UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 23 1979

MEMORANDUM FOR: Robert B. Minogue, Director
Office of Standards Development

Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 52
EARTHQUAKE INTENSITY SCALE

Introduction

This memorandum transmits the results of completed research on the systematic evaluation of the macroseismic data file compiled for over half a century by the U.S. Coast and Geodetic Survey and its successor organizations. A new seismic intensity scale was formed by revision of the Modified Mercalli Intensity Scale of 1931. The study was performed over a period of two years at the Environmental Data Service, NOAA, in Boulder, Colorado, for the Office of Nuclear Regulatory Research (RES). The results have been published as NOAA Technical Memorandum, EDS NGSDC 4, "Reevaluation of the Modified Mercalli Intensity Scale for Earthquakes, Using Distance as a Determinant." A paper based on this report is scheduled for publication in the Bulletin of the Seismological Society of America in April.

The purpose of the study was to relate earthquake intensity to the energy released and its attenuation with distance. This was done in order to provide a more uniform scale related more logically to the physical parameters of acceleration, velocity, displacement and spectral content.

Discussion

The determination of seismic risk at specific sites is based almost exclusively on historical seismicity, which is usually evaluated in terms of intensity. This is the basic parameter upon which the estimates of spectral input and recurrence depend, and which is translated eventually into engineering and design criteria.

The intensity (MM) scale now in use was based on limited data derived from the study of several selected earthquakes and represented a logical, although untested, progression of severity as evidenced by the reaction of the populace and damage to man-made and geologic structures. In recent years, it has become increasingly common practice to use MM intensities as mathematical statements equating them to acceleration, magnitude and other physical quantities. Since they were not intended for this type of analysis, any attempt to use intensities in this way is subject to many uncertainties. However, since the period of time for which instrumental data on seismic events are available is extremely short, earthquake intensity will have to be used for some years to come to augment seismographic information and to extend the time base for seismicity analyses.

Unfortunately, all intensity scales have serious inherent limitations stemming from the methods of collecting the data, the lack of a systematic approach to evaluation, and the misapplication of the results. The MM scale, which is used also as a basis for the present study, illustrates some of these problems. It contains many phrases subject to more than one interpretation, and depends for gradation of severity on subjective and ill-defined adjectives such as (felt by) few, some, many, most, or (damage) slight, moderate, severe. The method of collecting data has become more systematic and is still evolving, but past reports are often incomplete and sometimes exaggerated and unreliable.

The evaluation process presents the most problems of all. It involves personal bias, variations of interpretation of specific reports, and selective discounting of reports as exaggerated, spurious, or nontypical. The misuse of the resulting evaluations most often derives from necessity. They are accepted uncritically as the best data available and are used in further studies relating to recurrence rates, magnitude, accelerations, and so forth. This tends to perpetuate and even to increase the errors.

While this study does not eliminate the basic shortcomings of intensity as a parameter, it does present a more consistent and ordered approach to the determination of intensity as a measure of energy released.

The basic assumptions were made that the maximum intensity of an earthquake is proportional to the total energy released by the shock, and that under average geologic conditions, this energy attenuates regularly and is reflected in a regularly diminishing intensity as the distance from the source increases. Given these premises, the behavior of each elemental effect report was correlated with distance and maximum

intensity to determine its relative position in the new scale. This method has the advantage of using past intensity assignments, revised to the new scale, so historical data are not lost. Over 250,000 elemental reports have been selected, codified, and recorded on tape for statistical study. Each phrase in the MM Scale that describes an individual effect, such as "felt by many," "frightened few," "damage severe," and others, is examined in terms of the independent parameter--attenuation with distance. Each phrase is regarded as a scale element, and a curve based on 46 years of data is developed for it. This produces a complete population of curves ranging from Intensity I to XII. The elements are then grouped according to divisions indicated by a model constructed for the purpose. The model is based on the overall attenuation indicated by the unrevised data and constrained by key elements which are widely accepted as representative of their respective intensity levels. This assures that the elements that have the same attenuation with distance are placed in their proper relative position in the scale; thus, overlapping and other misassignments are minimized.

Results

The data base in magnetic tape form, based on the years 1927 to 1974, with either old or revised intensities, is available from the Environmental Data Service in Boulder. In the final evaluation, 46 percent of the elements remain at the same intensity, and only 12 percent are changed by more than one intensity. The number of upward and downward revisions of individual scale elements is approximately the same. More than 40 elements that have been reported often but are not covered in the MM Scale have been analyzed and added. Also, each element has been assigned a significance factor based on its conformity to other elements at the pertinent intensity level and the number of times it had been reported. In addition to reassignment of the elements, the grammar of the scale has been made consistent, and each element is described as unambiguously as possible. NOAA Technical Memorandum EDS NGSDC-4 entitled, "Reevaluation of the Modified Mercalli Intensity Scale for Earthquakes Using Distance as a Determinant," describes the analysis in detail, gives the specific data descriptions and basic calculations, and presents the complete revised scale. The new scale should be applied literally and should reduce the scatter that results when intensity values are used as mathematical or physical entities. It will facilitate the objective assignment of intensities by analysts or computers.

Recommendations

It is suggested that the Nuclear Regulatory Commission make a formal recommendation to the U.S. Geological Survey that a new intensity scale based on this or a similar analysis be promulgated as an official standard. The new scale should permit a transition from the MM Intensity Scale and make full use of the extensive data base already available. This transition should be reflected in subsequent revisions of official catalogues such as the "Earthquake History of the United States."

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