4.4.5. Slope Stability

The following three methods are indicated as the slope stability estimation methods in the "Manual for Zonation on Seismic Geotechnical Hazards" by TC4, ISSMFE (1993).

1) Method Grade 1: simple and synthetic analysis by using seismic intensity or magnitude without information of geological condition
2) Method Grade 2: rather detail analysis with geological information by using site reconnaissance result or existing geological information
3) Method Grade 3: detail analysis by using geological investigation result and numerical analysis

It is considered that Method Grade 3 is appropriate in quality and content, compared to the other estimation items of the Study. This method requires information on detailed shape of slope, load conditions and strength of soils. Slopes in the Study Area are categorised as follows:

<u>Large-scale slope</u>

- The northern edge of the Study Area is at the foot of the Alborz Mountains and steep slopes are distributed throughout.
- The northern half of the Study Area consists of alluvial fans. A gentle slope with the same gradient is prevalent in the area.
- A deep valley is distributed alongside a major river in the northern part of the Study Area.
- Elevation data from the Beautification Organisation is available. It is possible to determine the slope gradient within every 50-mesh unit. Statistical treatment is applicable.

<u>Small-scale slope</u>

- Cut slopes are distributed alongside major highways in the northern part of the Study Area. Most of these have no slope protection and tall buildings are constructed on top of the slopes.
- Information on location of slope, shape of slope and soil strength is not available.

Considering the above condition, only large-scale slopes were examined in the Study. For cases of small-scale slopes, it is recommended that the stability of each slope be analysed.

The outline of the evaluation method is described below and shown in Figure 4.4.20.

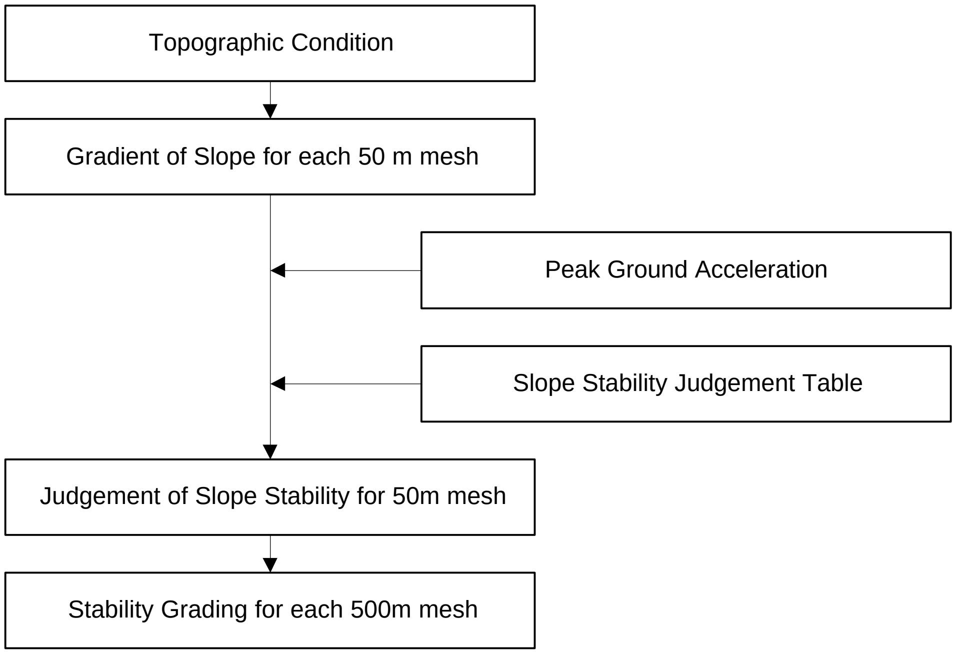
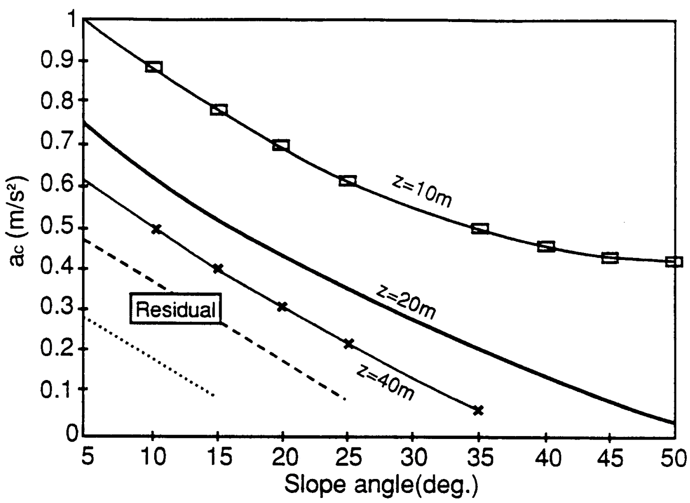


Figure 4.4.20 Flowchart of Slope Failure Evaluation

(1) Method of the Slope Failure Evaluation

Komak Panah and Hefezi Moghaddas (1992) studied slope failure caused by the 1990 Majil Earthquake in Iran using the Grade 3 Method and compiled the slope stability chart shown in Figure 4.4.21.



z: depth from ground surface to sliding surface
a_c: peak ground acceleration (m/sec^2)

Figure 4.4.21 Judgement of Slope Stability, Panah et al. (1993)

This chart indicates the relationship between stable slope gradient and peak ground acceleration. The studied slopes are distributed in the western Alborz Mountains, which belong to the same mountain range of the Study Area.

In this study, the slope gradient for each 50-m mesh was calculated first. Then the slope stability of each mesh was judged based upon the chart, taking into account the peak ground acceleration value for the mesh. The z = 20 m curve in the chart was used in this Study. Panah et al.(1993) concluded that the result of the slope analysis using the z = 20 m curve showed good agreement with actual failures. It is considered that ground condition of the Study Area is similar to the Manjil Area.

In stability judgement, a score F = 0 for a stable mesh or F = 1 for an unstable mesh was given. Based on this judgement, the stability ranking for each 500 m mesh was estimated by using the following formula:

$$Score = \sum_{i=1}^{100} F_i$$

Rank 3	Score 60-100	60-100% of the area is unstable
Rank 2	Score 30-60	30-60% of the area is unstable
Rank 1	Score 0 – 30	0-30% of the area is unstable
Rank 0	Score 0	All of the area is stable

(2) Slope Stability

The current condition of the slopes is shown in Figure 4.4.22. The result of the slope stability estimation is shown in Figure 4.4.23 to Figure 4.4.26. Characteristics of the results are as follows:

Ray Fault Model, Mosha Fault Model, Floating Model

Most of the meshes are judged as stable.

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, but many houses exist in the Rudkahneh-ye-Suleqan Valley. Raw water transmission tunnels are planed to be constructed in the high-risk area. Furthermore, slopes located behind the oil tank are judged as high-risk.

The analysis shows that there is not very much slope-failure risk in the hill, terrace and fan areas, which are mainly used for residential and commercial purposes now. However, the analysis in the Study is limited to large-scale slope failures and landslides. It should be noted that many small-scale slope failures and stone failures will occur during an earthquake. In addition, cut slopes will also be unstable during an earthquake.

It is recommended that a detailed geological survey and numerical analysis for residential areas and important facilities found on slopes of high risk be conducted. Based on these results, slope protection measures should be executed for critical and unstable slopes. Further, an integrated and detailed slope study should be conducted for the entire city of Tehran. Based on the result of this study, regulation for land-use and standards for slope protection shall be established.

Figure 4.4.22

Slope Gradient

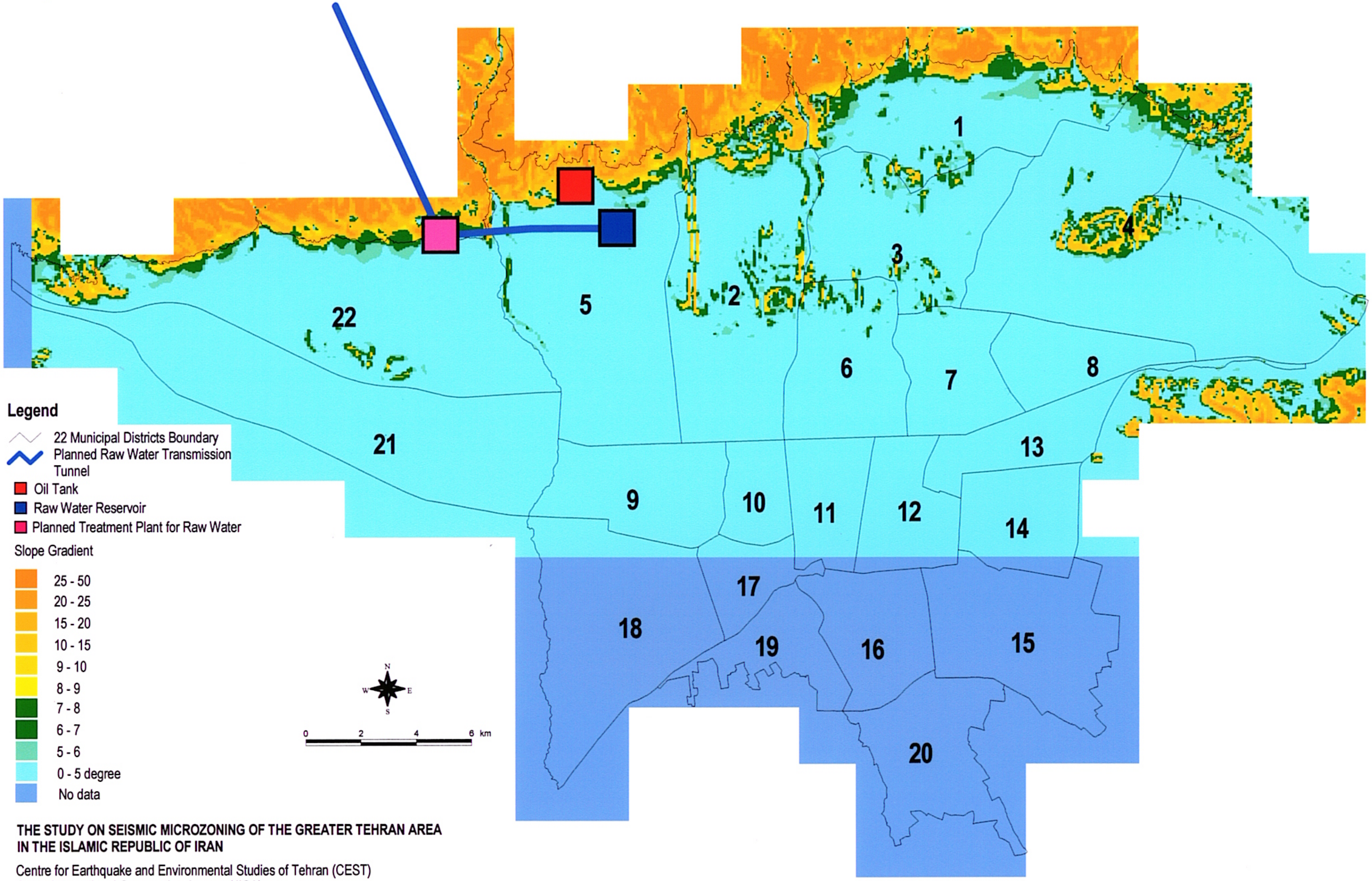


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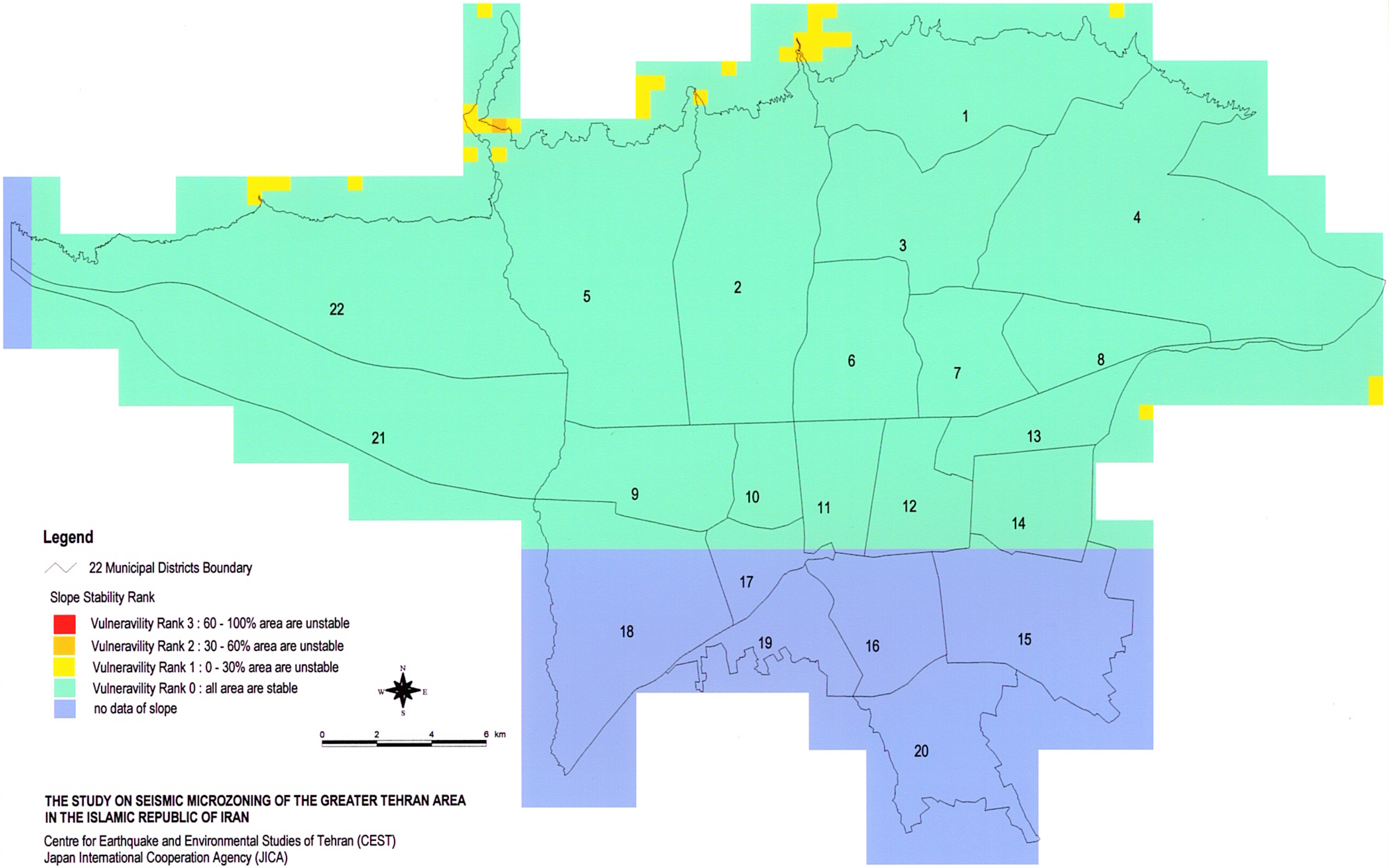
Figure 4.4.23

Slope Stability (Ray Fault model)



Legend

22 Municipal Districts Boundary

Slope Stability Rank

- Vulneravility Rank 3 : 60 - 100% area are unstable
- Vulneravility Rank 2 : 30 - 60% area are unstable
- Vulneravility Rank 1 : 0 - 30% area are unstable
- Vulneravility Rank 0 : all area are stable
- no data of slope

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