is not caused by a specific earthquake was evaluated using the Floating Model. District 10 is evaluated as the most hazardous, followed by Districts 12 and 17.

E. Pilot Study

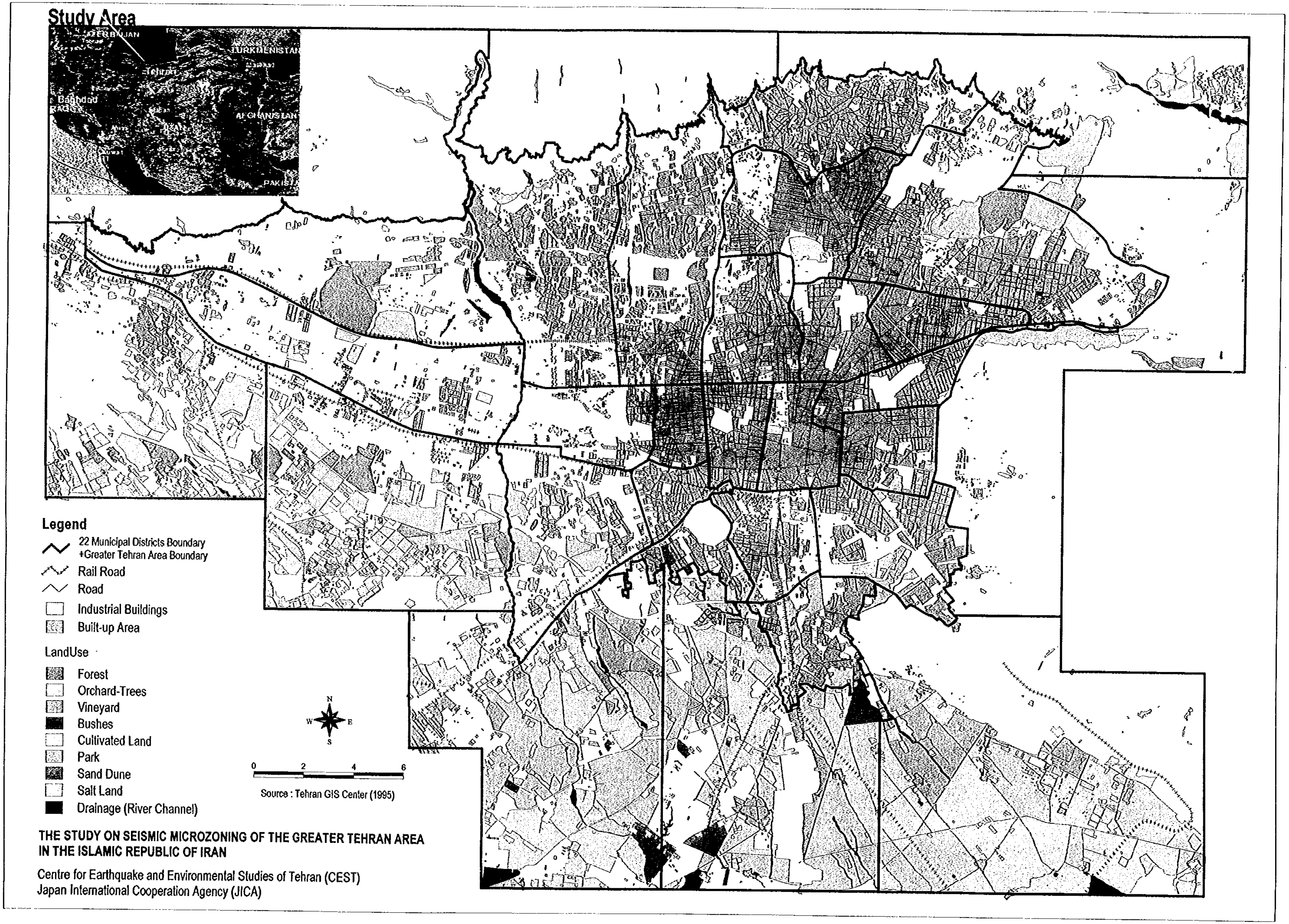
E-1 Area of Large Peak Ground Acceleration (Ray Fault model)
E-2 Area of Large Peak Ground Acceleration (NTF model)
E-3 Area of Building Structure "Others" is prevailing
E-4 Area of High Population Density
E-5 Location Map (Pilot Study Area)
E-6 Building
E-7 Building Distribution by Structure
E-8 Building Distribution by Number of Stories
E-9 Population Density
E-10 Landuse
E-11 Road Network
E-12 3D Image View – Existing Condition
E-13 3D Image View – After Damage

The Pilot Study Area (PSA) has been set in District 17 in order to identify and collect basic information for the preparation of necessary measures to mitigate a seismic disaster.

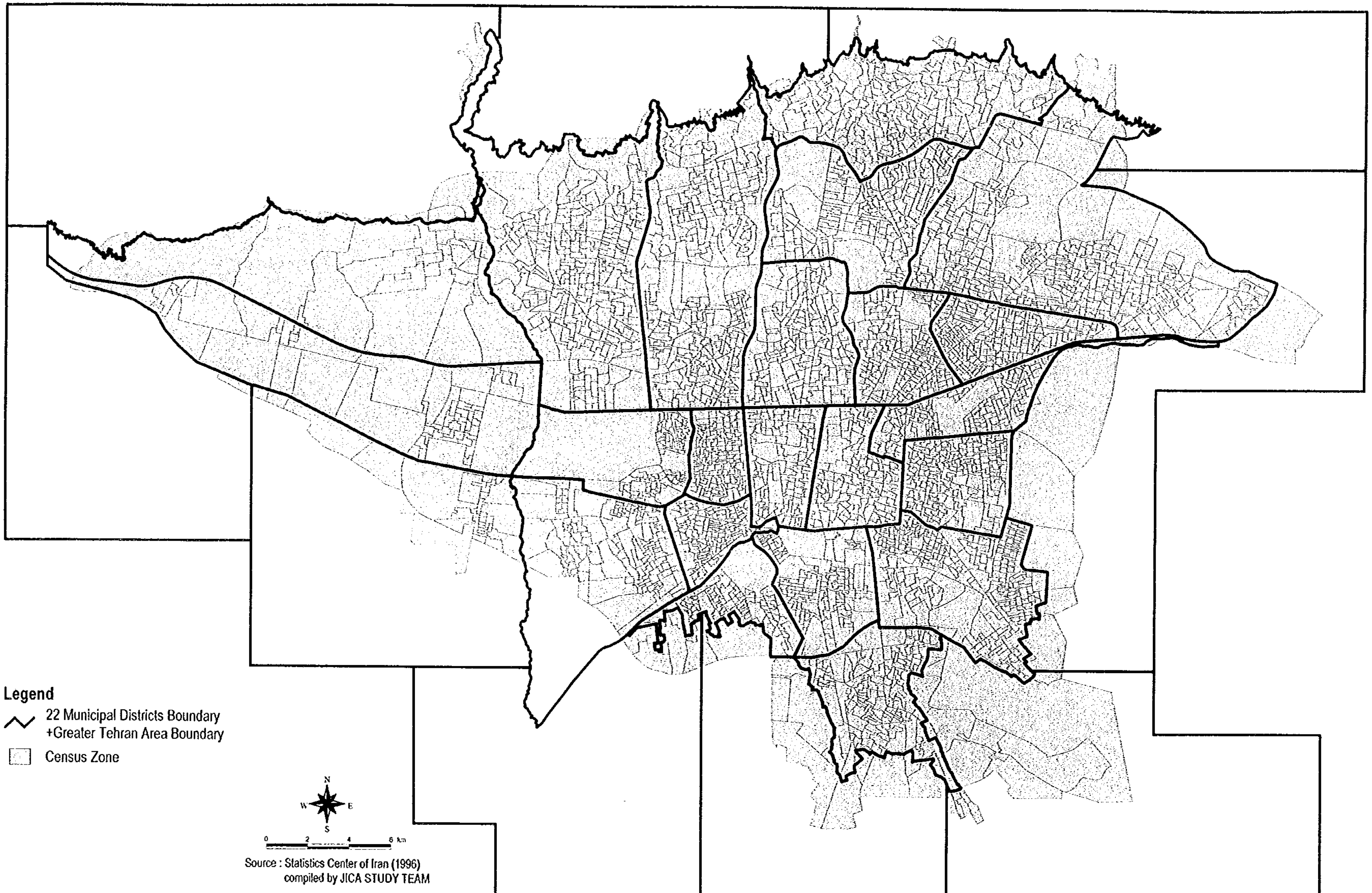
Detailed building and urban land use survey were carried out based on large scale topographical map provided by Tehran GIS Center. Results were compiled into series of maps, which are showing the existing urban condition of the area. These data maps were also digitised and analysed from viewpoints of seismic disaster prevention. Attached maps are the output of the GIS for Pilot Study. Because of the details of the Pilot Study were described in the main report, series of maps, which are well showing the regional/urban characteristics of the area were selected and attached here.

A. Existing Conditions

A-1


Study Area
TURKMENISTAN
Tehran
Baghdad
AFGHANISTAN
Legend
22 Municipal Districts Boundary
+Greater Tehran Area Boundary
Rail Road
Road
Industrial Buildings
Built-up Area
LandUse
Forest
Orchard-Trees
Vineyard
Bushes
Cultivated Land
Park
Sand Dune
Salt Land
Drainage (River Channel)
N
W
E
S
0
2
4
6
Source : Tehran GIS Center (1995)
THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA
IN THE ISLAMIC REPUBLIC OF IRAN
Centre for Earthquake and Environmental Studies of Tehran (CEST)
Japan International Cooperation Agency (JICA)

Census Zone

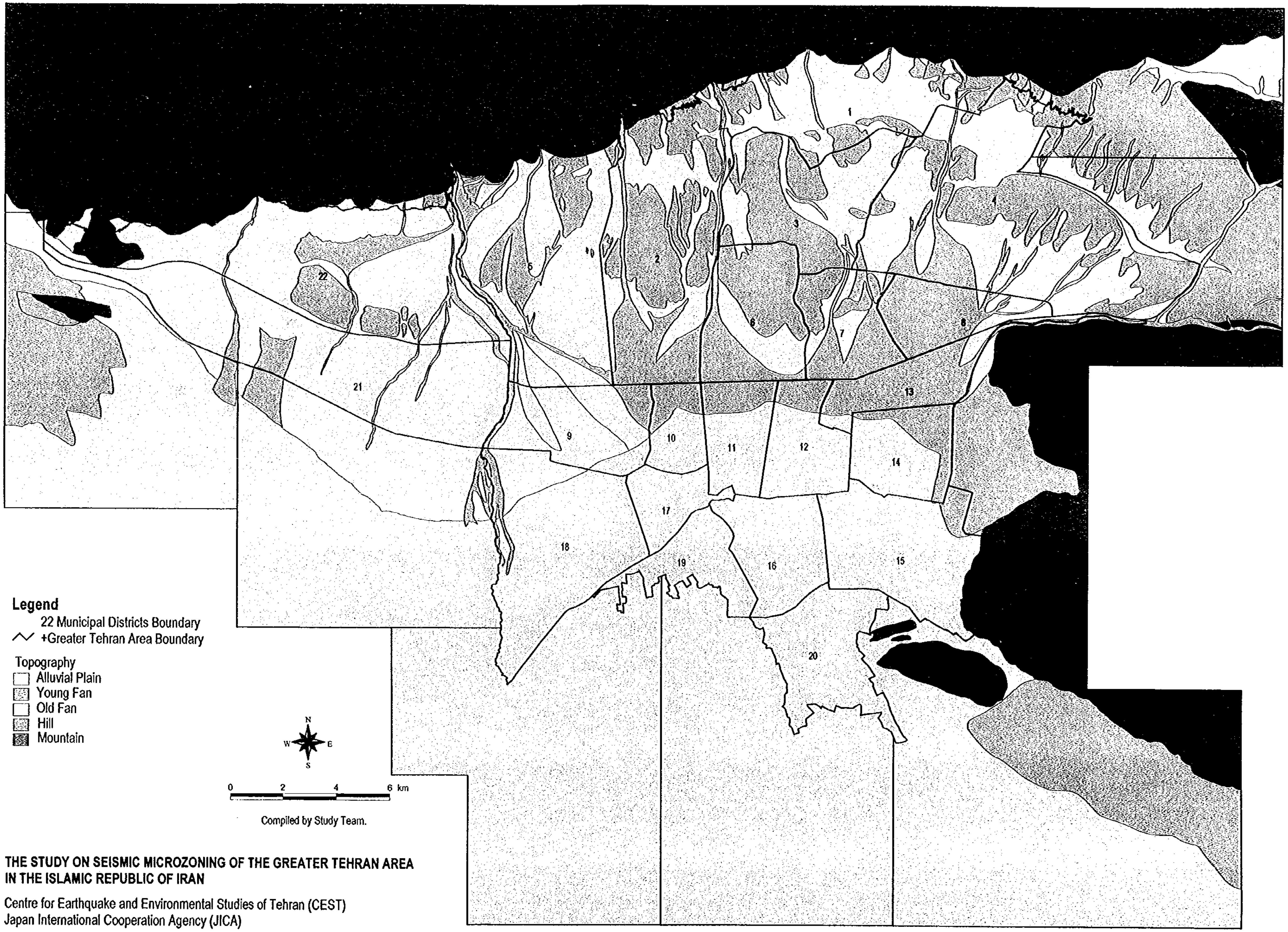


THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

Centre for Earthquake and Environmental Studies of Tehran (CEST)

Japan International Cooperation Agency (JICA)

Topography

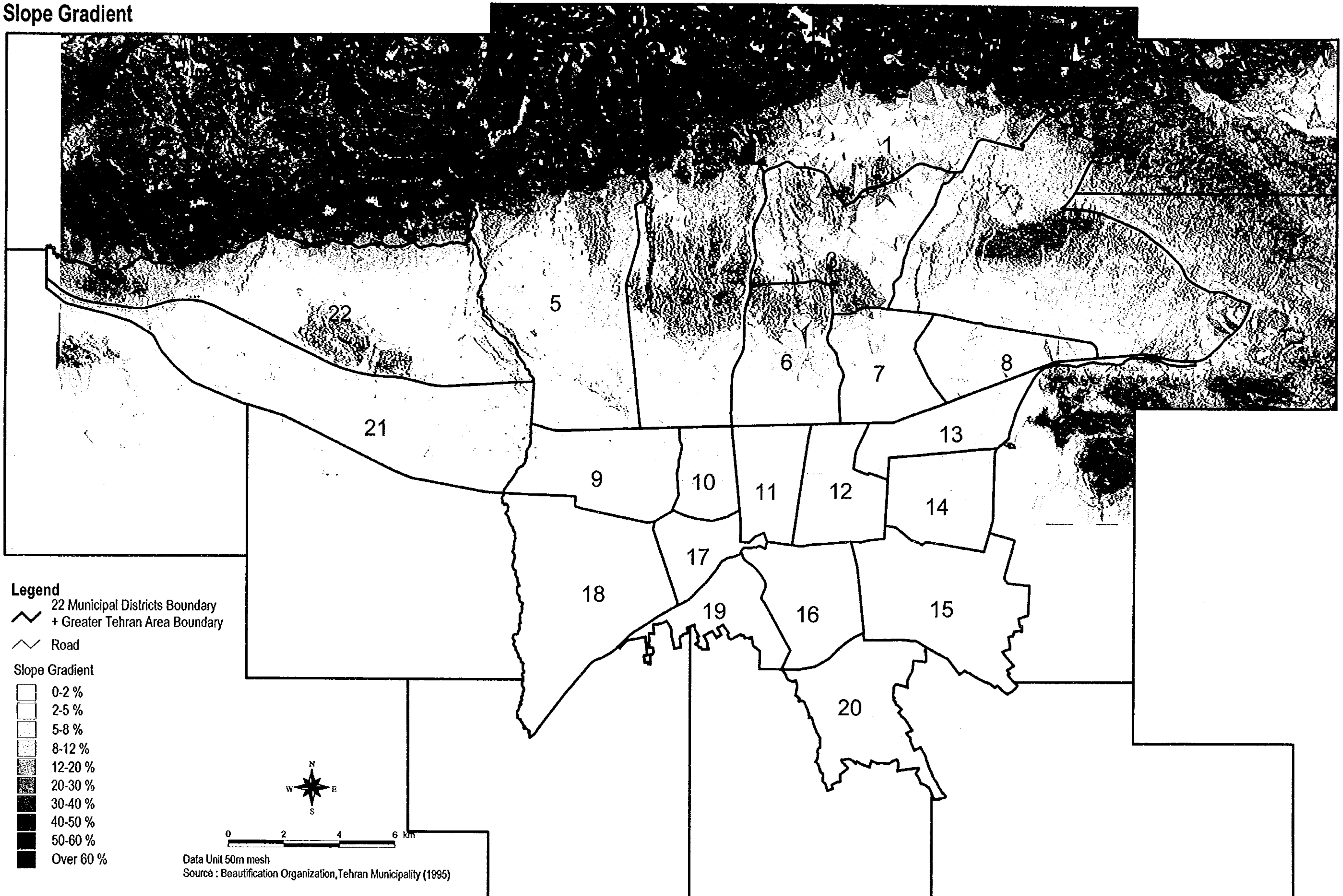


Compiled by Study Team.

THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

Centre for Earthquake and Environmental Studies of Tehran (CEST)
Japan International Cooperation Agency (JICA)

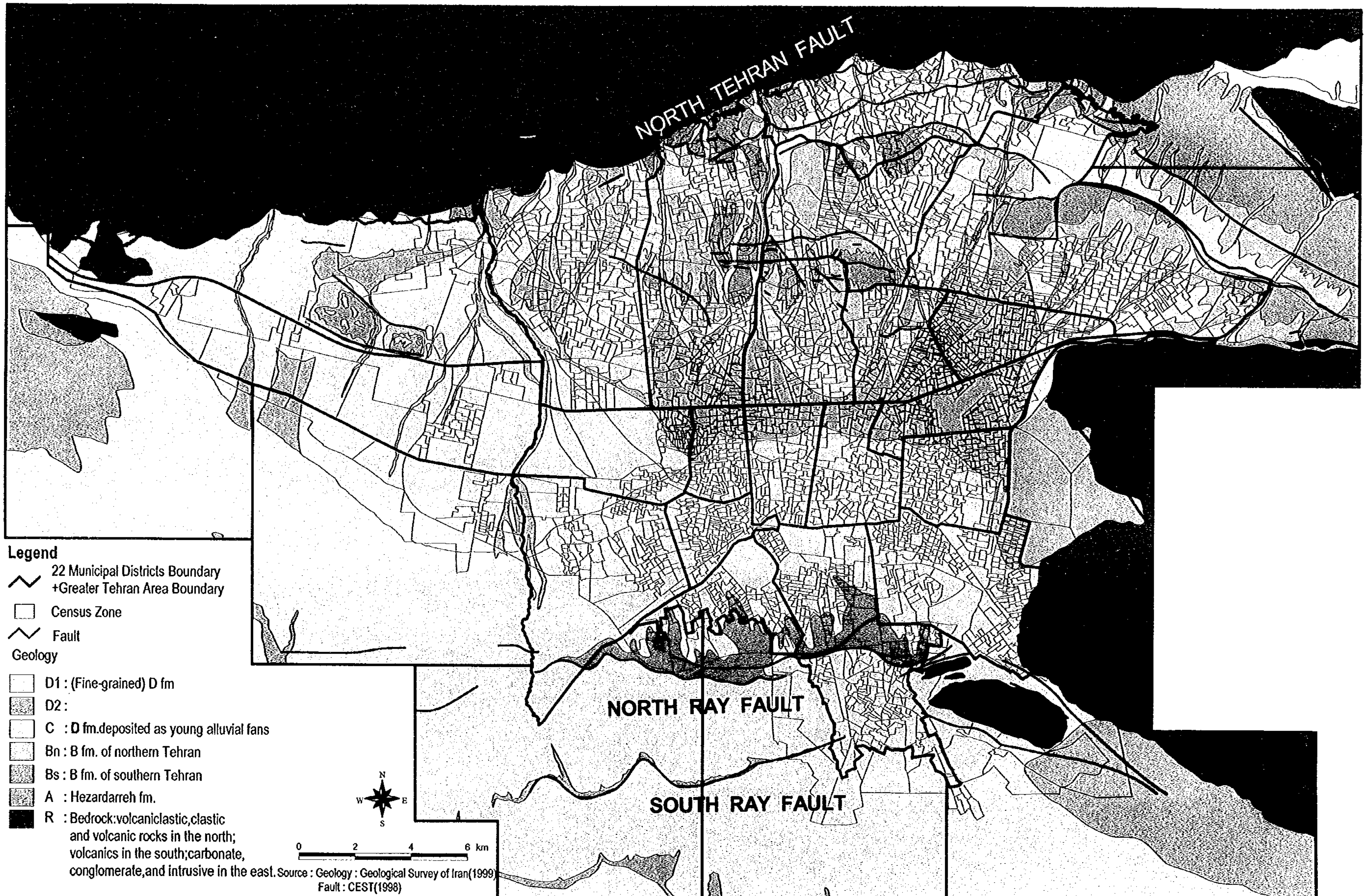
Slope Gradient



THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

Centre for Earthquake and Environmental Studies of Tehran (CEST)
Japan International Cooperation Agency (JICA)

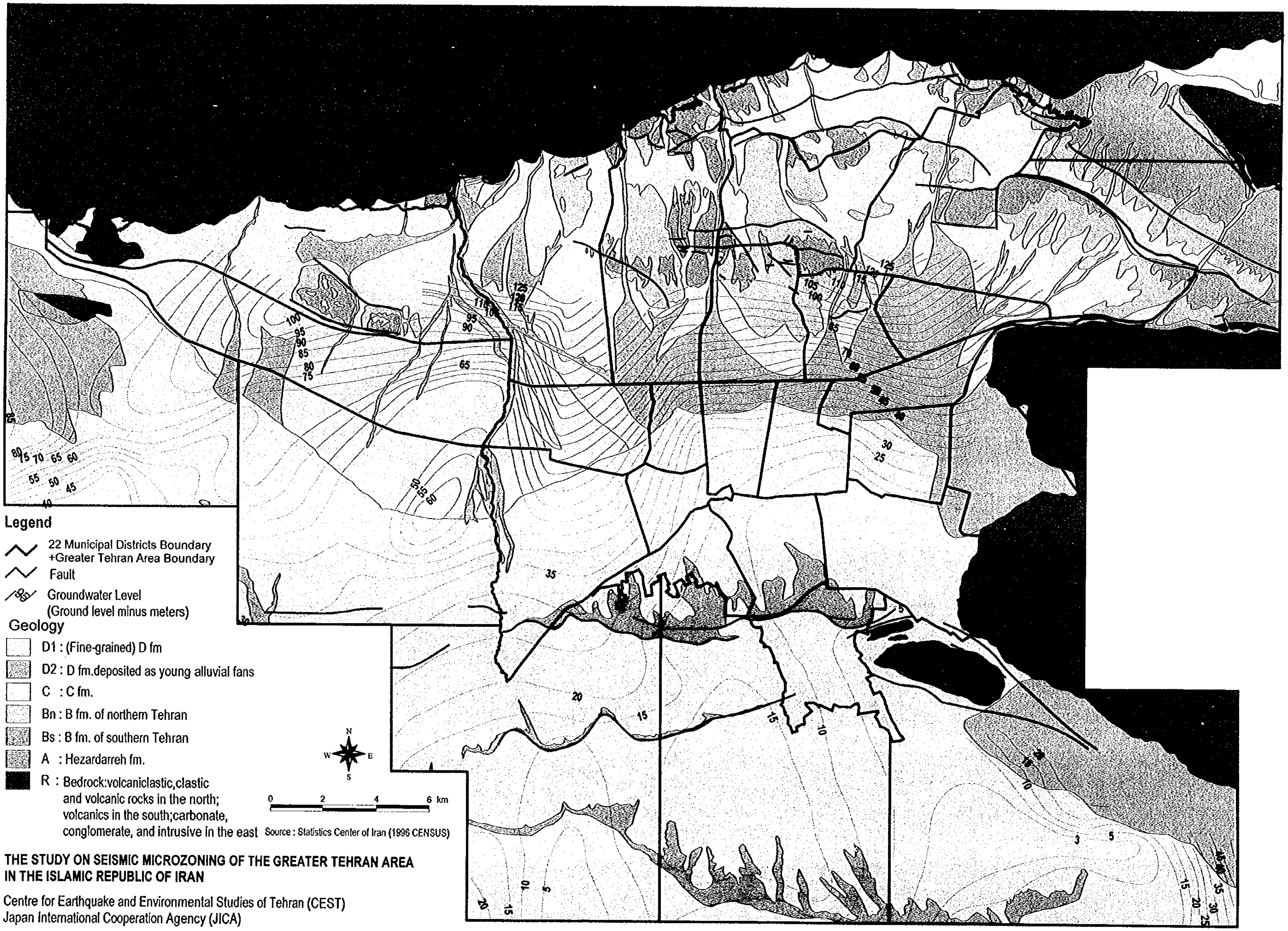
Geology



THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

Centre for Earthquake and Environmental Studies of Tehran (CEST)
Japan International Cooperation Agency (JICA)

Groundwater Table



THE STUDY ON SEISMIC MICROZONING OF THE GREATER TEHRAN AREA IN THE ISLAMIC REPUBLIC OF IRAN

Centre for Earthquake and Environmental Studies of Tehran (CEST)
Japan International Cooperation Agency (JICA)