ZONING FOR SURFACE FAULT RUPTURE
MANAGUA, NICARAGUA

by:

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SYNOPSIS

Damage accompanying the Managua, Nicaragua, earthquake of December 23, 1972, demonstrated that surface fault rupture is a significant hazard there and must be considered in seismic zoning. This paper describes the approach to the development of a fault hazard zone map and a planning matrix used to reduce the impact of surface faulting in Managua. The study was performed by a multidisciplinary team including Nicaraguan Government architects and planners, and private geotechnical consultants. The method could be adapted and applied to other areas where surface faulting is expected to occur.

INTRODUCTION

Preliminary geologic studies (1, 2, 3, 4) indicated that Managua has a very high density of active faults. The Nicaraguan Government was confronted with the decision to move the capital city to a fault-free location or to rebuild between the hazardous fault zones (5). Even though damage to Managua was severe, most of the city's infrastructure, including thousands of homes and most industrial buildings survived the earthquake. Therefore, it was evident that the combined economic, social, and political impact would preclude relocating the city. The Nicaraguan Government decided to rebuild in the same area, using zoning that would mitigate the hazards of surface faulting.

The initial scope of geotechnical evaluations called for broad geological, seismological, and earthquake engineering studies to support regional planning for reconstructing and expanding the city. Discussions in this paper will deal principally with that part of the work that led to the preliminary surface fault hazard zone map that was released for public use in 1975 (6).

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PREPARATION OF THE PRELIMINARY FAULT HAZARD MAP AND PLANNING MATRIX

The study area was delineated by Nicaragua's Vice Ministry of Urban Planning (VMPU). The National Geographic Institute made a series of planning maps consisting of topographic contours and cultural features printed over a photomosaic at a scale of 1:10,000, to serve as a base for further geotechnical and planning studies.

A preliminary fault and lineament map was compiled by Woodward-Clyde Consultants (WCC) geologists from existing maps, geologic literature, geologic interpretation of aerial photographs, some field reconnaissance, and limited exploratory trenching (7). Known faults and linear features observed on aerial photographs and believed to be related to faulting were plotted on the map. The known faults and linear features were ranked in four categories based on the available data, topographic expression, and judgement of the team of geologists.

VMPU made a preliminary evaluation of the structures usually built in Managua. They ranked them in accordance with their function, susceptibility to major damage due to surface fault rupture, and replacement cost. The amount of anticipated fault displacement or warping was considered when determining the types of structures that may be built in certain of the less hazardous fault zones.

Structures and fault hazards were classified and matched on a planning matrix (Table 1). This work was accomplished in a working meeting attended by architects and structural engineers from VMPU, geologists from WCC, and an independent Consulting and Review Board.

The preliminary fault and lineament map was modified to produce the preliminary fault hazard map (Figure 1). The fault hazards were divided into five categories; two classifications of known faults, two classifications of postulated faults, and areas where there was no apparent evidence of a hazard due to faulting. Used together, the hazard map and the planning matrix constitute a basis for decisions regarding land-use planning, siting, and determining where additional geologic study should be a prerequisite to construction.

EVALUATION OF THE FAULT HAZARD ZONES AND PLANNING MATRIX

The planning matrix and the preliminary fault hazard map were released to the public by VMPU in 1975 (6). At that time, WCC had completed more than 16 km of exploratory trenches for fault hazard investigations in 28 separate property developments within the mapped area. The published map was reproduced at a larger scale and trench locations and trenching data acquired by WCC were plotted on it to evaluate the reliability and accuracy of the preliminary map and provide a basis for modifying it. The results were as follows:

1. Known Major Fault Zone (Red): 5 zones investigated; all contain faults; more than half of the area presents a hazard due to faulting.

2. Known Minor Fault Zone (Orange): 7 zones investigated; all contain faults; more than half of the area presents a hazard due to faulting.

3. Postulated Fault Zone (Blue): 10 zones investigated; 9 contain faults; the amount of hazardous area due to faulting varies from zone to zone.

4. Possible Faults, Area of Concern (Green): 21 zones investigated; 10 faults found; less than one-fourth of the area presents a hazard due to faulting.

5. Areas of No Evidence of a Hazard Due to Faulting (White): 33 areas investigated; 5 minor faults found; less than 0.3 percent of the area presents a hazard due to faulting.

CONCLUSIONS

Detailed geologic studies of 16 km of trenches indicated that the initial draft of the preliminary fault hazard map had a high degree of reliability for land-use planning. This high degree of reliability emphasizes the value of skilled geologic photointerpretation to recognize initially the geomorphic features characteristic of active faulting. The preliminary fault hazard map and planning matrix were adequate for the initial phases of land-use planning and these methods could be applied to other areas where there are hazards due to surface faulting.

RECOMMENDATIONS FOR APPLICATION TO OTHER AREAS

The work described in this paper should be used only as a guide; the classification of linear features should reflect the characteristics and geomorphological expression of the local faults. The classification of structures and selection of surface fault hazard zones should consider local social values, economics, structural design, and construction practices. One of the most formidable problems in hazard zoning is making decisions concerning the base risk or acceptable risk the local population is willing to assume. The regulatory bodies, business and community leaders, and local engineering profession should play a major part in establishing the base risks for their own society.

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TABLE 1

PLANNING MATRIX
GUIDE TO MINIMIZE THE RISKS OF SURFACE FAULTS

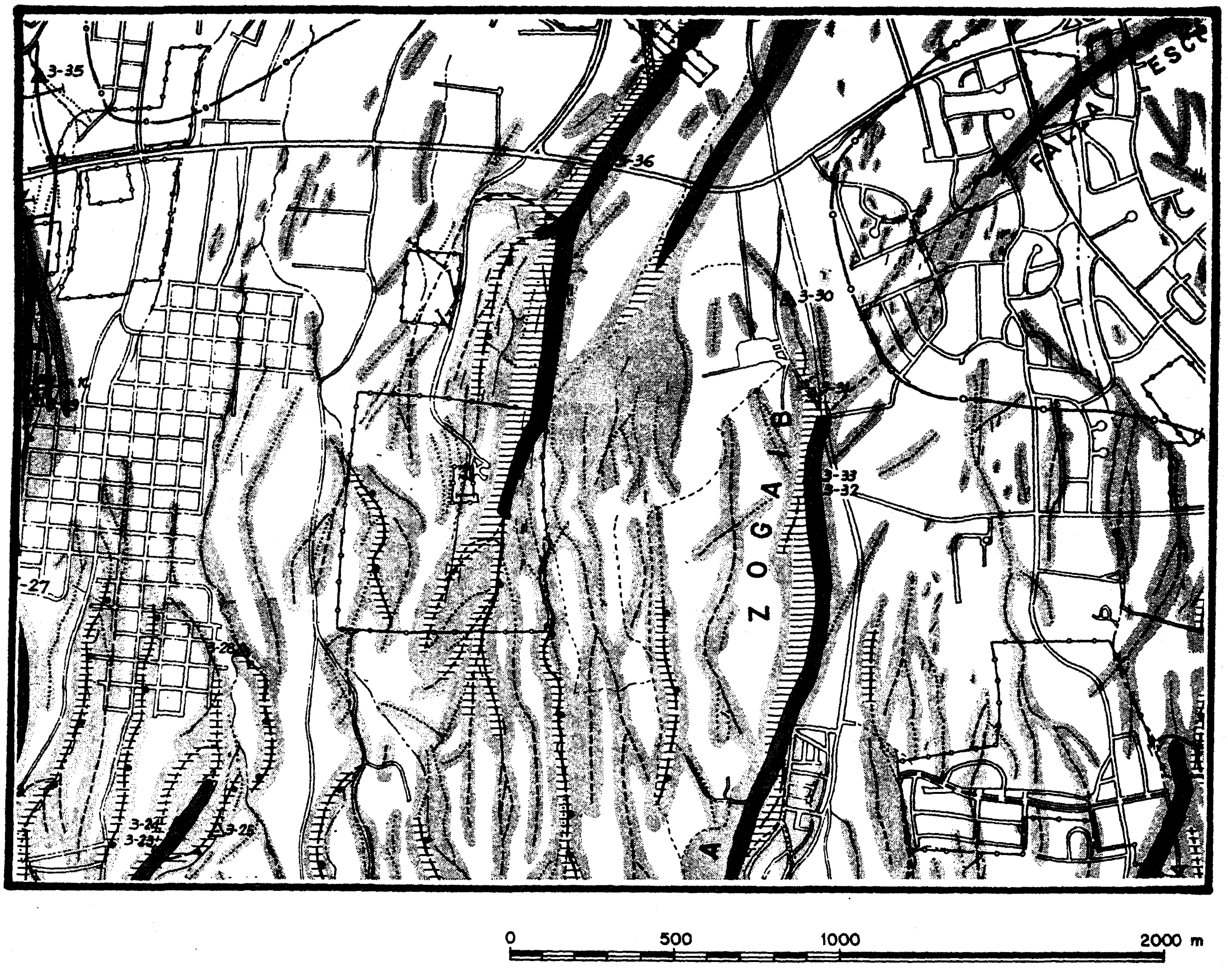
USES	KNOWN ACTIVE FAULTS		PROBABLE ACTIVE FAULTS	DOUBTFUL AREAS*	NO EVIDENCE
	MAJOR FAULT RED	MINOR FAULT ORANGE	MAJOR TRACE BLUE	MINOR TRACE GREEN	WHITE
1. Hospitals, electric power stations, water plants and pumping stations, fire departments, medicine and drug centers, overpass roadways and buildings with more than eight stories which height is at least 1.5 times larger than minimum plan dimension	Exclude	Exclude	Exclude	N	N
1A Underground public utilities, fire mains, main sewer lines, electric conduits	Special Design	Special Design	Special Design	N	N
2. Schools, large hotels, churches, government centers, museums, theaters, auditoriums, ammunition storage	Exclude	Exclude	N	N	N
3. Housing developments, multi-family apartment houses, small hotels, office buildings, commercial buildings (all structures in this category less than three stories high)	Exclude	Exclude	N	N or Standard A	N or Standard A
4. Open markets, one-family homes, industrial buildings, parking buildings, repair shops, inhabited warehouses	Exclude	Standard A	N	Standard B	Standard B
5. Uninhabited warehouses, animal shelters, car shelters, parking lots, wood-frame houses, special construction with light roofs not for permanent habitation, light structures for bus terminals or pick-up points	Standard B	Standard B	Standard B	Standard B	Standard B

N: Local Fault Study Needed.

Standard A: Structures designed to resist the maximum surface fault displacement, tilting, or warping. Foundations are designed as a single unit.

Standard B: Comply with Building Code.

*Doubtful Areas: **Faults may be located somewhere within the indicated area.**



EXPLANATION

PHOTOLINEAMENTS: (DOWNSLOPE DIRECTION INDICATED BY LARGE DOTS).

CLASS 1: MAJOR LINEAMENT; KNOWN FAULT CHARACTERIZED BY BROAD, STEEP SCARPS CONTAINING ANOMALOUS STREAM DRAINAGES AND ELONGATED LINEAR RIDGES PARALLEL TO MAIN SCARP.

CLASS 2: MAJOR LINEAMENT: PROBABLE FAULT, SAME FEATURES AS CLASS 1 BUT HEIGHT AND WIDTH OF SCARP ARE LESS.

CLASS 3: LINEAMENT; CHARACTERIZED BY GENERALLY CONTINUOUS LINEAR BREAKS IN SLOPE; ASYMMETRIC VALLEYS AND DRAINAGES.

CLASS 4: MINOR LINEAR FEATURE; CHARACTERIZED BY ALIGNMENTS OF DISCONTINUOUS BREAKS IN SLOPE, UNUSUALLY LINEAR SYMMETRIC VALLEYS; VEGETATION ALIGNMENTS AND TONAL CONTRASTS.

SCARP ALONG KNOWN PROBABLE FAULT, LINEAMENT, OR VOLCANIC COLLAPSE FEATURE.

HAZARD ZONE EXPLANATION

KNOWN ACTIVE FAULTS	MAJOR	RED	IDENTIFICATION BASED UPON SUBSURFACE DATA OR EXPOSURE OF OFFSET BEDS. CLASSIFICATION BASED UPON ONE OR MORE OF THE FOLLOWING CRITERIA: (1) SAN JUDAS FORMATION OFFSET MORE THAN 35 CM; (2) FONTANA LAPILLI OFFSET MORE THAN 100 CM; (3) PROMINENT TOPOGRAPHIC EXPRESSION. FAULT CONSIDERED CAPABLE OF RELATIVELY LARGE DISPLACEMENT IN FUTURE EARTHQUAKES, WITH MAXIMUM VERTICAL COMPONENT AS MUCH AS 50 CM.
KNOWN ACTIVE FAULTS	MINOR	ORANGE	IDENTIFICATION BASED UPON SUBSURFACE DATA OR EXPOSURE OF OFFSET BEDS. CLASSIFICATION BASED UPON ONE OR MORE OF THE FOLLOWING CRITERIA: (1) SAN JUDAS FORMATION OFFSET 35 CM. OR LESS; (2) FONTANA LAPILLI OFFSET 100 CM. OR LESS; (3) TOPOGRAPHIC EXPRESSION (SCARP) MINOR OR LACKING. FAULT NOT CONSIDERED CAPABLE OF LARGE DISPLACEMENT IN FUTURE EARTHQUAKES; MAXIMUM EXPECTED VERTICAL COMPONENT APPROXIMATELY 15 CM.
PROBABLE ACTIVE FAULT		BLUE	IDENTIFICATION BASED UPON STRONG PHOTOGEOLOGIC OR SURFACE EVIDENCE, WITHOUT CONFIRMATION FROM SUBSURFACE DATA. SCARPS OF KNOWN MAJOR FAULTS INCLUDED IN THIS CATEGORY.
DOUBTFUL AREAS		GREEN	FEATURE INFERRED FROM WEAK PHOTOGEOLOGIC EVIDENCE, WITHOUT CONFIRMATION FROM SUBSURFACE DATA. INCLUDES GROUPINGS OF MINOR LINEAR FEATURES OF QUESTIONABLE ORIGIN, INFERRED EXTENSIONS OF PROBABLE OR KNOWN FAULTS, MARGINS OF APPROXIMATELY LOCATED MAJOR FEATURES, AND VOLCANIC COLLAPSE FEATURES. MAY INCLUDE MAJOR FAULTS, THE TOPOGRAPHIC EXPRESSIONS OF WHICH HAVE BEEN OBLITERATED BY EROSION, DEPOSITION, CULTIVATION, OR GRADING.
NO EVIDENCE		WHITE	PHOTOGEOLOGIC OR OTHER EVIDENCE LACKING, BUT THE PRESENCE OF CONCEALED ACTIVE FAULTS CANNOT BE PRECLUDED.

Figure 1. DETAIL OF THE SURFACE FAULT HAZARD MAP, MANAGUA, NICARAGUA FAULT HAZARD STUDY