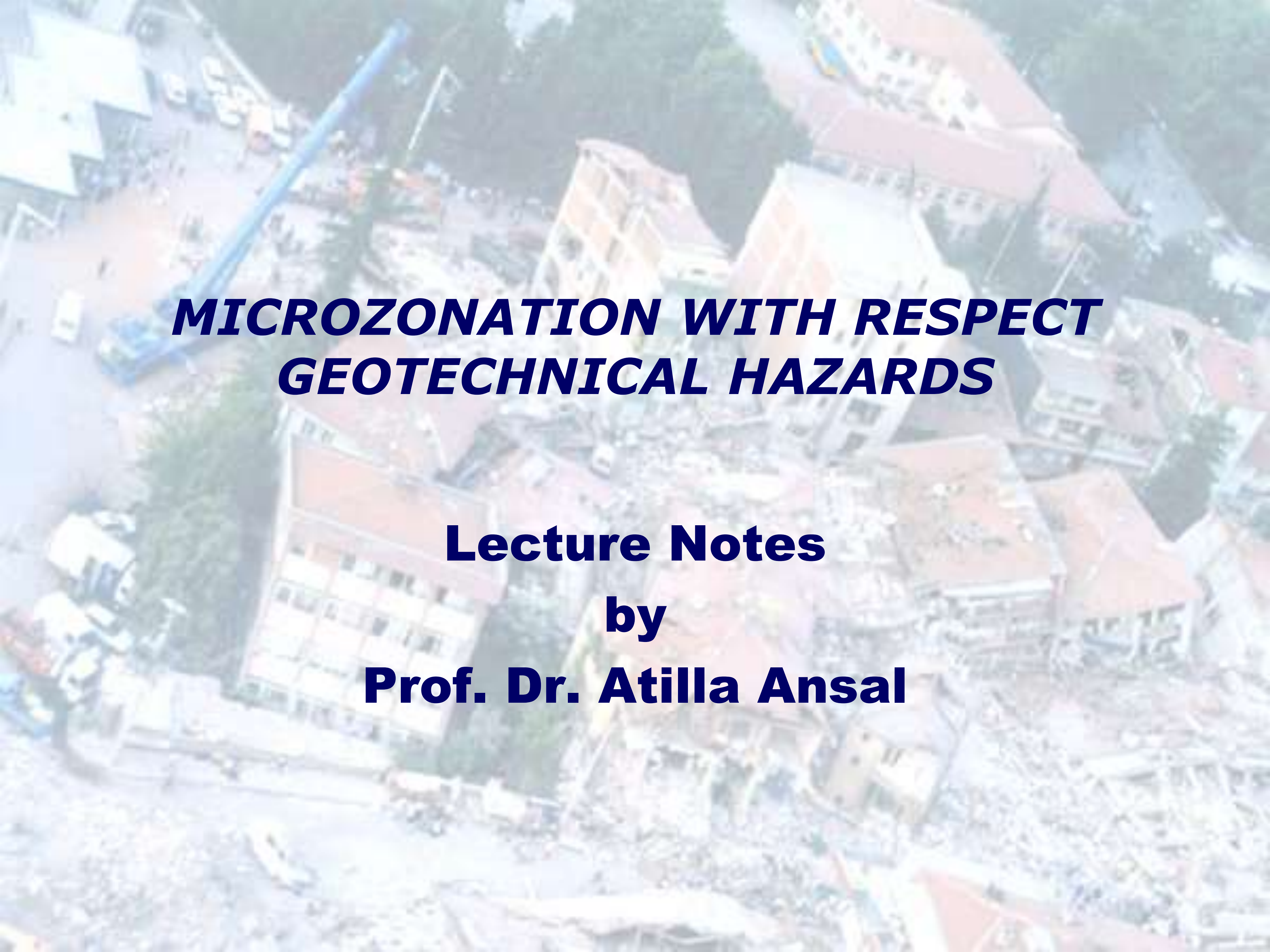


MICROZONATION WITH RESPECT GEOTECHNICAL HAZARDS

Lecture Notes

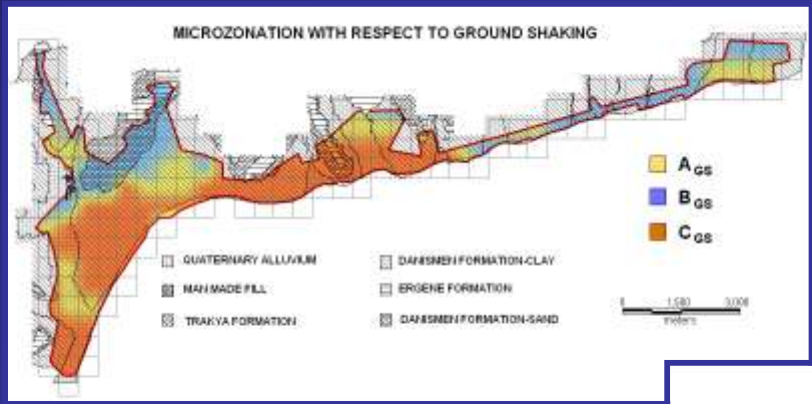
by

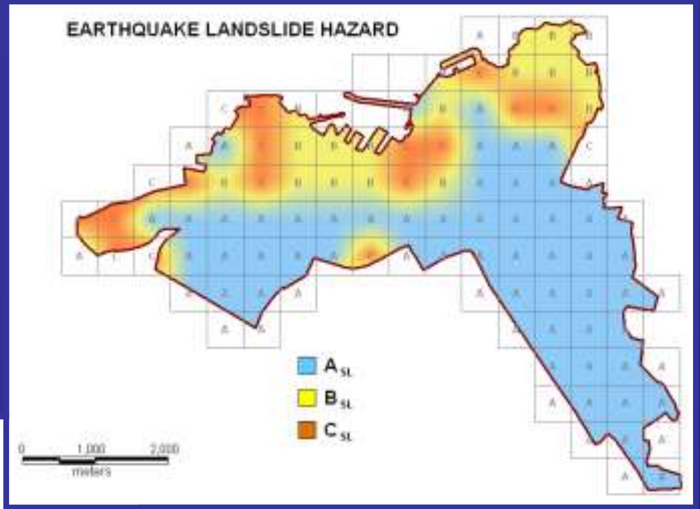
Prof. Dr. Atilla Ansal

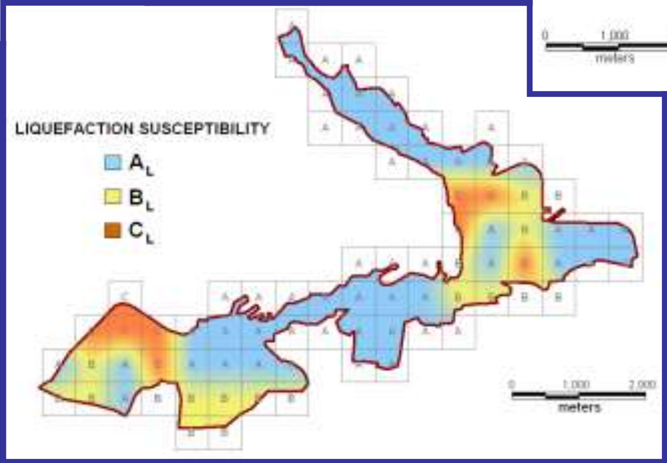
MICROZONATION

MAIN PURPOSE:

To estimate *variation of the selected parameters* for land use and urban planning for the mitigation of earthquake risk to man-made environment







URBAN AND LAND USE PLANNING

1. Use of seismic microzonation maps as guidelines to specify building and population density and for functional layouts
2. Selection of new locations for important buildings

Seismic Macrozonation
National Seismic Zoning Maps

- in small scales such as 1:1,000,000 or less and mostly based on seismic source zones defined in similar scales
- Independent of site conditions
- Used in the earthquake codes for seismic design

Seismic Microzonation

- zonation with respect to ground motion characteristics taking into account source and site conditions
- major purpose is to estimate the variation of the earthquake ground motion characteristics at a scale of 1:5,000

MICROZONATION METHODOLOGY

- REGIONAL EARTHQUAKE HAZARD
- SITE CHARACTERIZATION
- SITE RESPONSE ANALYSIS
- ANALYSIS AND INTERPRETATION

MICROZONATION WITH RESPECT TO:

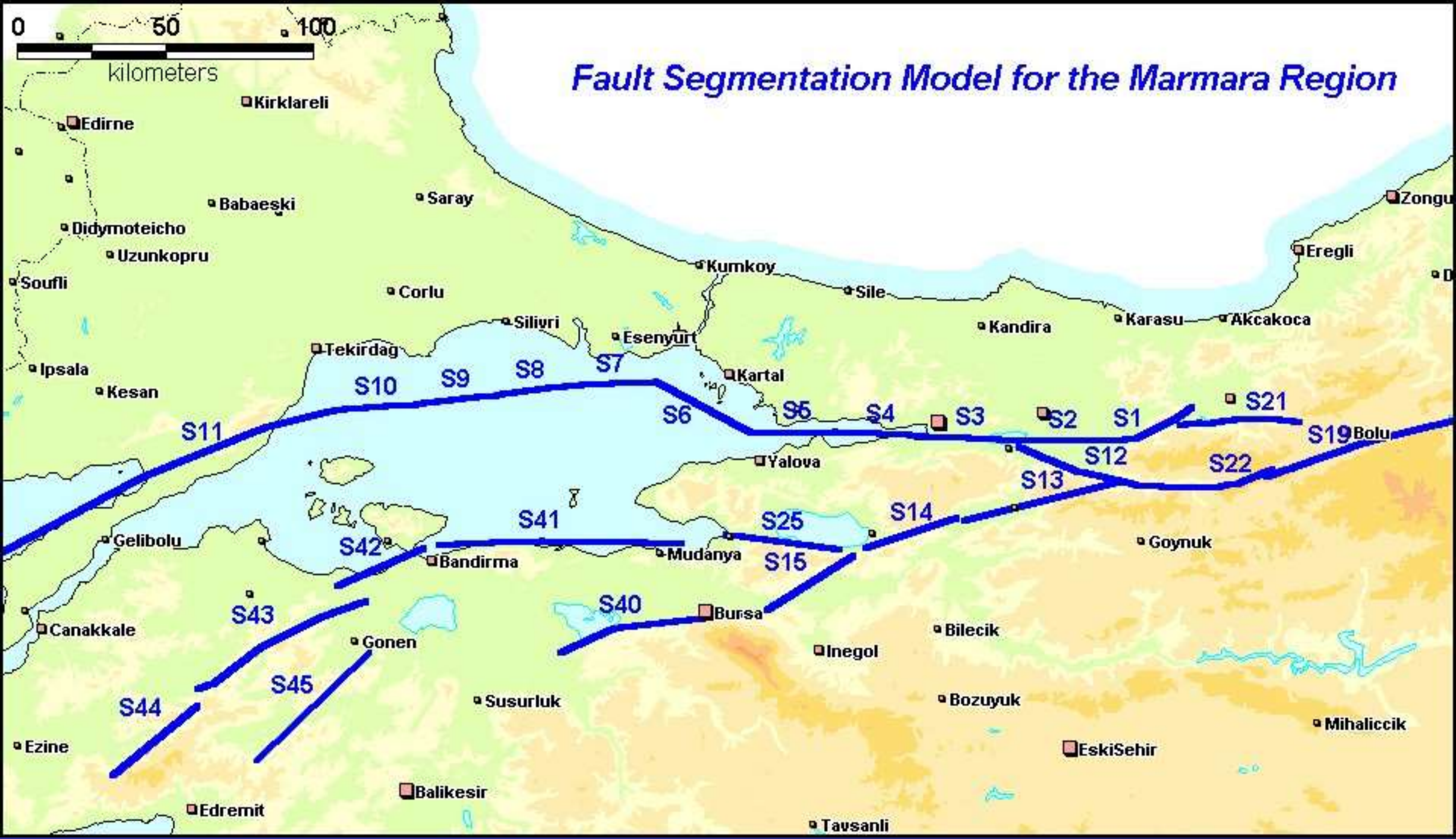
- GROUND SHAKING
- LIQUEAFACTION SUSCEPTIBILITY
- LANDSLIDE HAZARD

ADDITIONAL PURPOSE: ***To calculate elastic acceleration response spectra of the acceleration time history, for the assessment of the vulnerability of the building stock.***

Basic Stages of Earthquake Hazard Scenarios

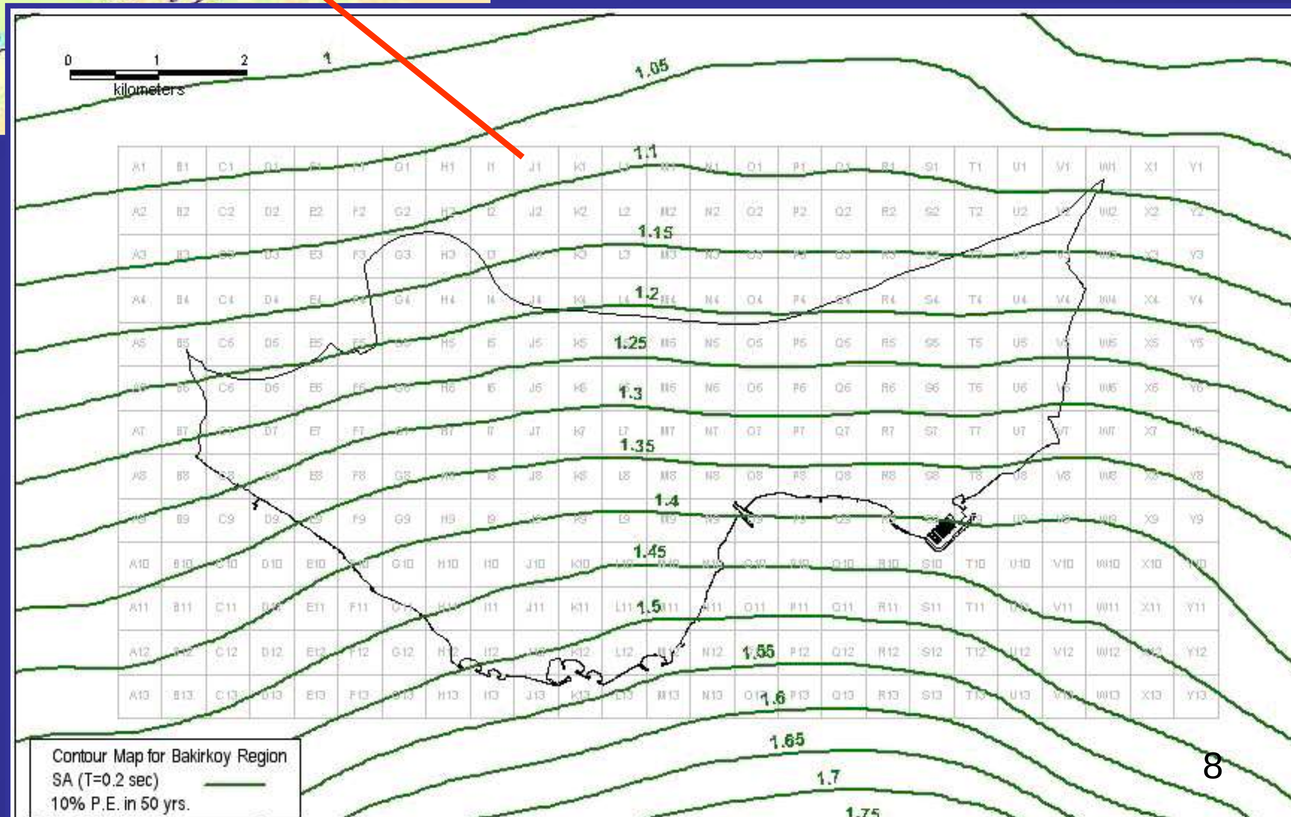
- Regional earthquake hazard
- Site characterisation
- 1D site response analyses
- Selection of input ground motion
- Microzonation for ground shaking intensity
- Earthquake characteristics on the ground surface

Fault Segmentation Model (Erdik et al., 2005)



REGIONAL EARTHQUAKE HAZARD

SA (T=0.2sec) Contour Map at NEHRP B/C Boundary for 475 Years Return Period



Geological and Geotechnical Site Characterisation

- Regional geology of the area
- Local geology of the region
- Detailed geotechnical characterisation
- Site classification with respect to equivalent shear wave velocity, NEHRP, Borcherdt (1994), and Turkish Earthquake Code

SITE CHARACTERIZATION

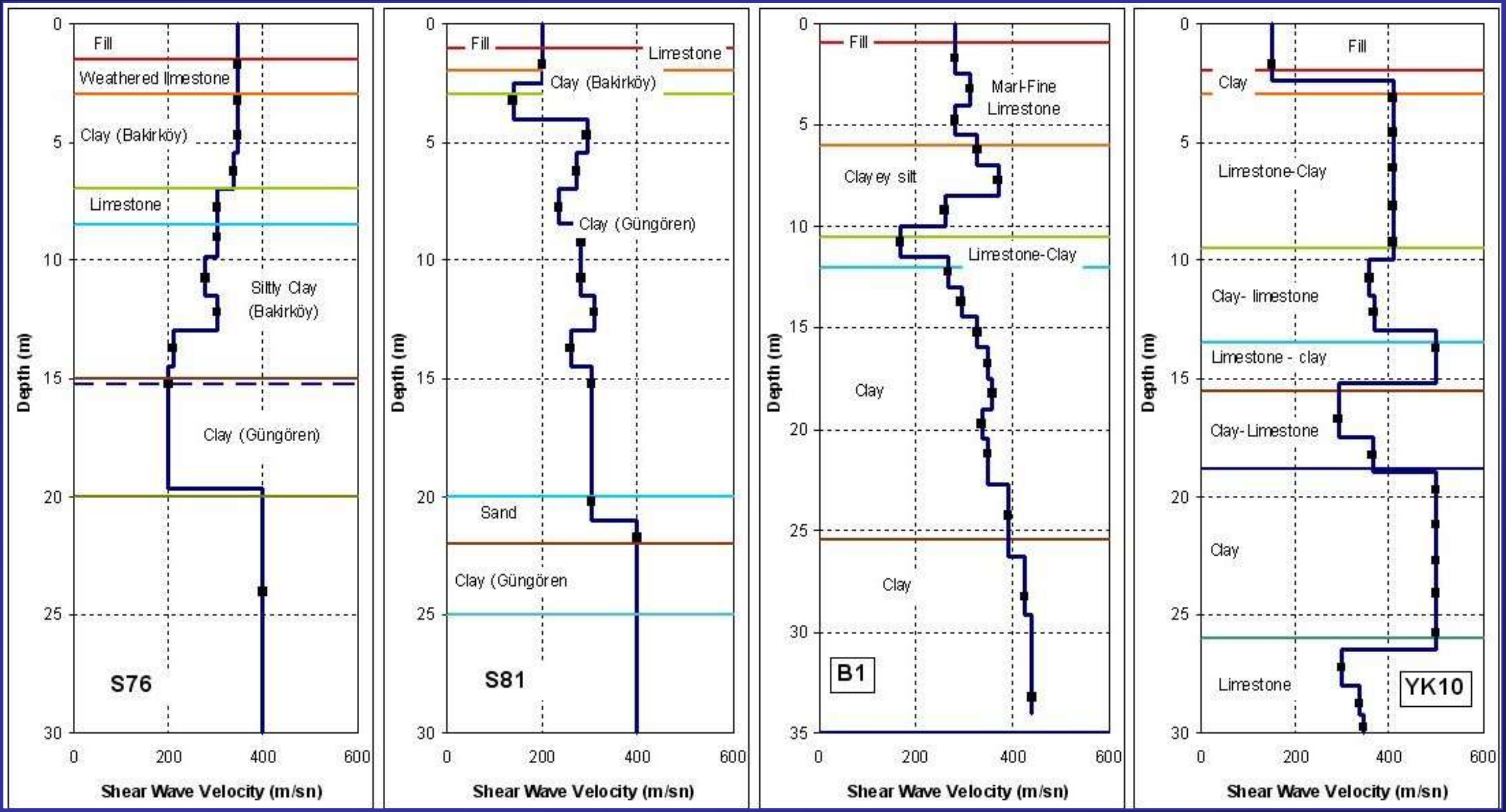
Assigning partly hypothetical boreholes at the centre of each cell

1. **to utilise all available data in each cell to have more comprehensive and reliable data for the soil profile;**
2. **to eliminate the effects of distance among boreholes or site investigation points during the GIS mapping**

	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	
4												SK21	SK23	SK26	SK26			4
5											SK15	SK21	SK23	SK26	S16			5
6					SK4	SK4	SK6			SK15	SK15	SK22	S18	S18	S16			6
7				SK3	SK3	S7	SK5	SK11	SK11	SK13	SK18	SK18	SK24	SK27	SK27			7
8			SK2	SK2	S8	S9	SK10	SK10	SK13	SK17	SK16	SK25	SK25	S14	SK29			8
9	S10	S10	SK2	SK2	SK7	S6	SK9	SK12	SK14	SK17	SK20	SK25	SK28	SK28	SK29	SK29		9
10	SK1	SK1	SK1	SK2	SK7	SK7	SK9	SK12	SK14	S5	SK20	SK20	SK30	SK30	S12	SK29		10
11				SK7	SK7	SK7	SK9					S11	S11	SK30	SK31	SK31	SK31	11
12					SK7	SK7							S11	SK32	SK32	SK32		12
13														SK32	SK32	SK33	SK33	13
14														SK32	SK33	SK33	SK33	14
15															SK34	SK34	SK34	15
16																SK34	SK34	16
	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	

BANDIRMA

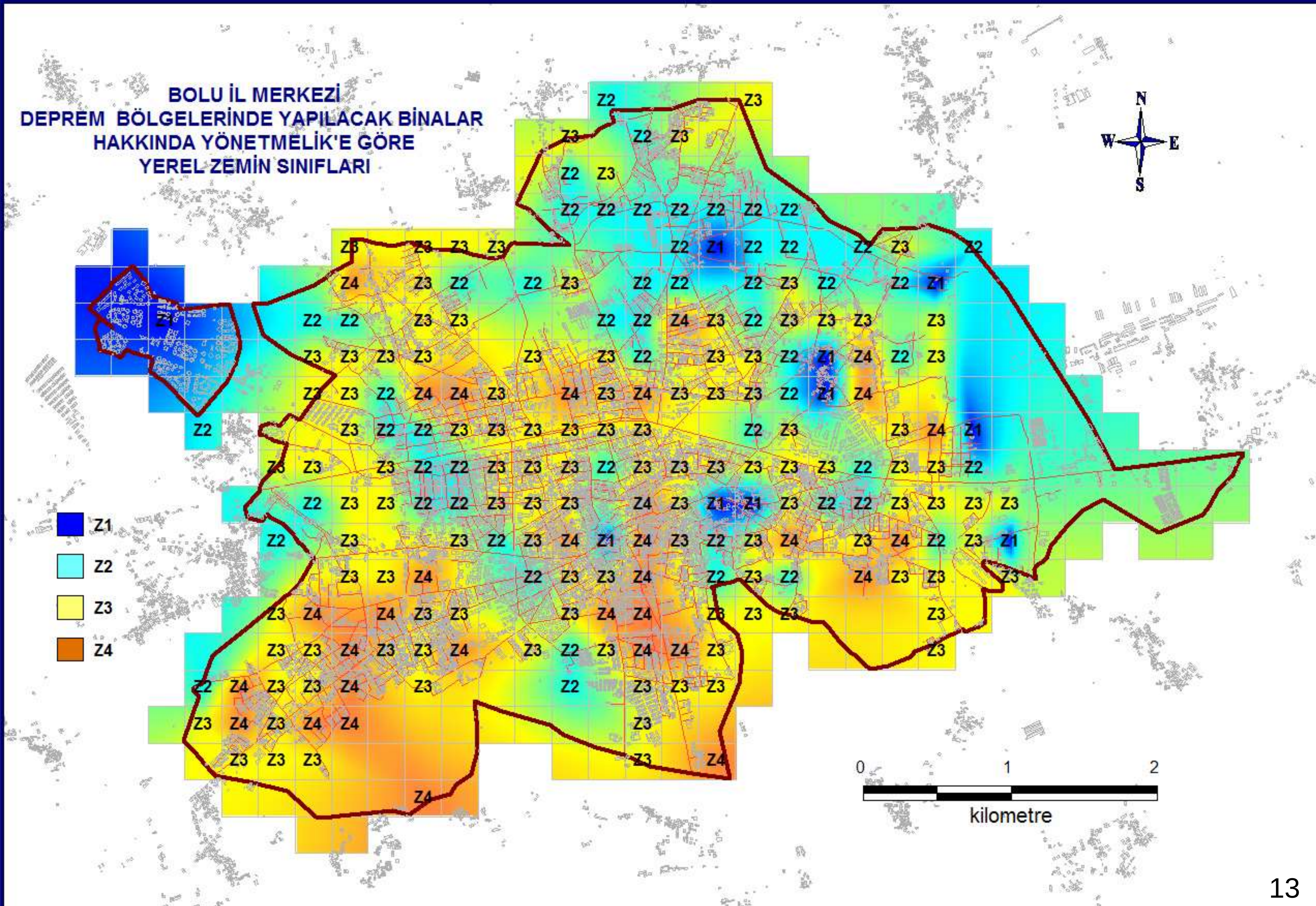
Site Characterisation



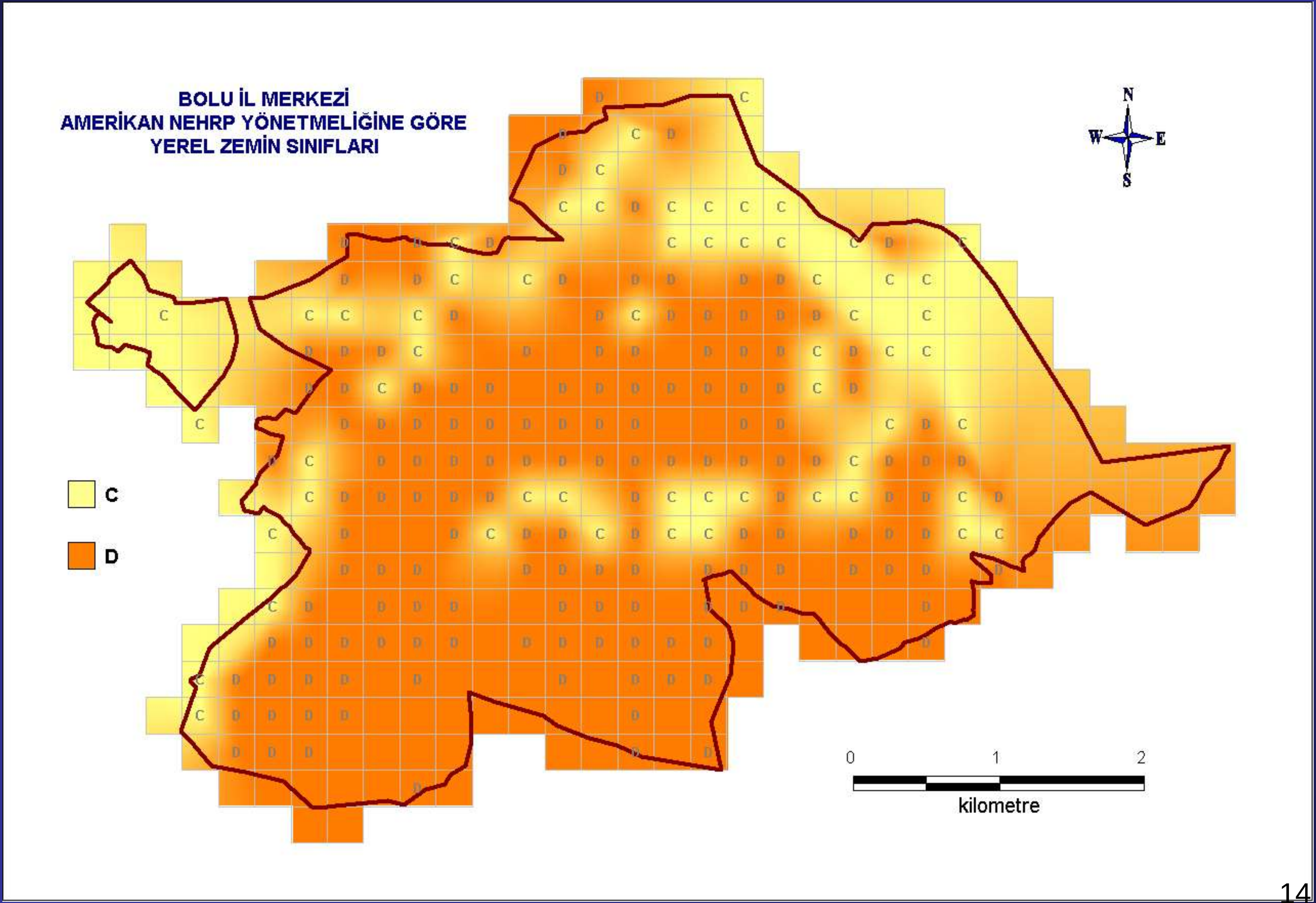
Two Stage Site Classification in Turkish Earthquake Code

Local Site Class	***Soil Group according to Table 12.1 and Topmost Layer Thickness*** **(h_1)**
Z1	Group **(A)** soils Group **(B)** soils with **$h_1 \leq 15$ m**
Z2	Group **(B)** soils with **$h_1 > 15$ m** Group **(C)** soils with **$h_1 \leq 15$ m**
Z3	Group **(C)** soils with **15 m $< h_1 \leq 50$ m** **Group (D)** soils with **$h_1 \leq 10$ m**
Z4	Group **(C)** soils with **$h_1 > 50$ m** Group **(D)** soils with **$h_1 > 10$ m**

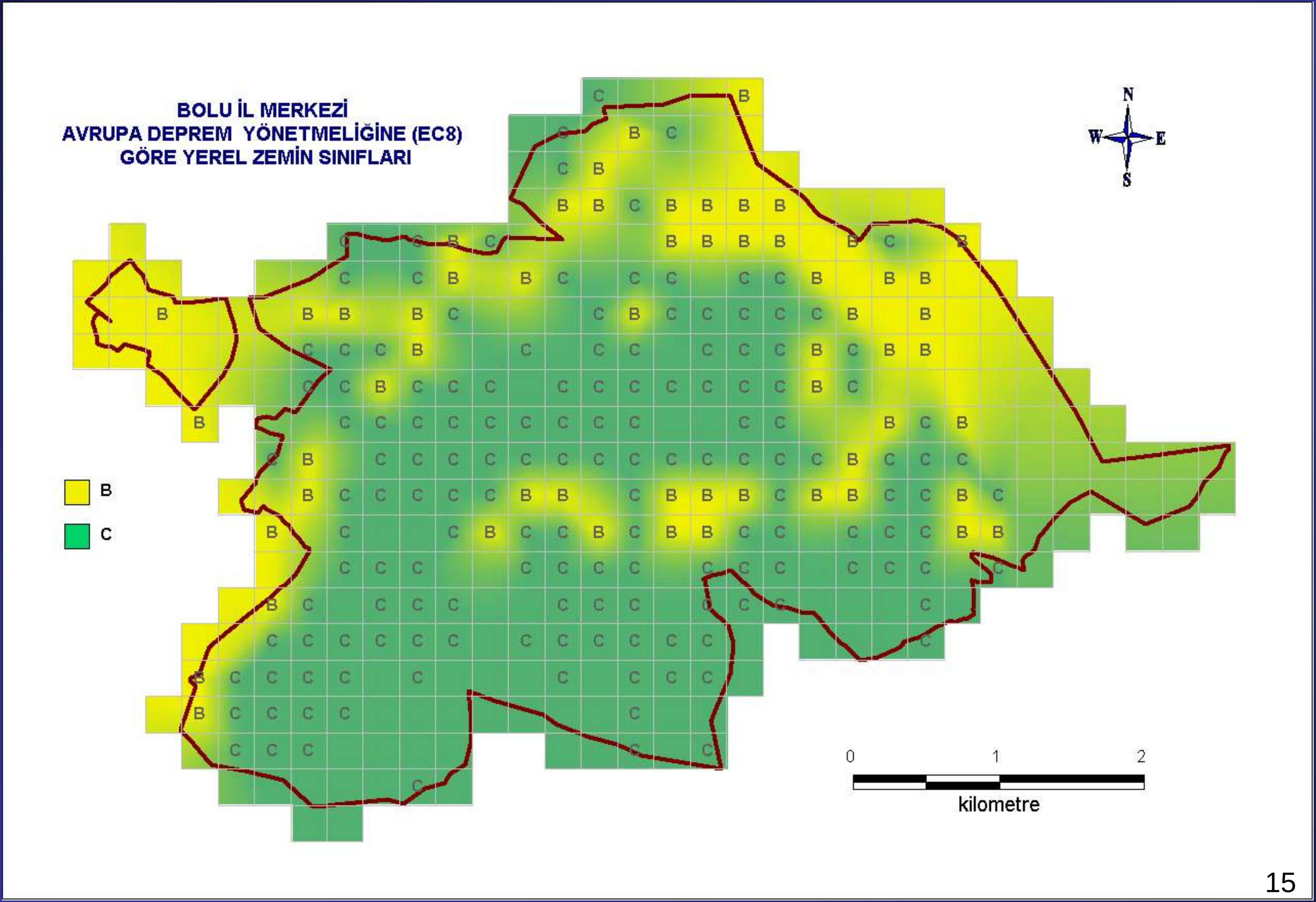
Site Classification according to TEC



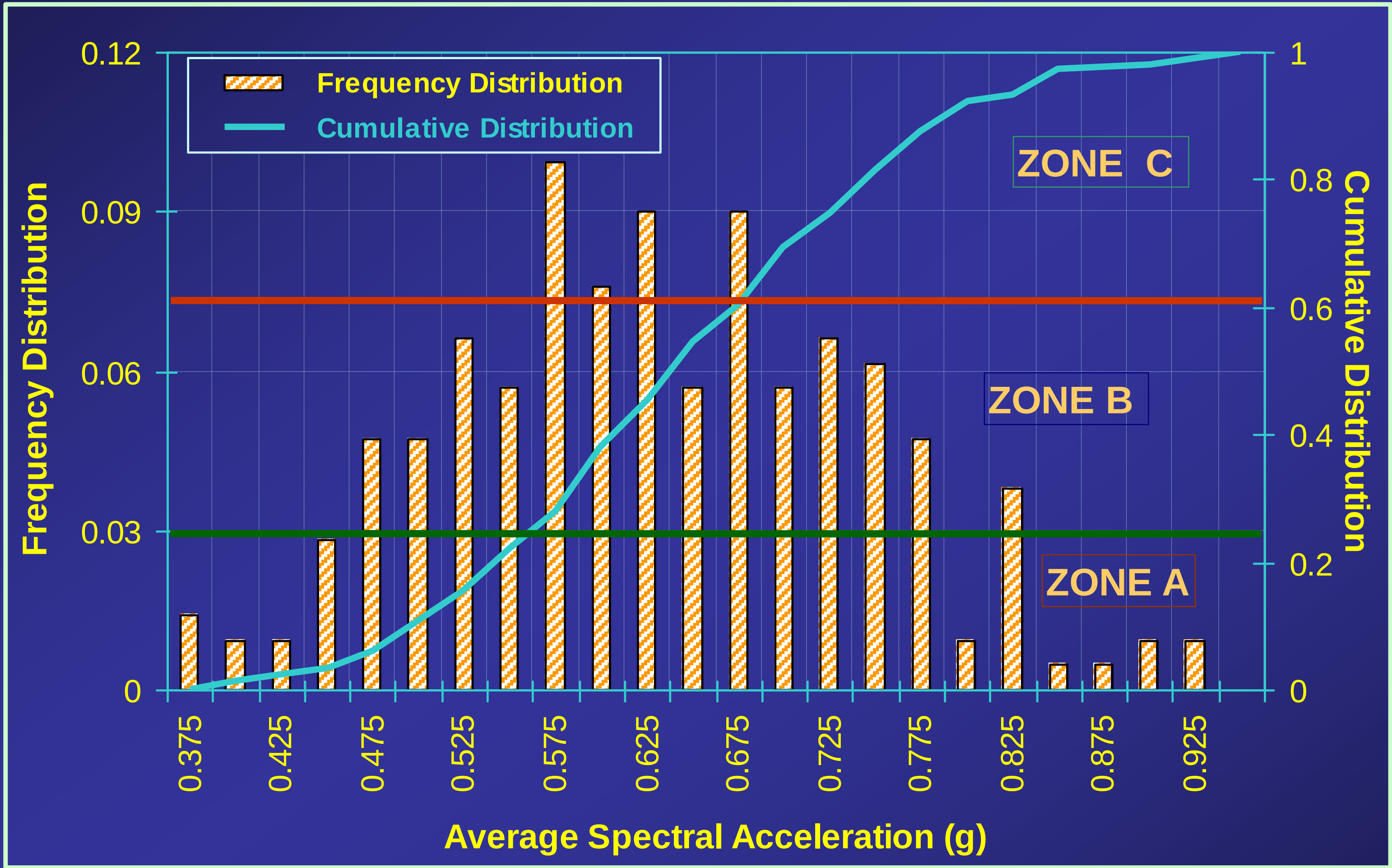
Site classification according to NEHRP



Site classification according to EC8



Relative microzonation procedure



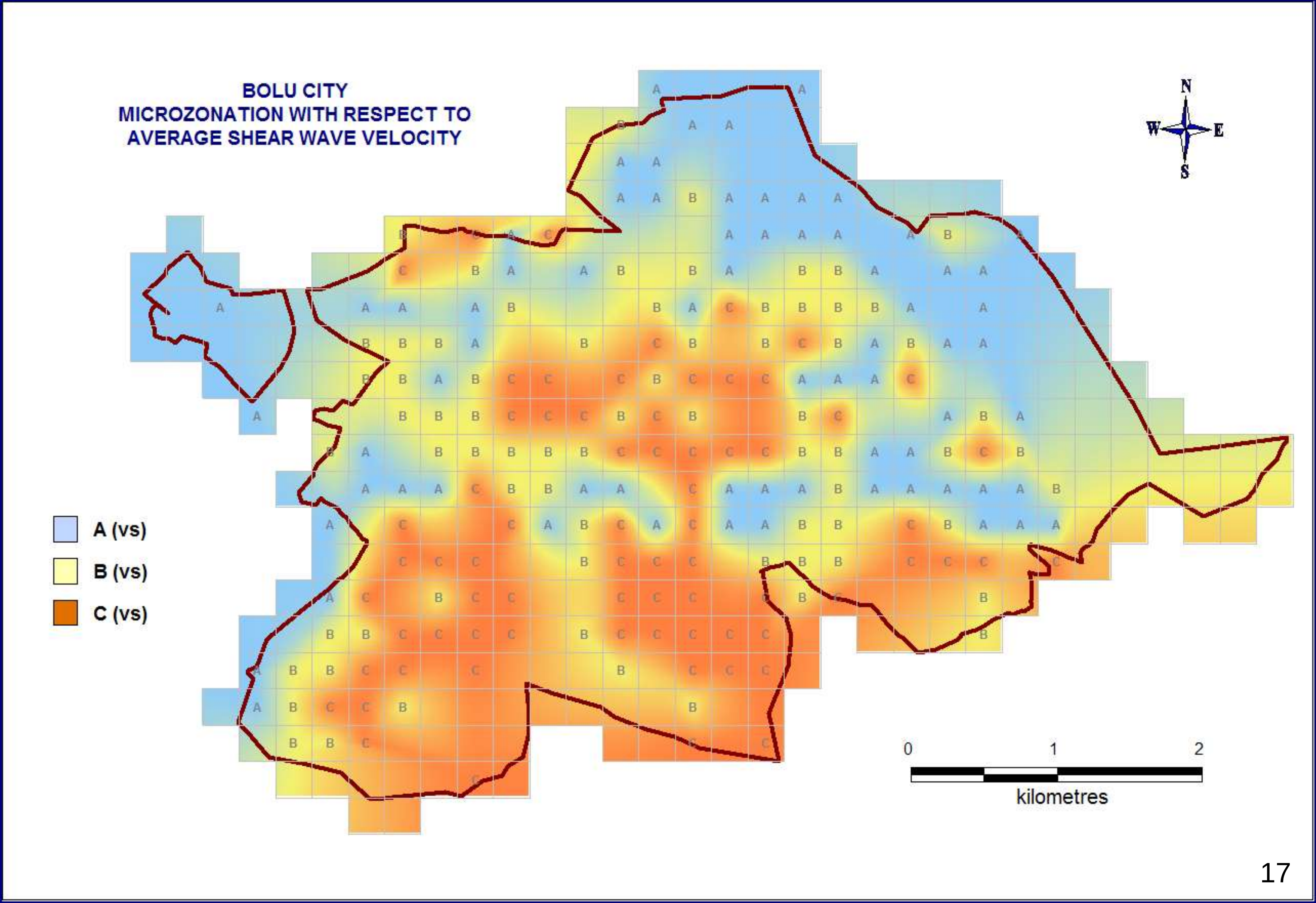
C Upper 33% percentile

B Intermediate 34 % percentile

A Lower 33% percentile

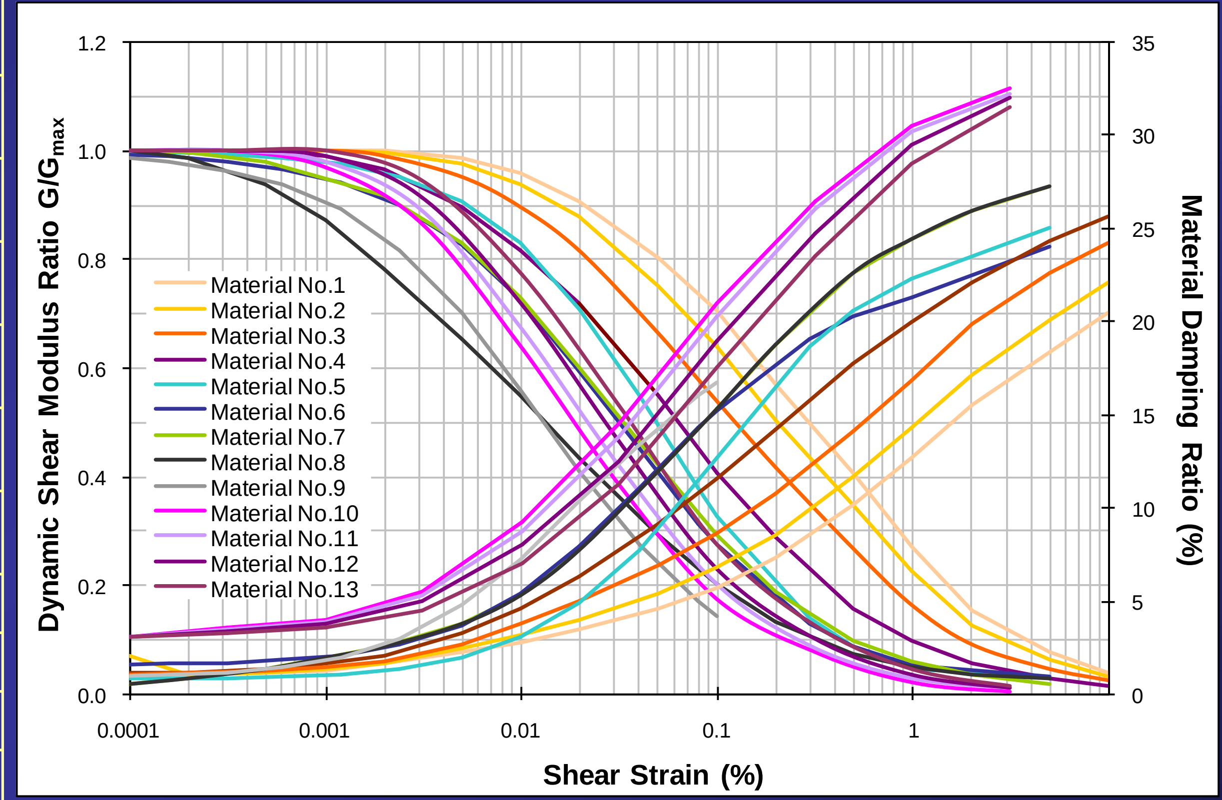
***NOTE:* If the difference between 33% and 67% percentiles is smaller than 20%, the area is divided into two zones using 50% percentile (median).**

Microzonation with respect to equivalent (average) shear wave velocity*



Dynamic shear modulus and damping ratio*

Material No	Soil Type	Reference
1	Clay (CH) PI=60%	Vucetic ve Dobry (1991)
2	Clay (CL) PI=45%	Vucetic ve Dobry (1991)
3	Clay (CH) PI=30%	Vucetic ve Dobry (1991)
4	Clay (CL) PI=15%	Vucetic ve Dobry (1991)
5	Silt	Darendeli (2001)
6	Sand (SC-SM)	Darendeli (2001)
7	Sand	Seed and Idriss
8	Gravel	Seed
9	Gravel	Menq
10	Rock 0-6 m	EPRI
11	Rock 6-16 m	EPRI
12	Rock 16-37 m	EPRI
13	Rock 37-76 m	EPRI



Selection of Input Ground Motion*

Simulated

- Hazard compatibility with respect to calculated acceleration spectra on rock outcrop

Real Acceleration Records

- Compatibility with probable fault type, fault distance, and magnitude
- Scaled with respect to calculated peak ground acceleration on rock outcrop

Scaling real acceleration records

- Set of earthquake hazard compatible real acceleration records,
- Scaled to different intensity measures;
  peak ground acceleration, peak ground velocity and Arias intensity
- To evaluate the response variability

back

Ground shaking intensity

SPECTRAL ACCELERATIONS ON THE GROUND SURFACE

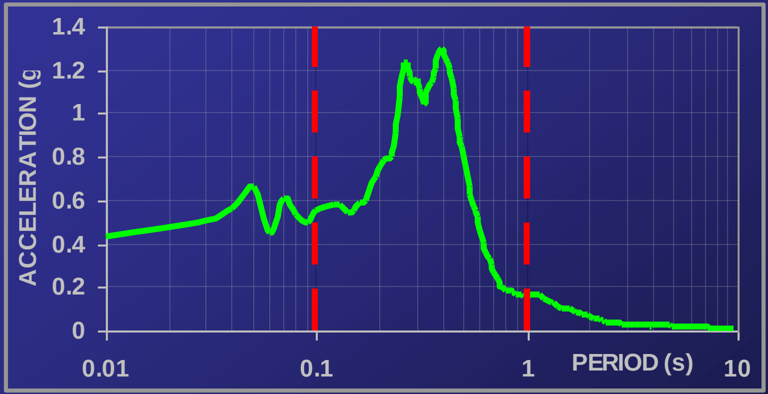
BY SUPERPOSITION OF

Spectral accelerations (short period) based on average shear wave velocity (Borcherdt, 1994)

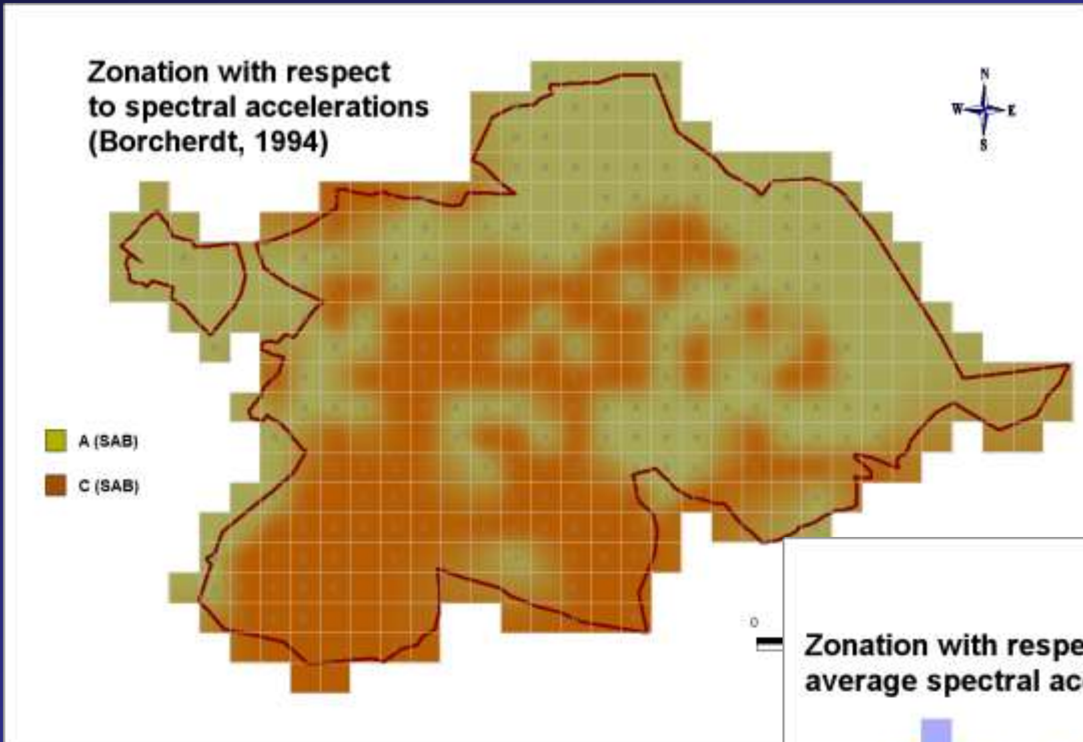
$$F_a = (760/v)^{m_a}$$

$$S_a = F_a S_s$$

Average spectral accelerations (0.1-1s) calculated by site response analysis



Microzonation with respect to ground shaking



A_{GS} =

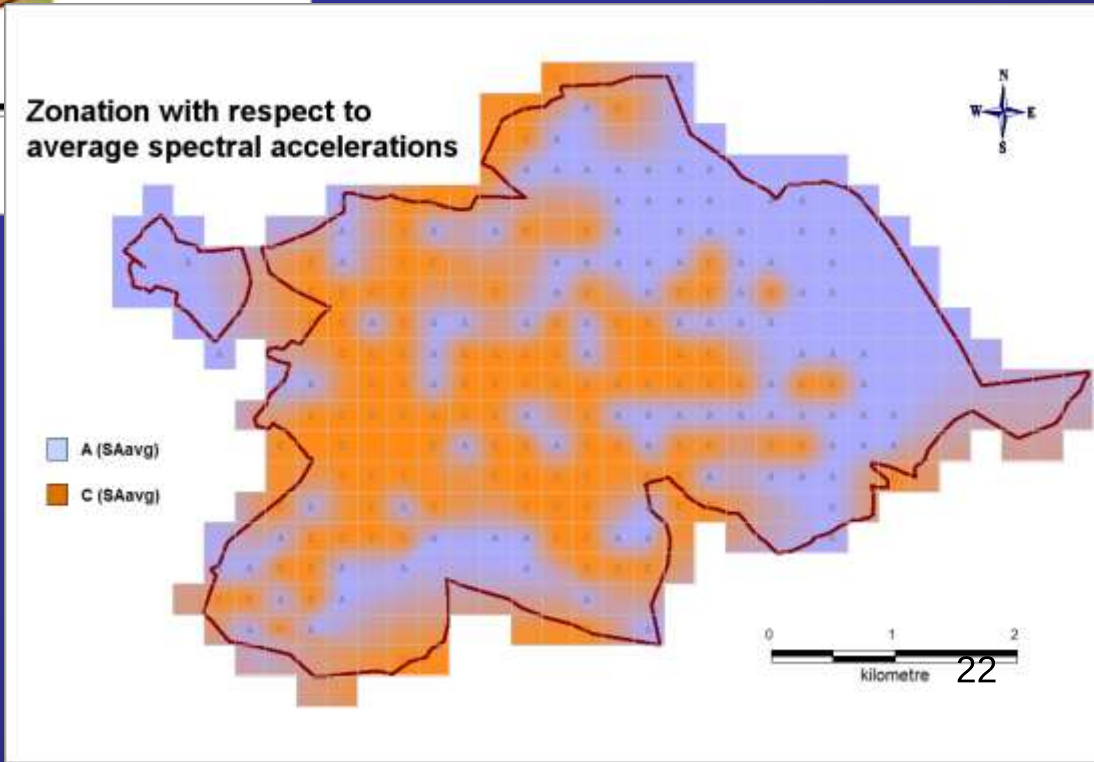
A_B & A_S + A_B& B_S + B_B & A_S

B_{GS} =

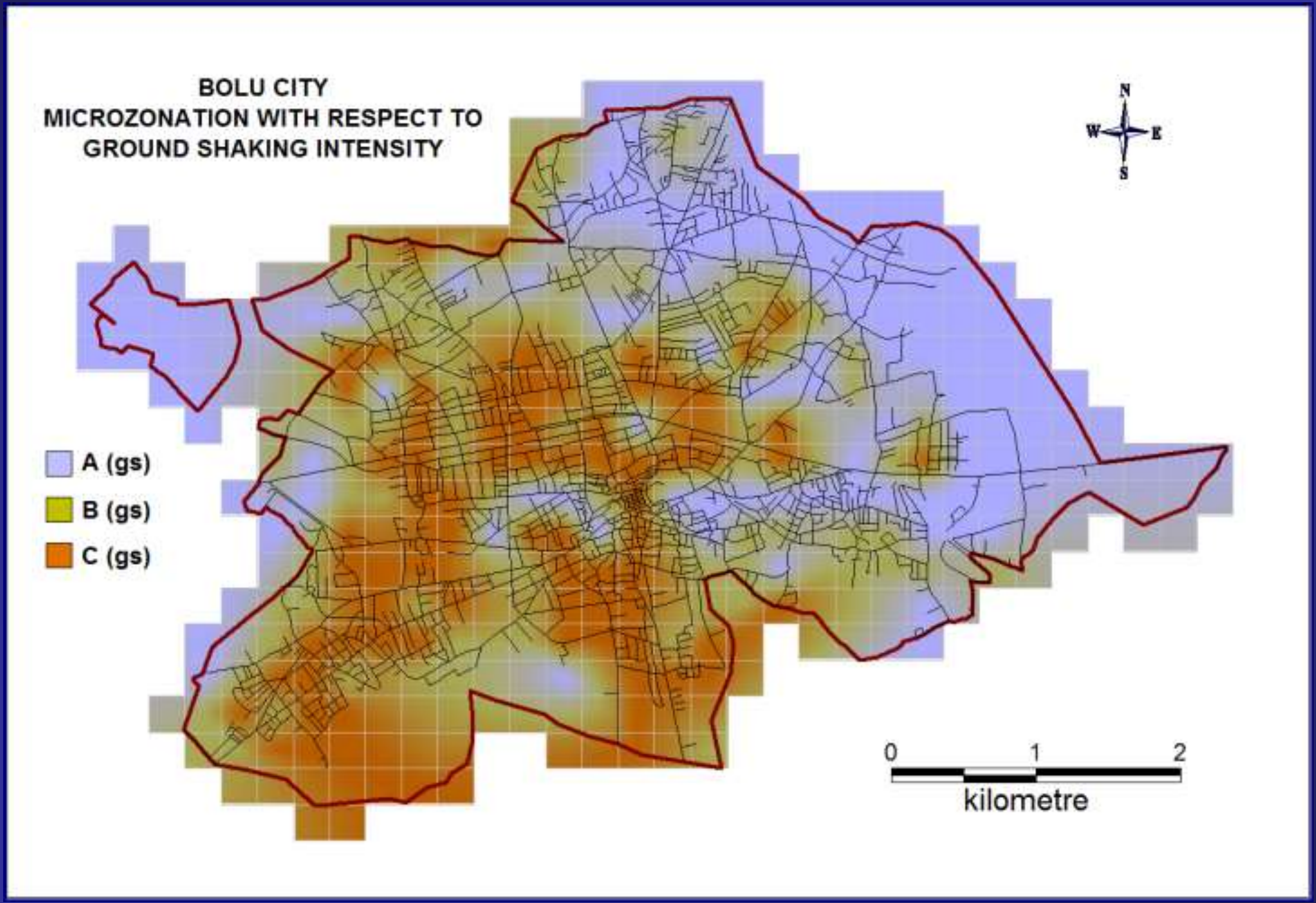
B_B & B_S + C_B & A_S + A_B & C_S

C_{GS} =

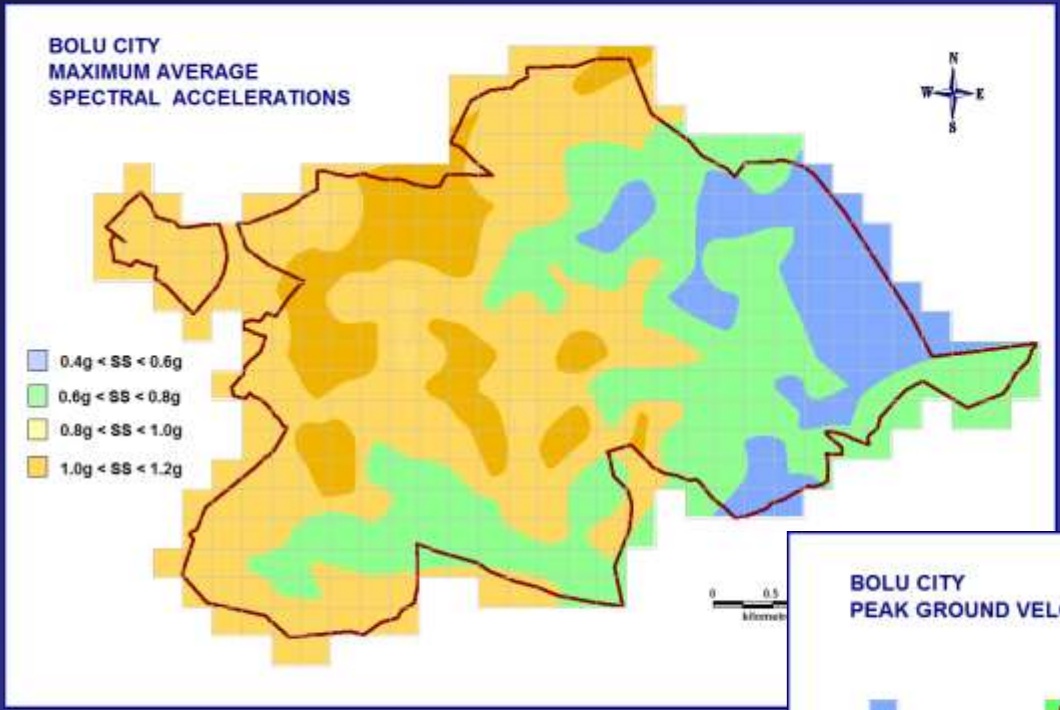
C_B & C_S + C_B & B_S + B_B & C_S

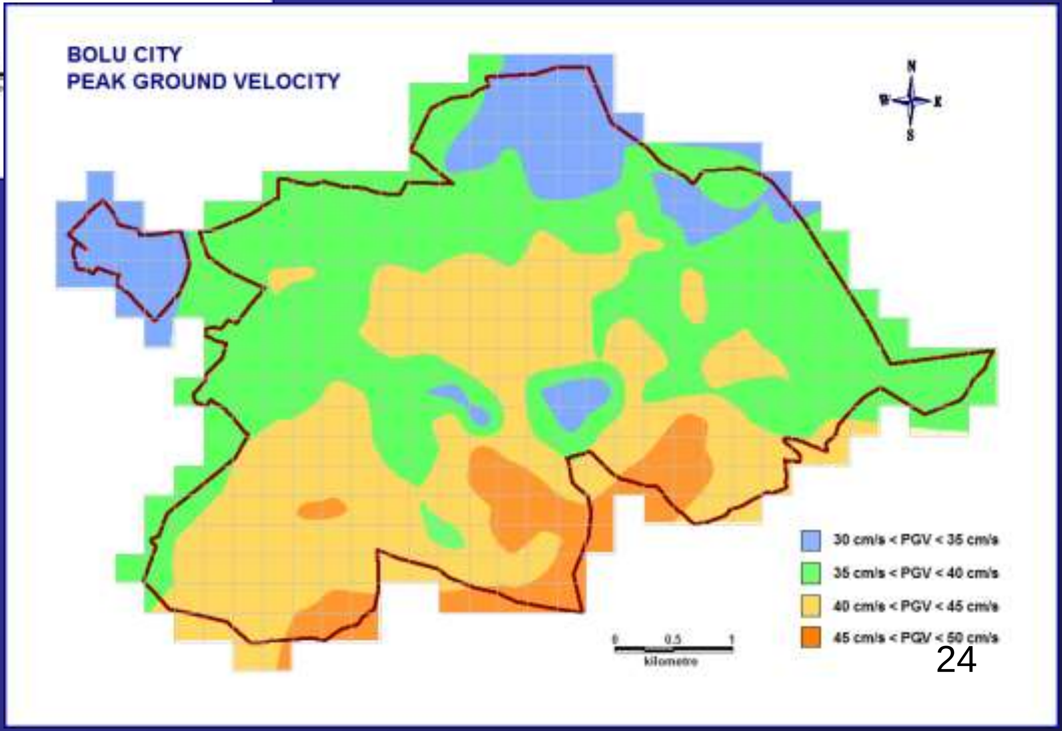


Microzonation with respect to ground shaking

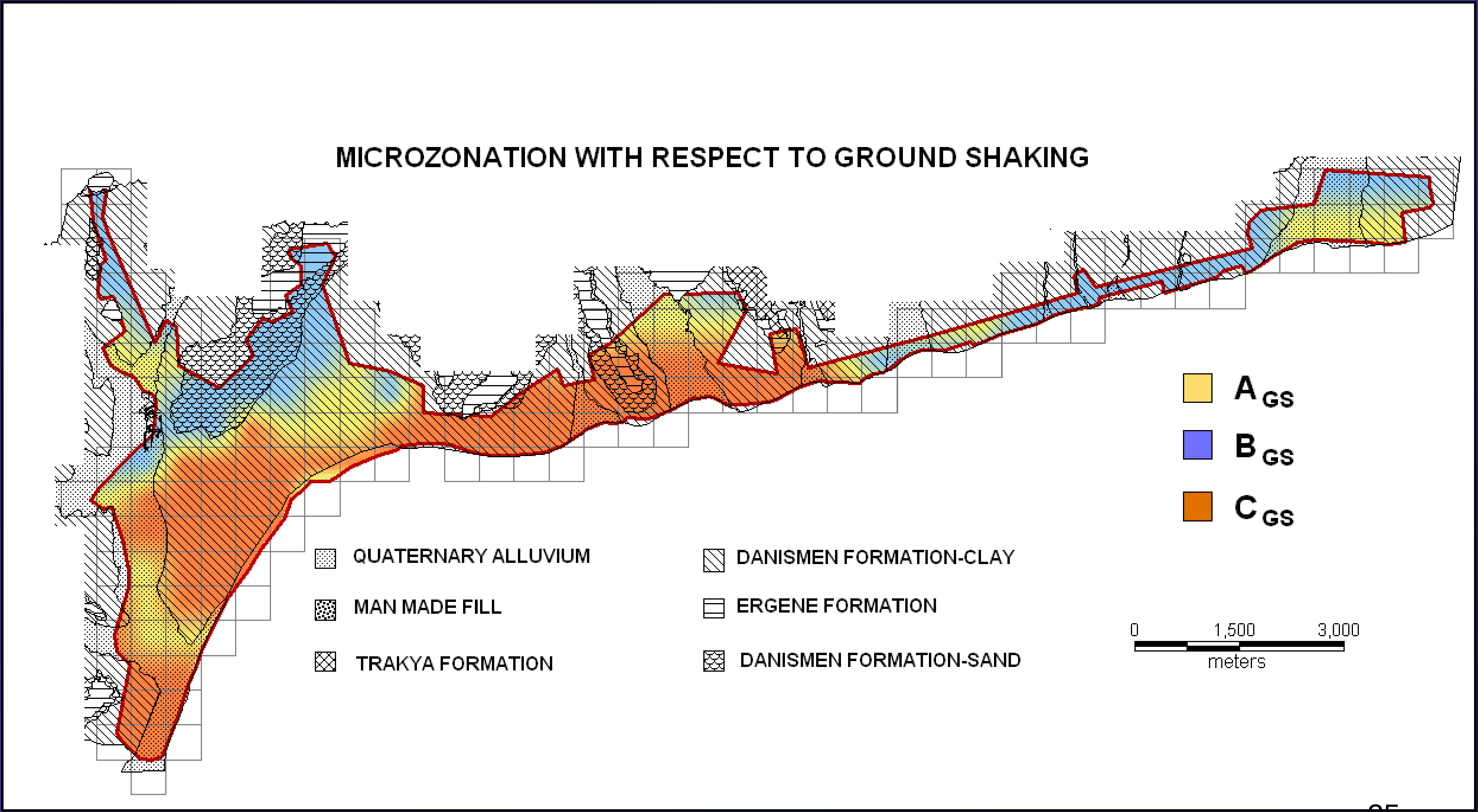


Microzonation wrt maximum average SA and average PGV

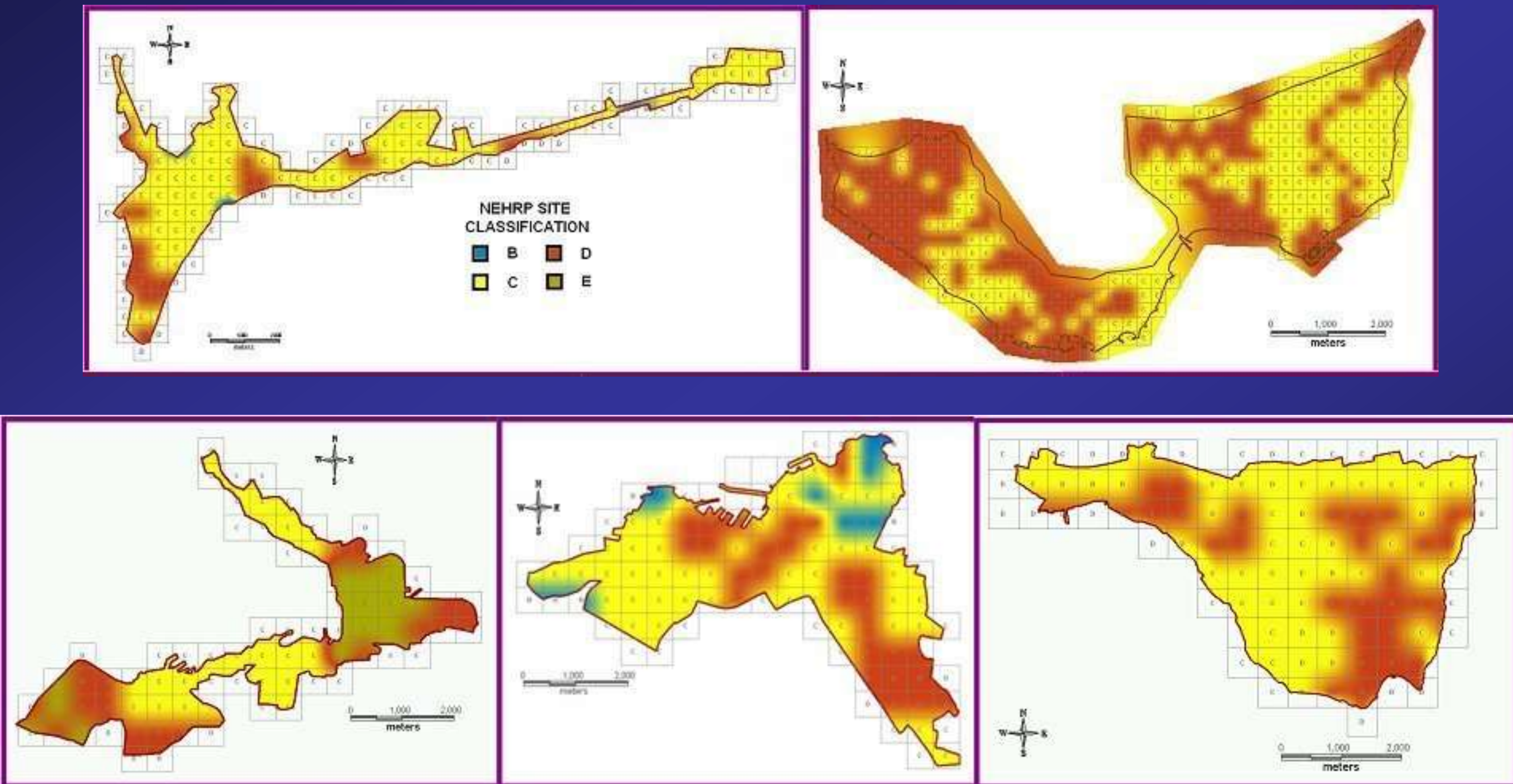




ZONATION MAP wrt GROUND SHAKING
In comparison with Surface Geology



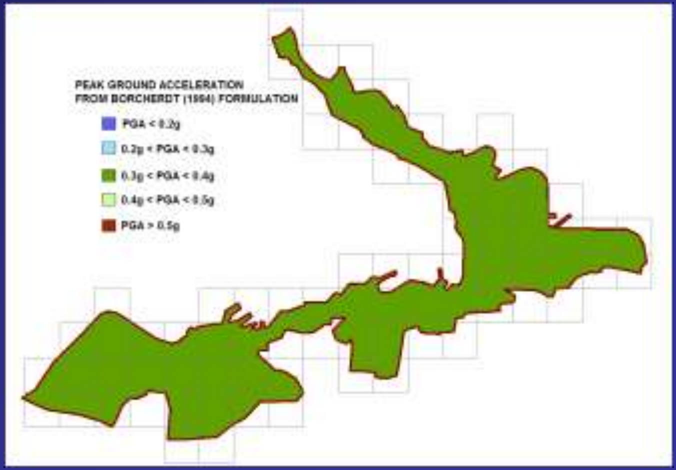
Site Classification - NEHRP

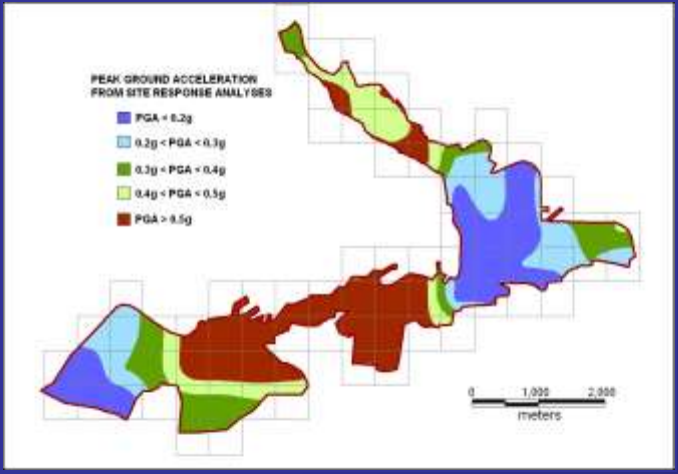


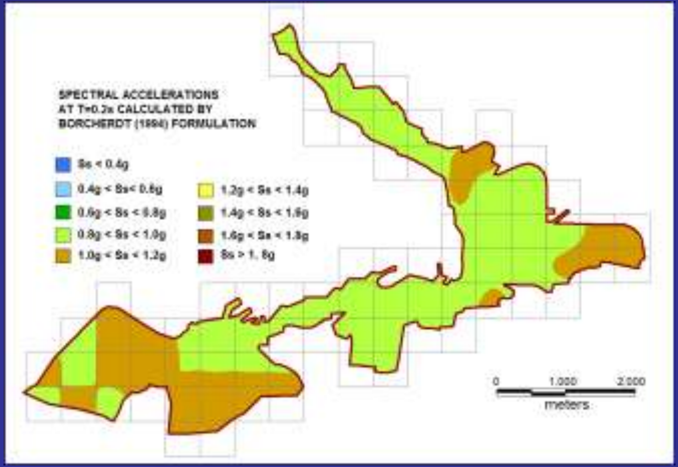
NEHRP versus Site Response Analysis

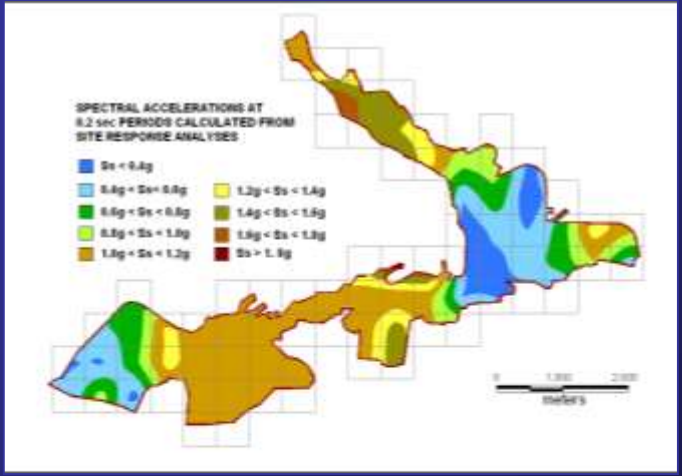
Variation of PGA and spectral acceleration at 0.2s based on NEHRP

Variation of PGA and spectral acceleration at 0.2s by site response analysis





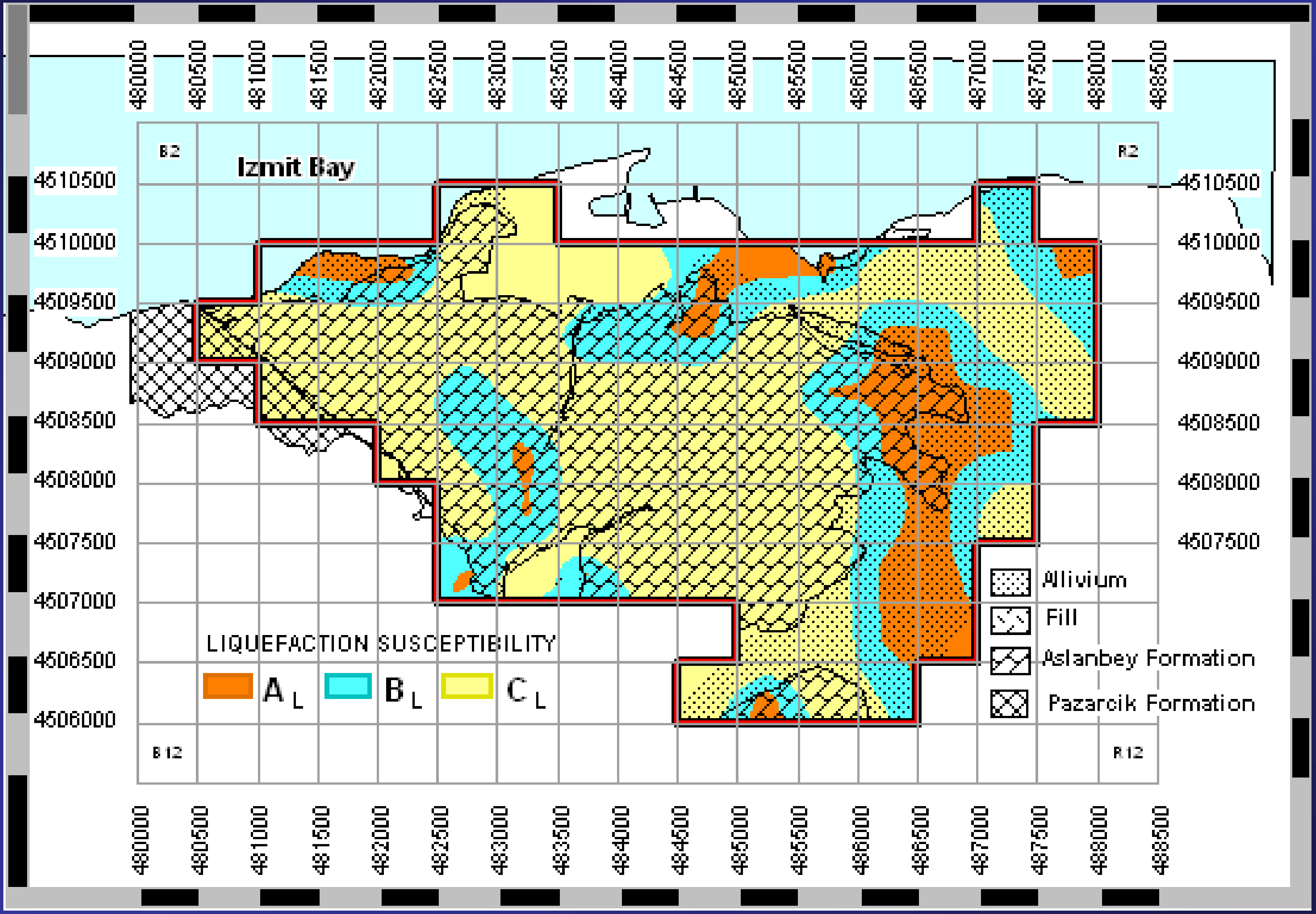


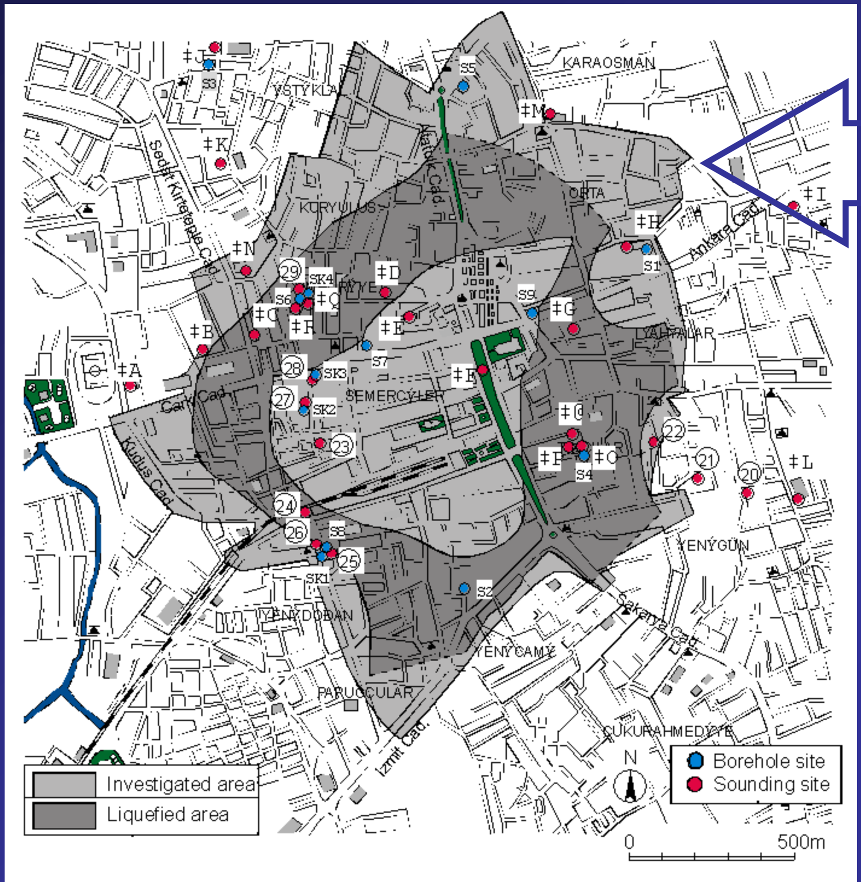


GEMLIK MUNICIPALITY

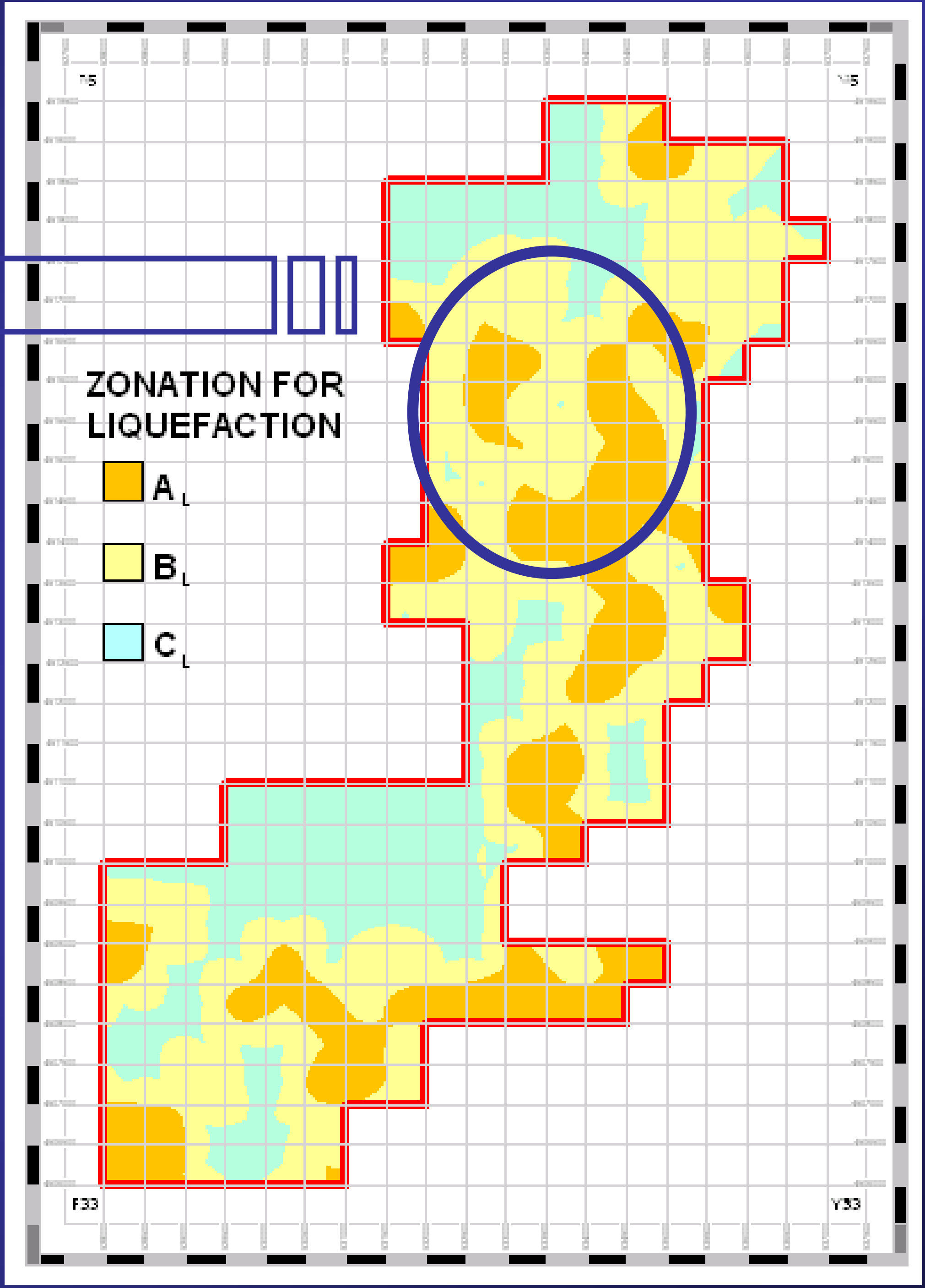
MICROZONATION WRT LIQUEFACTON

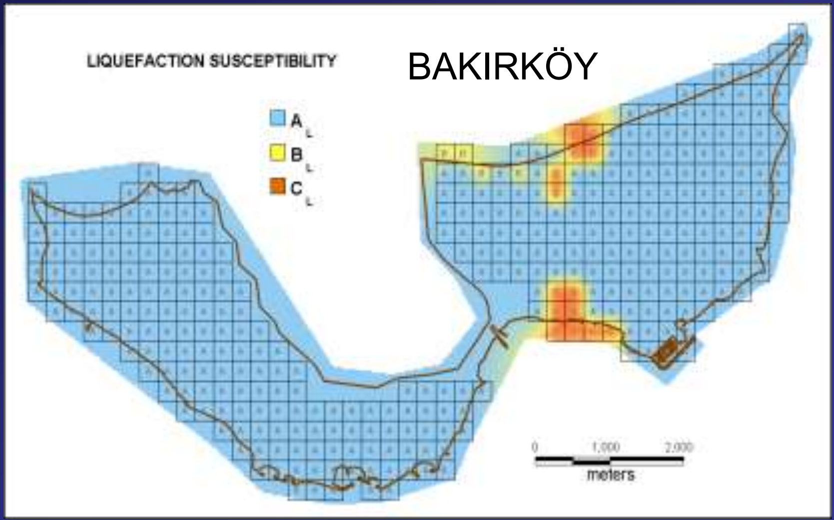
A: PL>15; B: 5>PL>15; C: PL<5

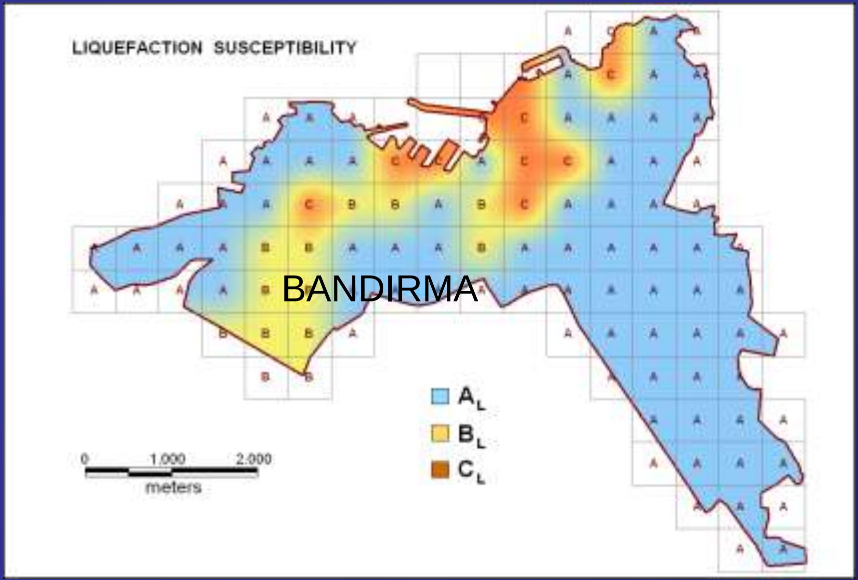


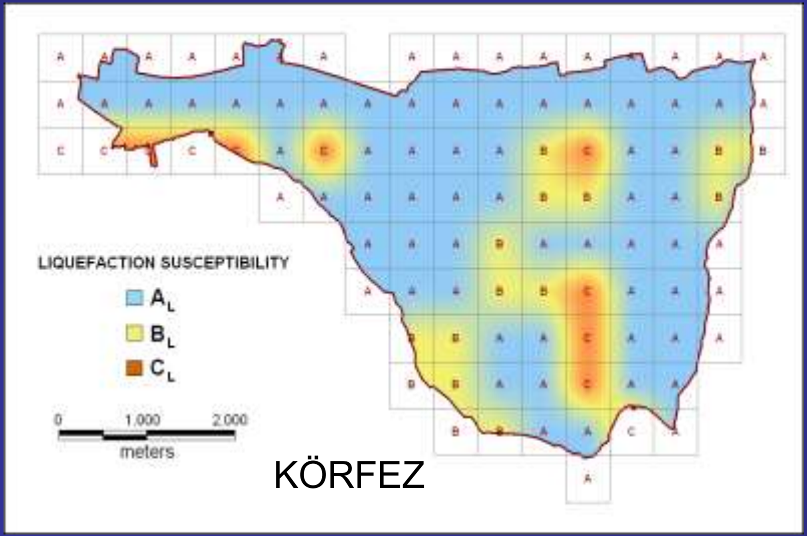


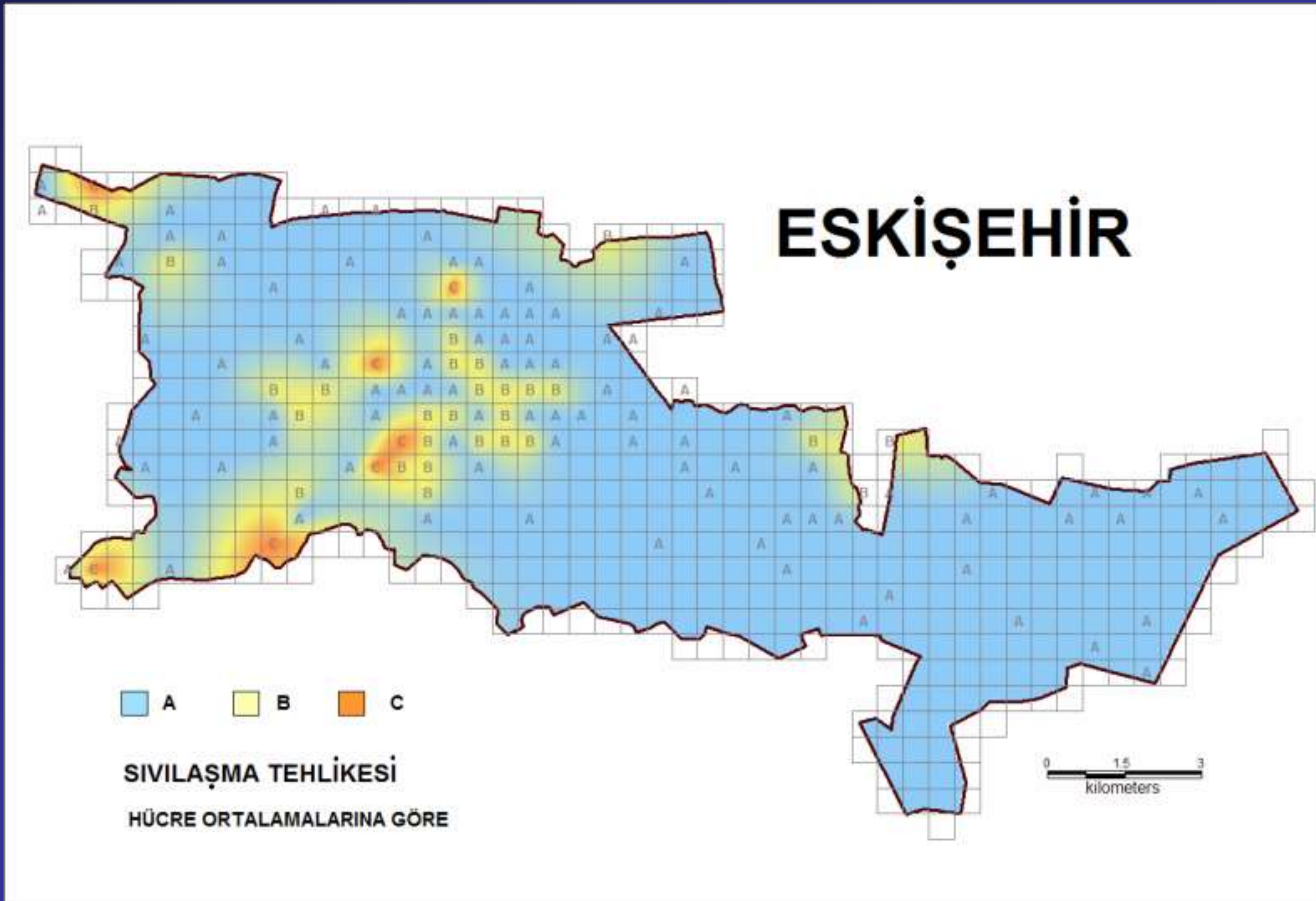
Location of site (Swedish Sounding)

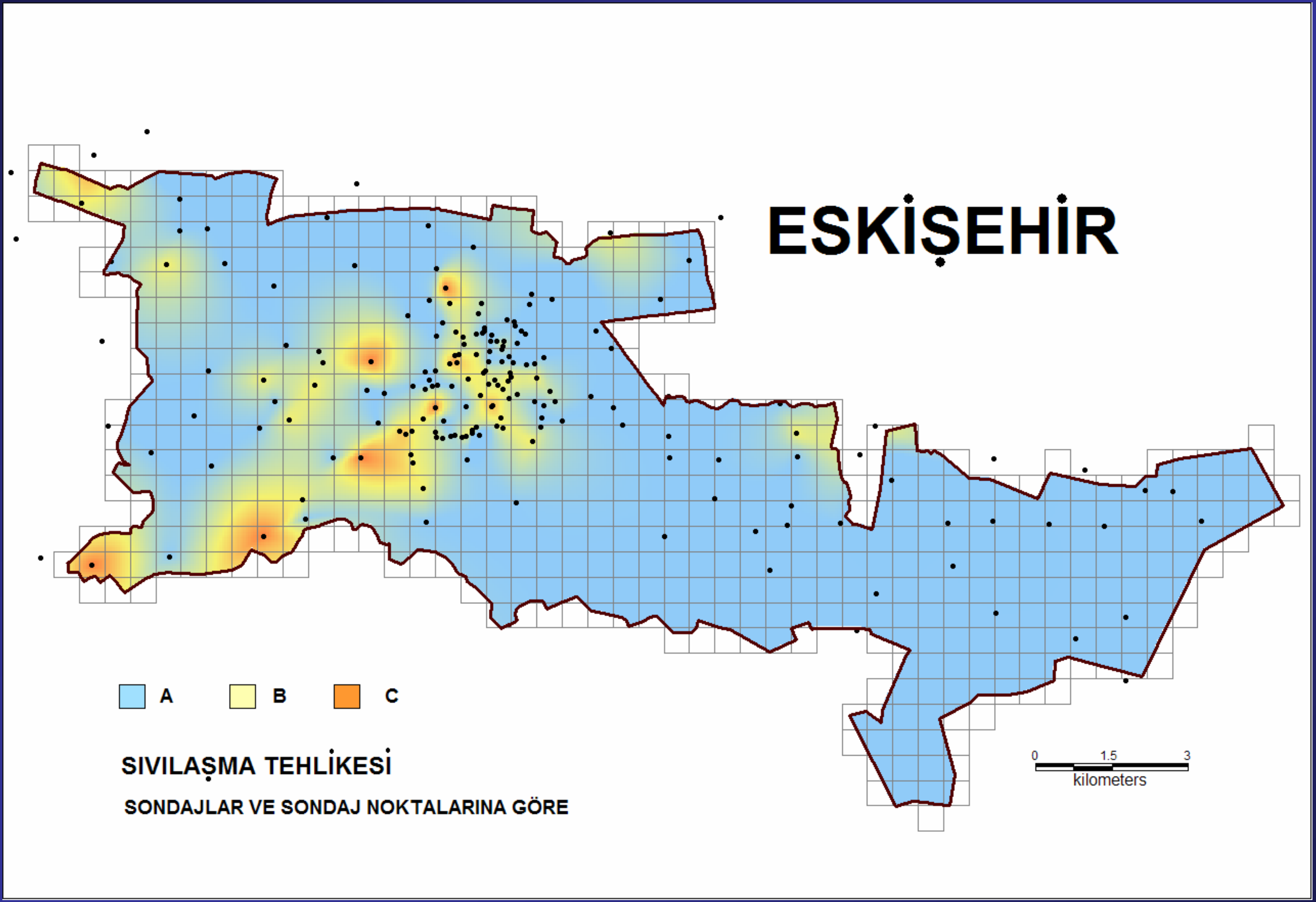


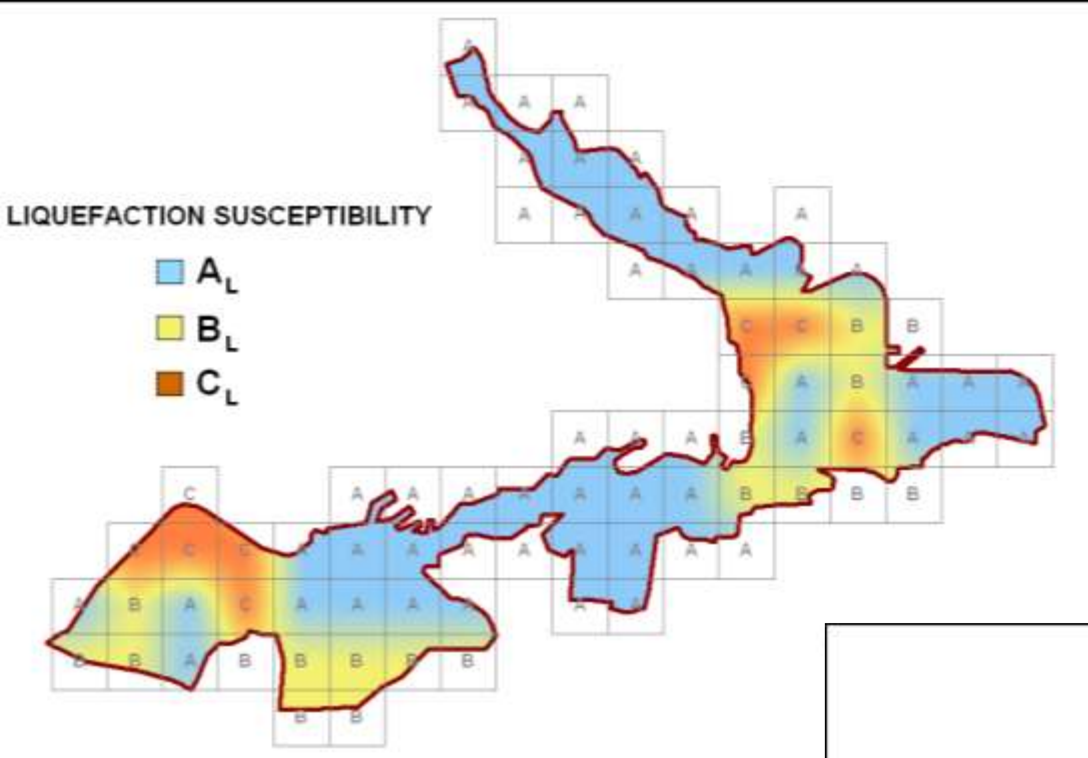

BAKIRKÖY
LIQUEFACTION SUSCEPTIBILITY
A_L
B_L
C_L
0 1,000 2,000
meters

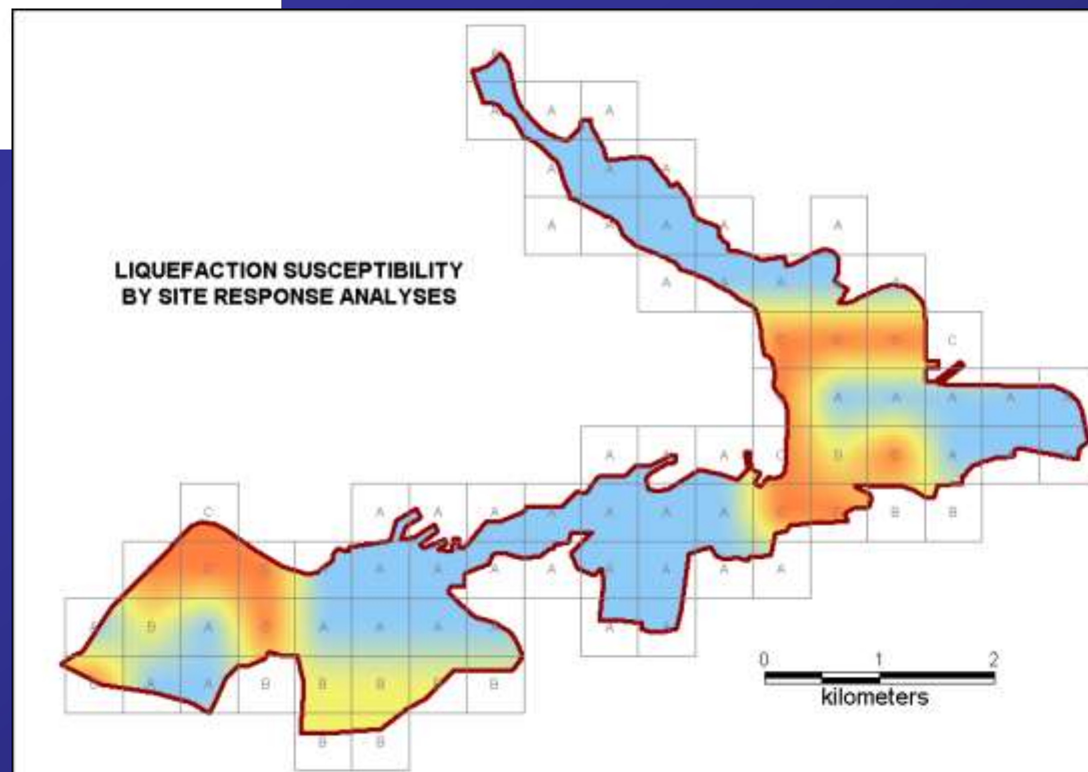

BANDIRMA
LIQUEFACTION SUSCEPTIBILITY
A_L
B_L
C_L
0 1,000 2,000
meters


KÖRFEZ
LIQUEFACTION SUSCEPTIBILITY
A_L
B_L
C_L
0 1,000 2,000
meters


ESKİŞEHİR
A
B
C
SIVILAŞMA TEHLİKESİ
HÜCRE ORTALAMALARINA GÖRE
0
1.5
3
kilometers

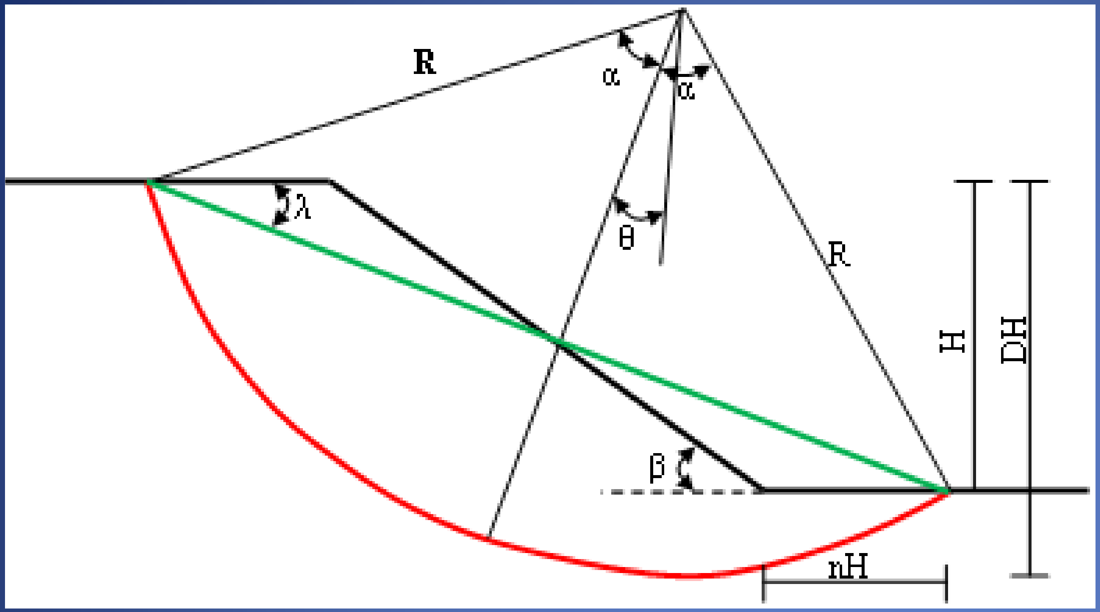

ESKİŞEHİR
A
B
C
0
1.5
3
kilometers
SIVILAŞMA TEHLİKESİ
SONDAJLAR VE SONDAJ NOKTALARINA GÖRE

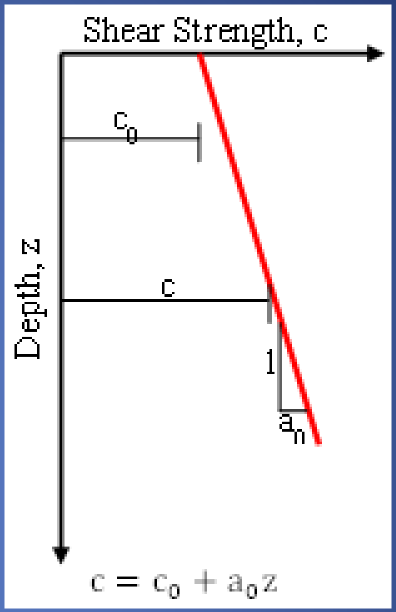

LIQUEFACTION SUSCEPTIBILITY
A_L
B_L
C_L


LIQUEFACTION SUSCEPTIBILITY
BY SITE RESPONSE ANALYSES
0 1 2
kilometers

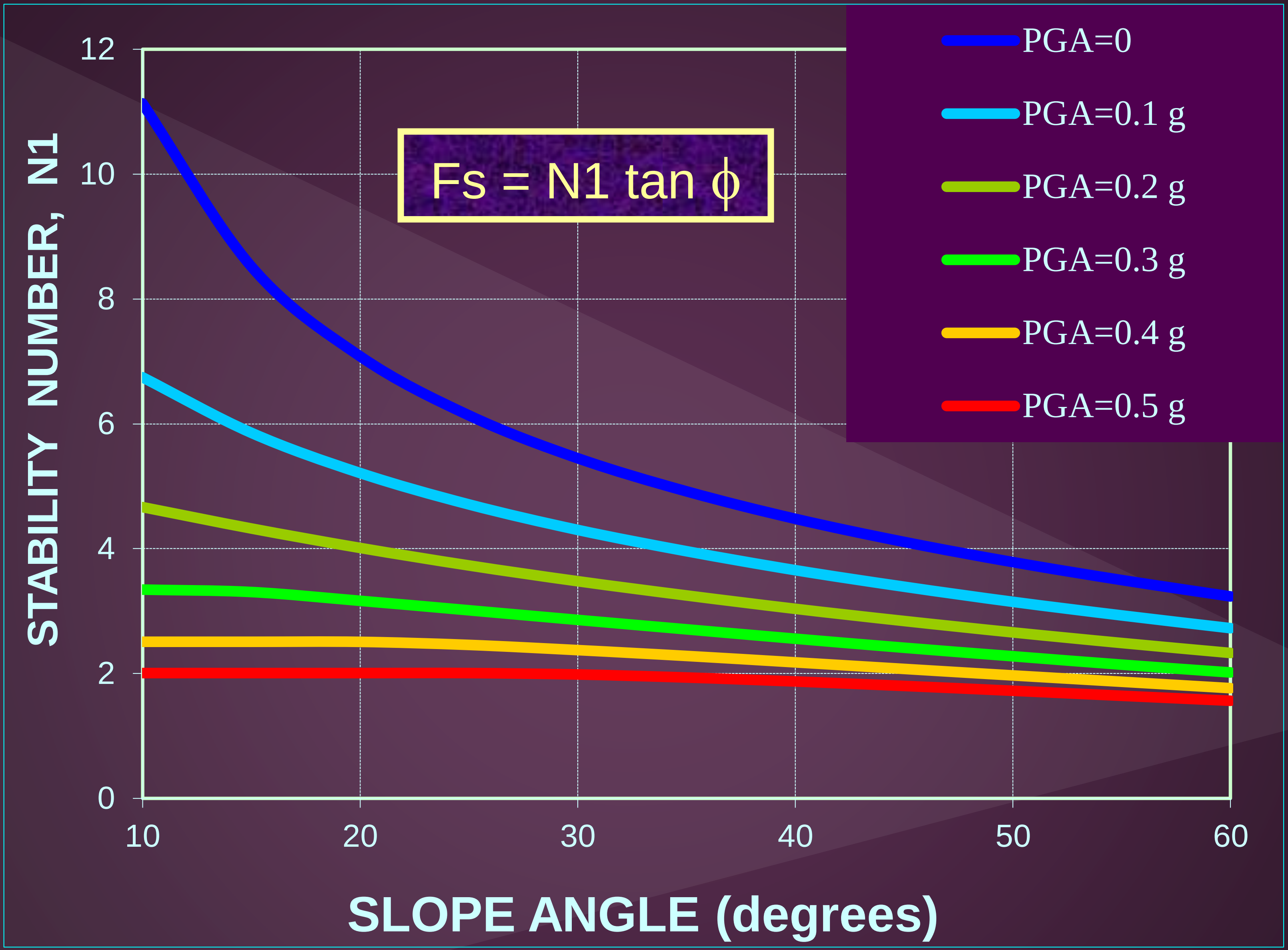
MICROZONATION WRT LANDSLIDE

Siyahi and Ansal (1993)

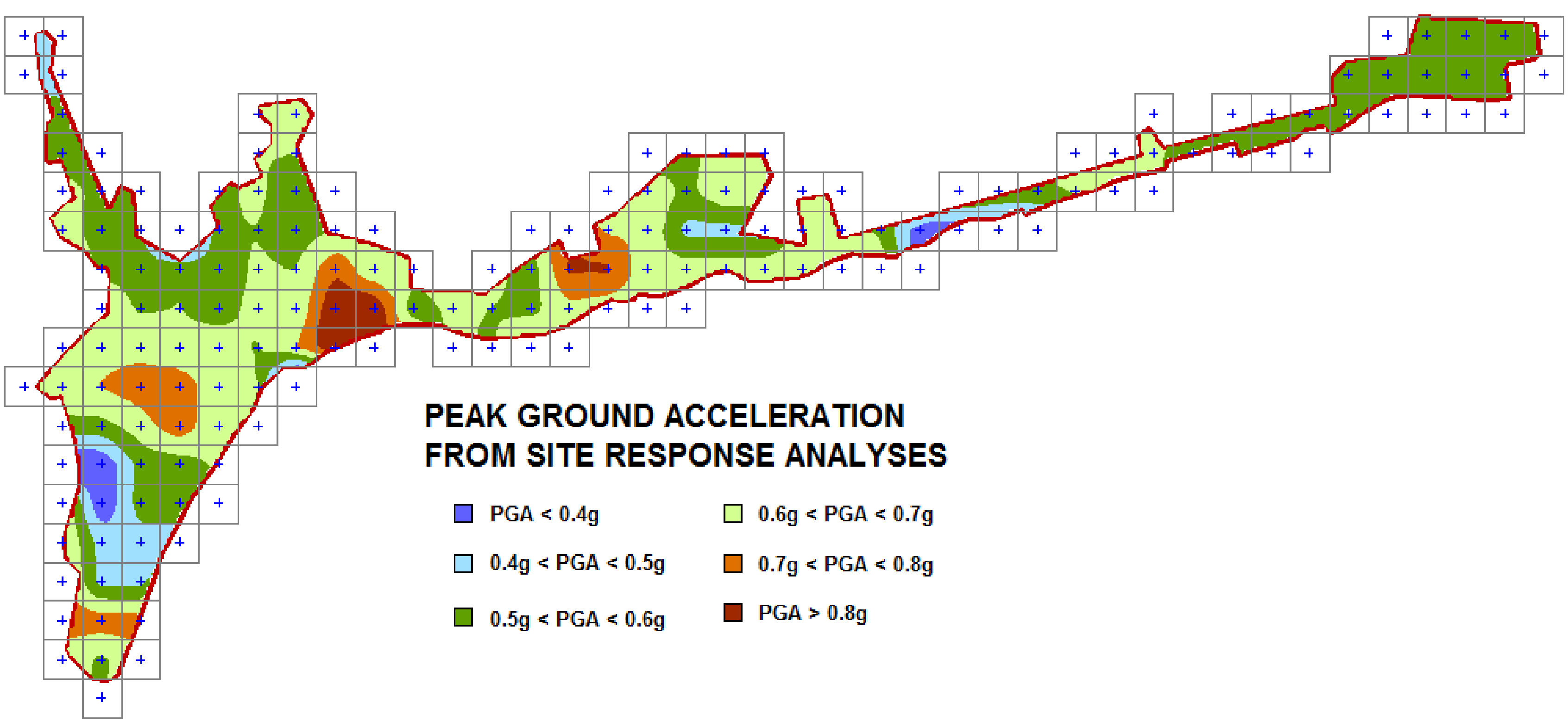




α = 50, ..., 850
β = 100, 10.50,..., 600
λ = 100,..., 550
n = 0 (toe failure presumption)
A (g) = 0.00, 0.02, ..., 1.00



LANDSLIDE HAZARD DURING EARTHQUAKES, Siyahi & Ansal, 1993


PEAK GROUND ACCELERATION
FROM SITE RESPONSE ANALYSES
PGA < 0.4g
0.4g < PGA < 0.5g
0.5g < PGA < 0.6g
0.6g < PGA < 0.7g
0.7g < PGA < 0.8g
PGA > 0.8g


Tekirdağ
Factor of Safety
(Siyahi & Ansal, 1993)
FOS >= 1.5
1 <= FOS < 1.5
FOS < 1
Google earth

ZEYTINBURNU PILOT PROJECT

1. **MICROZONATION WITH RESPECT TO GROUND SHAKING INTENSITY FOR URBAN PLANNING**

   Regional Earthquake Hazard,
   Site Characterization,
   Analysis and Interpretation

2. **VULNERABILITY ASSESSMENT OF BUILDING STOCK FOR REHABILITATION**

   Spectral acceleration at 0.2s & 1.0s on the ground surface

REGIONAL EARTHQUAKE HAZARD

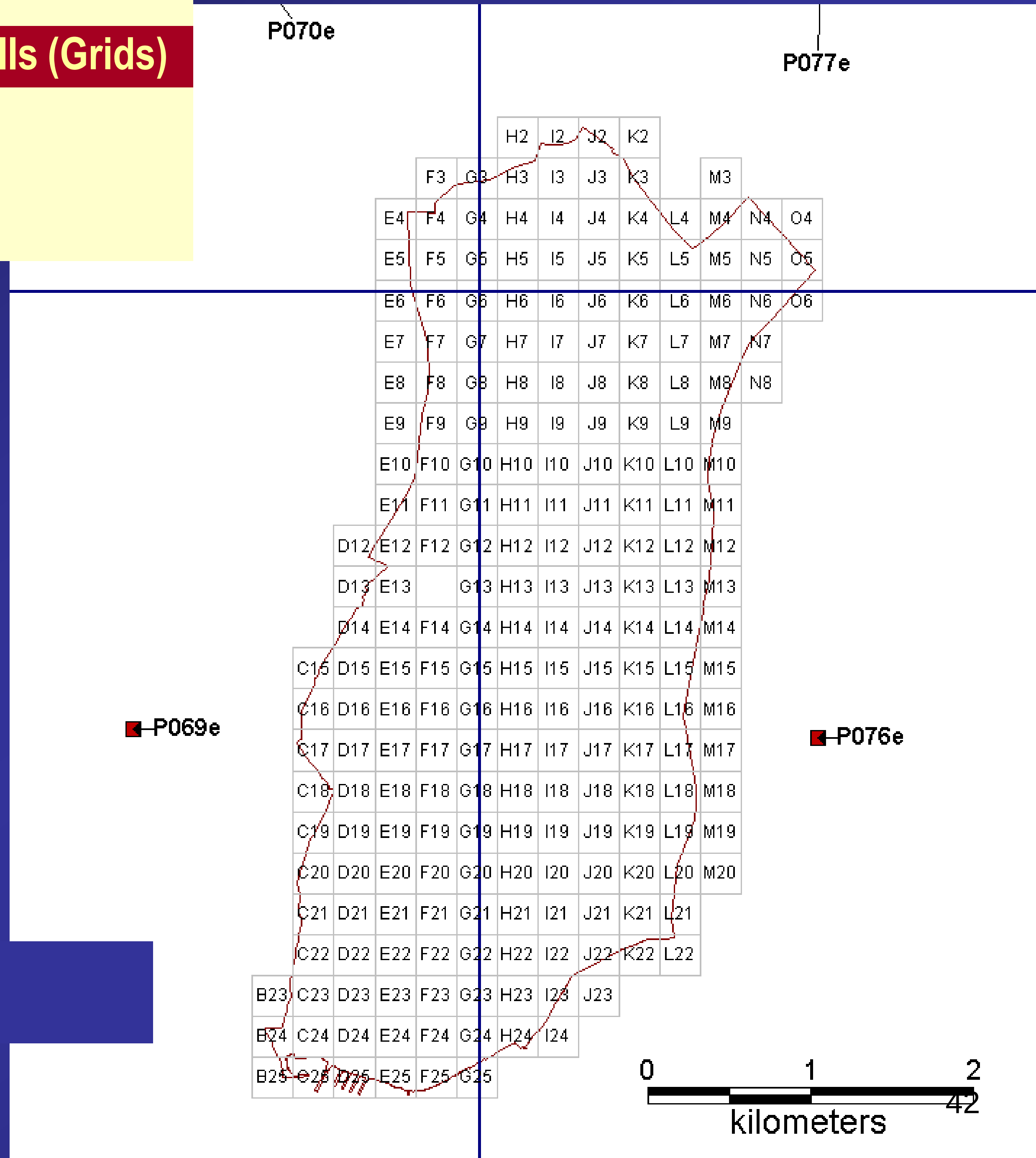
- **Probabilistic earthquake hazard estimation**

  For a return period of 475 years or 10% exceedance probability in 50 years
- **A grid system composed of 250 x 250m cells**
- **Calculation of the spectral accelerations**
- **Simulation of the spectrum compatible design basis ground motion**

METHODOLOGY

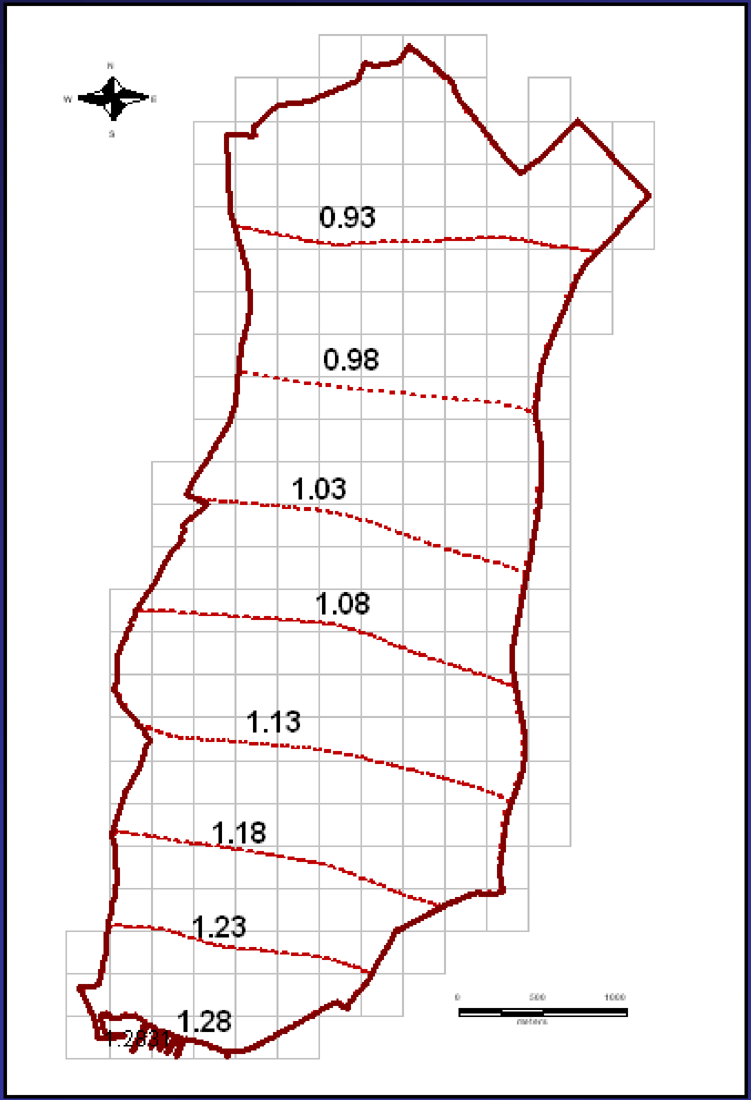
• Input Data Based on Geo-Cells (Grids)

- Site Response Analysis
- Seismic Hazard Maps
- Building Inventory Data Base
- Vulnerabilities
- Loss Estimation

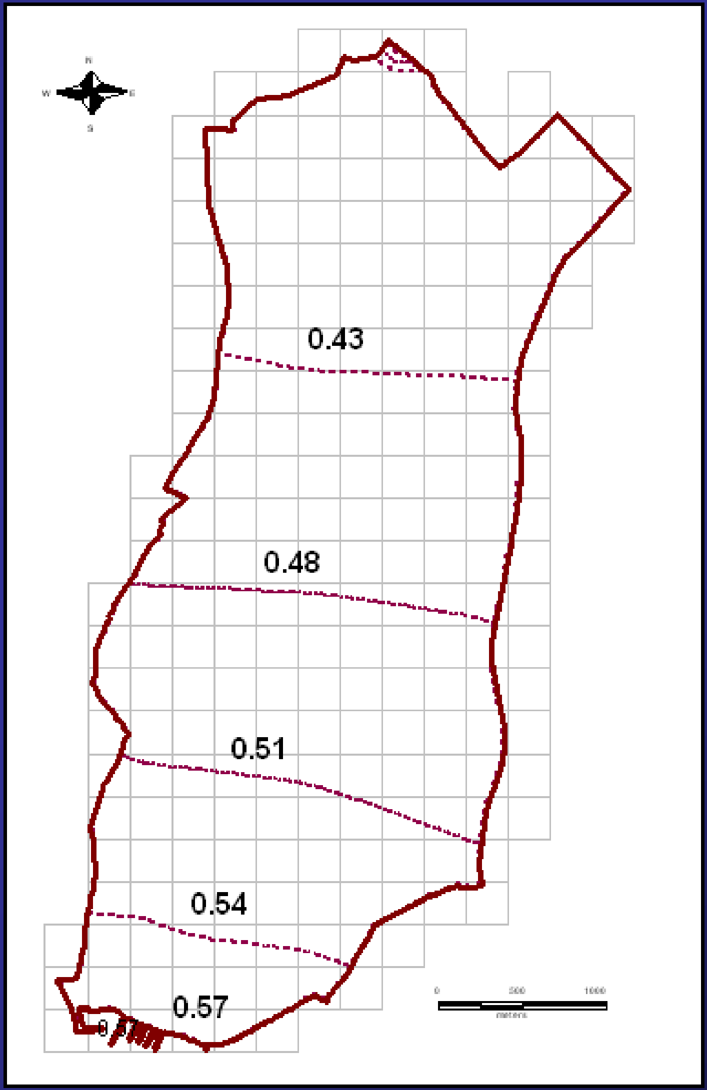


Zeytinburnu Grid System
INGV Stations

Spectral accelerations at 0.2 sec



Spectral accelerations at 1.0 sec

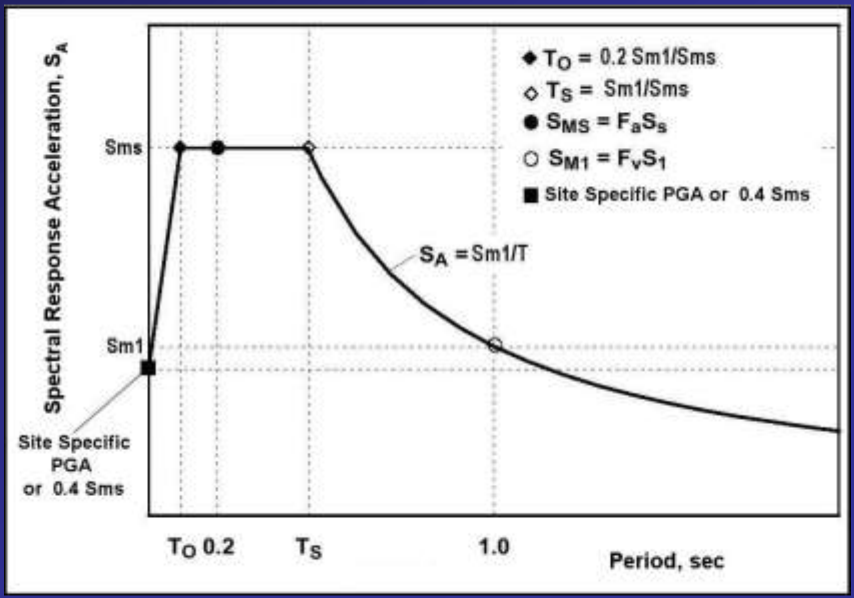


PROBABILISTIC SEISMIC HAZARD: 10% EXCEEDANCE IN 50 YEARS

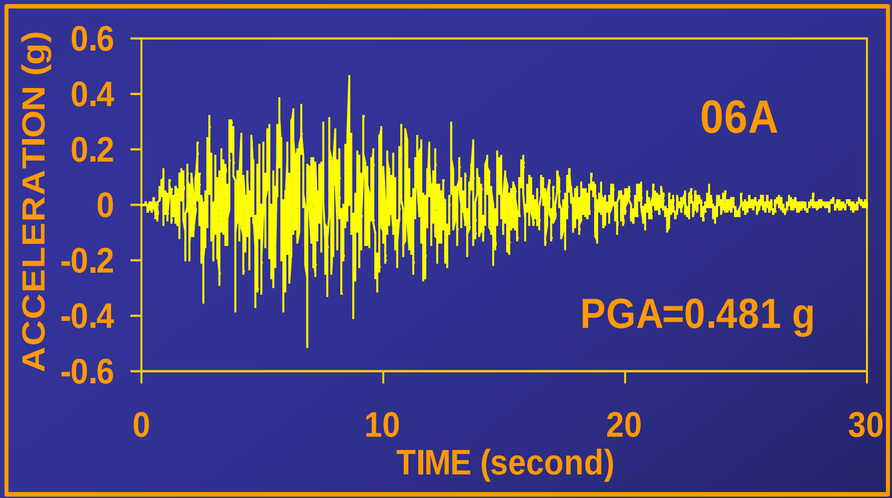
Simulated Input Ground Motion

Acceleration Response Spectra Compatible: Tarscths, Rascal

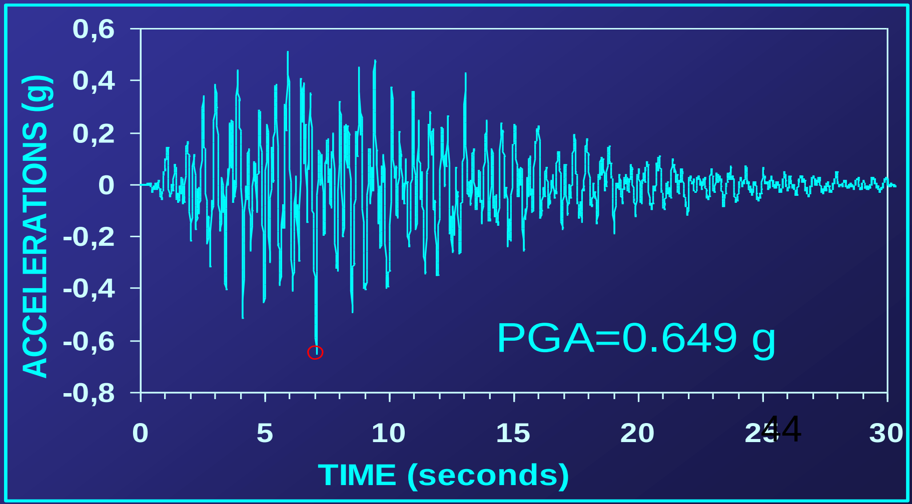
NEHRP UNIFORM HAZARD SPECTRUM



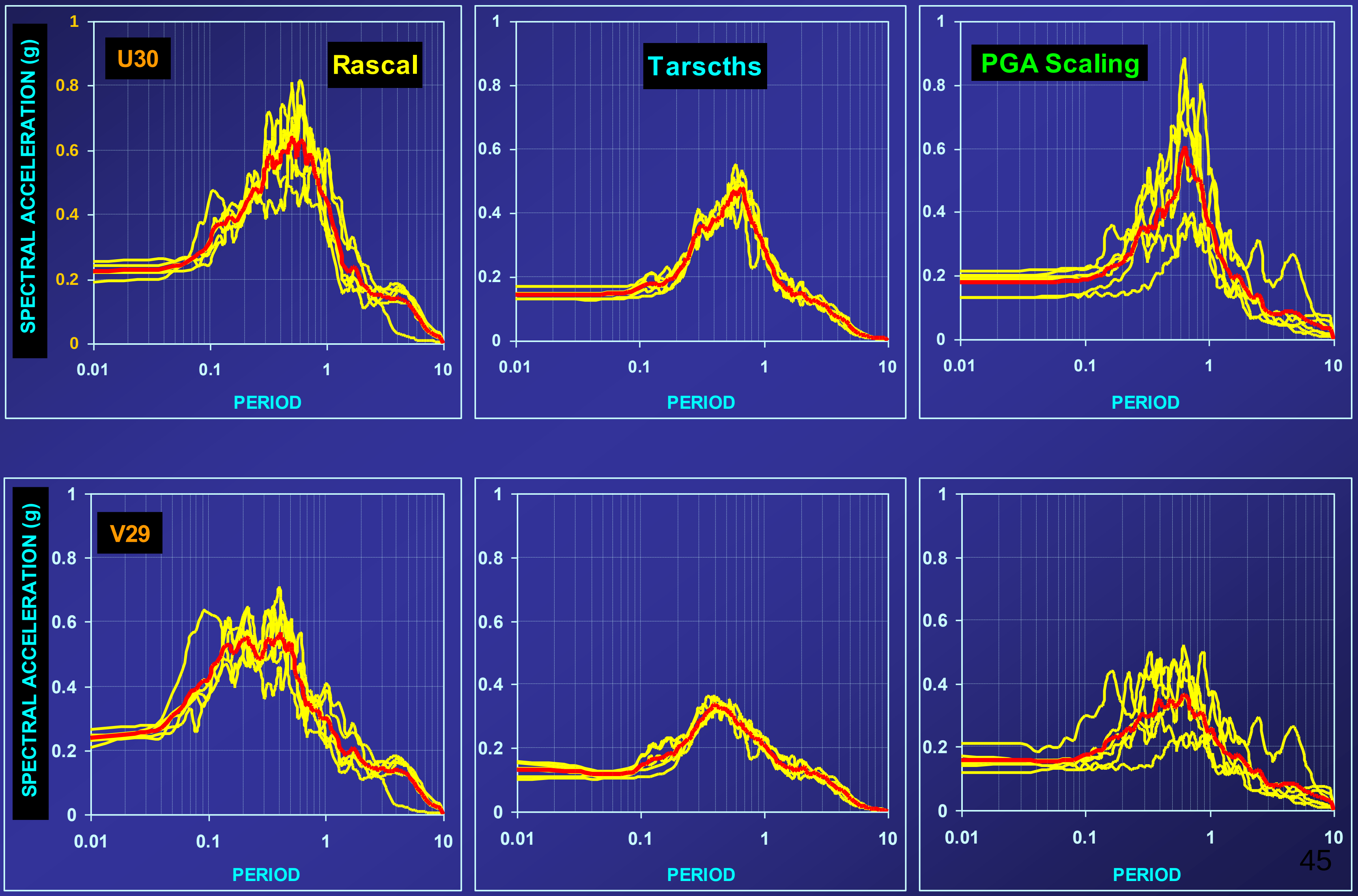
RESPONSE SPECTRUM COMPATIBLE RANDOM HORIZONTAL GROUND MOTION



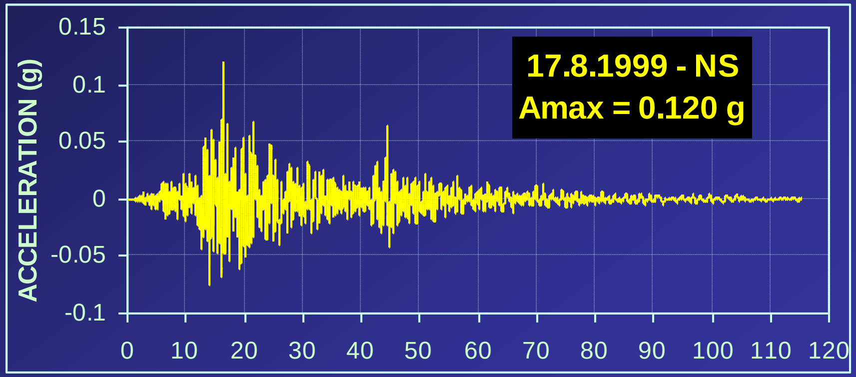
ACCELERATION TIME HISTORY ON THE GROUND SURFACE CALCULATED BY ONE DIMENSIONAL SITE RESPONSE ANALYSIS

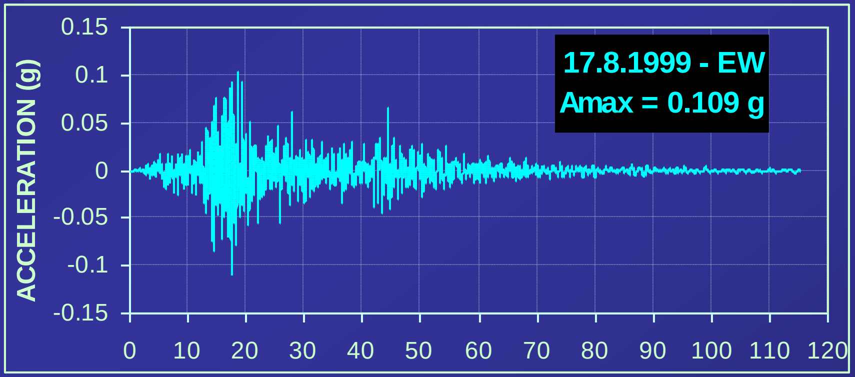


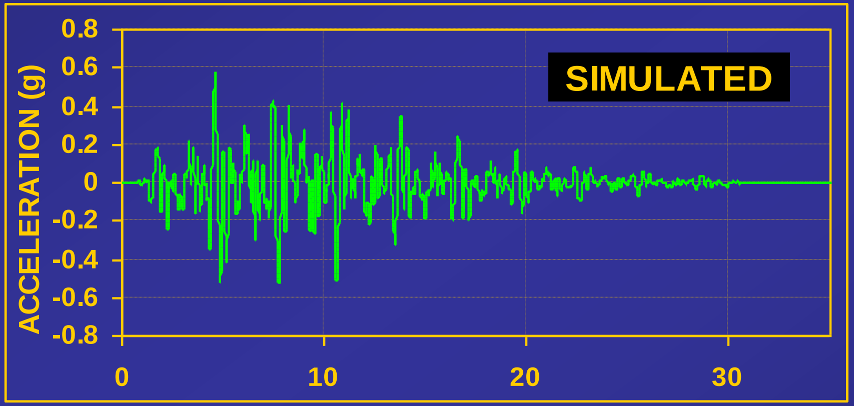
Effect of input motion on site response analyses on two soil profiles

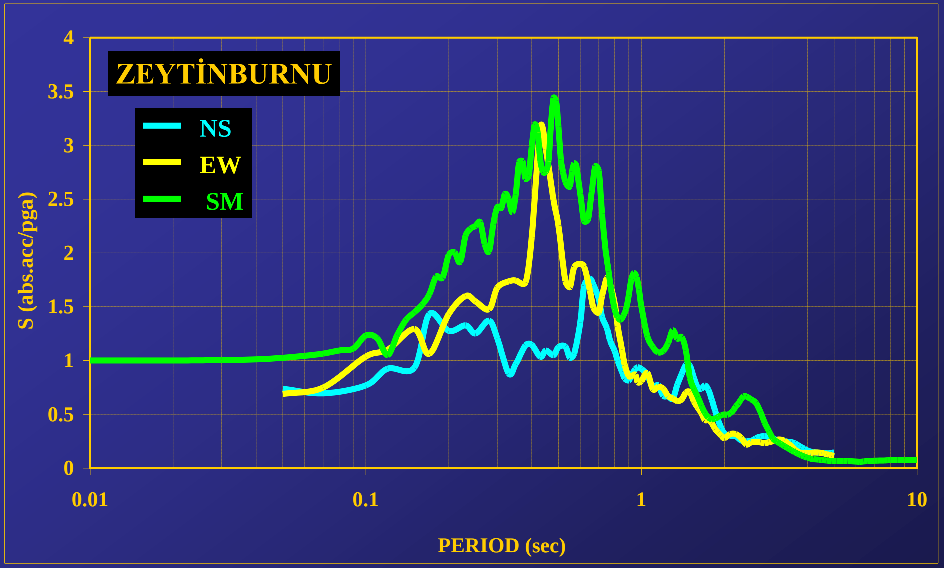


COMPARISON WITH 17 AUGUST 1999 RECORD

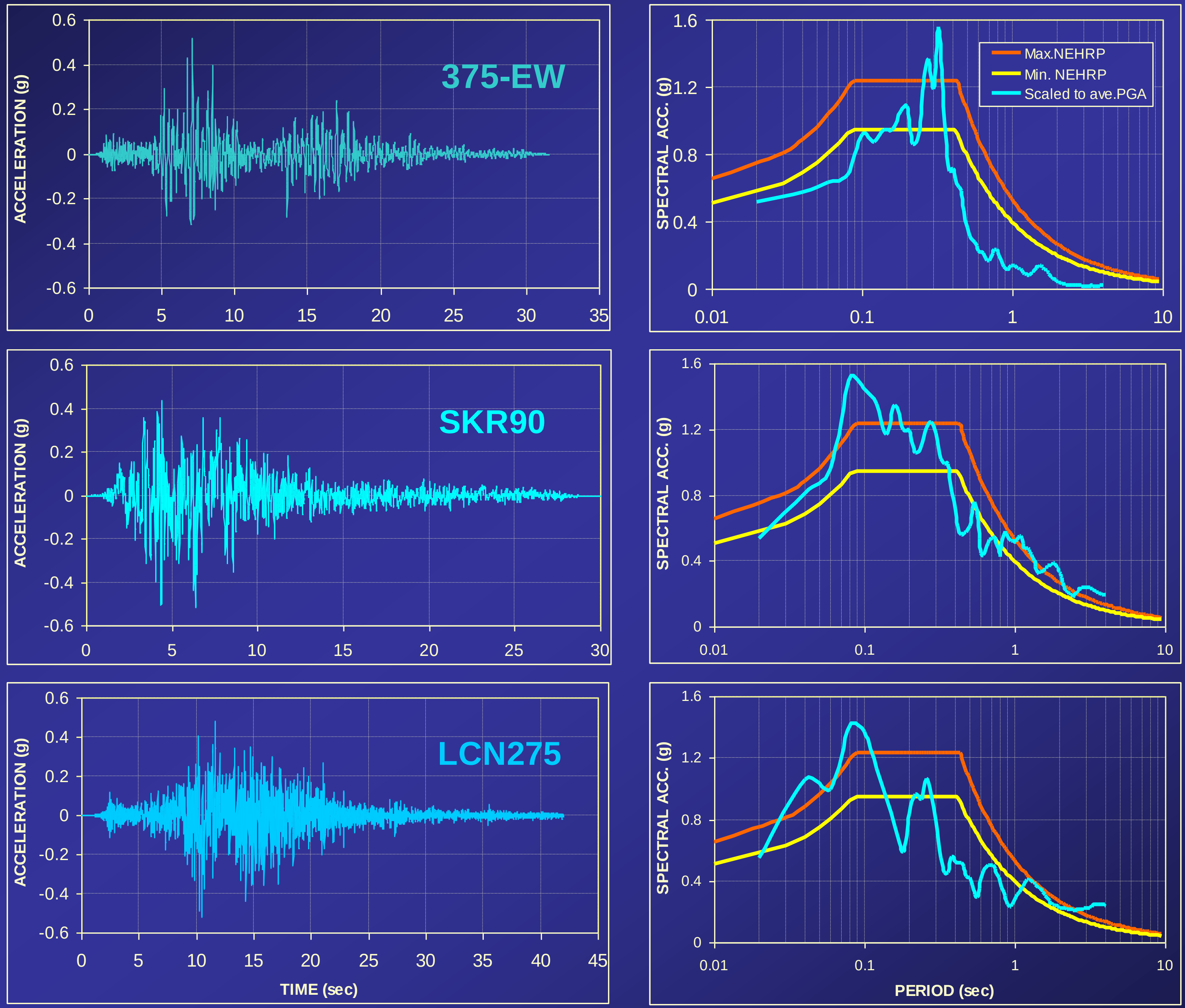




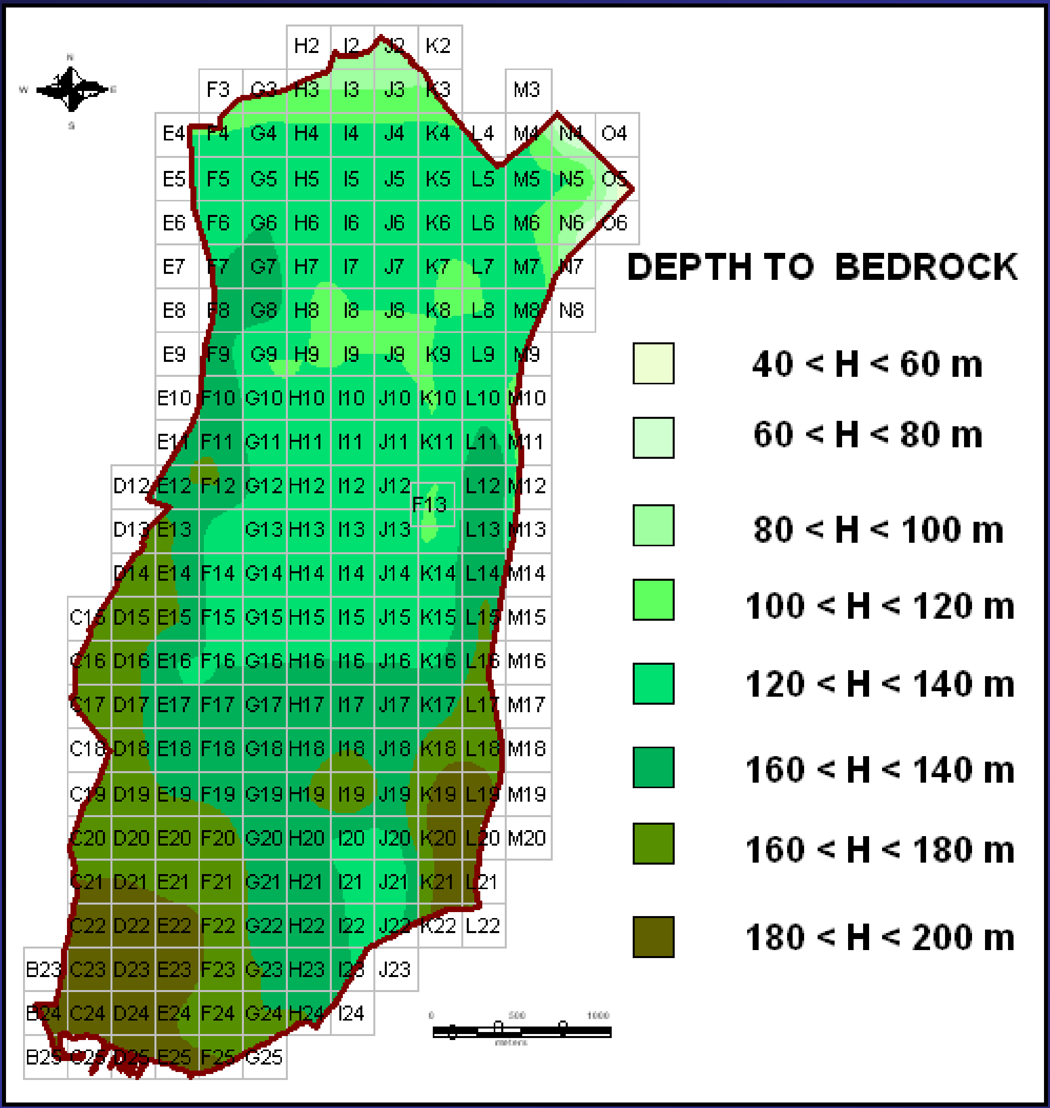


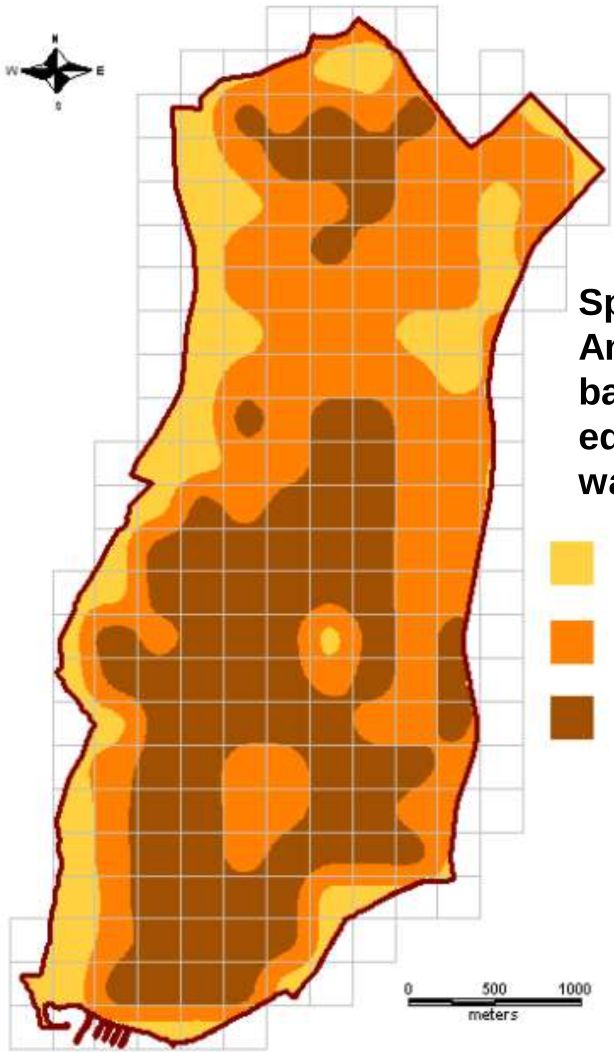


INPUT MOTION: EARTHQUAKE HAZARD COMPATIBLE



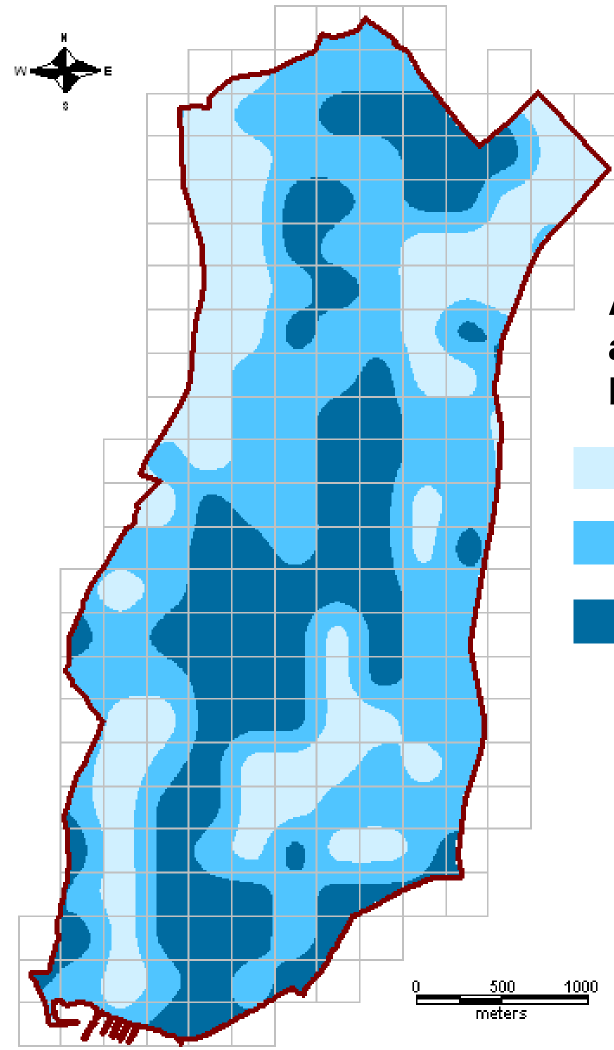
SITE CHARACTERISATION





Spectral Amplification based on equivalent shear wave velocity

- Av (3.64 < S < 2.31)
- Bv (2.31 < S < 2.13)
- Cv (2.13 < S < 1.77)



Average spectral acceleration between 0.1-1.0 sec

- As (1.66 < Savg < 0.89 g)
- Bs (0.89 < Savg < 0.78 g)
- Cs (0.78 < Savg < 0.56 g)

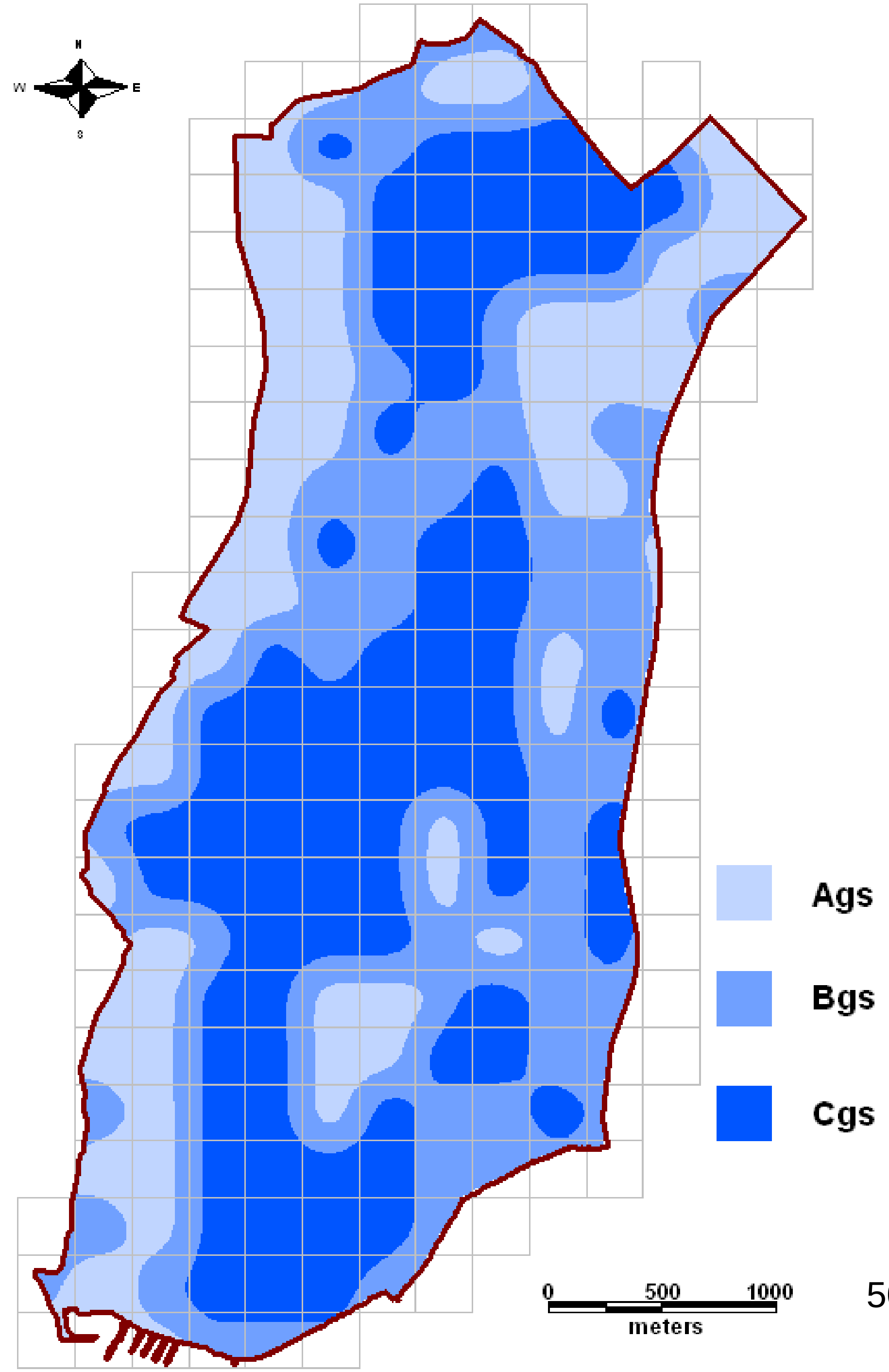
Combination of these two maps gives microzonation map with respect ground shaking.

MICROZONATION WITH RESPECT TO GROUND SHAKING

A_{GS} =
A_V & A_S + A_V & B_S + B_V & A_S

B_{GS} =
B_V & B_S + C_V & A_S + A_V & C_S

C_{GS} =
C_V & C_S + C_V & B_S + B_V & C_S

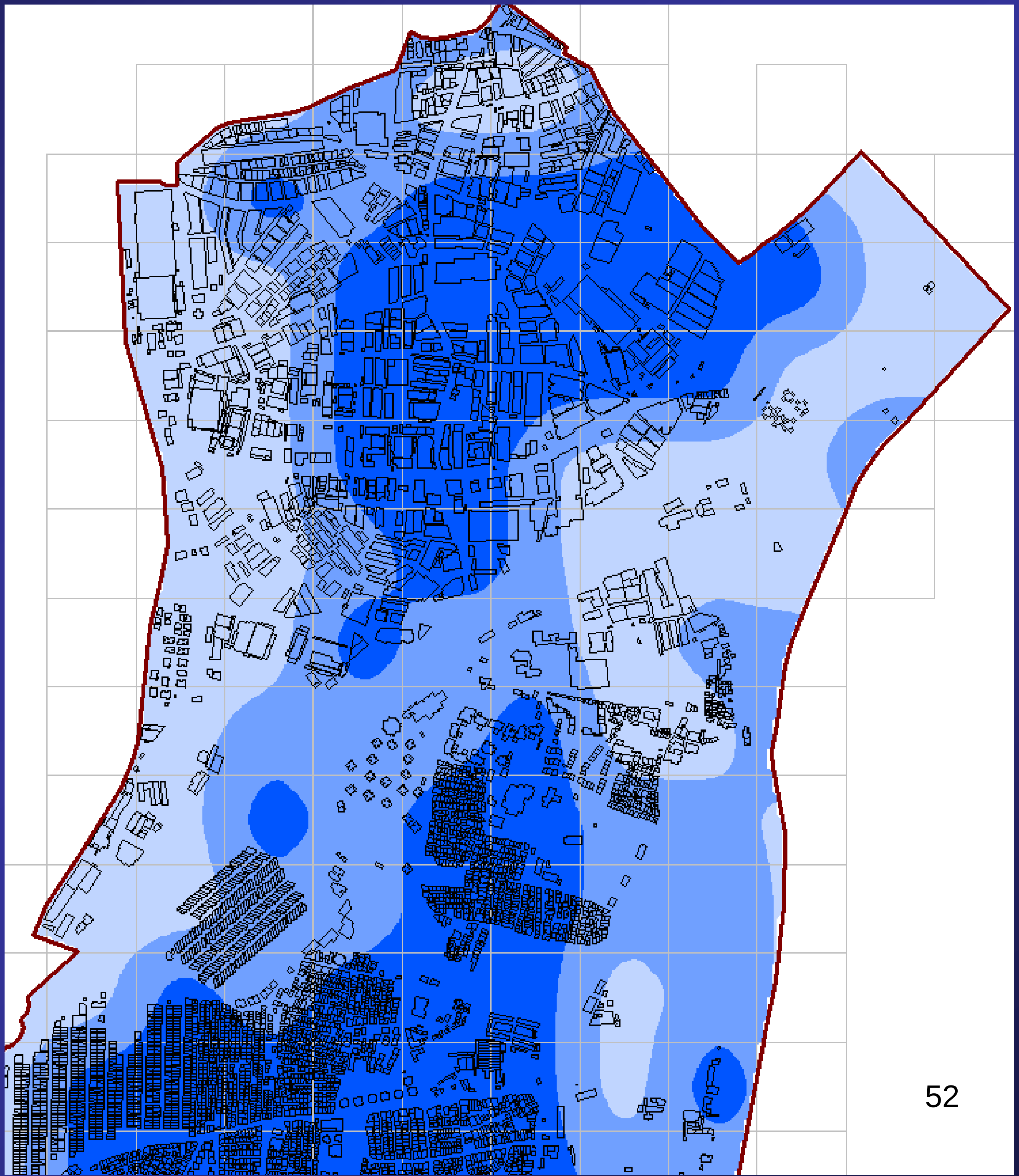


URBAN AND LAND USE PLANNING

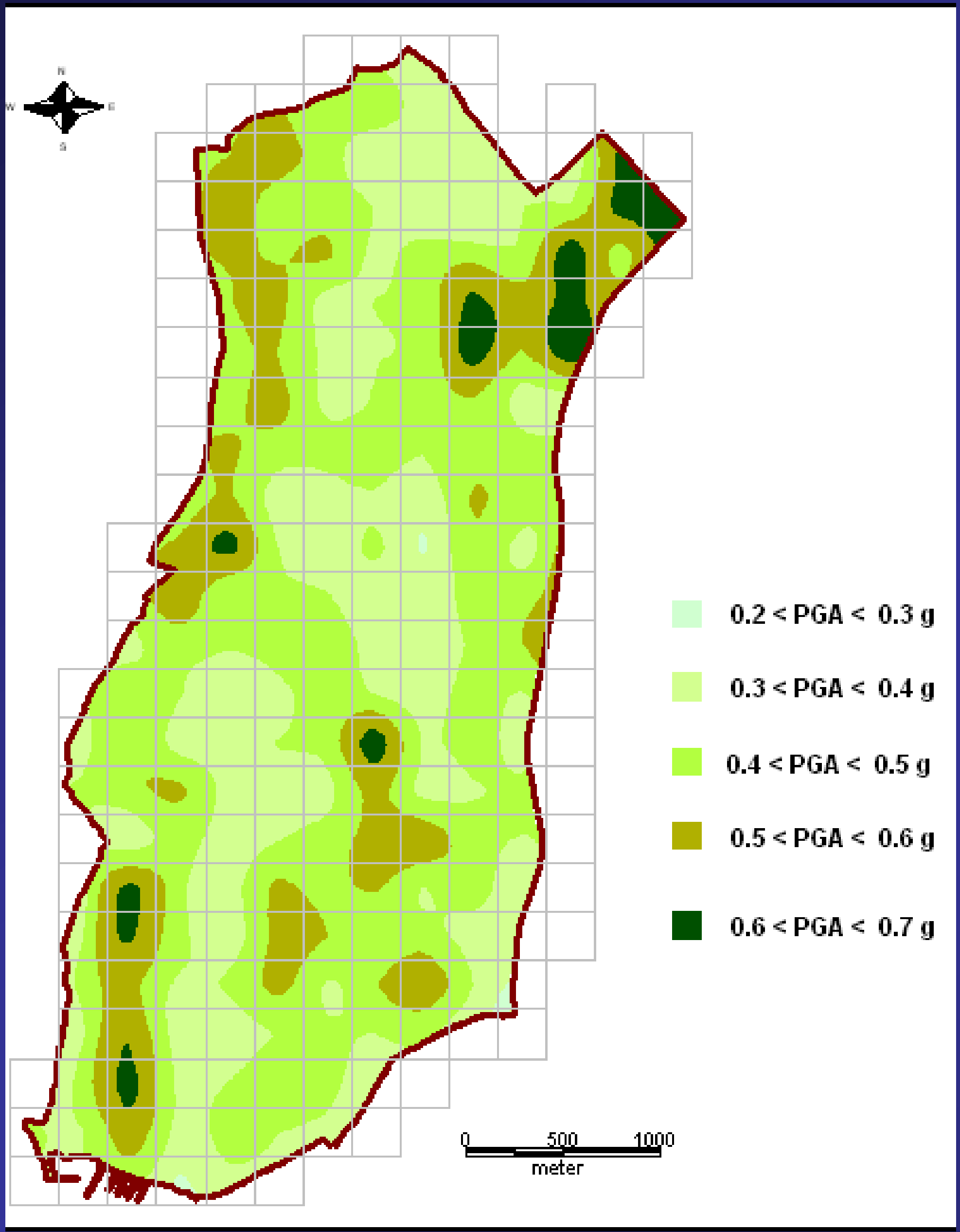
1. To specify building and population densities and
2. To evaluate functional layouts
3. For selection of locations for important buildings and lifelines

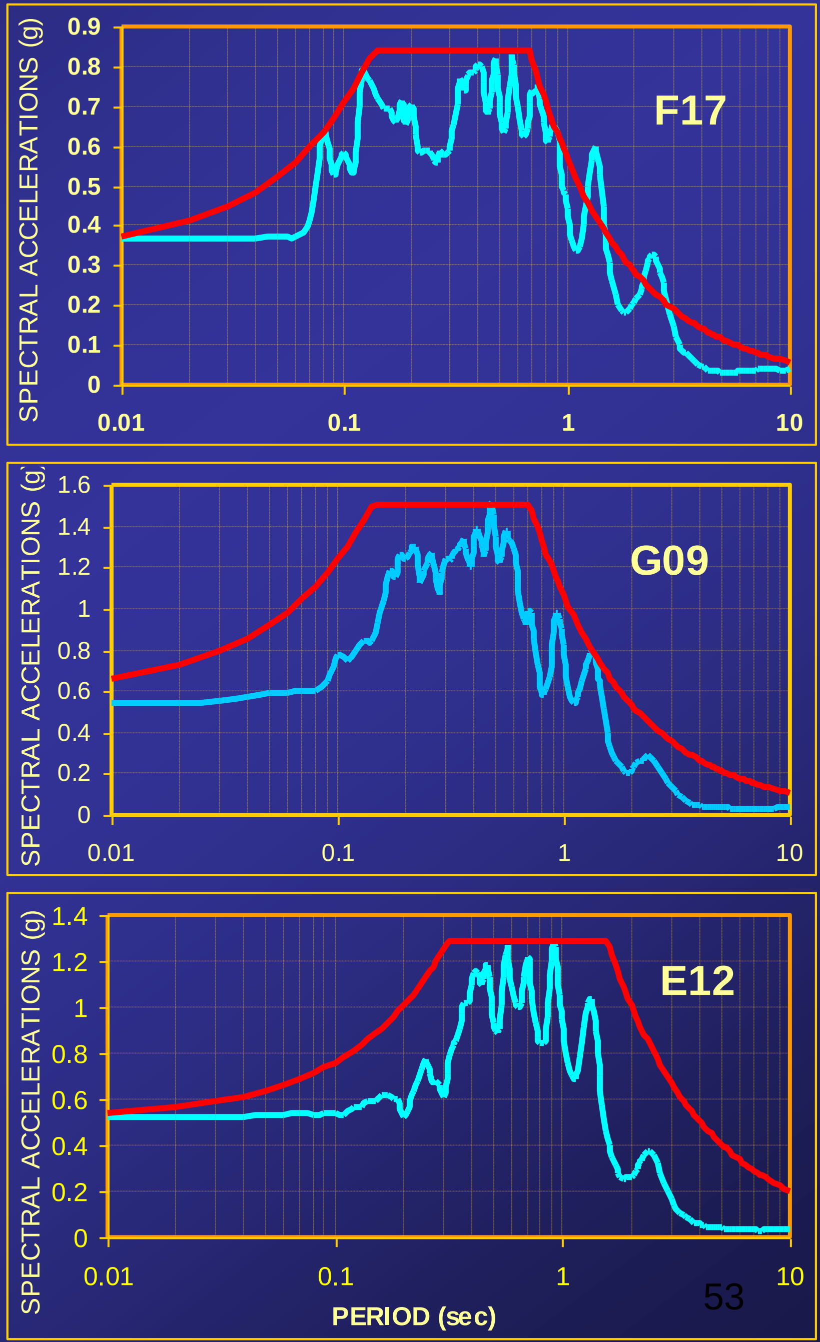
1. URBAN PLANNING
   Building and population density

1. EARTHQUAKE SCENARIO
   Vulnerability relationships

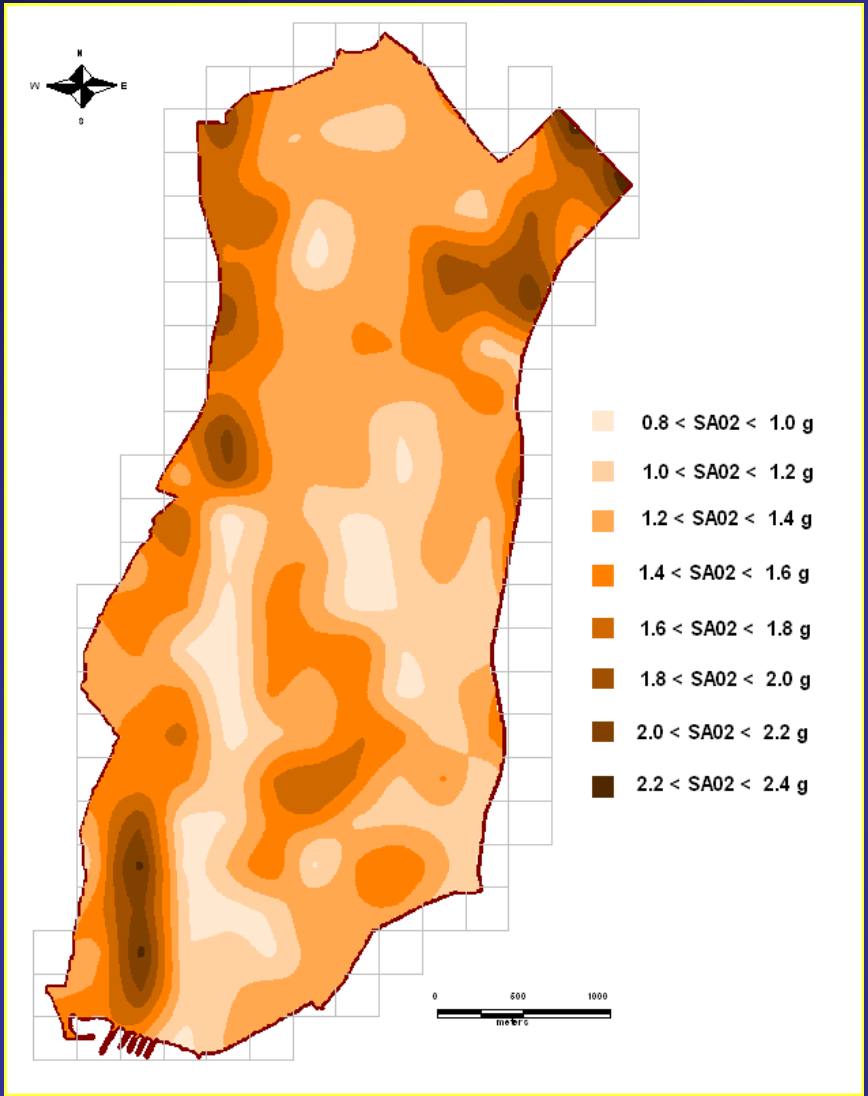


Variation of PGA

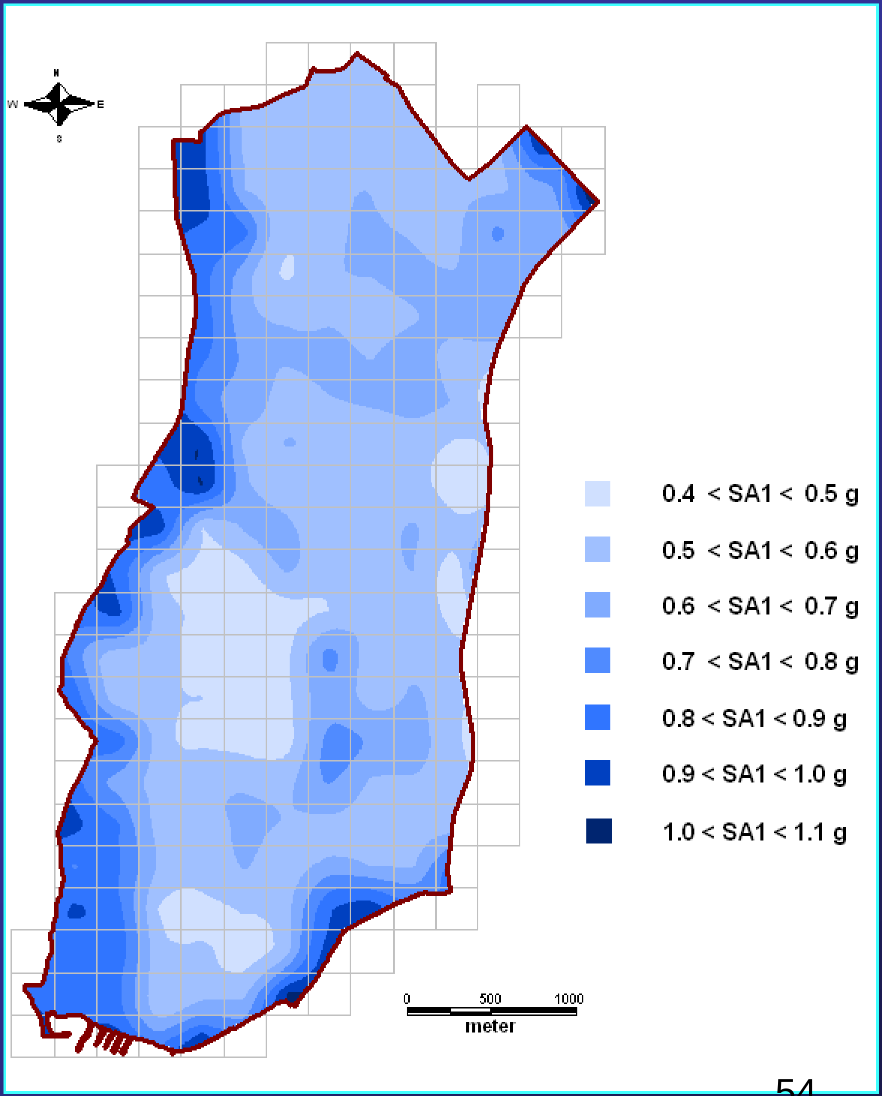


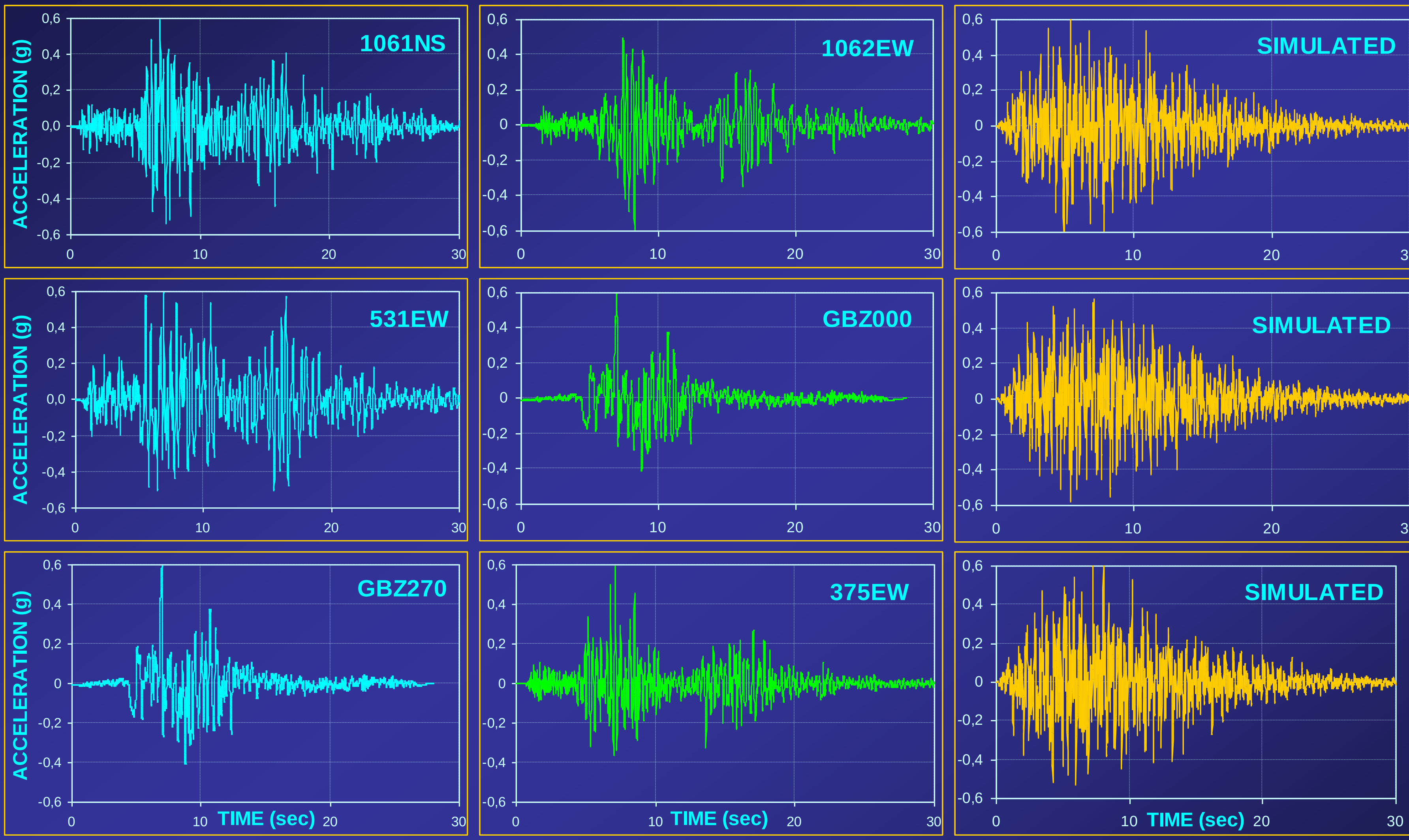


Variation of spectral accelerations at 0.2s determined by best envelop



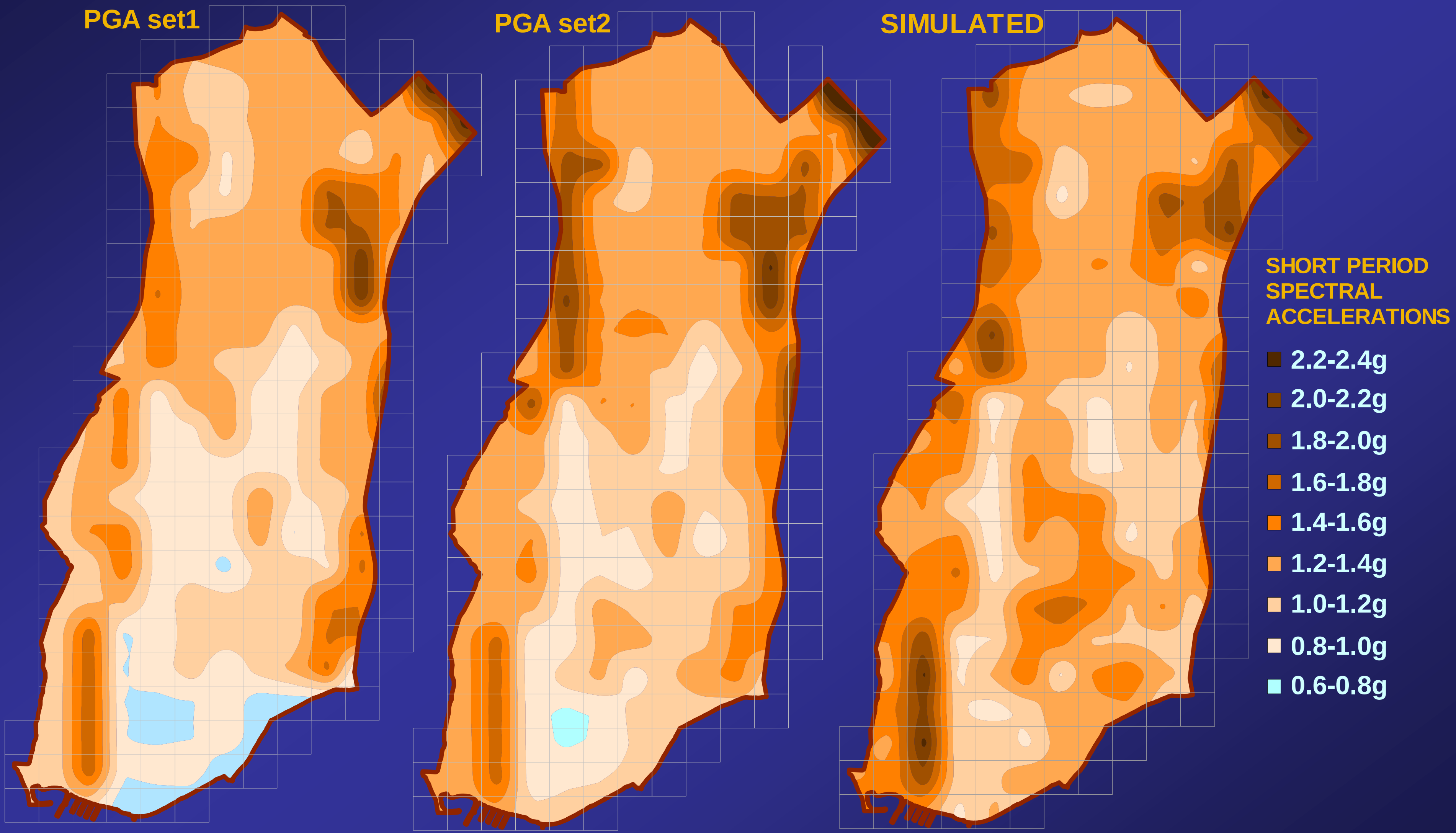
Variation of spectral accelerations at 1.0s determined by best envelop



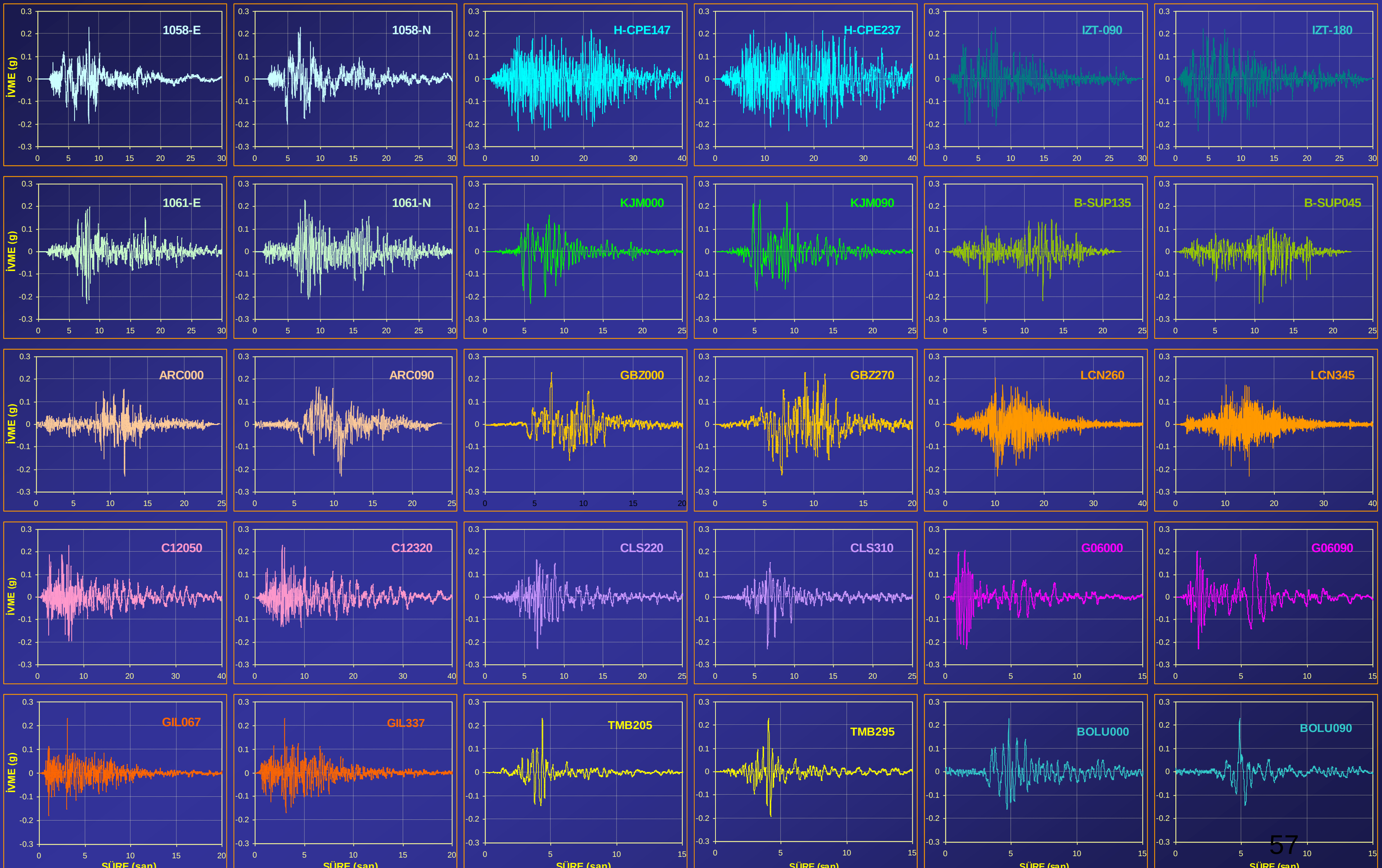


Two sets of scaled real and one set of simulated acceleration records used for site response analyses for one cell

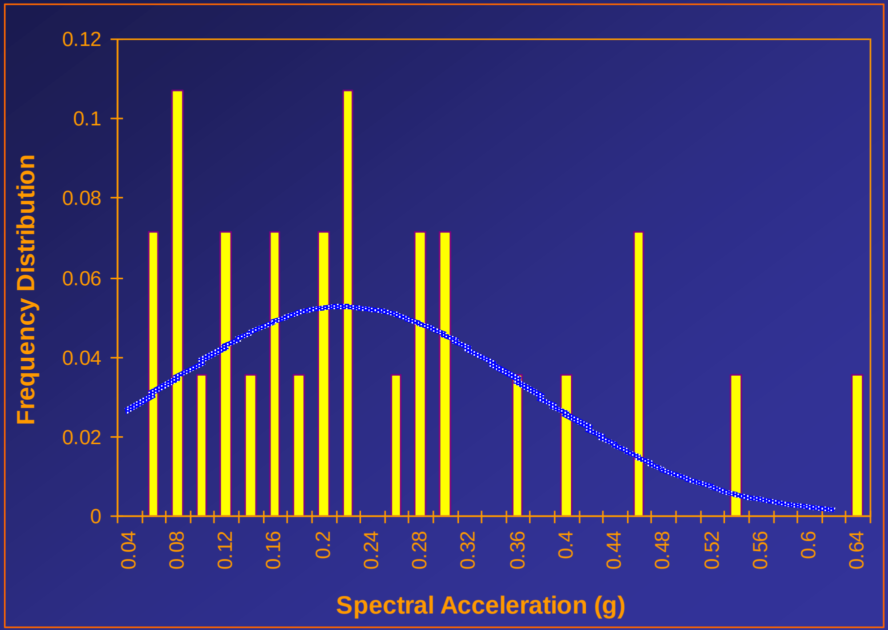
Microzonation maps for average short period spectral accelerations

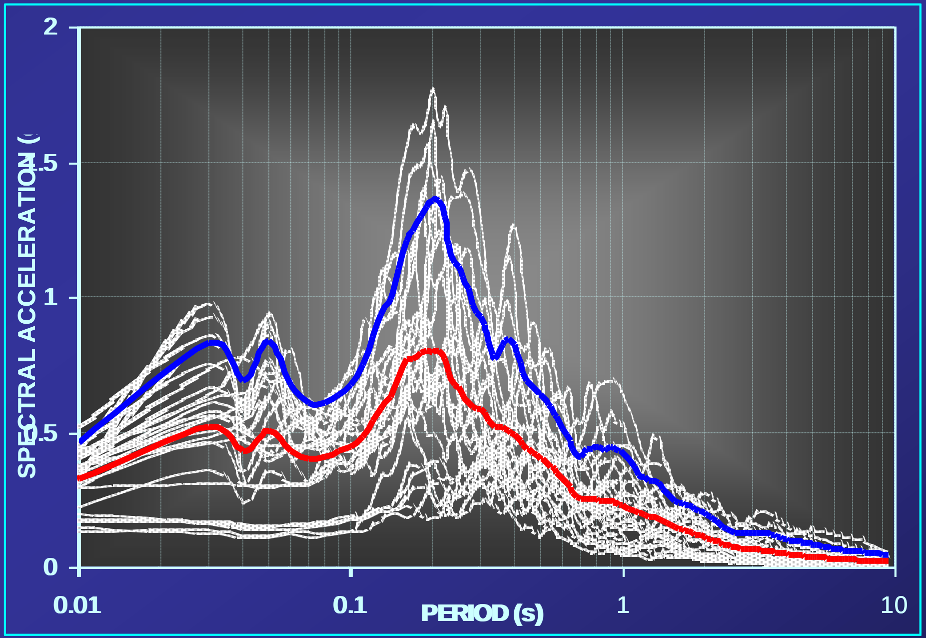


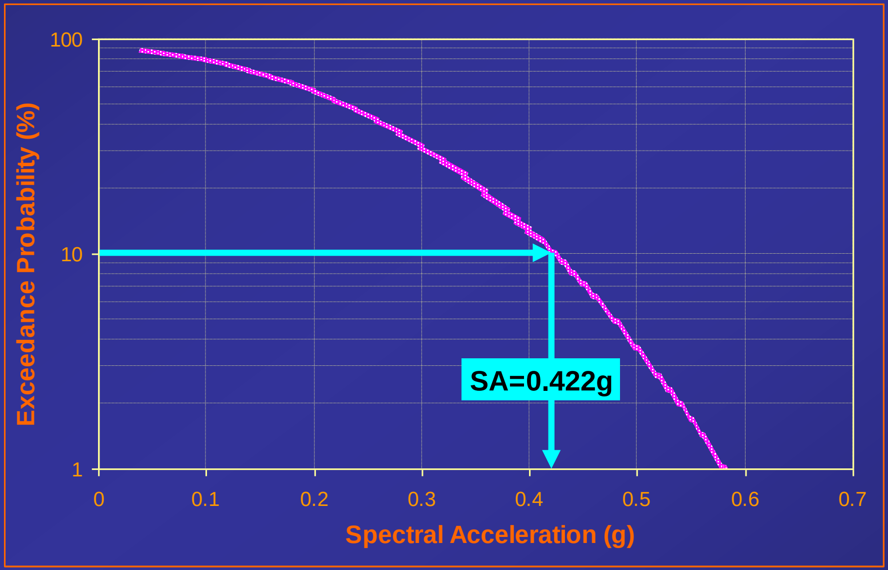
PGA scaled acceleration records



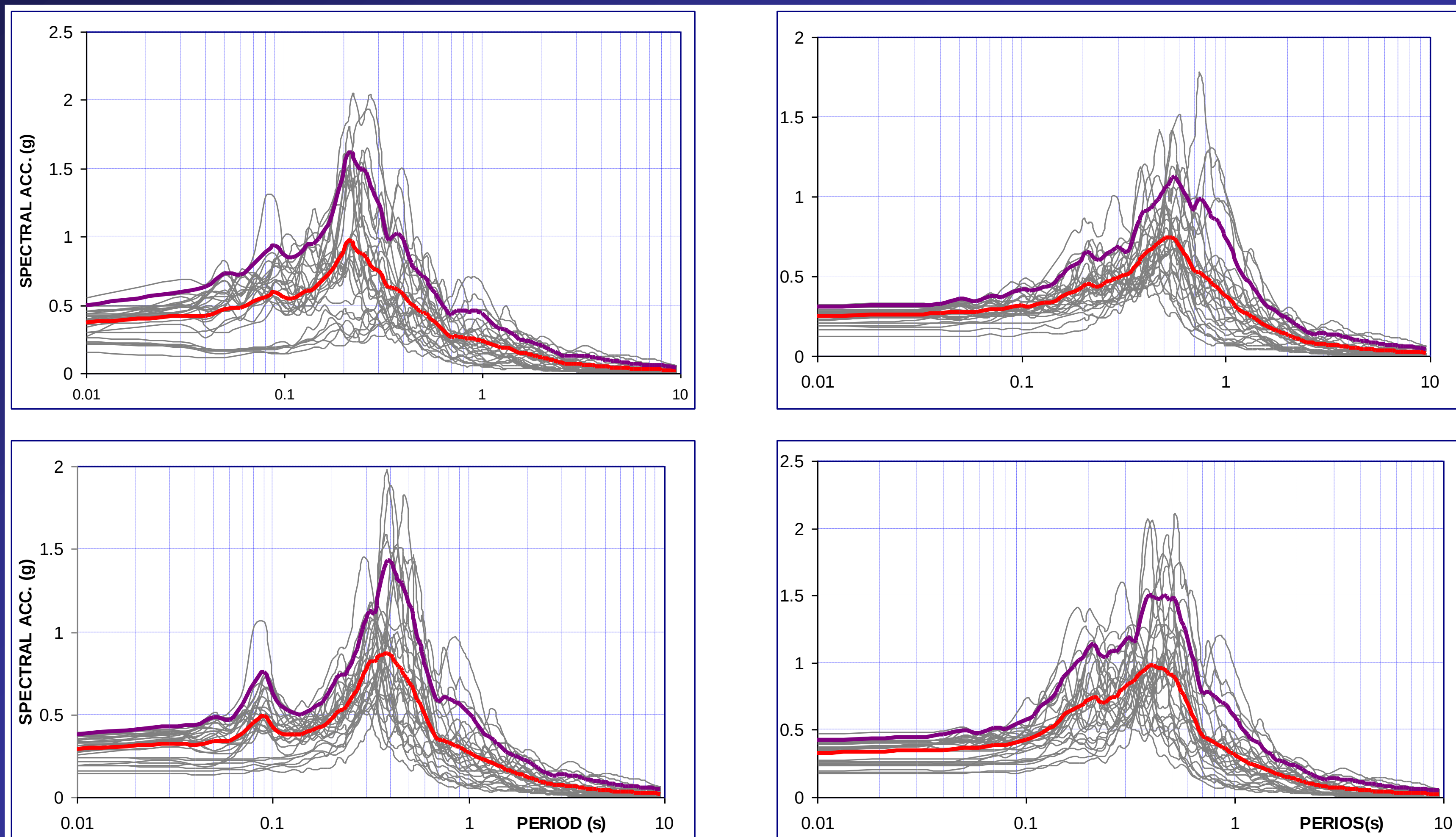
Probabilitic interpretation of multiple site response analyses



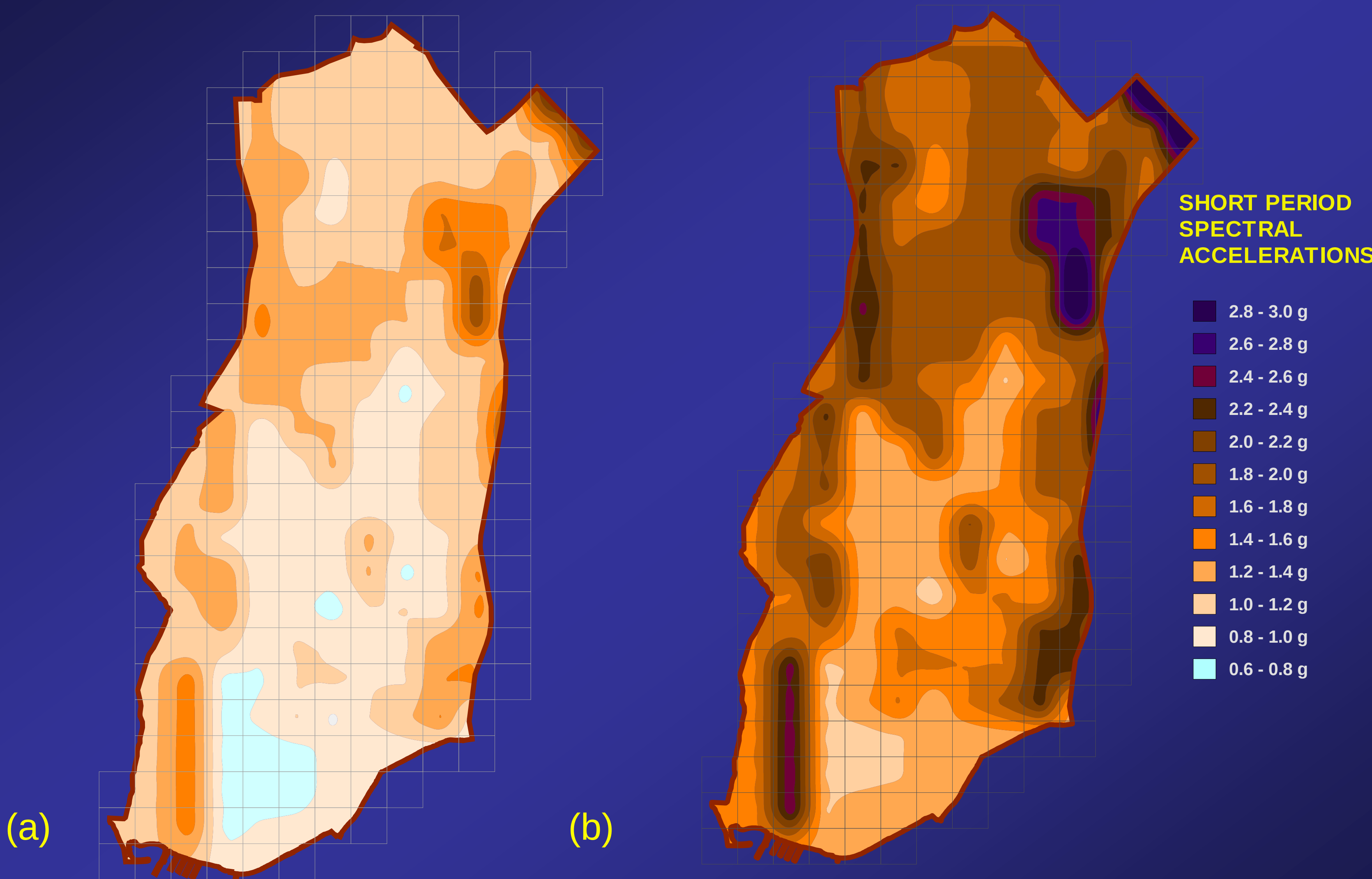




CALCULATED SPECTRAL ACCELERATIONS



Spectral acceleration zonation*



Spectral acceleration at short period calculated as (a) the average of all site response analyses and (b) corresponding to 10% exceedance level

FOR ESTIMATING SPECTRAL ACCELERATIONS ON THE GROUND SURFACE

FIRST OPTION IS TO USE SIMPLIFIED ASSESSMENT BASED AVERAGE SHEAR WAVE VELOCITY

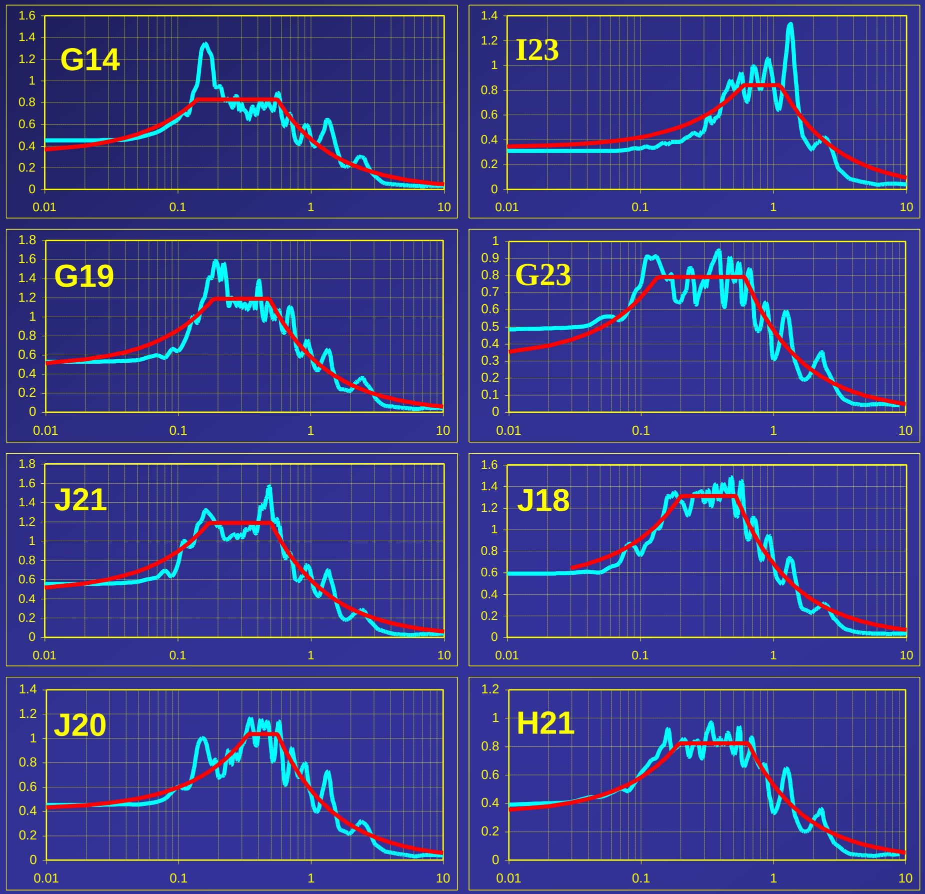
- NEHRP
- BORCHERDT (1994)

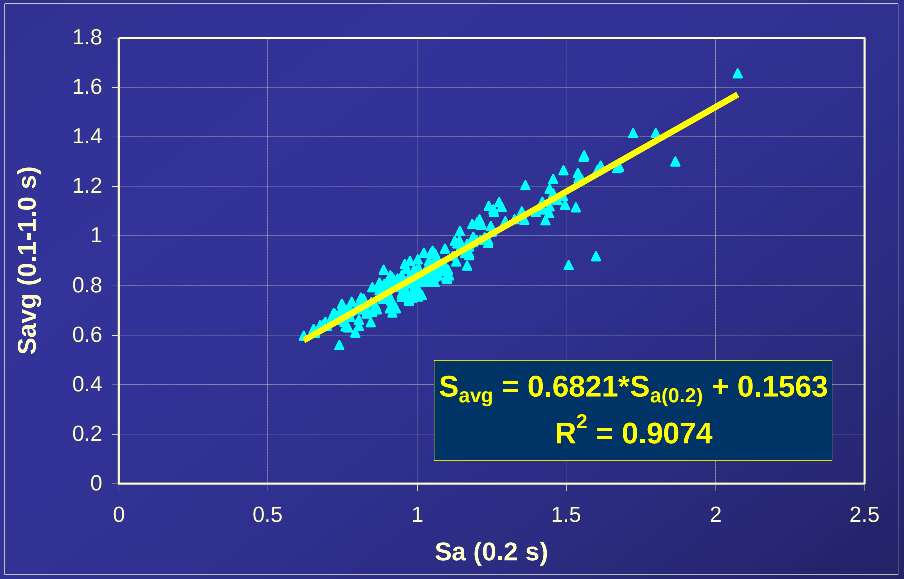
$S_{MS} = F_a S_S \quad S_{M1} = F_V S_1$

SECOND OPTION IS TO USE SPECTRAL ACCELERATIONS CALCULATED BY SITE RESPONSE ANALYSIS

FITTING A NEHRP SPECTRA BY AN OPTIMISATION SCHEME

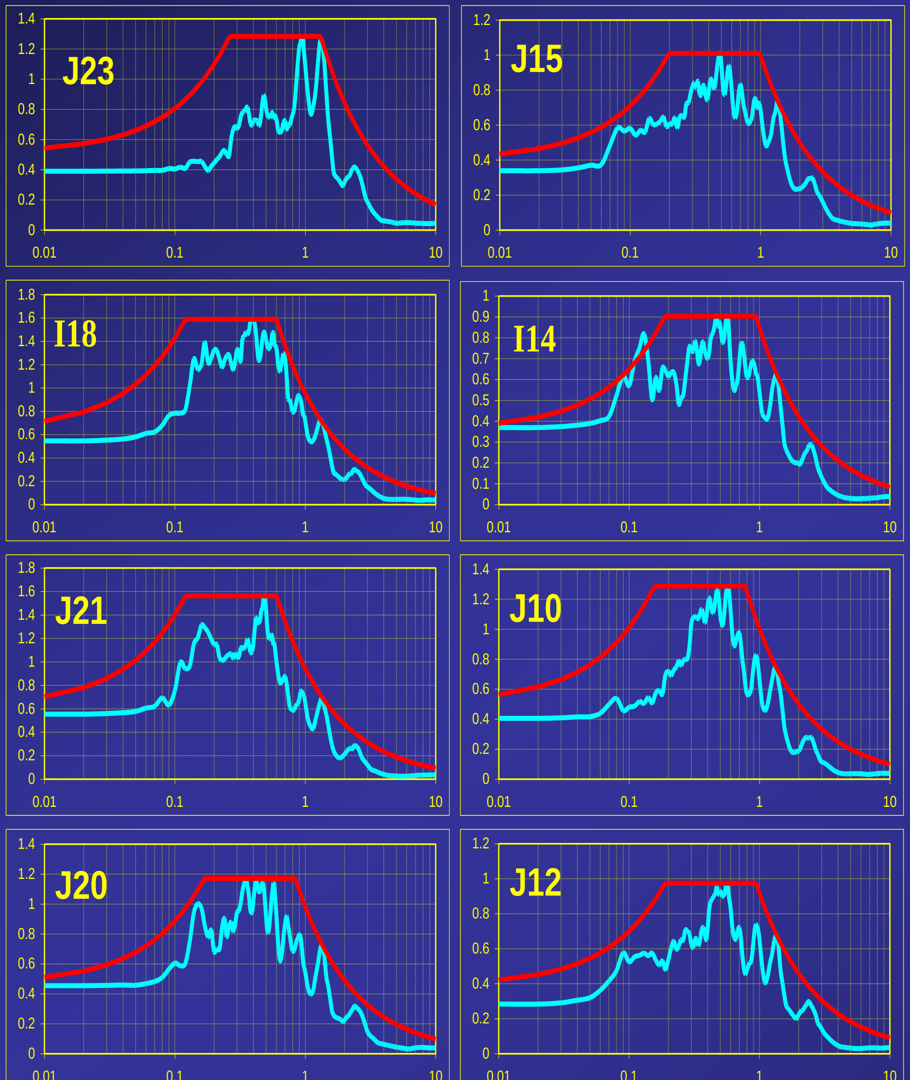
BEST FIT USING AN OPTIMIZATION SCHEME ALLOWING T_0 TO BE INDEPENDENT OF T_s



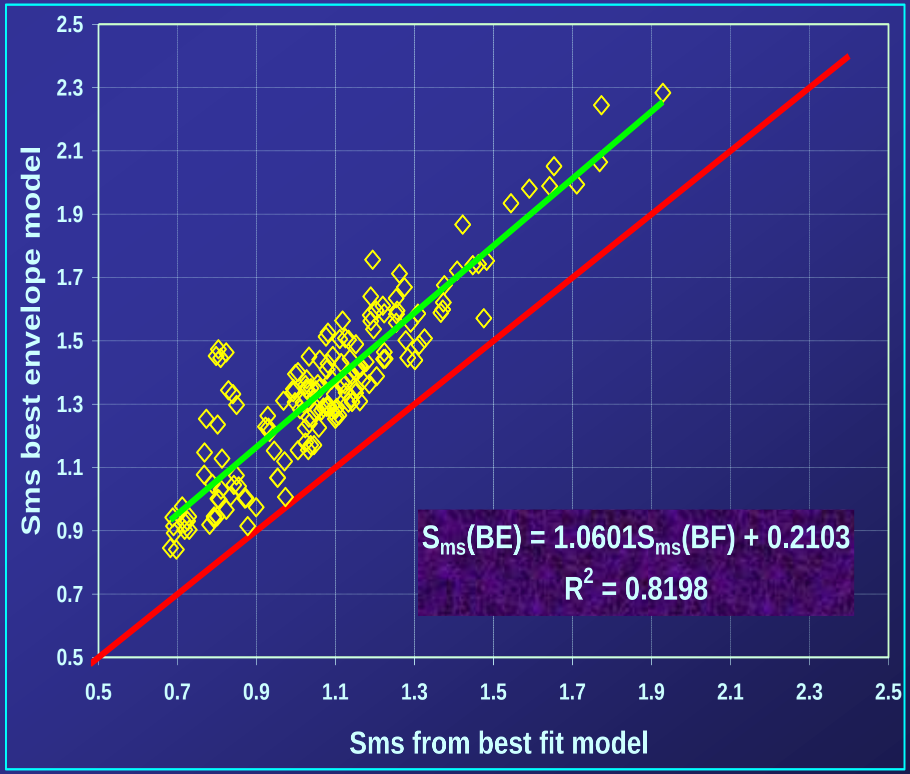


Comparison of average spectral Accelerations with the calculated SS (0.2 s) based on best fit approach

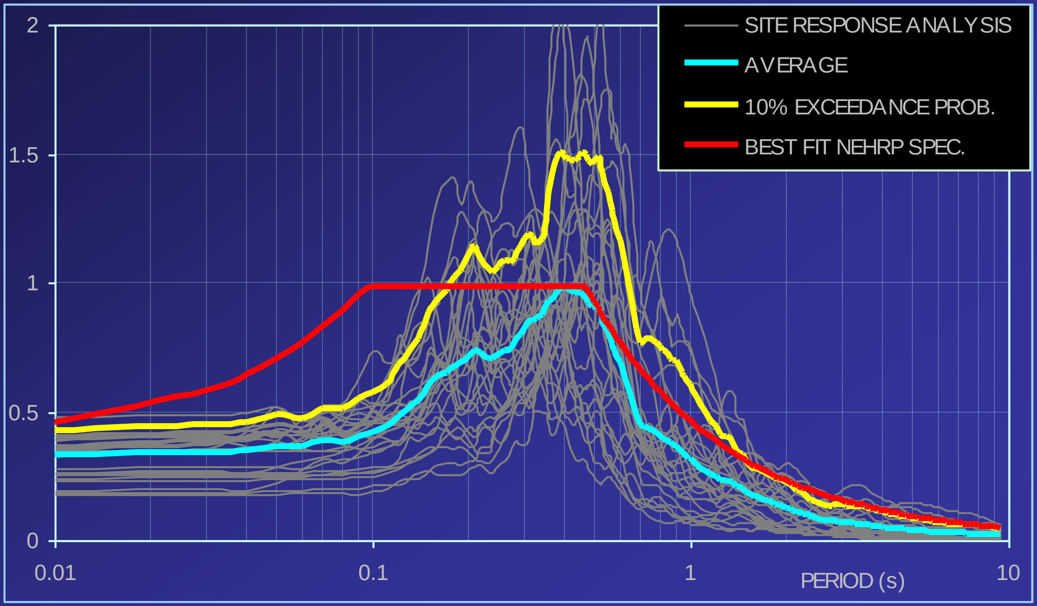
BEST FIT ENVELOPE USING AN OPTIMIZATION SCEME KEEPING ALL DEFINITIONS FOR NEHRP SPECTRUM

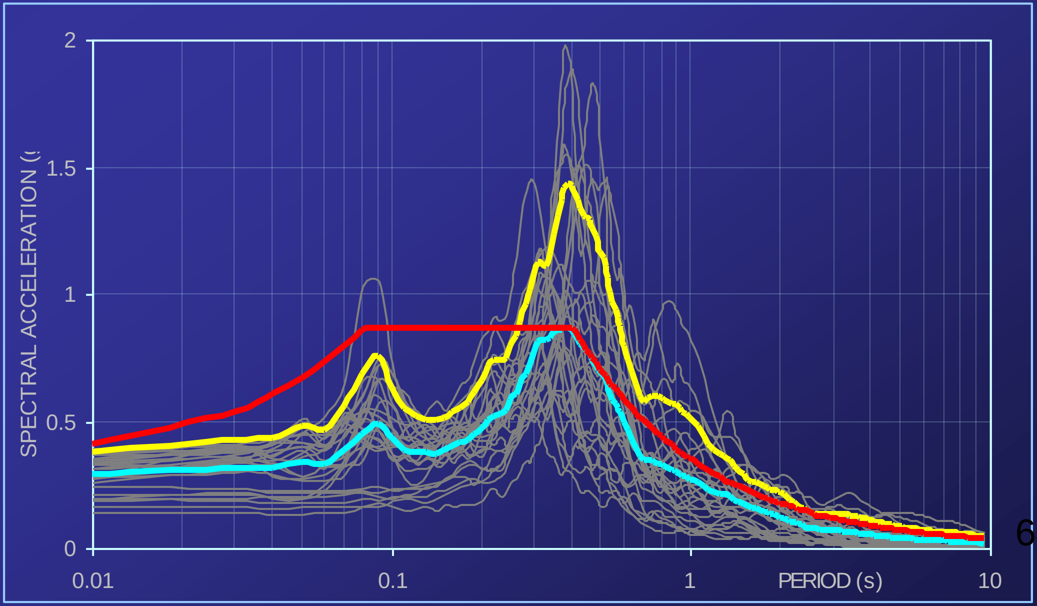


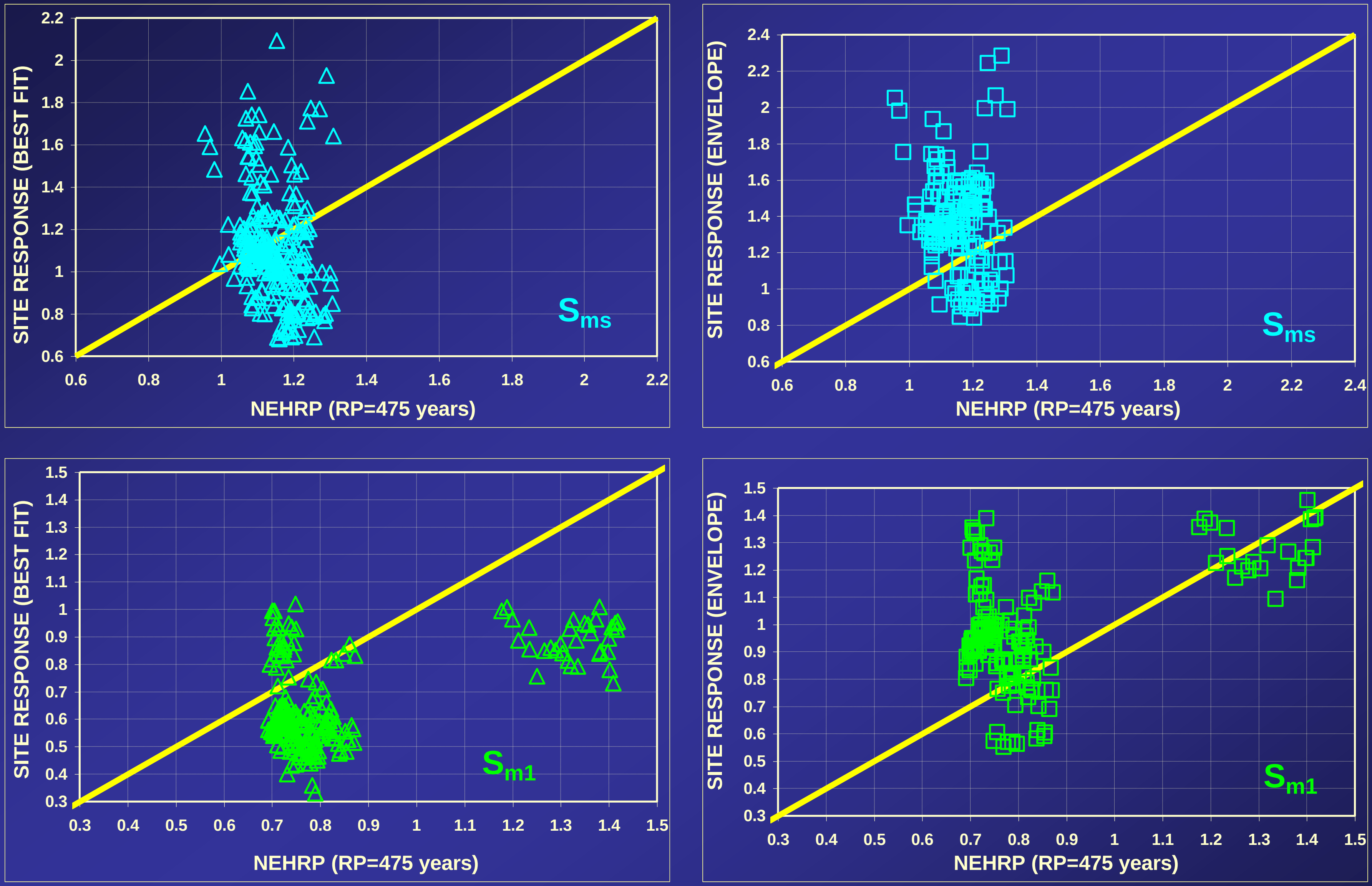
Comparison of SS (0.2s) spectral accelerations calculated by best fit and best envelope approaches



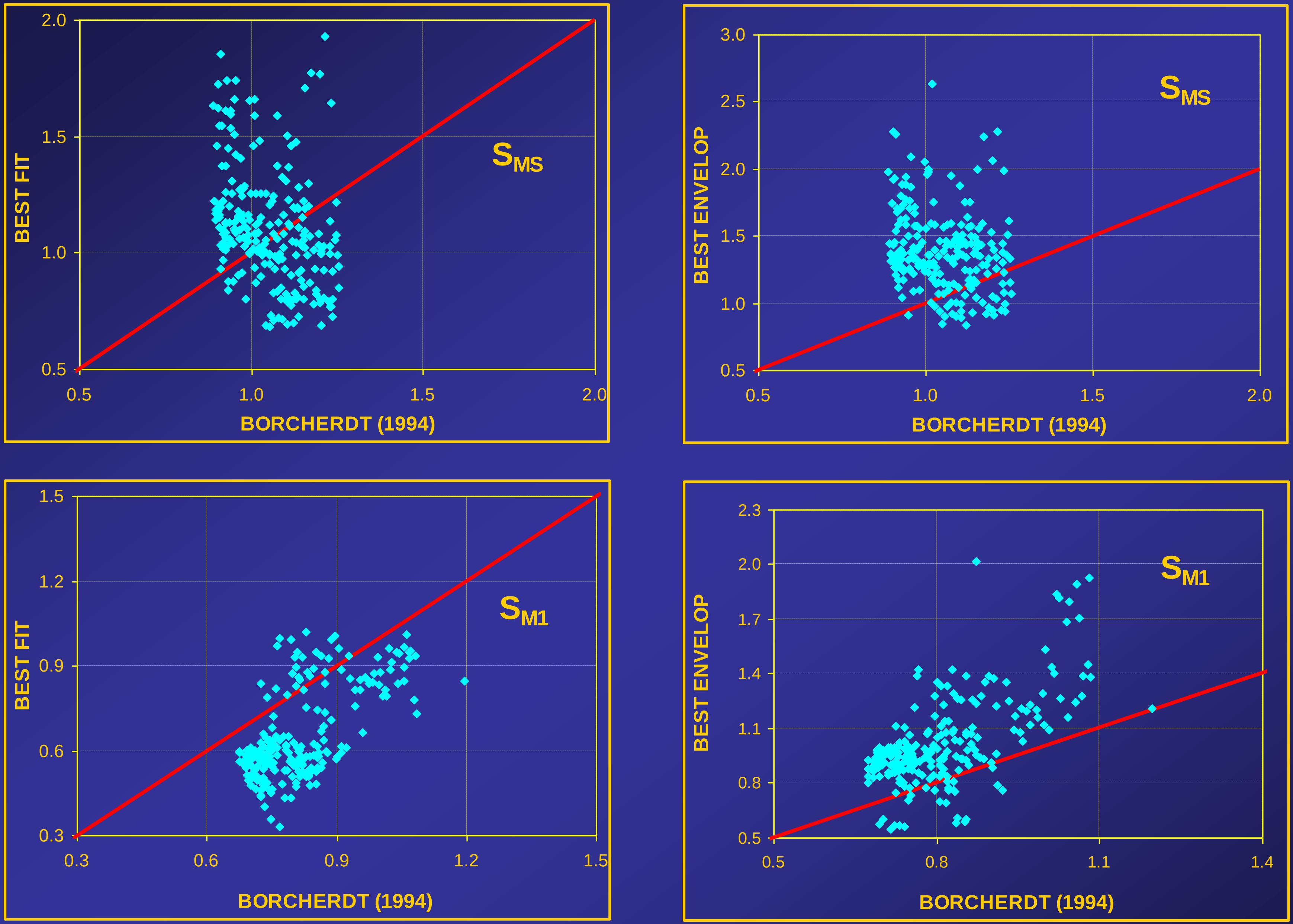
BEST FIT NEHRP ENVELOPE SPECTRUM





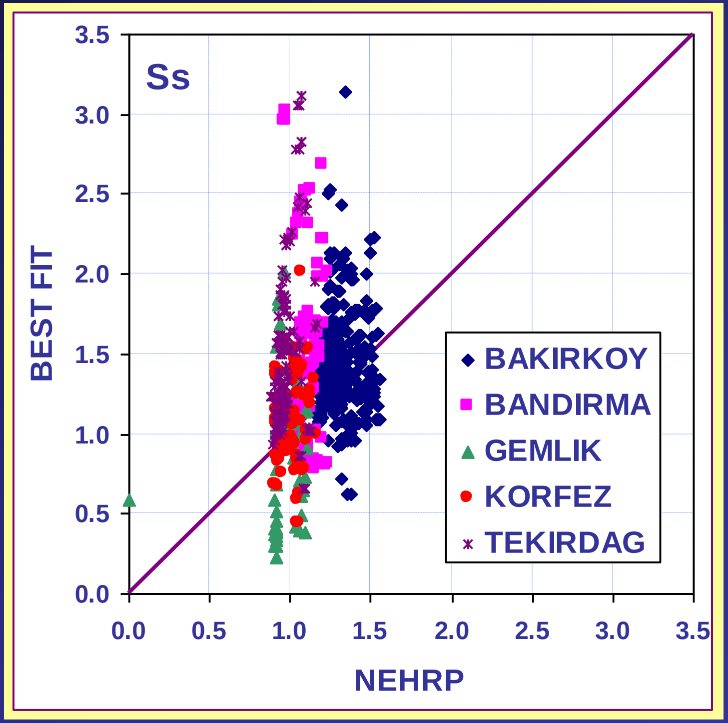


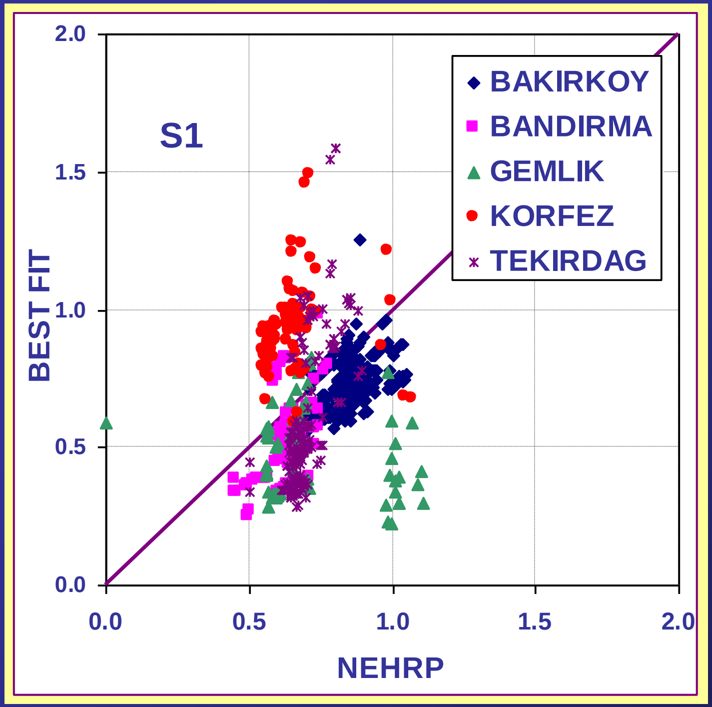
COMPARISON OF SITE RESPONSE WITH NEHRP BASED EVALUATION OF GROUND MOTION CHARACTERISTICS

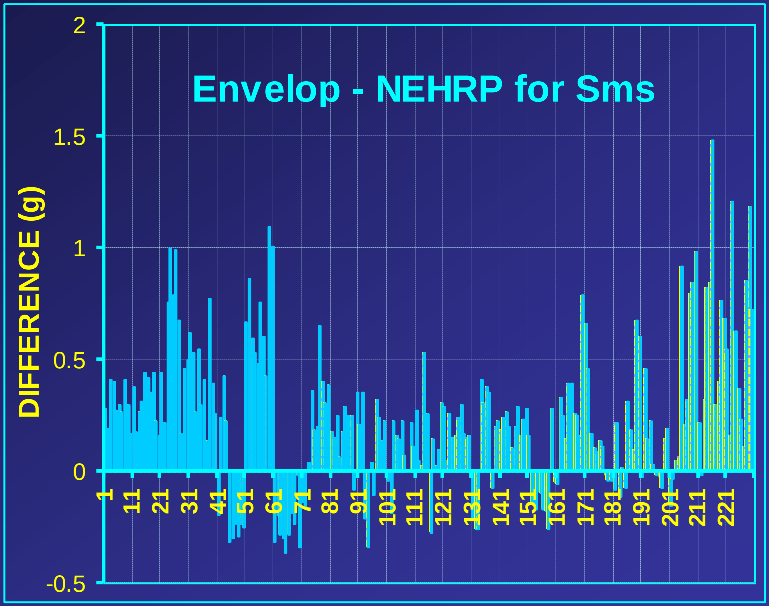


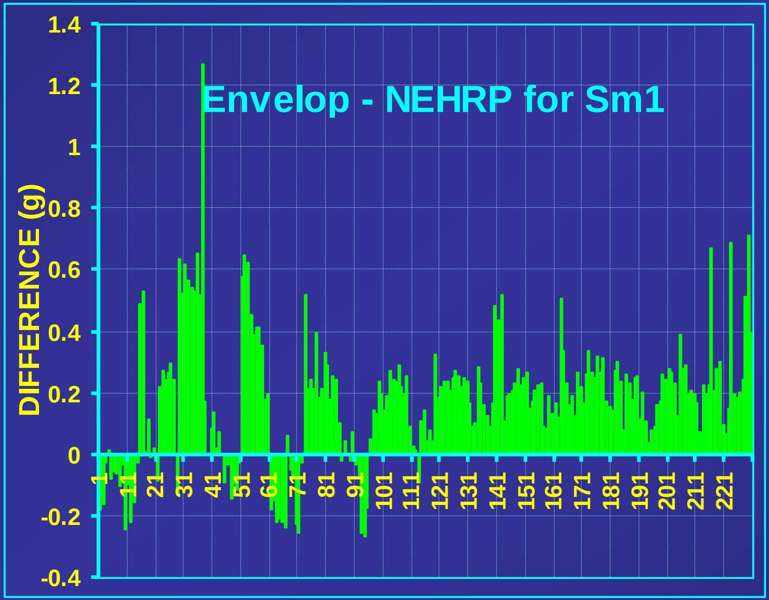
COMPARISON OF SITE RESPONSE WITH BORCHERDT (1994) BASED EVALUATION OF GROUND MOTION CHARACTERISTICS

Comparison of Spectral Accelerations*

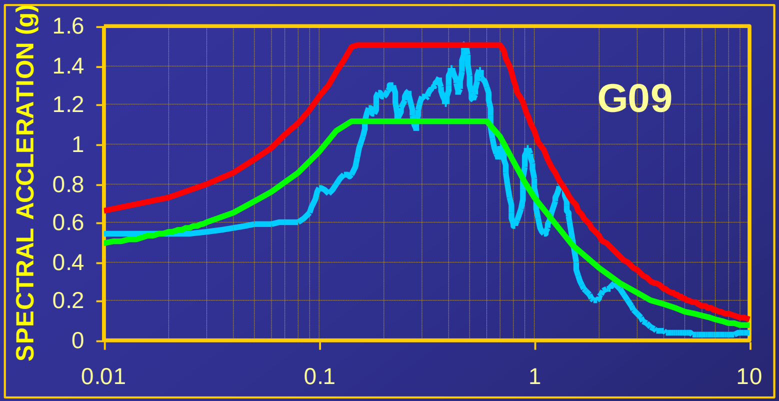


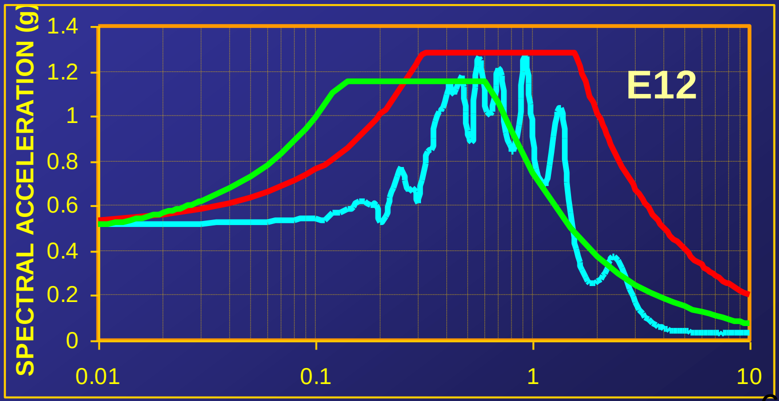



Envelop - NEHRP for Sms
DIFFERENCE (g)
2
1.5
1
0.5
0
-0.5
1 11 21 31 41 51 61 71 81 91 101 111 121 131 141 151 161 171 181 191 201 211 221

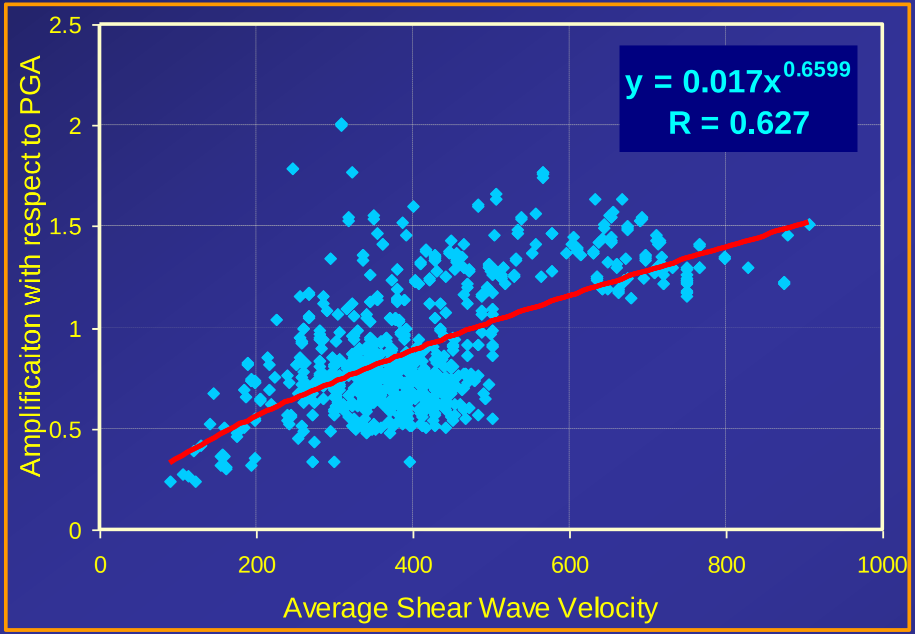

Envelop - NEHRP for Sm1
DIFFERENCE (g)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
1 11 21 31 41 51 61 71 81 91 101 111 121 131 141 151 161 171 181 191 201 211 221

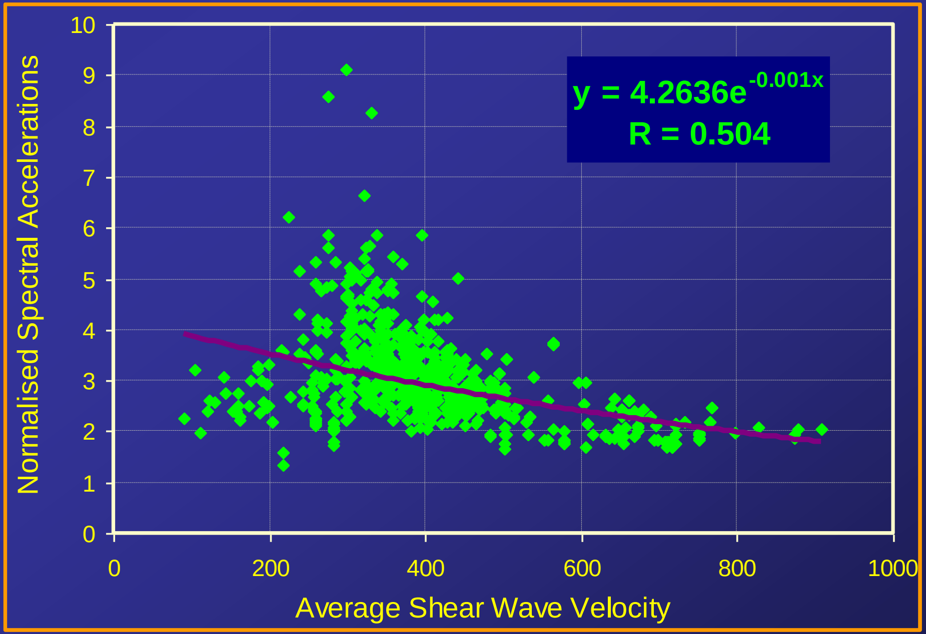

M14
SPECTRAL ACCELERATION (g)
3
2.5
2
1.5
1
0.5
0
0.01 0.1 1 10


G09
SPECTRAL ACCELERATION (g)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.01 0.1 1 10


E12
SPECTRAL ACCELERATION (g)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.01 0.1 1 10

Correlations based on site response analysis





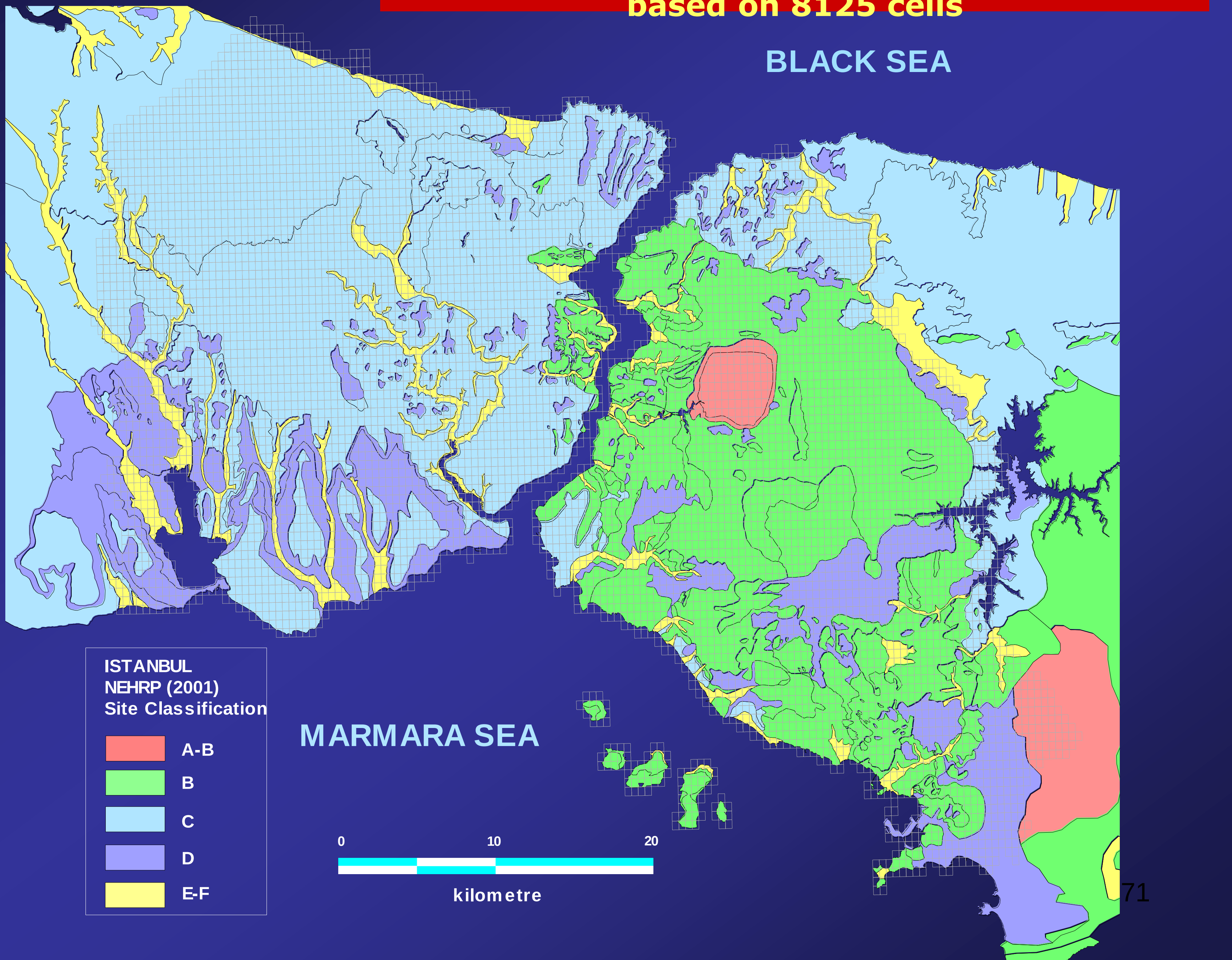
Purpose and Process

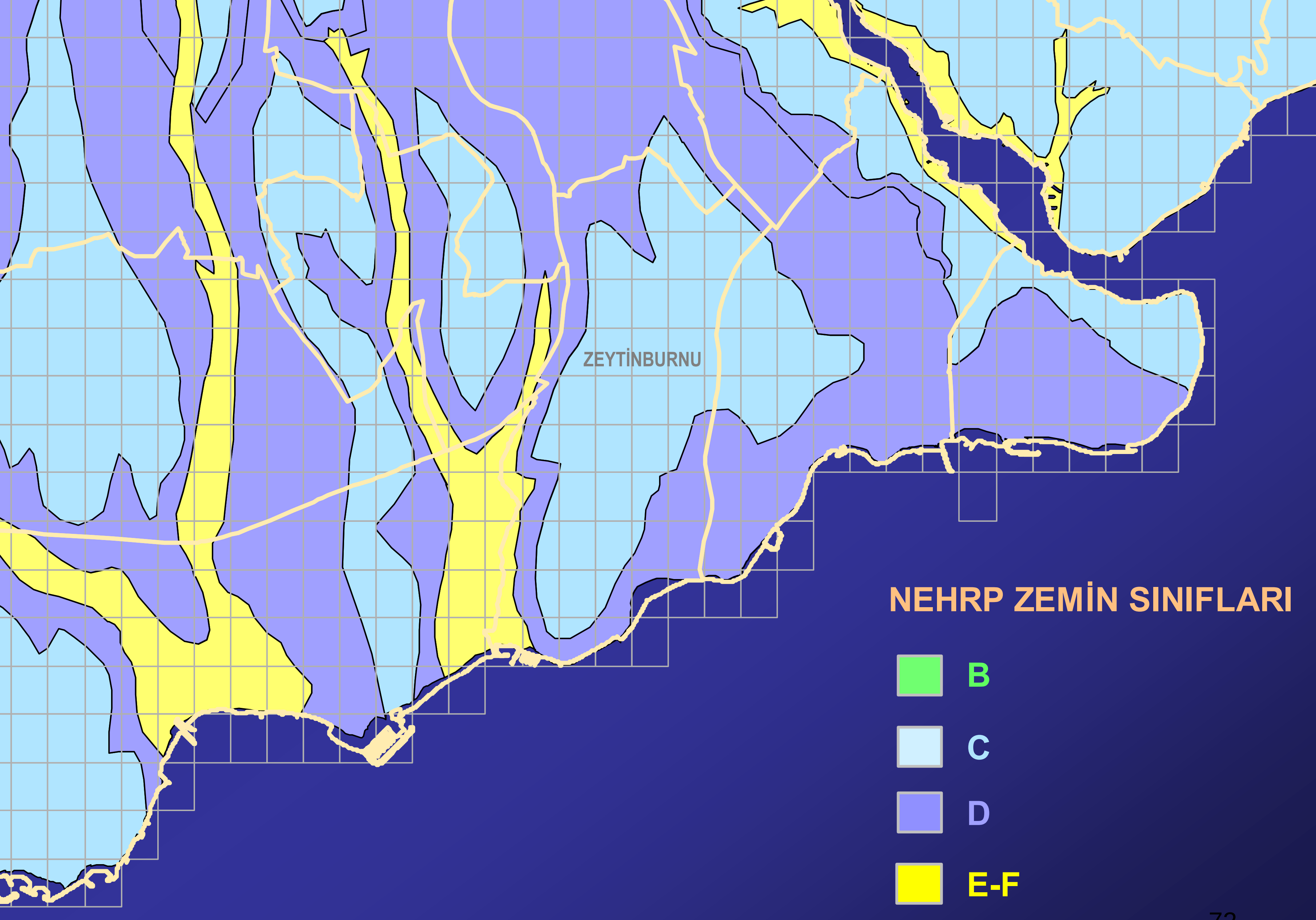
The purpose for earthquake loss estimation scenarios are for assigning the priorities in the implementation of the risk reduction, hazard mitigation measures, and for disaster preparedness.

The process of loss estimation due to earthquakes involves:

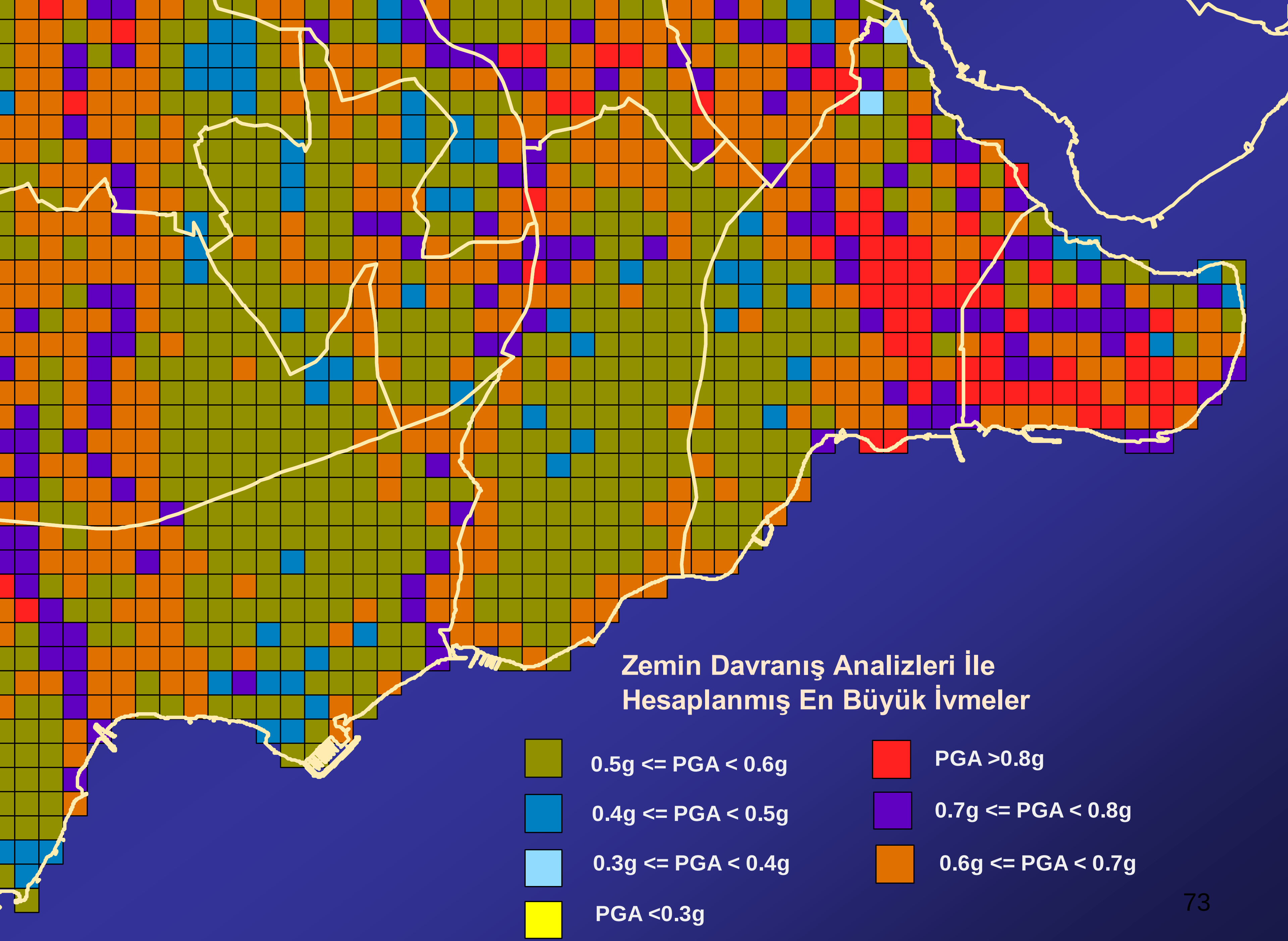
1. Compilation of building inventories,
2. Analysis of seismic hazard on the engineering bedrock,
3. Site dependent earthquake ground motion characteristics,
4. Estimation of vulnerability of the building inventories.

Istanbul site classification according to NEHRP based on 8125 cells

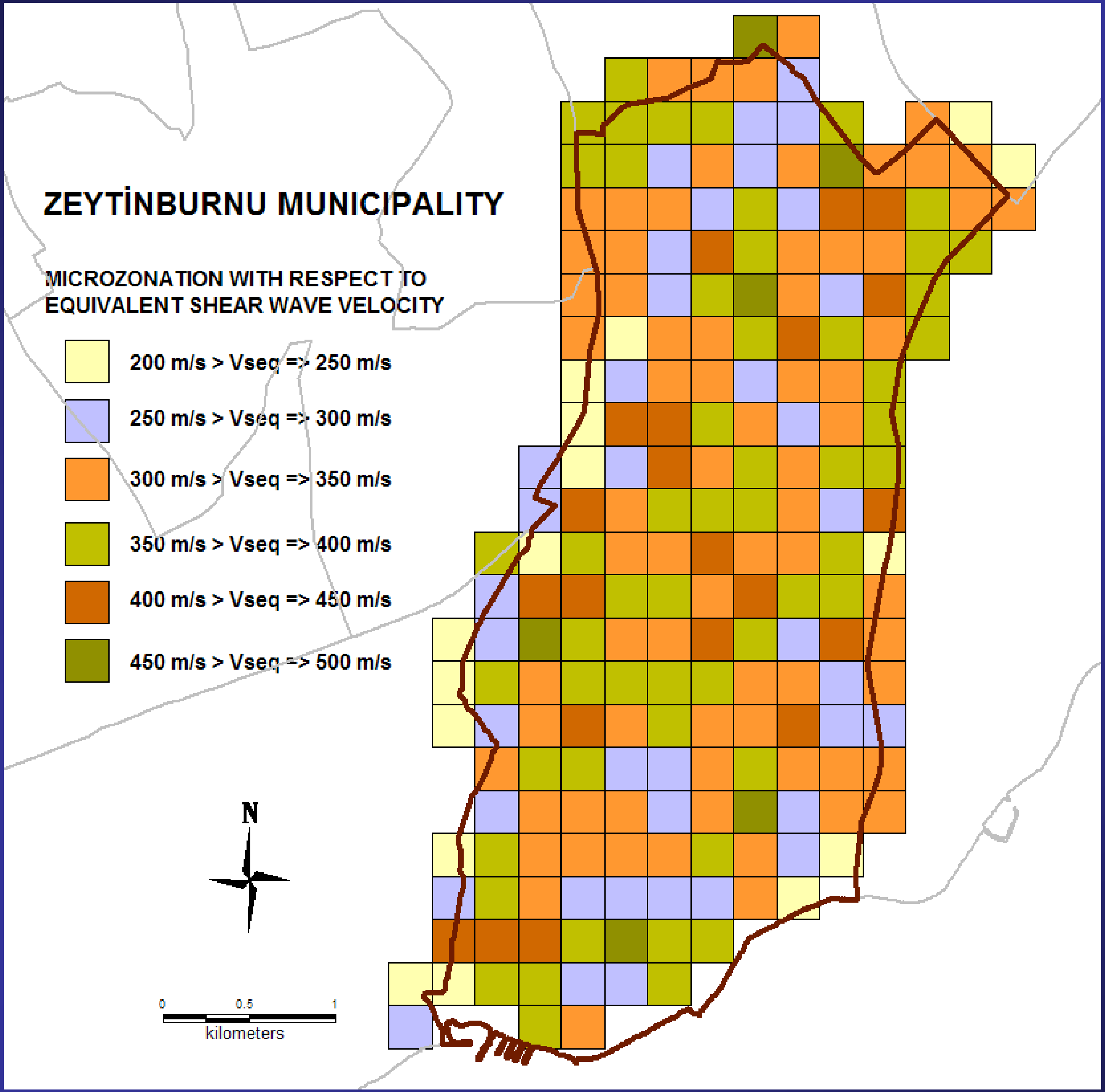




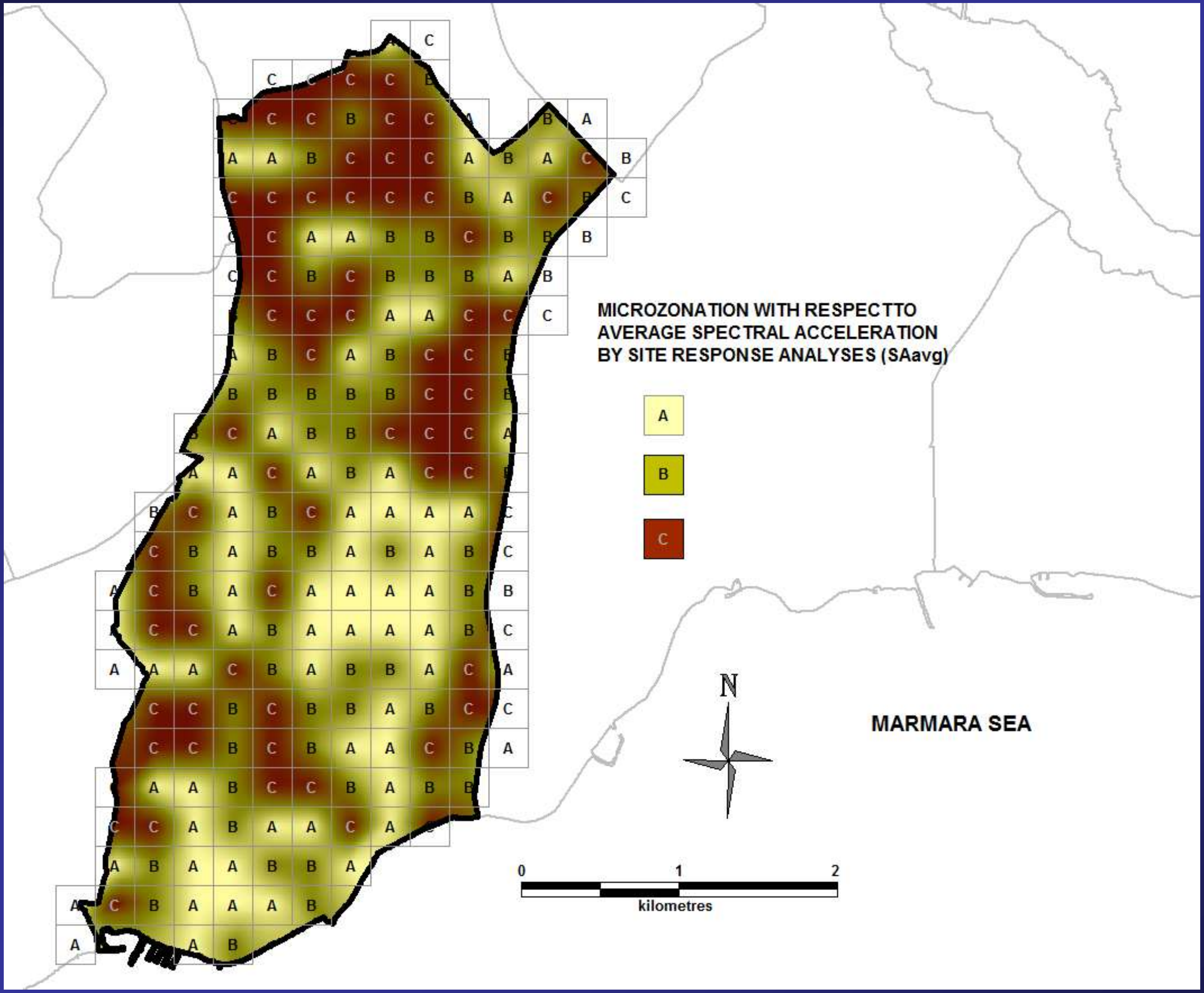
ZEYTİNBURNU
NEHRP ZEMİN SINIFLARI
B
C
D
E-F

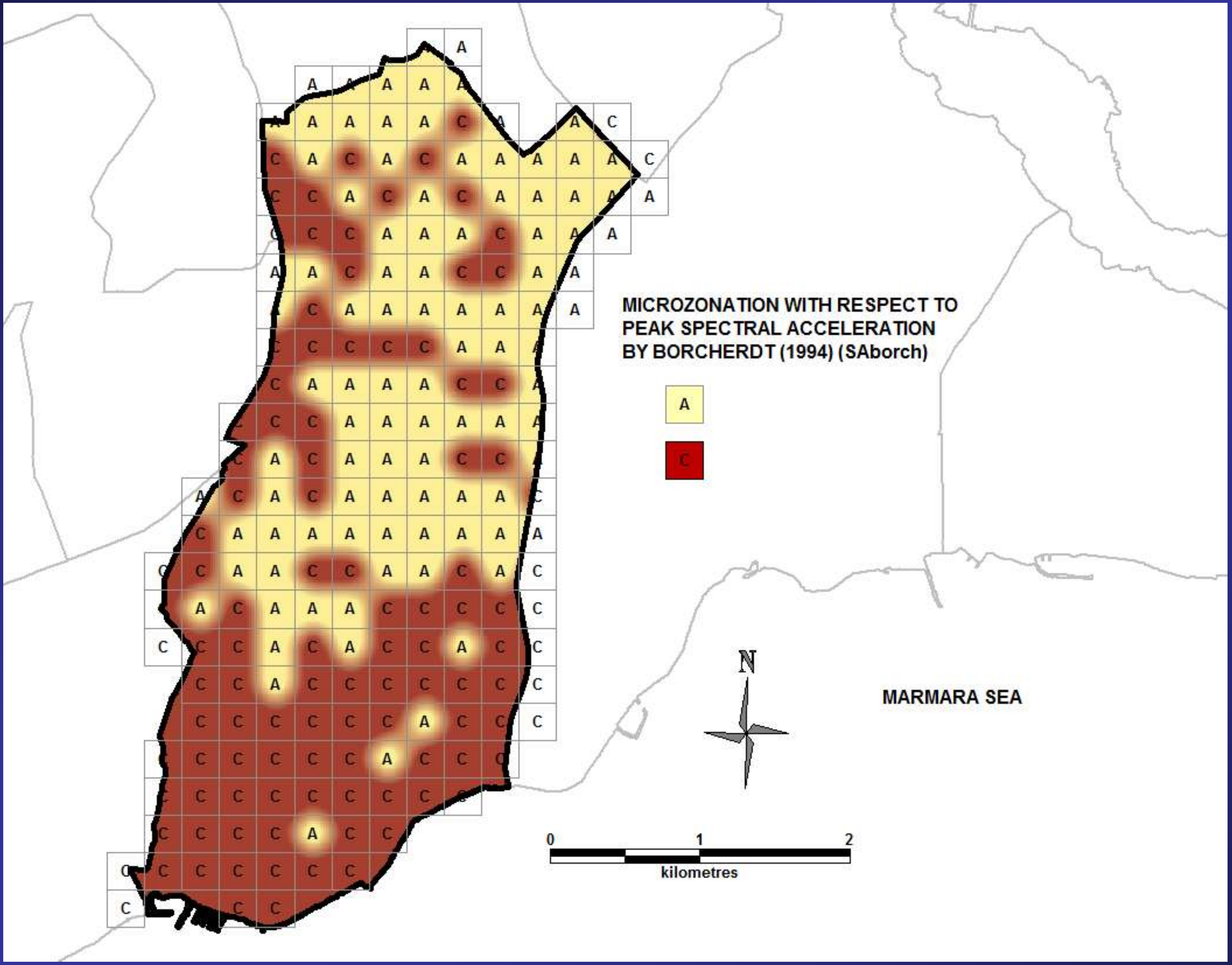


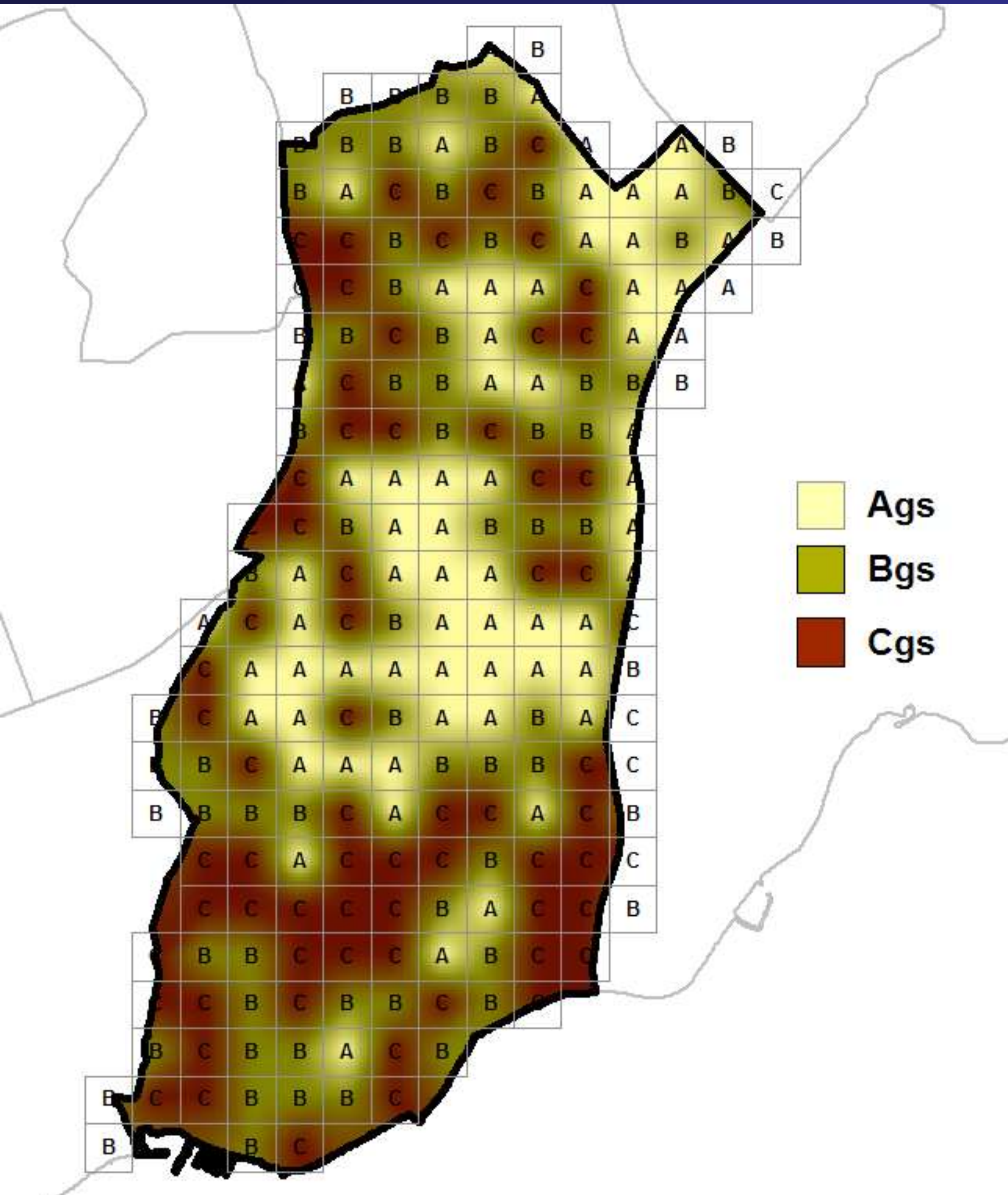
Zemin Davranış Analizleri İle Hesaplanmış En Büyük İvmeler



ZEYTİNBURNU MUNICIPALITY
MICROZONATION WITH RESPECT TO
EQUIVALENT SHEAR WAVE VELOCITY
200 m/s > Vseq => 250 m/s
250 m/s > Vseq => 300 m/s
300 m/s > Vseq => 350 m/s
350 m/s > Vseq => 400 m/s
400 m/s > Vseq => 450 m/s
450 m/s > Vseq => 500 m/s
N
0
0.5
1
kilometers

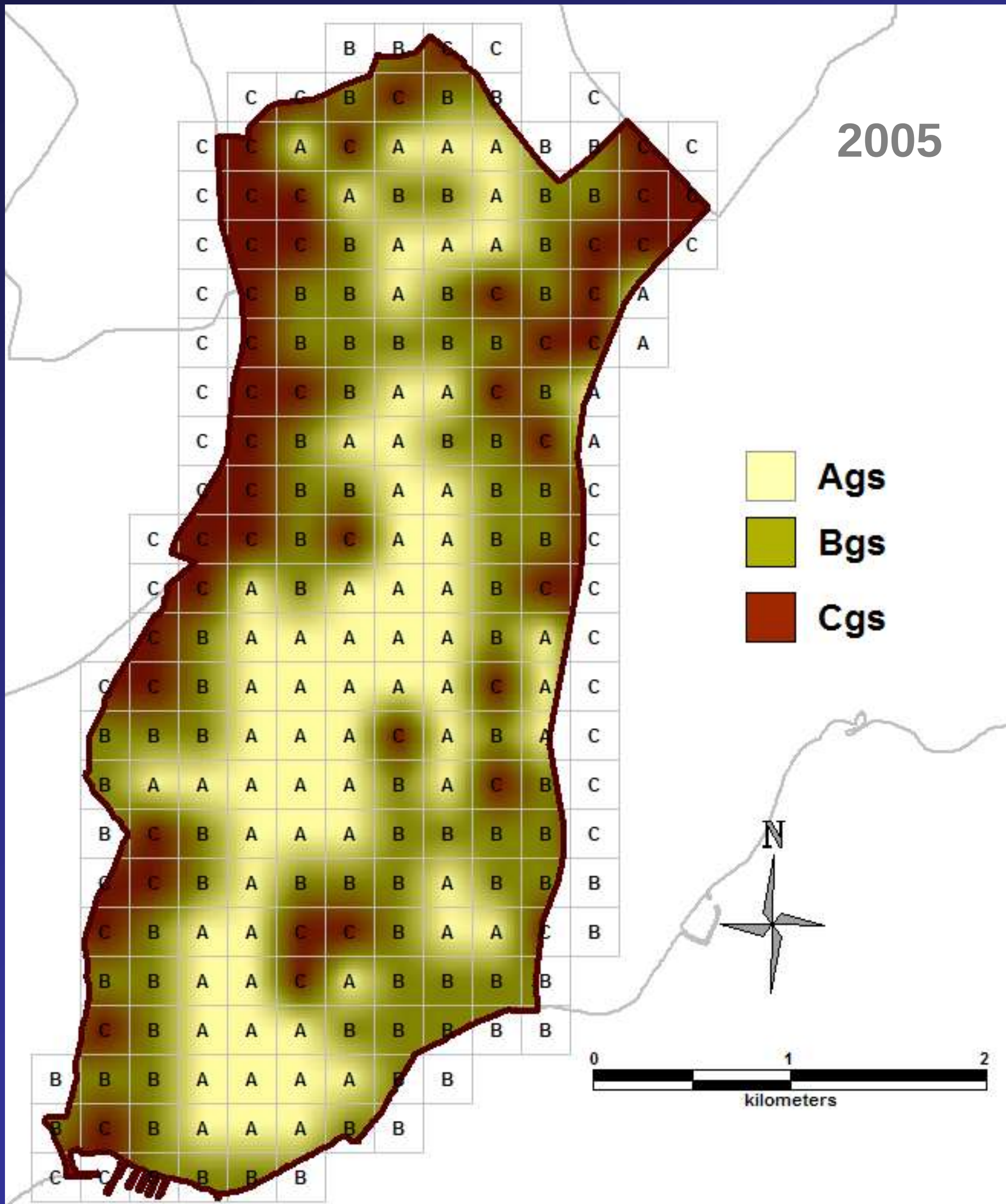

MICROZONATION WITH RESPECTTO
AVERAGE SPECTRAL ACCELERATION
BY SITE RESPONSE ANALYSES (SAavg)
A
B
C
N
MARMARA SEA
0
1
2
kilometres


MICROZONATION WITH RESPECT TO
PEAK SPECTRAL ACCELERATION
BY BORCHERDT (1994) (SAborch)
A
C
N
MARMARA SEA
0
1
2
kilometres



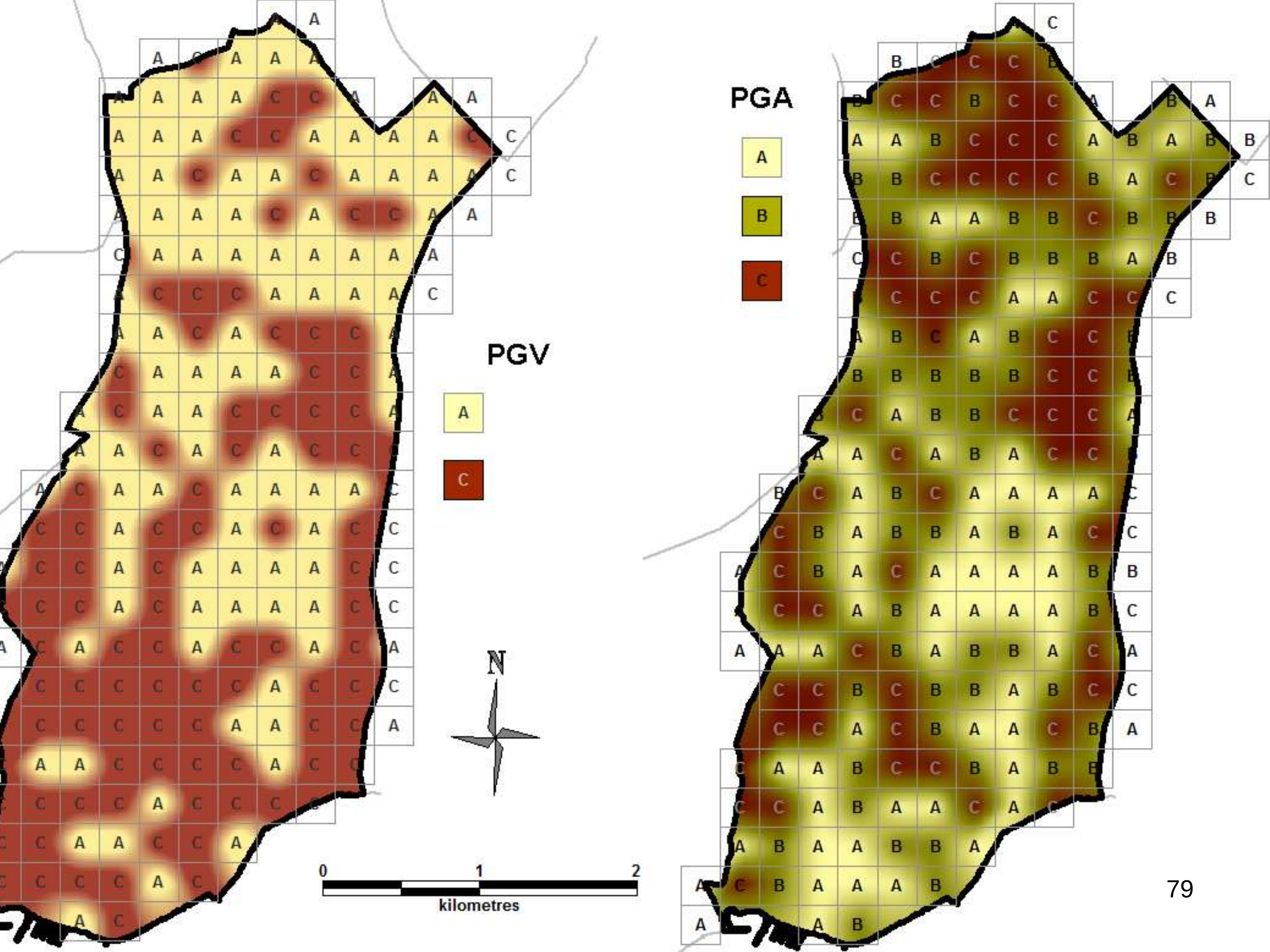
MICROZONATION WITH RESPECT TO GROUND SHAKING INTENSITY

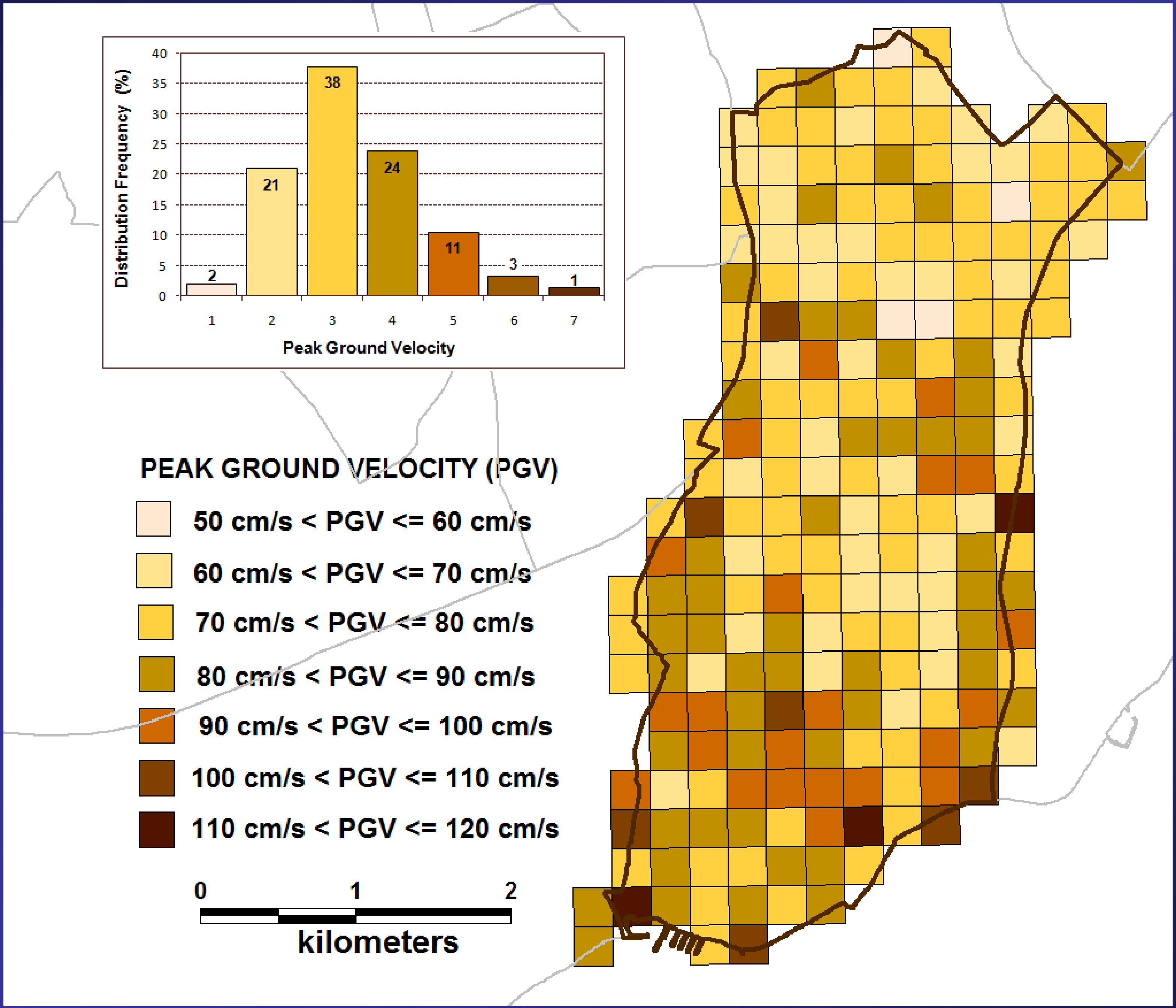
Borings in all cells and site response analysis based on 28 real (hazard compatible) acceleration time histories

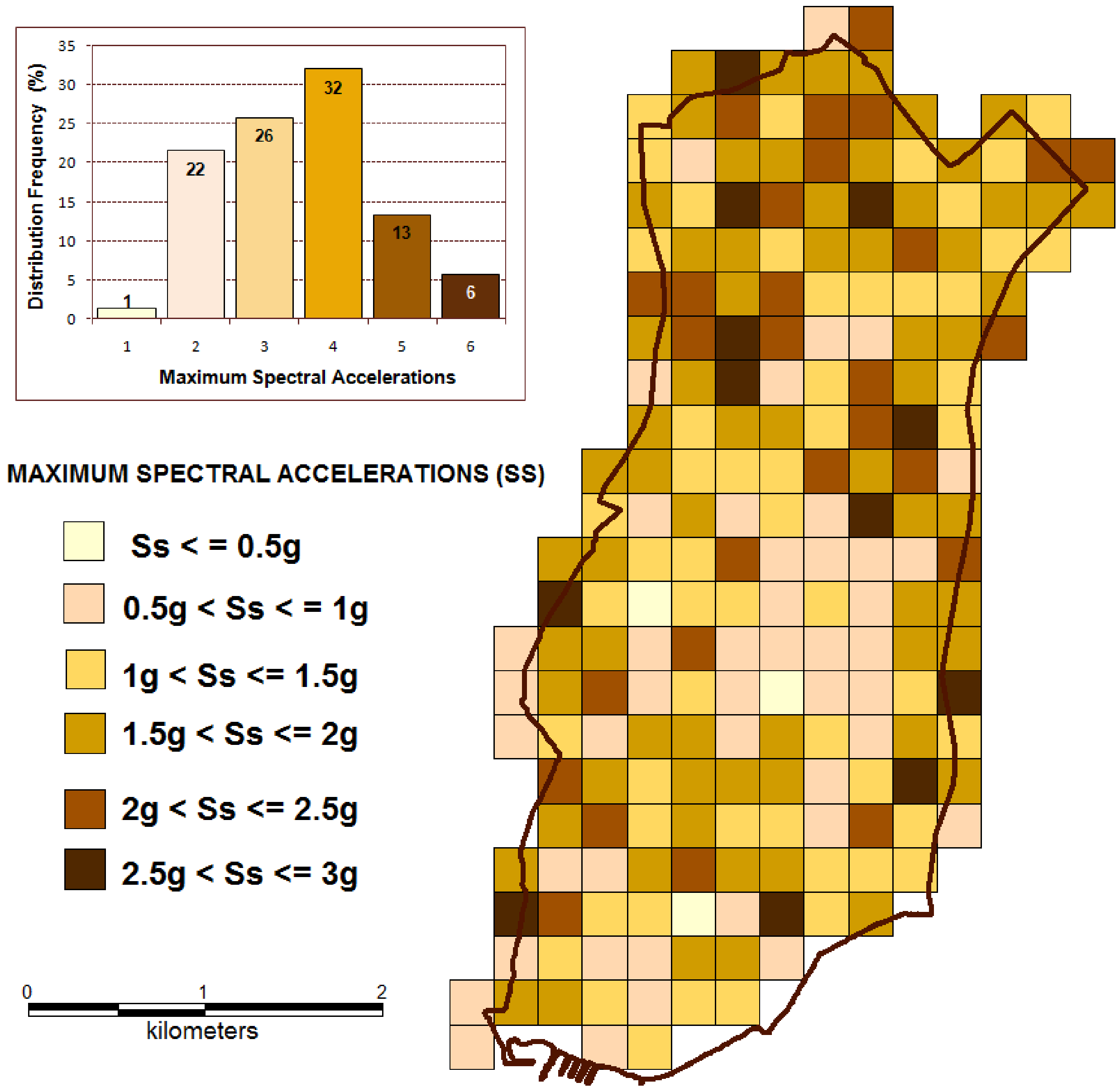


MICROZONATION WITH RESPECT TO GROUND SHAKING INTENSITY

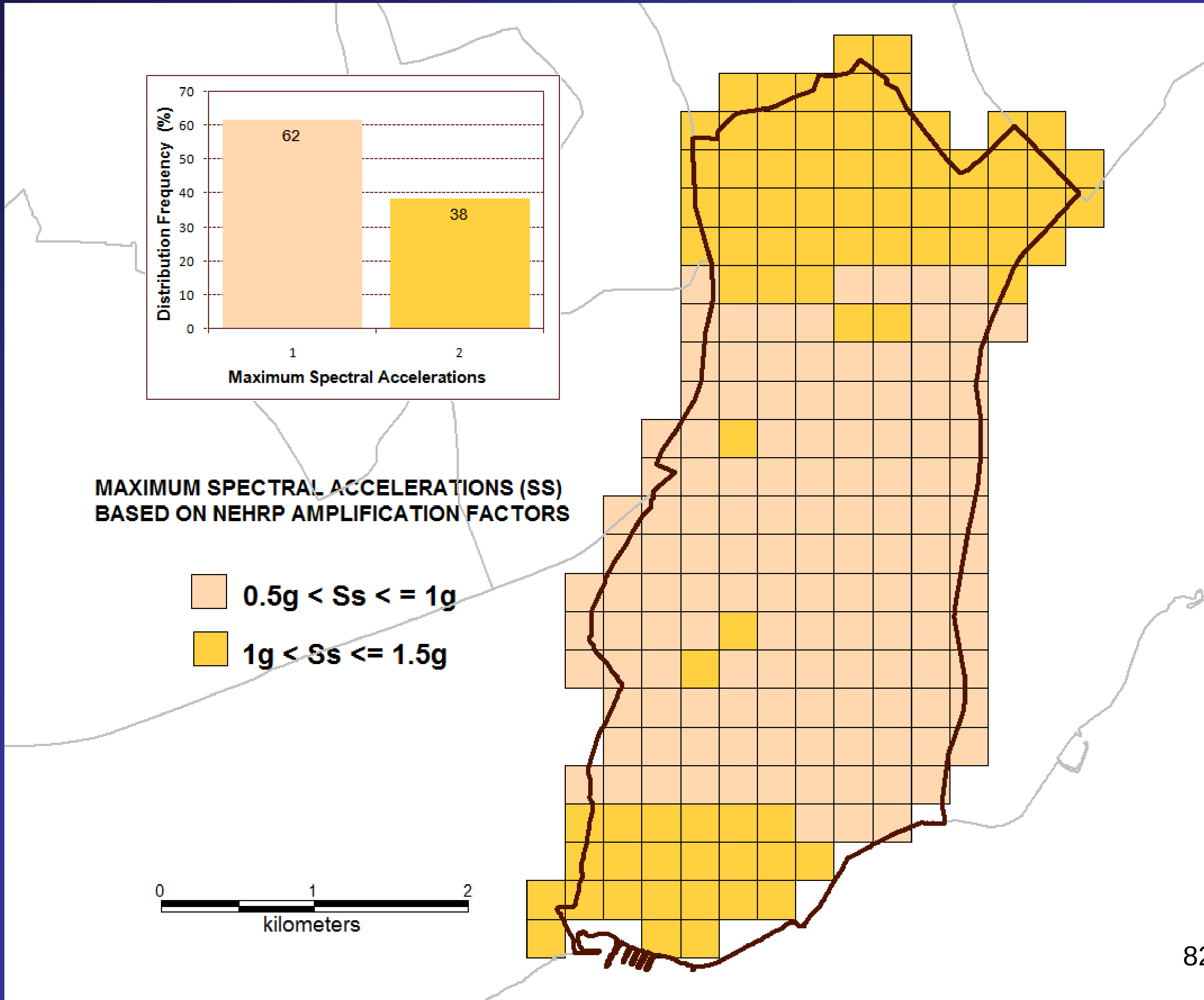
Limited number of borings and site response analysis based on 3 simulated acceleration time histories

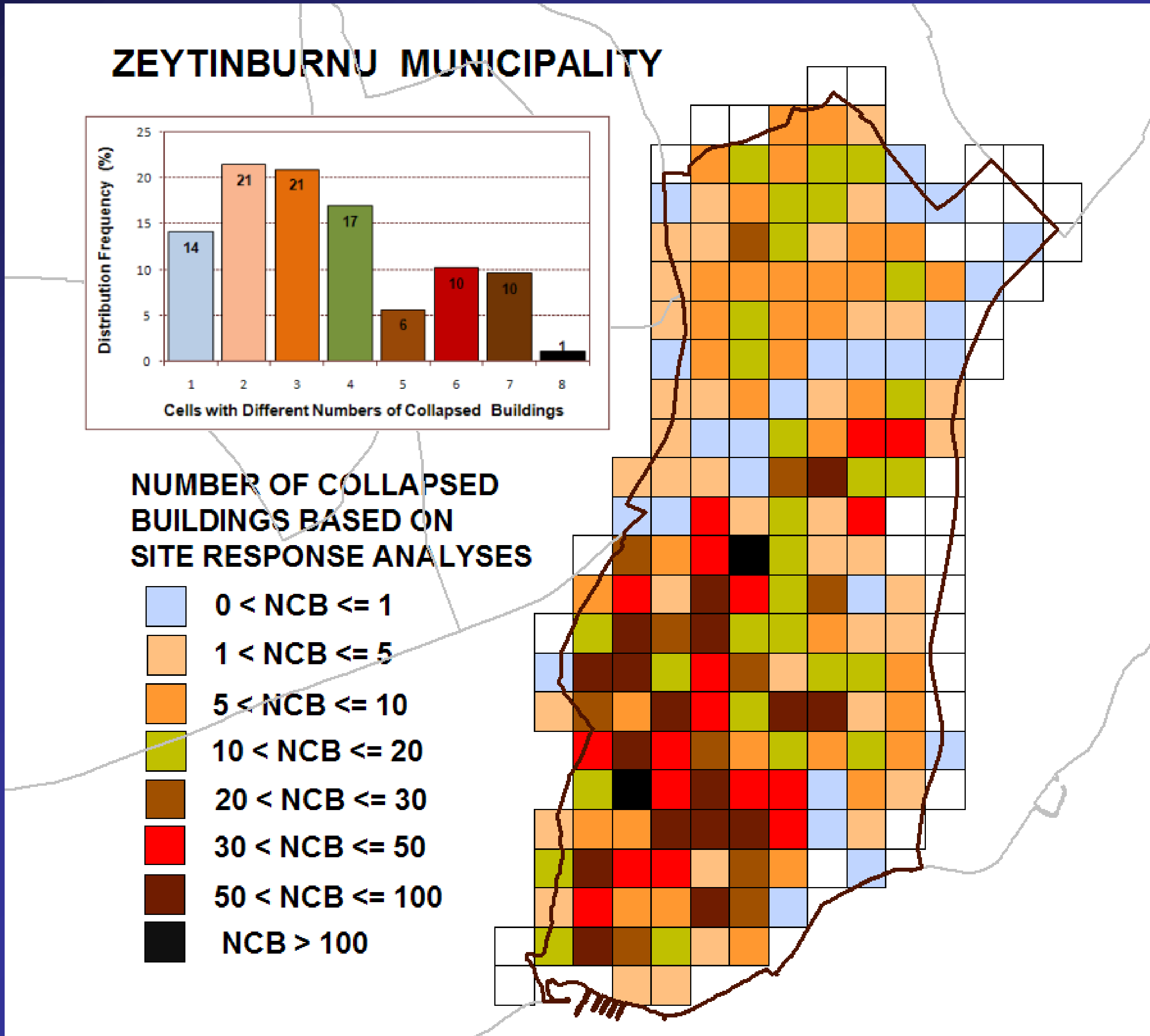

PGV
A
C
PGA
A
B
C
N
0
1
2
kilometres


Distribution Frequency (%)
0
5
10
15
20
25
30
35
40
2
21
38
24
11
3
1
1
2
3
4
5
6
7
Peak Ground Velocity
PEAK GROUND VELOCITY (PGV)
50 cm/s < PGV <= 60 cm/s
60 cm/s < PGV <= 70 cm/s
70 cm/s < PGV <= 80 cm/s
80 cm/s < PGV <= 90 cm/s
90 cm/s < PGV <= 100 cm/s
100 cm/s < PGV <= 110 cm/s
110 cm/s < PGV <= 120 cm/s
0
1
2
kilometers

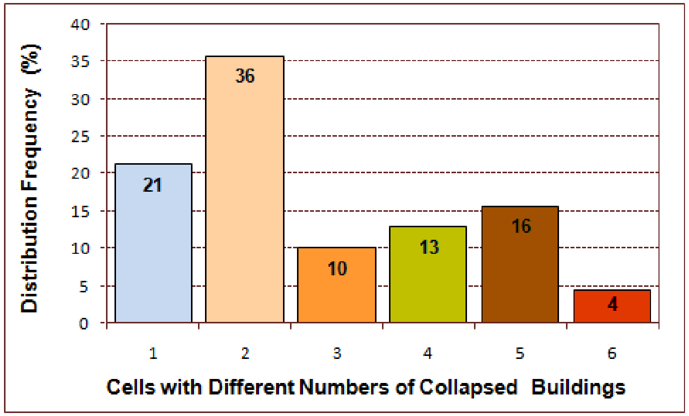


35
30
25
20
15
10
5
0
Distribution Frequency (%)
1
22
26
32
13
6
1
2
3
4
5
6
Maximum Spectral Accelerations
MAXIMUM SPECTRAL ACCELERATIONS (SS)
Ss < = 0.5g
0.5g < Ss < = 1g
1g < Ss <= 1.5g
1.5g < Ss <= 2g
2g < Ss <= 2.5g
2.5g < Ss <= 3g
0
1
2
kilometers


MAXIMUM SPECTRAL ACCELERATIONS (SS)
BASED ON NEHRP AMPLIFICATION FACTORS
Distribution Frequency (%)
70
60
50
40
30
20
10
0
62
38
1
2
Maximum Spectral Accelerations
0.5g < Ss < = 1g
1g < Ss <= 1.5g
0
1
2
kilometers


ZEYTINBURNU MUNICIPALITY
Distribution Frequency (%)
25
20
15
10
5
0
14
21
21
17
6
10
10
1
1
2
3
4
5
6
7
8
Cells with Different Numbers of Collapsed Buildings
NUMBER OF COLLAPSED BUILDINGS BASED ON SITE RESPONSE ANALYSES
0 < NCB <= 1
1 < NCB <= 5
5 < NCB <= 10
10 < NCB <= 20
20 < NCB <= 30
30 < NCB <= 50
50 < NCB <= 100
NCB > 100

ZEYTINBURNU MUNICIPALITY



NUMBER OF COLLAPSED BUILDINGS BASED ON NEHRP

- 0 < NCB <= 1
- 1 < NCB <= 5
- 5 < NCB <= 10
- 10 < NCB <= 20
- 20 < NCB <= 30
- 30 < NCB <= 50