ASSESSING COMMUNITY VULNERABILITY TO HAZARDOUS MATERIALS WITH A GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

The purpose of this study is to demonstrate the utility of a risk assessment model as an anticipatory hazardous management tool using a grid-based geographic information system. Specifically, the risks resulting from the on-site storage of hazardous materials and from transport of dangerous commodities through a city has been analyzed. Santa Monica, California, was one of the first cities in the U.S. to enact a hazardous materials disclosure ordinance and, therefore, was selected for the community vulnerability analysis. A comprehensive geographic data base of Santa Monica was developed at a 100 meter resolution. In all, fifty variables were incorporated into the data base, including transportation networks in varying detail, traffic volume along major routes, ethnicity, population density, age structures, landuse, earthquake fault lines, institutions, elevation, and nine categories of hazardous material based on the United Nations classification. These data were then analyzed using the Map Analysis Package (MAPS) developed at Yale University in order to derive a series of maps depicting the contoured risk surface of the city. Based on the results of this analysis, a set of strategies designed to reduce the risk of hazardous materials incidents in Santa Monica are being formulated in conjunction with local emergency managers.

INTRODUCTION

In the United States incidents involving unintentional releases of hazardous materials into the environment occur frequently. A recent EPA study revealed, for example, that during the first five years of this decade about five accidents a day resulted in the release of toxic materials into the environment from small and large production facilities (Diamond, 1985). During the ten year period ending in 1983, there were 126,086 transportation accidents involving accidental releases of hazardous materials, an average of nearly 13,000 a year. These incidents claimed 260 lives, caused more than 700 injuries, and resulted in property and equipment damage in excess of $146 million (U.S. Department of Transportation, 1983). In addition, during the ten year period ending in 1982, there were 18,470 gas pipeline failures which claimed 340 lives and injured another 3536 people. Nearly two-thirds of these pipeline failures were attributed to damage, caused by excavations, and the remainder to corrosion, construction defects, and material failures (U.S. Department of Transportation, 1984).

The U.S. government has taken steps both to reduce substantially the occurrence of hazardous materials incidents and to minimize the potentially adverse effects on people and property when accidents actually occur (Hohenesmer, Kates and Slovic, 1983). It has been estimated, for example, that in 1979 the U.S. spent $30 billion on hazard mitigation and emergency preparedness (Hohenesmer and Kasperson, 1982). However, we tend to concur with Tierney when she states that "local emergency personnel are in the best position to know about the hazards in their own community" (1980, p. 78). Building upon this view, Johnson and Zeigler (1986) have developed a simple risk assessment model which should enable local emergency managers to determine the extent to which their communities are vulnerable to hazardous materials incidents. Their risk assessment model requires local emergency managers first, to identify the hazards present in their community and to map the hazard zone each enscribes on the landscape; second, to superimpose on the map population distribution and land-use data; and third, to use this information to develop site-specific strategies to reduce the risks and to mitigate the potential negative consequences should an accident occur. Application of the model requires local jurisdictions to enact legislation which stipulates, as part of the licensing process, that businesses disclose the kinds and amounts of hazardous materials used, generated, or stored onsite. These data serve as the basis for the development of a comprehensive hazardous materials tracking system which, in turn, is used to assess the vulnerability of population and areas within local jurisdictions to hazardous materials incidents.

In this paper, we focus on application of the hazardous materials risk assessment model developed by Johnson and Zeigler (1986), advocating the use of a geographic information system called MAP (Map Analysis Package) in the hazards identification and community vulnerability assessment process. Toward this end, we shall proceed in the following manner. First, we outline the major components of MAP and discuss the requisite data bases. Next, we apply MAP in the actual hazardous materials risk assessment, arriving at a series of maps depicting the contoured risk surface of the City of Santa Monica, one of the first municipalities to enact a hazardous materials disclosure ordinance (Staff Reporter, 1985). Finally, we identify several steps which can be taken to reduce substantially the risks of hazardous materials incidents in Santa Monica.

MAP AND THE DATABASE

Since it was decided to geocode data in raster format, the Map Analysis Package (MAP) developed at

Yale University was selected for storing and analyzing the spatial data. The four significant capabilities of this package, including reclassification, overlay, cartographic mensuration, and neighborhood analysis, proved ideal in revealing the relationship between the hazardous materials and the population and institutions at risk. Currently, a vector-based system is being developed in order to generate contour and 3-D mapping capability.

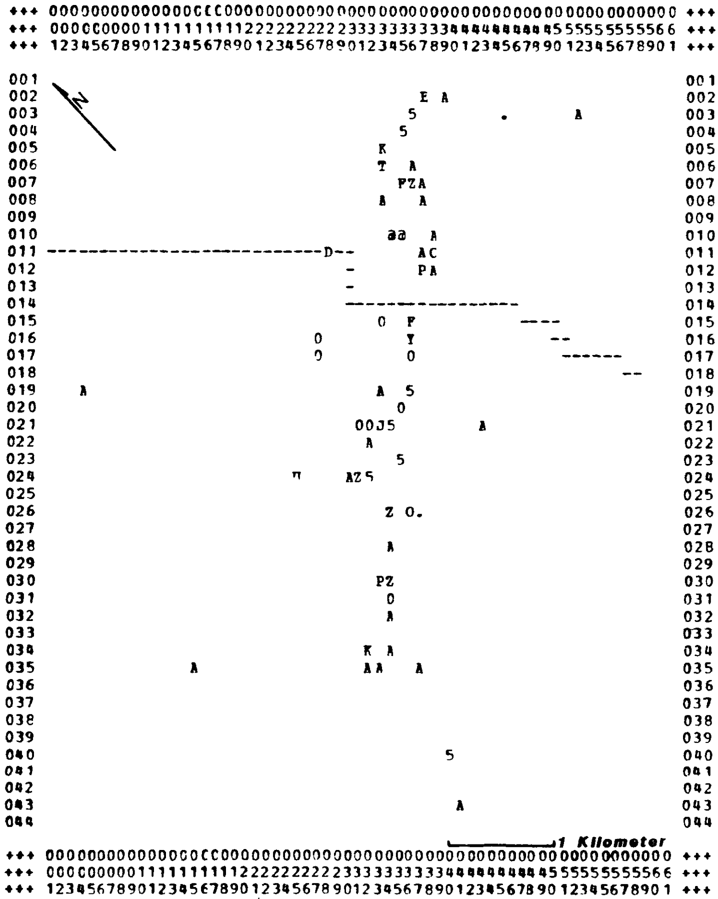
For the purposes of this study, four categories of data (demographics, landuse, physiography, and hazardous materials) were geocoded at a resolution of 100M and entered into the Map Analysis Package (MAP) (Table 1). The demographic data were taken from the 1980 Census of Population and Housing. The land use data were obtained from the Santa Monica City Planning Office. The City's Office of Emergency Preparedness provided the data pertaining to the types and location of hazardous materials.

Category	Specific variables
Demographic	population under 5, 5 to 15, 15 to 65, and over 65, language, population density, percent white, asian, black, hispanic, other minority, institutions
Land Use	land use, storm drains, transportation, freeway, roads, traffic flow
Physiography	topography, earthquakes
Hazardous Materials	explosives, gases, flammable liquids, flammable solids, oxidizers and organic peroxides, poisonous and infectious materials, radioactive materials, corrosives, miscellaneous hazardous materials, cleaners, gunshops, major oil pipes, polychlorinated Biphenyls (PCBs) and underground gas tanks

Table 1. Variables Included in the Data Base

ANALYSIS

Figure 1 depicts the distribution of hazardous materials in Santa Monica. In developing this map, we utilized the United Nations Classification of Hazardous Materials as well as Zeigler, Johnson, and Brunn's (1983) typology of technological hazards to arrive at a total of fourteen classes of hazardous materials. As the figure shows, many of the sites were found to contain only 1 or 2 types of hazardous materials, but others contained as many as five categories. For example, two sites, located in close proximity to the Santa Monica Freeway, stored flammable liquids, explosives, gases, poisons, and corrosives. In general, the



Types of Hazardous Materials

----------	1	OILPIPE	0000000000	40	FL; RA
....	5	CORROSIVE (CR)	ZZZZZZZZZZ	45	FL; PS
0000000000	10	RADIOACTIVE (RA)	0000000000	50	FL; PS; CR
5555555555	15	POISONOUS (PS)	5555555555	55	FL; PS; RA; CR
AAAAAAAAAA	20	PS; CR	EEEEEEEEEE	60	OXIDZR(OX);FL;CR
DDDDDDDDDD	23	OILPIPE; PS; CR	JJJJJJJJJJ	65	FLM SOLID(FS);FL
FFFFFFFFFF	25	PCBS(PB); PS; CR	0000C00000	70	GAS(S) (GS); FL
KKKKKKKKKK	30	FLM LIQ(FL) PS;CR	TTTTTTTTTT	75	FL; GS; PS
PPPPPPPPPP	35	FLM LIQUD(FL);CR	YYYYYYYYYY	80	EXPLSVE(EX);FLFS
			aaaaaaaaaa	85	FL;EX;GS;PS;CR

Figure 1. Types of Hazardous Materials in Santa Monica

distribution of hazardous materials parallels the Santa Monica Freeway in a northeast-southwest direction.

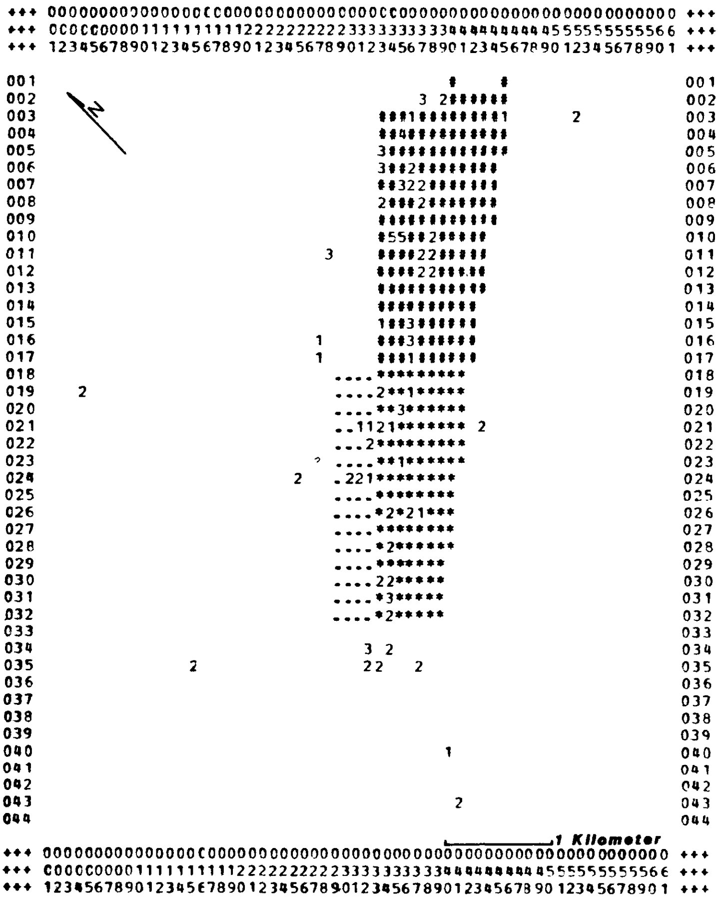
Following the methodology proposed by Johnson and Zeigler (1986), the next step in the risk assessment process was to identify both the population and the institutions at risk to hazardous materials in Santa Monica. For the purpose of determining the population at risk, the actual number of hazards per grid cell was used instead of the types of hazards in each cell, as in Figure 1. Analyses of the demographic data revealed that three subgroup of the population are especially vulnerable to hazardous materials. Minority group members in Santa Monica (i.e., Asians, Blacks, and Hispanics) reside extremely close to the "high intensity" storage of hazardous materials--basically paralleling the Santa Monica Freeway (Figure 2). Directly adjacent to this "hazardous corridor," there exists a high concentration of population under age 5 and over age 65 (Figure 3). For reasons discussed in detail elsewhere (Perry 1985), all three of these groups may very well require special attention and assistance should an incident involving the unintentional release of hazardous materials into the local environment occur.

The distribution of institutions in Santa Monica is depicted in Figure 4. To determine which of these institutions are at risk, the spatial operators existing with MAP were used to create an "at risk" buffer zone should a hazardous material incident occur. For the purpose of illustration here, we assumed that an area within 500 m of the hazard materials site would be at risk. We then superimposed on this map seven categories of institutions which can be found in Santa Monica (Figure 4). As Figure 5 shows, many of the institutions lie within the "at risk" zone as it is defined for the purpose of this analysis. Of particular note is the significant number of schools (S) and hospitals (H) which lie immediately adjacent to sites which either produce, store, or use hazardous materials.

CONCLUSION

In this paper we have attempted to demonstrate the utility of the Map Analysis Package in the identification of community vulnerability. Our analysis revealed that in Santa Monica both the resident population (mainly Blacks, Hispanics, and Asians) and the institutions (especially schools and hospitals) along the freeway are most vulnerable to the risks of hazardous materials incidents. Based on these results, local emergency planners can take several steps to (1) minimize the probability of such incidents and (2) reduce substantially the risks to public health and safety in the event of such an accident. These include:

(1) Conduct periodic inspection of local businesses to insure that hazardous materials are being handled safely.

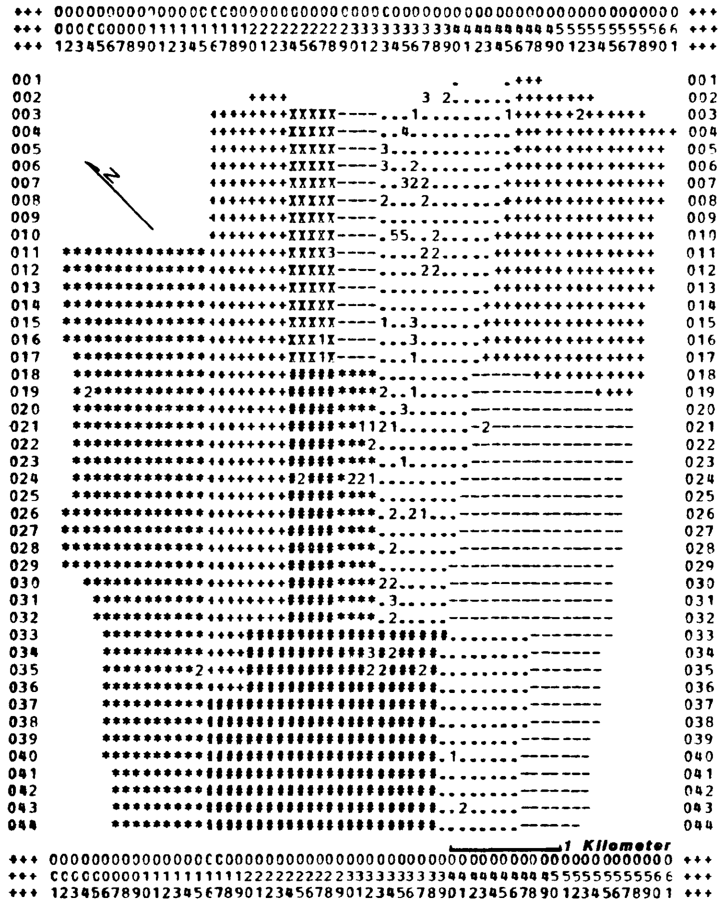


Toxic Hazards and Minority Population

HAZBINTY

	0	....	2306 CELLS	85.9%
1111111111	1	1 TOXIC HAZARD	14 CELLS	0.5%
2222222222	2	2 TOXIC HAZARDS	32 CELLS	1.2%
3333333333	3	3 TOXIC HAZARDS	10 CELLS	0.4%
4444444444	4	4 TOXIC HAZARDS	1 CELLS	0.0%
5555555555	5	5 TOXIC HAZARDS	2 CELLS	0.1%
....	31	10-15% BLACK POP	54 CELLS	2.0%
**********	32	24% BL 14% HS	108 CELLS	4.0%
##########	33	8%AS 24%BL 21%HS	157 CELLS	5.8%

Figure 2. Toxic Hazards and Minority Population



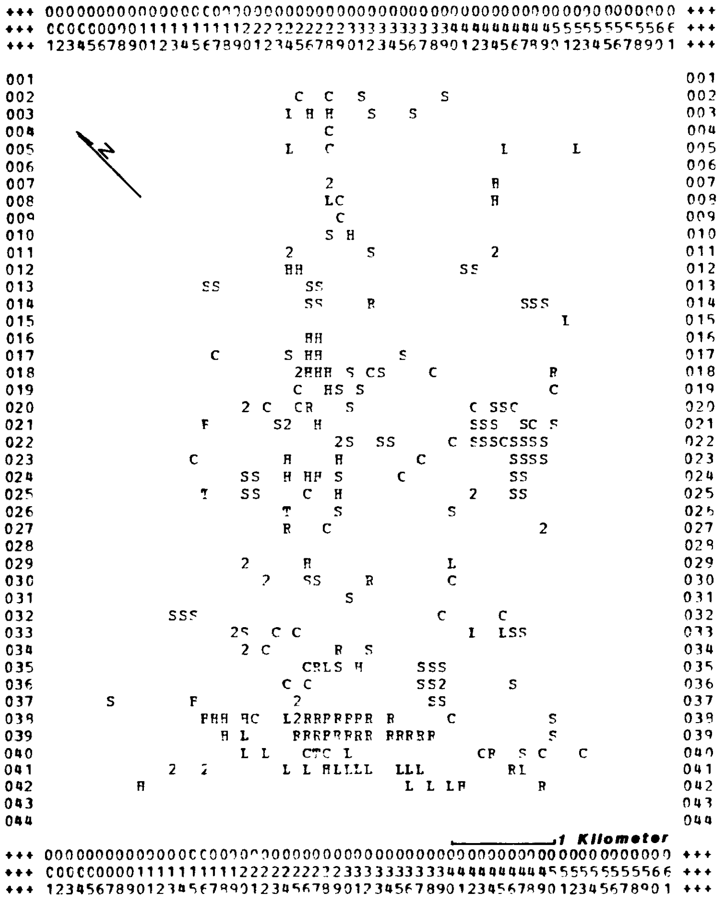
Toxic Hazards and Population Under 5/Over 65

HAZPOP

1111111111	1	1 HAZARD
2222222222	2	2 HAZARDS
3333333333	3	3 HAZARDS
4444444444	4	4 HAZARDS
5555555555	5	5 HAZARDS

	7	UND 5	OVER 65
....	8	1-2%	5-9%
....	9	8-9%	5-9%
----------	12	3-4%	10-14%
----------	13	5%	10-14%
++++++++++	16	1-2%	15-19%
++++++++++	17	3-4%	15-19%
**********	18	5%	15-19%
**********	21	1-2%	20-24%
XXXXXXXXXX	22	3-4%	20-24%
##########	26	1-2%	25-35%

Fifure 3. Toxic Hazards and Population Under 5 / Over 65



Services

SERVICES

	0	....	2451 CELLS	91.3%
CCCCCCCCCC	21	CHURCH(S)	39 CELLS	1.5%
RRRRRRRRRR	22	COMM SERVICE(S)	32 CELLS	1.2%
TTTTTTTTTT	23	MOVIE THEATRE(S)	3 CELLS	0.1%
HHHHHHHHHH	24	HOSPITAL(S)	33 CELLS	1.2%
SSSSSSSSSS	25	SCHOOL(S)	80 CELLS	3.0%
LLLLLLLLLL	26	LODGING	28 CELLS	1.0%
2222222222	27	> THN 1 OF ABOVE	18 CELLS	0.7%

Figure 4. Institutions in Santa Monica

Services and Hazardous Buffer Zone

	0	0.5 KM TO HAZARD	1234 CELLS	46.0%
....	1	0.4 KM TO HAZARD	207 CELLS	7.7%
++++++++++	2	0.3 KM TO HAZARD	260 CELLS	9.7%
**********	3	0.2 KM TO HAZARD	318 CELLS	11.8%
%%%%%%%%%%	4	0.1 KM TO HAZARD	320 CELLS	11.9%
##########	5	TOXIC HAZARD	112 CELLS	4.2%
CCCCCCCCCC	21	CHURCH(S)	39 CELLS	1.5%
RRRRRRRRRR	22	COMM SERVICE(S)	32 CELLS	1.2%
TTTTTTTTTT	23	MOVIE THEATRE(S)	3 CELLS	0.1%
HHHHHHHHHH	24	HOSPITAL(S)	33 CELLS	1.2%
SSSSSSSSSS	25	SCHOOL(S)	80 CELLS	3.0%
LLLLLLLLLL	26	LODGING	28 CELLS	1.0%
2222222222	27	> OF ABOVE	18 CELLS	0.7%

Figure 5. Institutions (SERVICES) and Hazardous Buffer Zone

(2) Design public education programs which inform the population at risk of not only the potential hazards that exist in their vicinity, but also of the range of protective actions possible in the event of an accident.

(3) Develop emergency response plans to evacuate both the resident and institutional population from the "high risk" corridor along the freeway.

(4) Identify host facilities which could serve as emergency relocation centers for both the resident and institutional population.

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