UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
Metropolitan Edison Co.	)	Docket 50-289
	)	
Three Mile Island Unit One	)	

TESTIMONY OF

DR. DONALD ZEIGLER

ON EMERGENCY PLANNING FOR THE THREE MILE ISLAND AREA COMMUNITIES

TESTIMONY ON BEHALF OF THE ANTI NUCLEAR GROUP REPRESENTING YORK

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EVACUATION FROM A NUCLEAR TECHNOLOGICAL DISASTER*

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A unique peacetime technological disaster occurred in northeastern United States in the spring of 1979: an accident in a nuclear-generating plant. Because of the proliferation of nuclear power plants throughout the world, the possibility of comparable disasters elsewhere increases. We chose to examine one aspect of the 1979 American disaster: evacuation of the affected population. The nuclear accident at Three Mile Island (TMI) near Harrisburg, Pennsylvania, on Wednesday, March 28, 1979, dramatically emphasized the need to broaden the range of evacuation studies to include technological disasters, particularly ones of nuclear origin. The crisis at Three Mile Island provided the first opportunity for an empirical examination of the evacuation process in the aftermath of an unexpected and unprecedented nuclear disaster. We used it as a case study in order to seek a foundation for geographical research in the nascent field of evacuation behavior and planning in response to technological disasters. Our objectives are to identify the spatial and temporal dimensions of evacuation behavior among TMI residents, to offer a conceptual model of evacuation-decision making in response to a nuclear disaster, and to suggest the role for geographers in evacuation planning. Because of the uniqueness of the case study, we offer generalizations and models to explain the decision-making process for nuclear evacuation not as definitive conclusions but rather as hypotheses for future studies.

Joseph Hans and Thomas Sell compiled a list of more than 500 natural and technological disasters that required evacuation during the period 1960 to 1973.[1] Their figures indicated that an average of almost 90,000 persons per year were forced to evacuate their homes because of hurricanes, floods, train derailments

* We thank Gyula Pauer, director of the Cartography Laboratory, University of Kentucky, for constructing the graphics.

[1] Joseph M. Hans Jr. and Thomas C. Sell, Evacuation Risks—An Evaluation (Las Vegas, Nev.: U.S. Environmental Protection Agency, 1974), pp. 101–153.

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involving toxic chemicals, and other types of disaster. Evacuations from technological disasters accounted for only one-fourth of the incidents listed by Hans and Sell. In terms of affected area and population each technological incident lacked the large-scale effect that characterized natural disasters.[2] Partly because of this limited scope of impact, study of evacuation from technological disaster has been neglected. Such evacuation has traditionally been viewed as a mechanistic problem, merely a question of logistics. In this article we hope to advance understanding of individual behavioral patterns during evacuation from a technological accident. This understanding will allow public officials and planners to base emergency-evacuation designs on documented behavioral responses rather than on assumptions derived from the experience of evacuations from natural disasters.

The data for this study, hereafter referred to as the Michigan State University (MSU) study, were obtained from a survey questionnaire mailed to a stratified random sample of 300 households in south central Pennsylvania approximately one month after the accident at TMI. The sample included 178 households within fifteen miles of the plant and 122 households in Carlisle, Duncannon, and Lancaster, three communities beyond the fifteen-mile radius that we chose to include in the sample. Of the 267 questionnaires that reached their destinations, 150 were completed and returned, a response rate of 56 percent. A detailed description of the survey design and a copy of the questionnaire appear in the final report on the TMI incident that we published elsewhere.[3] In this article we make reference to two other surveys of TMI area residents, although the final results of each survey are yet to be published. One survey was conducted by Mountain West Research for the Nuclear Regulatory Commission (NRC), and the second was done by a group of geographers at Rutgers University.[4]

These three TMI studies provide the basis for examining the emergency-planning process in general and evacuation planning in particular. Methods of

[2] Harry Estill Moore and others, Before the Wind: A Study of the Response to Hurricane Carla, *Disaster Study No. 19* (Washington, D. C.: National Academy of Sciences National Research Council, 1963); Thomas E. Drabek, Social Processes in Disaster: Family Evacuation, *Social Problems*, Vol. 16, 1969, pp. 336–349; E. M. Beck, Communication in Crisis: Explaining Evacuation Symbolically, *Communications Research*, Vol. 2, 1975, pp. 24–49; Earl J. Baker, Predicting Response to Hurricane Warnings: A Reanalysis of Data from Four Studies, *Mass Emergencies*, Vol. 4, 1979, pp. 9–24; and Ronald W. Perry, Evacuation Decision-Making in Natural Disasters, *Mass Emergencies*, Vol. 4, 1979, pp. 25–38.

[3] Stanley D. Brunn, James H. Johnson Jr., and Donald J. Zeigler, Final Report on a Social Survey of Three Mile Island Area Residents (East Lansing, Mich.: Michigan State University, Department of Geography, 1979), pp. 19–25.

[4] Mountain West Research, Inc., Three Mile Island Telephone Survey: Preliminary Report on Procedures and Findings by Cynthia B. Flynn, prepared for the Nuclear Regulatory Commission (Washington, D. C.: U.S. Government Printing Office, 1979); Mountain West Research, Inc., with Social Impact Research, Inc., The Social and Economic Effects of the Accident at Three Mile Island by Cynthia B. Flynn and James A. Chalmers, prepared for the Nuclear Regulatory Commission (Washington, D. C.: U.S. Government Printing Office, 1980); and Kent Barnes, James Brosius, Susan Cutter, and James Mitchell, Responses of Impacted Populations to the Three Mile Island Nuclear Reactor Accident: An Initial Assessment, *Discussion Paper No. 13* (New Brunswick, N. J.: Rutgers University, Department of Geography, 1979). The NRC study was conducted by telephone in July and August of 1979, and the Rutgers study was based on a questionnaire mailed in April of 1979. In general the results of the MSU, NRC, and Rutgers studies are mutually supportive; major differences are in the conceptualization and the spatial analysis of evacuation behavior and decision making, topics that are most fully developed in the MSU report.

coping with the consequences of nuclear disasters are certain to attract considerably more interest than they have to date for several reasons. The TMI accident demonstrated that "societies using nuclear power today must accept major accidents not only as a theoretical possibility of no practical consequence, but as a risk to include in actual planning."[3] The results of state and nationwide opinion polls conducted since the accident at TMI indicate that supporters of nuclear power, though now insisting on higher safety standards, still outnumber persons who oppose it.[4] Nuclear-generating facilities in the short run, at least, will probably continue to operate and to proliferate. Of the existing and planned reactors in the United States, 85 percent are sited within sixty miles of a metropolitan core and thus cast a nuclear threat over a large proportion of the population in the country.[5]

Evacuation-Decision Making

Our study of the Three Mile Island evacuation was one of the first attempts to document the process of evacuation under the threat of a severe technological disaster. We designed the questionnaire to ascertain whether the respondent evacuated and to identify the factors that influenced the decision. The results of the survey indicate that 53 percent of the population within twelve miles of TMI evacuated, while only 9 percent beyond this limit left their homes. We propose a tentative model of the evacuation decision-making process and the spatial outcome of those decisions (Fig. 1). The first question posed was whether even to consider evacuation; 21 percent of the sample never considered this question. The remainder considered evacuation, but only 31 percent of the sample decided to evacuate. Several external constraints on the flow of decisions existed. Some potential evacuees were undoubtedly dissuaded from leaving by temporal (when), spatial (where), and operational (how) constraints. The relationships in the diagram should thus be interpreted to present a system of interlocking decisions rather than a series of unrelated options. Further research on evacuations from nuclear and other technological disasters may suggest revision and refinement of the decision-making model and, perhaps even more importantly, may help to identify the critical factors that influence the decision-making process.

Two spatially distinct population groups were identified on the basis of their reaction to the TMI incident. One group, composed of individuals who remained in their usual place of residence during the crisis, may be called the residual population; the other group, comprising the individuals who departed, is the redistributed population or evacuees. The MSU study found no statistically significant differences between these two groups in terms of occupation, income, age of household head, length of residence in south central Pennsylvania, and political ideology. Similarly the NRC study found that differences in income, education, and occupation had no significant bearing on an individual's decision to evacuate.[6]

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[3] Bent Sorenson, Nuclear Power: The Answer That Became a Question, Impact, Vol. 8, 1978, p. 17.
[4] Robert C. Mitchell, Public Opinion and Nuclear Power Before and After Three Mile Island, Resources, Resources for the Future, January-April, 1980, pp. 3-7.
[5] Policy Research Associates, Socioeconomic Impacts, Nuclear Power Siting, (State College, Pa.: Policy Research Associates for the Nuclear Regulatory Commission, 1977), p. 43.
[6] Mountain West Research, Inc., with Social Impact Research, Inc., footnote 1 above, p. 24.

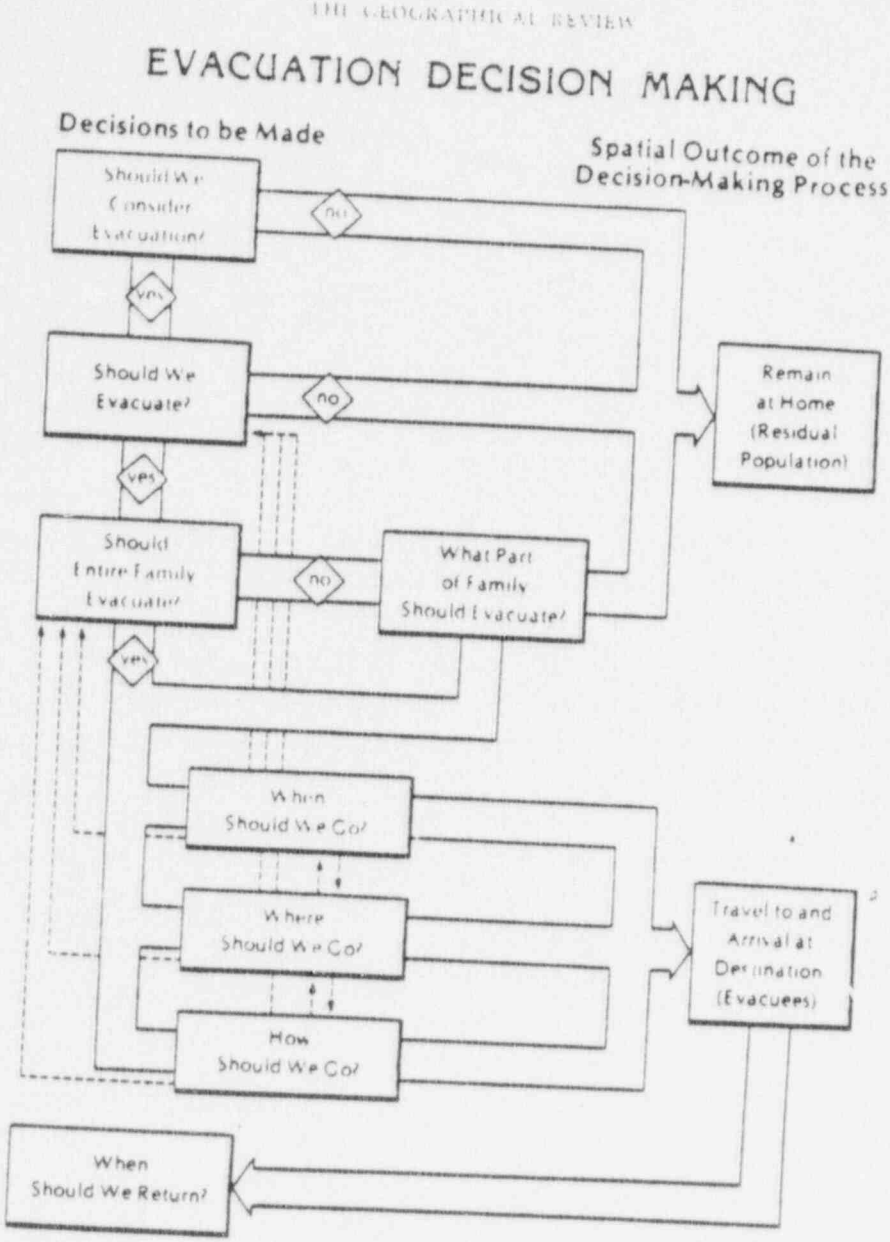

FIG. 1—Evacuation-decision making.

Beginning with the study of the population affected by Hurricane Carla, studies of natural disasters have repeatedly confirmed the hypothesis that a family is the unit making the decision about evacuation.[9] Evacuees from sudden natural catastrophes typically leave the hazard zone in family groups and remain together during the crisis. The results of our survey suggest that while the majority of evacuees left in complete family units, the proportion of partial

[9] Moore and others, footnote 2 above, p. 7.

families fleeing the disaster was larger than would be expected from the conclusions of natural-hazard research. In charting the basic patterns of evacuation behavior and in planning many phases of the evacuation process, the concept of an evacuation unit, as opposed to the individual or the family, may best serve as the fundamental analytical entity. We define an evacuation unit as a single individual acting alone or a group of individuals acting in unison during the evacuation process. Because the members of a household may be unable to agree on a decision or on procedures, a single household may generate several evacuation units. In the MSU survey, partial families composed one-third of all evacuation units, but in the sample communities beyond fifteen miles from the plant, evacuation units were more likely to be partial families than complete families. Within six miles of the plant, complete families outnumbered partial families by more than three to one. The high percentage of partial families evacuating the TMI area may be accounted for by the high degree of uncertainty surrounding the accident itself and by the inability of either individuals or public officials to gauge accurately the magnitude of the malfunction at the plant.

In his study of the sudden and unexpected impact of the Denver flood of 1965, Thomas E. Drabek demonstrated that evacuation is not always the result of a simple scenario in which families receive a warning, seek to confirm the danger, and decide to evacuate.[10] Instead he proposed four separate evacuation processes: evacuation by default, evacuation by invitation, evacuation by compromise, and evacuation by decision. Although Drabek's classification scheme was specific to forced evacuation in response to a natural disaster, we propose a similar, but somewhat modified classification system specific to voluntary evacuation in response to a technological disaster. In terms of the response of families in the Three Mile Island area, evacuation seemingly resulted from three different processes: evacuation by division, in which some members of a family decided to leave while other members decided to remain; evacuation by consensus, in which the whole family decided that evacuation was the best course of protective action to follow; and evacuation by compromise, in which a deadlock was resolved by a dominant family member in favor of evacuation. Drabek's model of evacuation by default would be applicable only in the event of a forced evacuation.

The principal factor motivating TMI residents to evacuate was concern about personal safety: 94 percent of the evacuees gave this reason (Table I). Conflicting reports from governmental and utility-company officials were another critical factor. One-fifth of the evacuees indicated that the news media played a role in their decision. The NRC study also cited the perception of danger and the volume of confusing information as the major reasons for evacuation.[11]

The reasons given by members of the residual population for not evacuating were varied (Table II). The most frequently given explanation was that no order to evacuate was issued. The NRC study also found this response to be the most frequent argument for staying.[12] The existence of many conflicting reports was

[10] Drabek, footnote 2 above, pp. 345–346.
[11] Mountain West Research, Inc., with Social Impact Research, Inc., footnote 4 above, p. 18.
[12] Mountain West Research, Inc., with Social Impact Research, Inc., footnote 4 above, p. 21.

TABLE I—REASONS FOR EVACUATING

REASONS	PERCENTAGE OF EVACUATION UNITS
Concerned about safety	91
Conflicting reports from government and utility-company officials	48
Conflicting reports from utility-company officials	26
Conflicting reports from government officials	24
News media	20
Everyone was evacuating	7
Ordered to evacuate	4

Source: MSU Survey, text footnote 3.

TABLE II—REASONS FOR NOT EVACUATING

REASONS	PERCENTAGE OF NONEVACUEES
No order to evacuate was issued	62
Too many conflicting reports	42
No apparent reason to evacuate	38
Home was a safe distance from plant	31
Fear of looting	24
No children involved	23
Could not leave job or business	21
No one else in area evacuated	16
Needed to take care of farm livestock	6
No place to go	5
Too old to evacuate	3
Handicapped	2

Source: MSU Survey, text footnote 3.

the second-most frequently cited reason for not evacuating. Paradoxically this was also the second-most widely cited reason among the persons who chose to evacuate. Conflicting information was thus used by some residents to justify a decision to leave and by others to justify a decision to stay.

THE GEOGRAPHY OF EVACUATION FROM TMI

On the basis of the redistribution of population in the immediate aftermath of the Three Mile Island disaster, we were able to delineate two distinct but overlapping regions: the zone of evacuation and the evacuation field. The first zone comprises the areas left by the evacuees, and the second was the area to which the evacuees fled.

ZONE OF EVACUATION

The pattern of voluntary evacuation from Three Mile Island clearly reveals a distance-decay relationship that illustrates both the effect of governmental directives and the evacuation-shadow phenomenon. The distance-decay function shows a sharp discontinuity approximately twelve miles from the plant (Table III). Within a twelve-mile radius of the disabled reactor, 53 percent of the sample reported that at least part of the household evacuated. Beyond twelve miles, only 9 percent of the sample reported evacuation. The sharp

TABLE III—DISTANCE AND EVACUATION RESPONSE

DISTANCE ZONE FROM TMI	PERCENTAGE OF RESPONDING HOUSEHOLDS FROM WHICH SOME MEMBERS EVACUATED
1 to 3 miles	55
4 to 6 miles	56
7 to 9 miles	53
10 to 12 miles	47
13 to 15 miles	13
More than 15 miles	9
Total sample	31

Source: MSU Survey, text footnote 3

discontinuity in the vicinity of twelve miles reveals the impact of two directives issued by the office of the governor of Pennsylvania on Friday, March 30. In the first, everyone within a ten-mile radius was advised to remain indoors, an action known as sheltering. In the second, all pregnant women and preschool children within a five-mile radius of the plant were advised to evacuate. The first directive seemed to establish the critical evacuation boundary in the minds of area residents. Beyond the ten-mile limit the proportion of respondents who evacuated declined sharply.

The evacuation-shadow phenomenon is the term used to describe the tendency of an official evacuation advisory to cause departure from a much larger area than was originally intended. The evacuation shadow cast by the public announcement of a very limited evacuation order extended well beyond the zone to which the order applied. If only the persons advised to evacuate had left the area, the number of evacuees would have been limited to approximately 2,500 preschool children and pregnant women. Instead an estimated 144,000 persons, or 39 percent of the population, evacuated their homes in the area as far as fifteen miles from the plant.[10] Although the evacuation-shadow phenomenon may be a minor consideration in evacuation planning for natural hazards, the impact of the phenomenon needs to be emphasized in planning for future nuclear accidents precisely because delineation of the geographical scope of an invisible danger such as ionizing radiation is difficult for public officials and private citizens to determine. In planning for an evacuation from a nuclear disaster, it can therefore be projected that any order to evacuate will cause the departure of residents not only from a designated zone but also from its peripheries. The planning process should accommodate responses from the two areas.

EVACUATION FIELD

In order to analyze the spatial patterns of evacuation behavior, we asked each evacuation unit to indicate its destination. Taken together, these destinations constitute the evacuation field of the survey respondents (Fig. 2). The spatial pattern, as inferred from the locations of these sites, suggests a calm and orderly movement rather than a hysterical flight. Evacuees fled a median distance of eighty-five miles from Three Mile Island. In the NRC study the median distance was found to be one hundred miles from the plant.[11] In com-

[10] Mountain West Research, Inc., with Social Impact Research, Inc., footnote 4 above, p. 22.
[11] Mountain West Research, Inc., with Social Impact Research, Inc., footnote 4 above, p. 17.

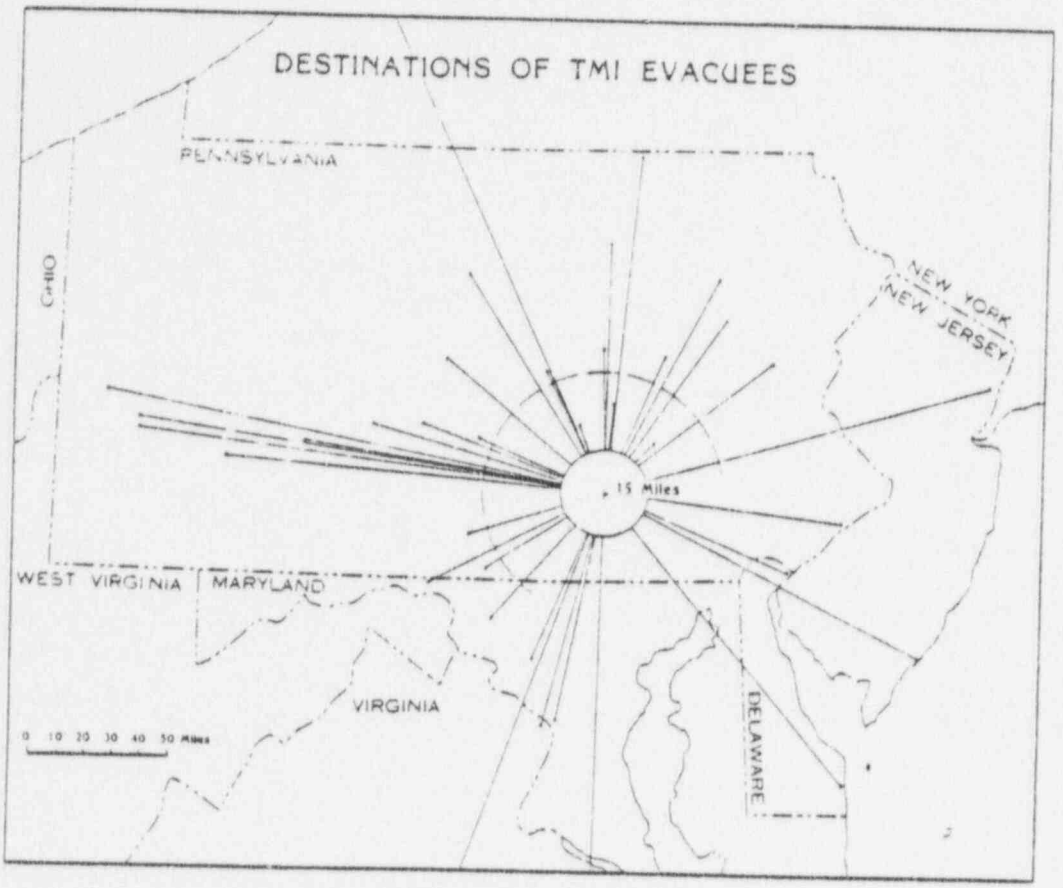

FIG. 2—Destinations of TMI evacuees

parison with the list of evacuations compiled by Hans and Sell, the median flight of evacuation from Three Mile Island is the longest on record. The longest median distance given in that study was eighty miles in response to Hurricane Carla in 1961.[15]

Half of the evacuation units in the MSU survey chose destinations between forty-five and ninety miles from the plant. We define the area within these limits as the zone of perceived safety far from the nuclear site. The inner boundary of this zone, shown on Fig. 2 by a dashed line, suggests that the evacuees sought destinations far enough from the plant to put a territorial buffer between themselves and the source of possible danger. The outer limit of the zone seems to imply a reluctance on the part of most evacuees to venture any farther than necessary from home. The zone of perceived safety represents the spatial outcome of the tension between centrifugal forces generated by the perception of danger and centripetal forces generated by the attachment to home.

A strong directional bias, similar to that identified in studies of the intra-urban mobility process, appears to have influenced the configuration of the

[15] Hans and Sell, footnote 1 above, pp. 83–90.

evacuation field. Although only one of every ten evacuation units chose destinations in the quadrant southeast of TMI, almost half chose destinations in the quadrant northwest of the crippled reactor. The directional bias was the consequence of several interrelated factors. The most important considerations seem to have been a preference for a site upwind from the plant, a psychological attraction to the mountains in time of danger, and a reluctance to select a destination in the more densely populated metropolitan areas to the east. These factors, and possibly others, require further investigation before behavioral models of the evacuation site-selection process can be constructed.

In addition to sketching the configuration of the actual evacuation field, we attempted to delineate a potential evacuation field for all respondents. Everyone was asked to supply a choice of destination, if a presidential order had required a full evacuation of the area. The map of potential sites displays a galaxy of destinations to the north and the west of Three Mile Island and an evacuation hollow, an area shunned by evacuees, around the reactor (Fig. 3). The maps of actual and potential fields are similar in many respects, although the map of potential destinations has a less clearly defined zone of perceived safety. The potential destinations were also more widely dispersed, and some were not shown on the map because they were as far away as California, Arizona, and Florida.

EVACUATION QUARTERS

The homes of relatives and friends proved to be the preferred evacuation quarters among both the actual and the potential evacuees. The MSU survey found that 81 percent of the evacuees stayed with relatives and friends. The comparable figures were 78 percent in the NRC study and 74 percent in the Rutgers study.[16] These proportions exceed those characteristic of evacuations from natural disasters.[17] Despite the ubiquity of hotels and motels in the evacuation field, their use by evacuees from Three Mile Island was limited, in all likelihood, by the financial strain that such accommodations would have imposed on family budgets. The use of the designated evacuation shelter in Hershey, ten miles from the plant, might have been limited by the perceived social stress of life in mass quarters and by the perceived locational stress that evacuees would have experienced in a site so close to the threatening reactor. No respondent in either the MSU or the Rutgers survey reported utilization of the public shelter in Hershey, and only one of the 1,300 households surveyed in the NRC study used the evacuation shelter.[18] The maximum number of persons who used the shelter in one day was estimated at only 180, a situation that seems to confirm the finding that "shelter centers are used only if nothing else is available or if one cannot financially care for himself."[19] A reasonable conclusion is that the low utilization of the shelter at Hershey was partially the

[16] Mountain West Research, Inc., with Social Impact Research, Inc., footnote 4 above, p. 17, and Barnes and others, footnote 4 above, p. 17.

[17] Moore and others, footnote 2 above, p. 93, and Thomas E. Drabek and Keith S. Boggs, Families in Disaster: Reactions and Relatives, *Journal of Marriage and the Family*, Vol. 30, 1968, pp. 443–451.

[18] Barnes and others, footnote 4 above, p. 17, and Mountain West Research, Inc., with Social Impact Research, Inc., footnote 4 above, p. 25.

[19] Hans and Sell, footnote 1 above, p. 52, and Mountain West Research, Inc., with Social Impact Research, Inc., footnote 4 above, p. 25.

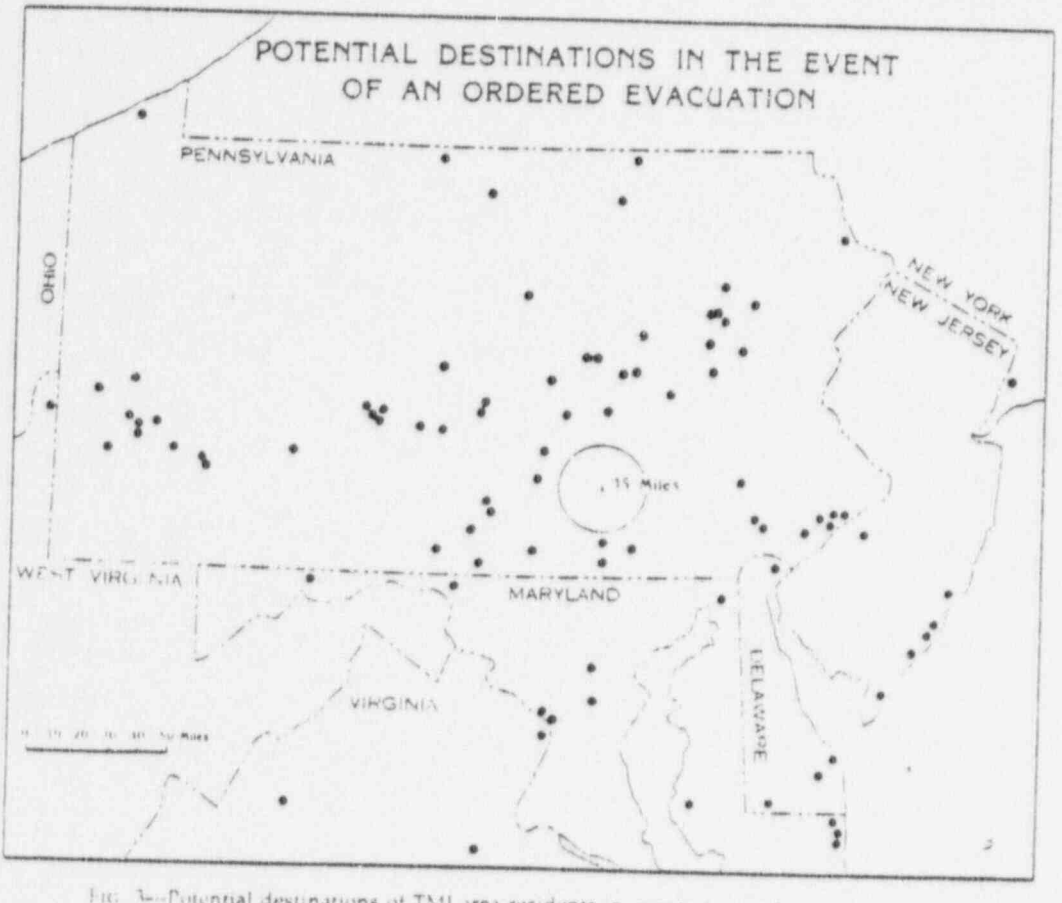

Fig. 3.—Potential destinations of TMI area residents in event of an ordered evacuation.

result of its location in the ten-mile zone from the reactor. Within ten to twelve miles of TMI, 47 percent of the survey respondents evacuated.

The pattern of evacuation was influenced by both spatial and temporal processes (Fig. 4). In this diagram each prism of the cube represents the average behavior of evacuees originating in each of the six distance zones used in this analysis. The distance of the home from Three Mile Island was found to be directly related to the destination chosen by an evacuee. In general, persons living farther from the plant fled to more distant locations than did individuals living close to the plant. The same tendency was observed in the NRC study.[20] This finding adds a new dimension to evacuation behavior that has not been previously observed or predicted, and several explanations may tentatively be offered. First, persons living closest to the plant were likely to be the most concerned about the safety of their homes and property. They were therefore inclined to remain as close as possible to home. Second, only in the closest distance zones were residents with high personal evacuation thresholds sufficiently motivated to abandon their homes. If these evacuees lived a few miles

[20] Mountain West Research, Inc., with Social Impact Research, Inc., footnote 4 above, p. 17.

SPATIAL AND TEMPORAL DIMENSIONS OF EVACUATION

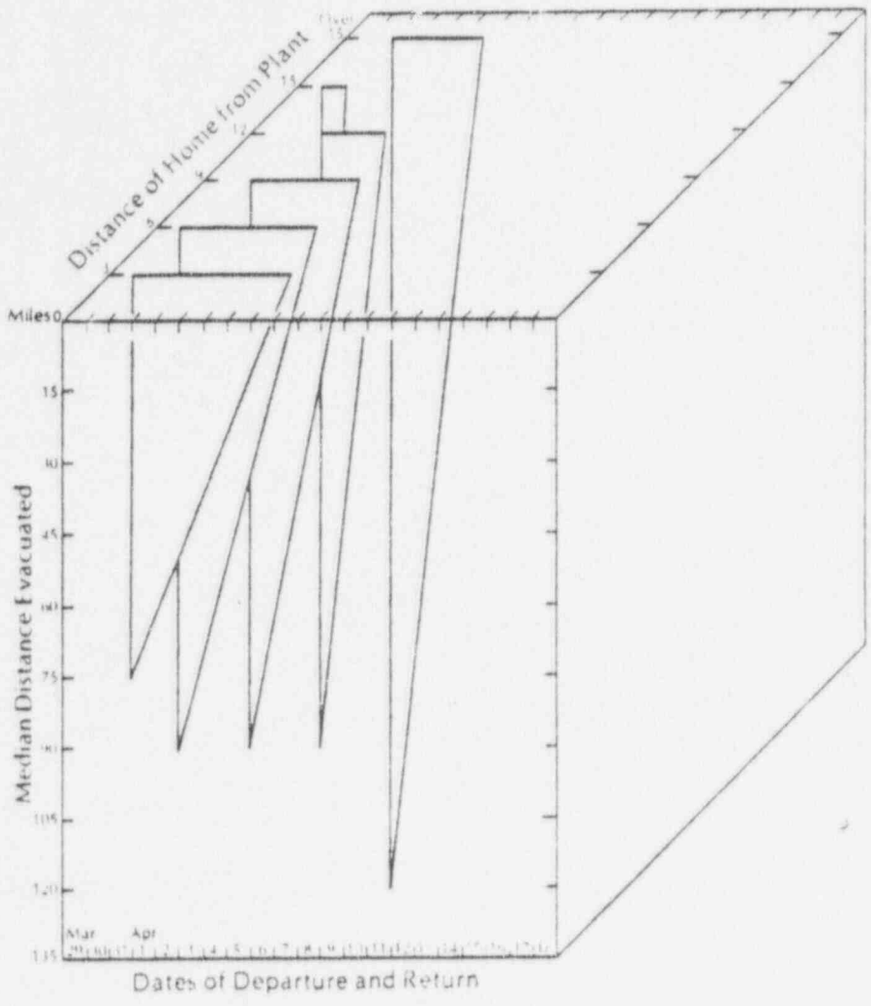

FIG. 4—Spatial and temporal dimensions of evacuation

further from TMI, they probably would not have evacuated at all. Third, residents who live far from the disabled reactor would be expected to shun evacuation sites in the closest zones because they would offer little or no improvement over the conditions of the home site. It can be hypothesized that evacuees originating at great distances from Three Mile Island would include the segment of the population with low personal evacuation thresholds that would consequently be likely to seek more distant destinations. Fourth, because evacuation units residing more than fifteen miles away were predominantly women and children, many constraints on evacuation might have lessened.

The temporal dimension of evacuation is along the third axis of the evacuation cube and represents the date and the duration of evacuation (Fig. 4). The length of the hinges on which the prisms hang denotes the average duration of evacuation, while the position of the hinges denotes the average date of departure and return. The length of stay away from home among respondents ranged from one to sixteen days, but 54 percent of all evacuation units returned home two to four days after departure. In the three-mile zone closest to the reactor, 58 percent (none of whom had preschool children) stayed away three to six days, and 42 percent (all of whom had preschool children) were absent nine to thirteen days. As distance between home and plant increased up to the fifteen-mile radius, the duration of stay away from home decreased. An increase in the duration of evacuation was observed in respondents from the three sample communities that were outside the fifteen-mile limit.

The majority of evacuation units (54 percent) left on Friday, March 30, two days after the accident and the beginning of what was termed the crisis-response period.[21] An identical percentage was cited by the Rutgers study, and the NRC study reported 55 percent.[22] The departure of so many persons that day can probably be attributed to a combination of factors. First, the governor's sheltering and evacuation directives were issued on Friday when serious consideration of a full evacuation first became public. Second, two major constraints on evacuation were lifted because Friday is the end of both the workweek and the school week. Evacuees living close to the plant were likely to leave earlier than those living in the outlying communities. Whereas 77 percent of the evacuation units living within six miles of the plant left on or before Friday, only one-third of the evacuation units living ten or more miles away evacuated on Friday. All of the evacuees who reported leaving on Monday lived ten or more miles from the plant.

A Conceptual Model of Stress-Induced Evacuation

The decision to evacuate from the Three Mile Island area may be conceptualized as a behavioral adjustment to the stressful environmental conditions caused by the sudden nuclear accident. Evacuation in anticipation of disaster therefore becomes a stress-management technique whereby an evacuee moves from one location to another in an effort to reduce the strain imposed by the perception of danger.[23] The stress-inducing factors during the TMI crisis were the knowledge that radioactivity had leaked into the environment and, more importantly, the fear of an even larger catastrophe, that is, a core meltdown.

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[21] Russell R. Dynes and others, Report of the Emergency Preparedness and Response Task Force, Staff Report to the President's Commission on the Accident at Three Mile Island (Washington, D. C.: U.S. Government Printing Office, 1979), p. 45. Dynes divided the time after the accident in the emergency-response period from Wednesday, March 28 to Friday morning, March 30, and the crisis-response period, beginning on Friday morning, March 30.

[22] Barnes and others, footnote 4 above, p. 17, and Mountain West Research, Inc., with Social Impact Research, Inc., footnote 4 above, p. 24.

[23] Stanley D. Brunn, Spatial Causes and Consequences of Psychosocial Stress, in The Geography of Health and Disease (edited by John M. Hunter, Chapel Hill, N. C.: University of North Carolina Department of Geography, 1974), pp. 138–153; W. A. V. Clark and Martin Cadwallader, Locational Stress and Residential Mobility, *Environment and Behavior*, Vol. 5, 1973, pp. 29–41; Harold D. Foster, The Geography of Stress, *Area*, Vol. 11, 1979, pp. 107–108; and Julian Wolpert, Migration as an Adjustment to Environmental Stress, *Journal of Social Issues*, Vol. 22, 1966, pp. 92–102.

GENERALIZED PERSONAL STRESS CURVES

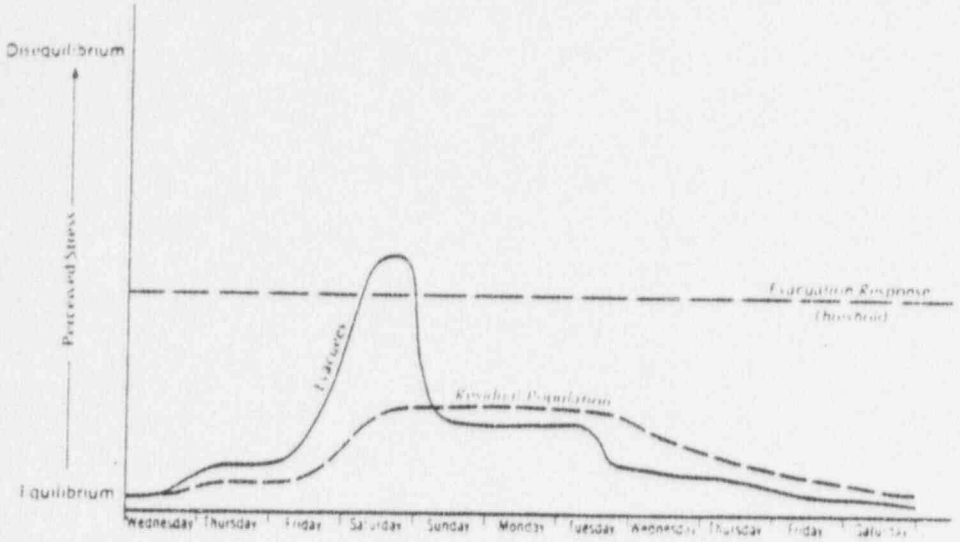

Fig. 5. Generalized personal stress curves.

at the plant. Only permanent relocation is a more radical adjustment to perceived risk than evacuation. Less radical adaptations surfaced among TMI area residents, for example, modifications of the daily personal routine such as remaining indoors and constant tuning to local and regional news.

EVACUATION–RESPONSE THRESHOLDS

At any given distance from Three Mile Island, the propensity of a household to evacuate depends on the evacuation-response thresholds of individual family members and on the availability and the desirability of evacuation quarters at varying distances from the source of danger. The evacuation-response threshold is that point along an individual's personal-stress continuum when the decision to evacuate is made. Individuals with low thresholds will tend to evacuate even if they live far from the source of danger, while persons with high thresholds will evacuate only if they live very near that source. As distance from the plant increases, the proportion of the evacuating population decreases, and the evacuating population includes an increased number of individuals with low evacuation-response thresholds. The tendency of persons with low thresholds to move farther from the stricken plant than persons with high thresholds helps to explain the pattern of evacuation-site selection with respect to the two distance variables presented in the evacuation cube (Fig. 4).

Generalized postaccident personal stress curves offer another temporal measure of responses to the disaster (Fig. 5). The increased perception of stress on Friday is apparent on both stress curves, but only the curve for the evacuees rises above the evacuation-response threshold. The precipitous drop in the evacuees' level of perceived stress on Saturday was the result of departing for

SELECTION OF EVACUATION QUARTERS

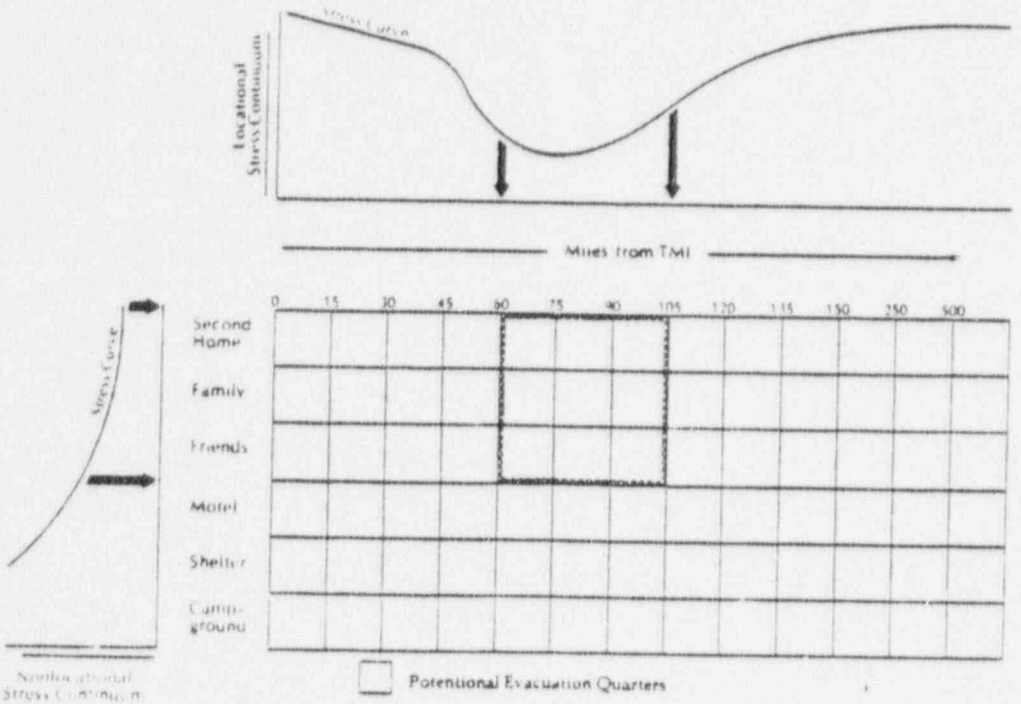

FIG. 6.—Selection of evacuation quarters.

a destination that was considered a safe distance from the plant. Consequently equilibrium was reestablished.

Evacuation may also be motivated by reasons other than the need to alleviate stress. Some evacuees' stress curves may peak below individual evacuation-response thresholds, an indication that the persons may have acquiesced in the decision by their family to evacuate, even though individually they would not have taken the action. Forced evacuation by governmental authorities and previously arranged plans to be absent would be other examples of such a phenomenon. The stress curve of an individual may also rise above the evacuation-response threshold, but evacuation is not an automatic result. For example, some individuals may have had no place to go, may have been confined to an institution, or may have had constraints imposed on their mobility by a job or other commitment.

The possible evacuation sites that a hypothetical evacuee might consider can be entered in a matrix of the search for evacuation quarters, which identifies available options (Fig. 6). Personalized stress curves may be projected along each axis of the matrix. On the basis of the map of actual evacuation destinations, the most desirable locations were between forty-five and ninety miles from the disabled reactor. The locational stress curve therefore appears to dip in this range and to demarcate a zone of perceived safety. A personal or nonlocational stress curve, representing the total social and finan-

cial strain perceived to be associated with various types of evacuation quarters, was drawn to conform to the preferences expressed by survey respondents. The curve peaks at public shelters and diminishes through motels, friends, and relatives. Although the use of second homes and campgrounds would be limited by personal circumstances, they are included as potential destinations.

EVACUATION SPACE–SEARCH MATRIX

In the space-search matrix the most desirable evacuation sites can be identified by projecting the "lowest" segment of each stress curve into the matrix. The area, delineated in Fig. 6 by a shaded border, has three potential sites that would be open to this particular evacuation unit. The final choice under such circumstances would be made on the basis of nonlocational factors that enter the selection process. While locational factors would prevail to discourage the selection of evacuation sites either very near or very far from the nuclear plant, nonlocational factors would influence the selection of a specific site in the geographical zone of perceived safety. Each individual would perceive the stress associated with location and types of evacuation quarters differently. This personalized decision-making schema is only a first attempt to analyze the thinking and the planning by which individuals and families search in the surrounding territory for an acceptable evacuation destination.

THE GEOGRAPHER'S ROLE IN EMERGENCY-RESPONSE PLANNING

Until the accident at Three Mile Island, emergency-response and evacuation planning received surprisingly little attention from either the Nuclear Regulatory Commission or government officials. Prior to the TMI accident, NRC had required nuclear plant operators to develop emergency plans only for the facility itself and the surrounding low-population zone. The zone around TMI extended only 2.2 miles from the facility. At the time of the accident, no evacuation plans existed for the local jurisdictions in the area. Although the three closest counties had five-mile emergency-response plans on file, only one plan incorporated a fully developed course of action. Two emergency plans were developed for the state at the time of the accident, but neither one had been approved by NRC.[21]

After noting the low priority that the Nuclear Regulatory Commission had accorded emergency-response planning, the President's Commission on the Accident at Three Mile Island recommended that emergency plans, including evacuation, be designed for existing and proposed nuclear power plants on the basis of alternative disaster scenarios for any given plant. Scenarios would specify appropriate responses from state and utility-company officials on the bases of both the magnitude of the disaster and the distance of residents from the generating station. The commission considered a single evacuation plan based on a fixed set of distances and a fixed set of responses to be inadequate.[22]

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[21] A thorough critique of the plans in effect on March 28, 1979, and of the *ad hoc* planning documents that evolved in response to the nuclear emergency is in Dynes and others, footnote 21 above, pp. 101–164.

[22] The President's Commission on the Accident at Three Mile Island, *The Need for Change: The Legacy of TMI* (Washington, D.C.: U.S. Government Printing Office, 1979), pp. 76–77.

In view of the minimal attention to emergency-response planning and the recommendation of the presidential commission to identify appropriate responses for a range of conditions, there seems to be ample opportunity for geographers to contribute to the design and the implementation of emergency-response plans for nuclear emergencies. The role of the geographer in emergency preparedness is considered most essential in the design of plans for evacuation and for delivery of emergency services. Expertise in spatial and locational matters is especially critical in response to nuclear accidents and other technological disasters. Specific contributions of the geographer include the identification of the areas to be evacuated on the bases of distance and direction from the disaster site, the description of the population and settlement geographies of the potentially affected areas as a basis for intelligent decision making, the determination of the transportation routes that would be most suitable for an evacuation, and the establishment of the locations for evacuation shelters. Additional important contributions that geographers may make are the prediction of the movement patterns of evacuees in order to regulate the mass evacuation of an area and to plan for the delivery of emergency services and supplies in the evacuation field, the creation of the networks for the communication of disaster information and for the delivery of emergency services in the zone of evacuation, and the identification of the locations that would be most difficult to evacuate because of physical constraints, personal immobility, or attitudinal resistances.

In addition to the magnitude of the accident, other factors may require the formulation of contingency plans to cope with the invisible danger and destruction associated with a nuclear emergency. Evacuation, particularly if it begins as a voluntary process, will vary according to the season of the year, the day of the week, the specific weather conditions, and the availability of gasoline supplies. Factors unique to the affected area will also need to be considered in anticipating the public response to an evacuation order, particularly rural-urban population mix, automobile ownership, ownership of campers, vans, and second homes, available public transportation, proportion of the population confined to institutions, location of friends and relatives, obstructions in the transportation network, and extent of cooperation among local governments. A clear understanding of responsibilities and prior planning of appropriate emergency responses will help to facilitate evacuation from nuclear and other technological disasters.

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Present Position

ASSISTANT PROFESSOR OF GEOGRAPHY (1980-present)
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Education

Ph.D. (1980)
Michigan State University, East Lansing, Michigan 48824
Grade Point Average: 3.94
Specializations: Urban Social and Economic Geography, Population Geography.

M.A. (1976)
University of Rhode Island, Kingston, Rhode Island 02881
Grade Point Average: 4.00
Specializations: Urban Social Geography, Economic Geography, Population Geography.

B.S. (1972)
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Grade Point Average: 3.43
Major: Geography. Minors: Social Science and Education.

Teaching Interests

Systematic: Economic and Urban Geography, Geography of Energy, Population Geography

Regional: Geography of the United States and Canada.

Methods: Research Design, Quantitative Methods, and Field Techniques in Geography

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Research Interests

Major: Urban financial geography; Impacts of high energy costs on metropolitan settlement patterns and processes; Technological hazards and evacuation planning; Geopolitical fragmentation and its impact on metropolitan America.

Minor: Growth and decline in the American metropolitan system; Patterns of population redistribution in the United States, Suburbanization of the central city and the citification of the suburbs.

Experience

ASSISTANT PROFESSOR (1980-present), Geography Program
Old Dominion University, Norfolk, VA 23508
Responsibilities: Currently teaching economic geography, geography of energy, cartography, and introductory physical geography; serving on the Geography Curriculum Committee; departmental representative to the Ph.D. in urban services policy committee.

RESEARCH ASSISTANT (1980), Center for Environmental Quality
Michigan State University, East Lansing, MI 48824
Responsibilities: Assisted in organizing a series of community and state level energy workshops and in preparing preliminary and final reports of the workshop project for the Michigan Energy Administration.

TEACHING ASSISTANT (1977-1979), Department of Geography
Michigan State University, East Lansing, MI 48824
Responsibilities: Taught economic geography (2 terms); assisted in field techniques in geography (5 terms); assisted in geography of environmental quality (1 term).

ARCHIVES ASSISTANT (Summers 1978 and 1979), State of Michigan Archives
Michigan History Division, Department of State, Lansing, MI 48918
Responsibilities: Organized newly acquired archival record groups and manuscript collections; wrote finding aids to facilitate public access to primary source materials.

GEOGRAPHER (1976-1977), Geographical Statistical Areas Branch
U.S. Bureau of the Census, Washington, DC 20233
Responsibilities: Applied the concepts of Census Geography to the establishment of statistical areas in the Southern states; analyzed statistical and cartographic documents to prepare and revise census tract plans in cooperation with local planning agencies; coordinated the enumeration district program for the South.

INSTRUCTOR (1976), Department of Geography
University of Rhode Island, Kingston, RI 02881
Responsibilities: Taught economic geography (2 terms); directed a tutorial in geographic education; served as University College advisor.

TEACHER (1974-1976), Social Studies Department
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DEPARTMENTAL ASSISTANT AND CARTOGRAPHER (1970-1972), Department of Geography
Shippensburg State College, Shippensburg, PA 17257

Research and Publications

DISSERTATION

"Central City Credit Ratings: Regional Patterns and Spatial Correlates," Unpublished Ph.D. Dissertation, Department of Geography, Michigan State University, 1980. (Advisor: Stanley D. Brunn. Committee Members: Joe T. Darden and Ian M. Matley.)

THESIS

"Selected Quality of Life Indicators and Demographic Characteristics of Standard Metropolitan Statistical Areas in the United States," Unpublished M.A. Thesis, Department of Geography, University of Rhode Island, 1976. (Advisor: Gerald H. Krausse. Second Reader: Henry J. Warman.)

ARTICLES:

"Human Settlements in Sparsely Populated Areas: A Conceptual Overview," in R. E. Lonsdale and J. W. Holmes, eds., Human Settlement Systems in Sparsely Populated Regions: The United States and Australia. New York: Pergamon Press, 1981. (With S. D. Brunn; forthcoming.)

"Evacuation From a Nuclear Technological Disaster," The Geographical Review 71 (January 1981): 1-16. (Principal author; with S. D. Brunn and J. H. Johnson, Jr.)

"Geopolitical Fragmentation and the Pattern of Growth and Need: Defining the Cleavage Between Sunbelt and Frostbelt Metropolises," in S. D. Brunn and J. O. Wheeler, eds., The American Metropolitan System: Present and Future. New York: Edward Arnold, 1980. pp. 77-92.

"The Regional and Environmental Social Studies: Frontiers for Geography and the PCGE ," The Pennsylvania Geographer 13 (July 1975); reprinted December 1976.

"Federal Support for Public Education: A Rationale," Kappa Delta Pi Record 12 (October 1975).

REPORTS (Co-author)

Final Report on a Social Survey of Three Mile Island Area Residents. East Lansing, Mich.: Department of Geography, Michigan State University, August 1979. 218 pp. (With S. D. Brunn and J. H. Johnson, Jr.)

Preliminary Report on a Social Survey of Three Mile Island Area Residents. East Lansing, Mich.: Department of Geography, Michigan State University, May 1979. (With S. D. Brunn and J. H. Johnson, Jr.)

REPORTS (Contributor)

Energy and the Adaptation of Human Settlements edited by H. E. Koenig and L. M. Sommers. East Lansing, Mich.: Center for Environmental Quality, Michigan State University, 1980. pp. 16-19, 22-25, 28-40, 43, 123-129.

PAPERS

"Changing Regional Patterns of Central City Credit Ratings: 1960-1980," Paper presented at the annual meeting of the Southeastern Division, Association of American Geographers, Blacksburg, Virginia, November 24, 1980.

"From Three Mile Island to Worlds End: Evacuation from a Nuclear Technological Disaster," Paper presented at the annual meeting of the Pennsylvania Council for Geography Education, Harrisburg, Pennsylvania, October 11, 1980.

"The Spatial Correlates of Municipal Bonds: A Geography of Assigned Credit Ratings," Paper presented at the annual meeting of the Association of American Geographers, Philadelphia, Pennsylvania, April 23, 1979.

FIELD TRIP GUIDE

Environmental Land Use in the Cumberland Valley. Field trip booklet written for the annual conference of the Pennsylvania Council for Geography Education held at Shippensburg State College, Shippensburg, Pennsylvania, May 1, 1971. 80 pp.

FILM STRIP SERIES (Consultant)

Seeing the New England States, Coronet Instructional Media, 1975.

Media Interviews

Radio: WKAR, East Lansing, Michigan, on the Three Mile Island survey, 1979.
Television: WELM, East Lansing, Michigan, on the Three Mile Island survey, 1979.

Activities, Honors, and Memberships

Professional Organizations:
- Association of American Geographers (since 1968)
- Southeastern Division, Association of American Geographers (since 1980)
- National Council for Geographic Education (since 1967)
- Pennsylvania Council for Geography Education (since 1970)

Undergraduate Activities and Honors:
- Bachelor of Science with Honors
- Gamma Theta Upsilon, Omicron Chapter, President
- Theta Geography Club, President
- College Geography Clubs of Pennsylvania, State President
- Kappa Delta Pi (honorary education society)
- Who's Who Among Students in American Universities and Colleges 1972

Graduate Activities and Honors:
- Graduate Office Fellowship, Summer 1980
- Graduate Curriculum Committee, 1980
- Visiting Chinese Geographers Reception Committee, 1979