of all injuries caused by the earthquake was anticipated to be moderate to minor in nature. Only five County residents were killed[13], and only 33 persons had injuries serious enough to be admitted to a hospital. Most of the moderately injured were probably seen at a County hospital or helicoptered out of the County within the ascertainment period, since alternative care was largely unavailable. Furthermore, the medical abstracts indicated that many of the hospital visitors sustained relatively minor injuries. Thus, considerable overlap in the level of injury severity among the hospital and population cases with minor injuries was expected. Therefore, collecting information on the population cases was seen as essential in estimating the true earthquake-related injury burden in the County.

[13]The sixth person killed in the County was a resident of Napa, California.

The sampling plan was deemed feasible because the expected 20 percent background injury rate was high enough to provide sufficient numbers of population cases to study in a meaningful fashion. In fact, population cases composed 15 percent of the population sample that was interviewed (see section "Preliminary Progress Report on Case-Control Study"). This injury rate was still adequate to produce enough population cases to study.

RISK FACTORS FOR PHYSICAL INJURY

Table 8 presents an outline of the risk factors for physical injury that were examined in the interview. The primary risk

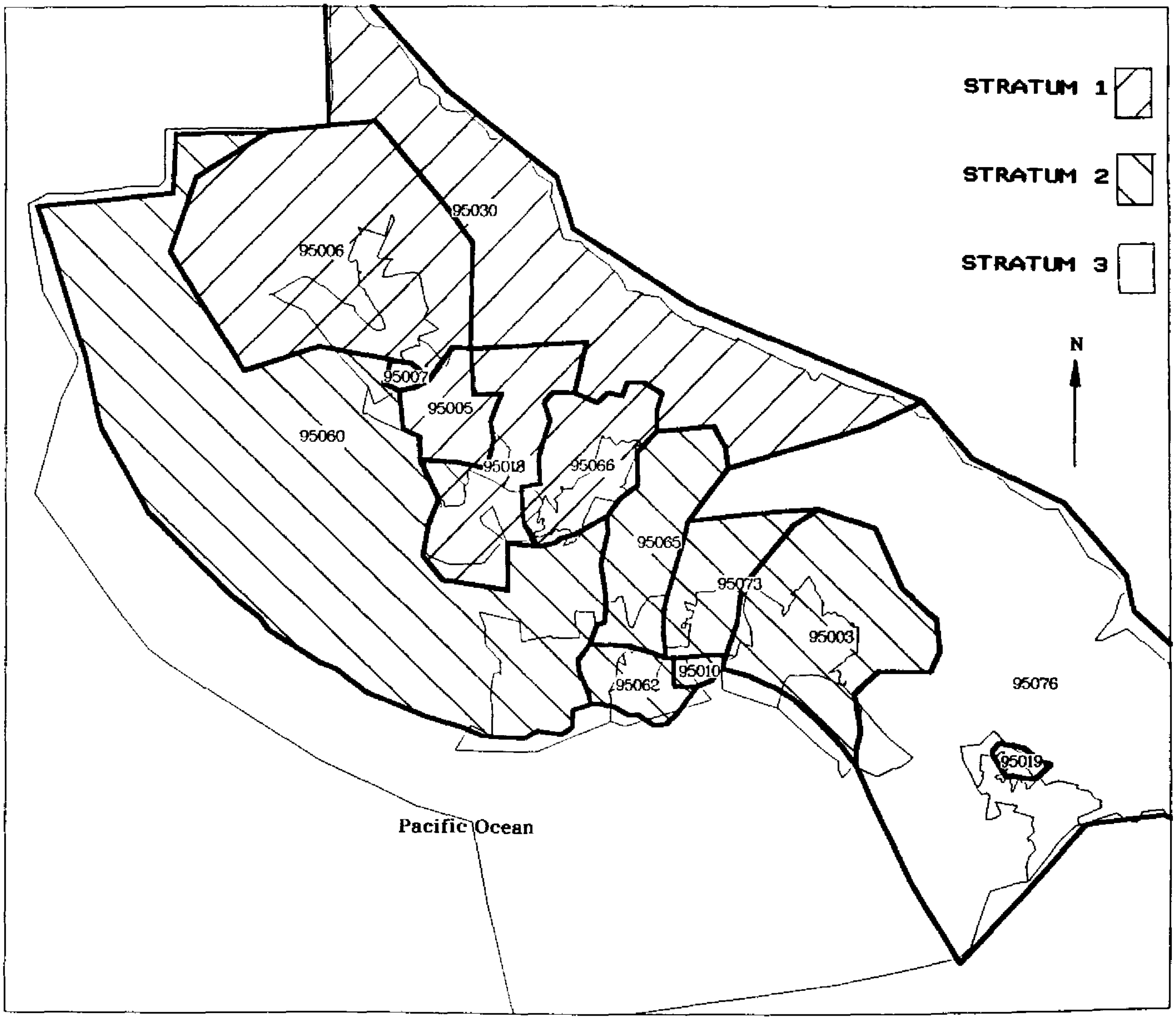

Figure 1.—Santa Cruz County residence strata. Bold lines are zip-code boundaries, light lines are County and city boundaries.

Table 8 —*Risk factors for physical injury*

During the shaking of the main earthquake	In the 72 hours after the shaking of the main earthquake stopped
Physical environment	Physical environment
Inside a building	Inside a building
Inside a vehicle	Inside a vehicle
Outside, within 20 feet of a building	Outside
Outside, further than 20 feet from a building	Other
Other	
Being trapped	Being trapped
Protective/rescue behaviors	Rescue/retrieval behaviors
Oneself	Oneself
Other people	Other people
Pets	Pets
Things/belongings	Things/belongings in buildings
	Clean-up activities

factors of interest were physical environments, entrapment, individual behaviors, and their interactions. Potential confounders, including demographic characteristics, were also explored. Risks posed during each time period—during the shaking of the mainshock and in the next 72 hours—were examined separately

Physical environments were broadly defined as being inside a building, in or on a vehicle, outside and within 20 feet of a building, outside and further than 20 feet from a building, and "other." The category of "other" would include, for example, persons in a car which is inside an enclosed garage. Risk factors within each environment will be explored through subgroup analysis. For example, for those within a building during the shaking, the hazards associated with falling furniture, collapsing walls, gas leaks, exposed live wiring, and so forth will be examined. The type of building will also be explored (that is, buildings were broadly classified as residential, commercial, industrial/farm, or public/institutional). The age, construction materials, and number of floor levels of the building, as well as respondent's location within it (floor level, room, and so forth) will be determined. Respondents were also asked whether or not the building was bolted to its foundation The year of construction is considered a potential risk factor because seismic building codes changed and improved over time, thus, for example, older brick buildings (which have not been retrofitted) are expected to be more hazardous than newer ones. For practical reasons (for example, knowledge limitations of layperson respondents), the only attempt made through the questionnaire to infer structural type was through a description of building materials (for example, wood, brick, and so forth).[14] For those outside further than 20 feet from a building, the dangers posed by landslides, floods, and human-made structures such as collapsing bridges and fences will be explored.

Entrapment, or inability to move, can be caused by both physical objects which restrict movement, or by injuries (which themselves could be the result of physical objects). The interview distinguished between these two types of entrapment, which will be treated separately in analysis. Elements of entrapment which were examined include the causative agent(s), the duration of entrapment, and the place of entrapment. The duration of entrapment was broken down into the intervals between first being trapped, discovered by others (when relevant), and rescued or self-freed.

Personal behaviors examined include actions taken to protect oneself, other people, pets, and belongings or things. Rescue or retrieval of other persons, pets, and things were also explored as well as clean-up in earthquake damaged areas. Behaviors specific to each environment were scrutinized. For example, for those in a building during the shaking, standing in a doorjamb, holding onto to something, getting under a table or desk, and running outside were examined. For those in a moving vehicle during the shaking, actions evaluated included continuing to drive, pulling over and stopping, getting out of the vehicle, and so forth.

Demographic characteristics which were collected include age, sex, marital status, occupation, ethnic origin, level of education, number of dependents, and home ownership. The importance of being with other people, including dependents or disabled persons, during the shaking was examined. Other risk factors which were explored include preexisting medical conditions and mobility, prescription drug use, and alcohol consumption in the 2 hours before the mainshock.

OUTCOME MEASURES FOR PHYSICAL INJURY

Injuries directly and indirectly associated with the earthquake were included in the study but will be analyzed sep-

[14] Verification of building type required a field follow-up after preliminary data analysis (Jones and others, 1993b)

arately. Directly related injuries were defined as those caused by the seismic forces during the shaking of the mainshock or its aftershocks. This class of injuries also included persons injured in the postdisaster period while engaged in protective, rescue, retrieval, or clean-up activities because of the earthquake. For example, this category would include persons injured while cleaning up or retrieving belongings from their earthquake-damaged homes Indirectly related injuries were those whose relationship to the earthquake is less clear. For example, a person injured in a car accident because of excess alcohol consumption due to stress brought on by the earthquake would fall into this category

Outcomes which were excluded from this study are: (1) intentional physical injuries, that is, injuries that were self-inflicted or caused by assaults, and (2) medical conditions other than injuries which may or may not have been associated with the earthquake, including but not limited to psychological trauma, communicable diseases, cardiovascular events, and complications of pregnancy.

The outcomes of interest are earthquake-related physical injuries that occurred during the shaking from the mainshock and the subsequent 72 hours. Injuries were defined as physical trauma of any severity level. Multiple injuries to the same person were described individually. Information collected on each injury included the type of injury, affected body part, the cause of the injury, and the location of the person when the injury occurred. Injuries that occurred during the shaking from the mainshock will be analyzed separately from those that occurred in the subsequent 72 hours

Each injury will be coded using the Abbreviated Injury Scale 1990 Revision (AIS) (Association for the Advancement of Automotive Medicine, 1990). The 1990 AIS assigns a unique seven digit number to each injury diagnosis. The code describes an injury according to body region where it occurs, the type of anatomical structure affected (nerves, and so forth), the specific nature of the injury or anatomic structure (for example, abrasion, amputation, loss of consciousness, cervical injury, and so forth), the severity level of injury, and the AIS severity score.

The AIS severity score is an anatomically based system that categorizes injuries by six body regions using a six point ordinal scale ranging from minor (AIS=1) to currently untreatable (AIS=6) injuries. The other four scores are AIS 2=moderate, AIS 3=serious, AIS 4=severe, and AIS 5=critical. A score of nine is assigned for injuries of unknown severity AIS scores reflect not only potential lethality but also diagnostic certainty, as well as the expected duration and degree of recovery with or without medical treatment (Association for the Advancement of Automotive Medicine, 1990).

The AIS severity scores are based on only anatomical injury and not physiological status. This property means that a particular injury can have only one AIS score that does not change with time. In contrast, injury severity systems which include physiological parameters, such as the Trauma Score, may produce many scores for the same injury as the patient's physiological status changes with time The AIS' anatomical basis also means that it is a measure of the severity of the injury itself and not of the consequences of injury such as death or disability, the latter which may be affected by availability and efficacy of treatment (Association for the Advancement of Automotive Medicine, 1990).

AIS scores will be computed from interview data (all case groups) and from medical abstracts and autopsies (hospital and dead cases only). The scoring from each source (interview and medical records) will be done separately and blinded. AIS scoring employs precise medical information of sufficient detail usually found only in medical records

Injury Severity Scores (ISS's) will be computed separately from AIS's derived from the interview data (all case groups) and from medical records/autopsies (hospital and dead cases only). Analyses which rely on the ISS will be done twice, using each set of ISS's.

For the purposes of analysis, outcomes for each individual will be described in two ways: (1) the absence or presence of physical injury of any level and (2) the overall level of injury severity. Overall injury severity is a measure of the total impact of all injuries a person may have. It will be assessed using the ISS (Baker and others, 1974). The ISS is the sum of the squares of the highest AIS severity code in each of the three most severely injured ISS body regions. The ISS body regions are slightly different from the AIS classifications but are intraconvertable. The ISS has a range of 1 to 75. The maximum score of 75 is produced in one of two ways: either a person has three AIS level 5 injuries, or at least one AIS level 6 injury

DATA COLLECTION PROCEDURES

MEDICAL ABSTRACTS

The majority of relevant County hospital records were abstracted by the team described above from November 1989 to June 1990; the rest were abstracted in September 1991. The helicopter-mediated visits to out-of-County hospitals will be abstracted by the same team in future work. The summary judgment of medical diagnosis was used to determine which County hospital visitors to target for a follow-up interview.

HELICOPTER AMBULANCE LOGS

The premedical care logs of all local ambulance services were reviewed for the ascertainment period by the California Office of Emergency Services. In addition, the California

Department of Forestry and Fire Protection was contacted for a list of persons they helicoptered to neighboring County hospitals. Persons whose premedical care record indicated they were injured or did not list a diagnosis were targeted for a follow-up interview.

QUESTIONNAIRE AND INTERVIEW

Information on potential hazards, injuries, and other factors of interest was collected through a structured interview. The same questionnaire was administered to cases and controls, and their proxies when necessary.

The questionnaire was developed in English, and translated into Spanish to accommodate the large Hispanic population that lives in the southern part of the County. The translation was done by a doctoral student in public health who has extensive experience in health survey design and translation. Like most of the Hispanic residents of the County, the translator is of Mexican descent and was able to translate the questionnaire into an appropriate Spanish dialect. The Spanish version was back-translated into English by two qualified persons selected by the translator. The English version was pilot tested in June and July 1990 on a random sample of approximately 30 County residents who were not hospital cases; the Spanish version was comparably tested on a sample of 10. The versions were modified based on the lessons learned from pilot testing.

The questionnaire had eight parts, sections A to H. Section A collected demographic information and determined the physical environment (in a building, in a vehicle, or outside) in which the case or control was when the main earthquake began. The answers given in section A directed the respondent to either section B, C, or D. These sections asked about exposures, human behaviors, and injuries during the 15-second shaking period of the mainshock for those in a building (section B), in or on a vehicle (section C), or outside (in close proximity to a building or away from buildings entirely) (section D) when the earthquake began. Section E gathered information about hazards and injuries in the 72 hours after the mainshock. It also queried about being trapped and rescued during the shaking and subsequent 72 hours and evaluates the use and efficacy of the 911 emergency response system. Section E was administered to all respondents. Section F collected information on health care utilization. It was given only to those who reported an injury during the shaking or the next 72 hours. Section F also collected information on disabilities associated with the reported injuries. Section G gathered more demographic information, and data on drug and alcohol use, physical mobility, health insurance and preexisting medical conditions. Section H was the closing section of the interview and asked for future contact information.

The questionnaire took approximately 30 minutes to an hour to administer depending on the experiences of the respondent. The interview was conducted by a staff of trained bilingual interviewers located in the County. It was done in either English or Spanish depending on the preference of the respondent. It was generally administered by telephone at the respondent's home. However, interviews were conducted at a work phone, or in person through home visits if the respondent requested it. In-person interviews were also done for hospital and dead cases (or their proxies) who could not be reached by home phone because either they lacked a home phone or the study could not trace the phone number.

Proxy interviews were obtained for dead cases or for hospital cases who died since the ascertainment period. Proxies were sought for hospital cases who were unavailable during the interviewing phase, or who refused to do the interview. Proxy interviews were also done for study subjects who were under 13 years old, or who were too mentally or physically disabled to do the interview.

For respondents under 13 years old, proxy interviews were requested of parents or guardians. For other categories, proxy interviews were sought from adult next of kin. However, when next of kin were unavailable, other adults who were knowledgeable about the respondent were solicited.

Minors between 13 and 17 years old were interviewed directly. However, permission to do the interview was first obtained from parents or guardians.

RECRUITMENT AND ENROLLMENT OF HOSPITAL AND DEAD CASES

The recruitment and enrollment of hospital and dead cases began on July 19, 1990, and was completed on March 31, 1991. The process involved tracing, contacting, and obtaining informed consent from cases or their proxies in order to administer the interview.

TRACING METHODS AND COMMUNITY OUTREACH EFFORTS

Tracing efforts began with the information contained in the medical records. However, phone numbers and addresses were either missing or outdated for many cases. Therefore, the following additional sources were employed to trace cases or their proxies: (1) individuals including neighbors, friends, relatives, and apartment managers; (2) private and public agencies (for example, nonprofit social service groups, the Red Cross, churches, and government agencies including U.S. Postal Service, Voter Registration, California Department of Motor Vehicles, Planning Departments of the incorporated cities and unincorporated areas of the County); (3) a national credit bureau; (4) former and current employers; (5) Federal Express, (6) publicly available sources (newspapers, Directory Assistance, hard-bound and on-line criss-cross directories); and (7) a prominent Hispanic community organizer hired as a consultant to the study.

Tracing methods were chosen to protect the confidentiality of cases No information about the study or the case was divulged to past or current employers. When speaking with other categories of individuals, or public and private agencies, interviewers identified themselves as from the study but did not reveal that the case was injured or visited a hospital.

A bilingual community outreach campaign was initiated in August 1990 with the assistance of the community organizer. The purpose of the campaign was to familiarize the community with the study, and to encourage people who met the hospital case definition to contact the study for an interview. Flyers in Spanish and English were prepared and distributed to social service agencies, labor camps, churches, employment agencies, supermarkets, and other public places. Radio and television public service announcements on the study ran on local stations. The major County newspapers donated advertisement space to explain the study. The authors were also interviewed by local radio stations and newspapers.

CONTACT AND ENROLLMENT

In general, the study first contacted cases or their proxies at their homes by phone. When this was not possible, initial contact was made through other phone numbers (when available), home visits, or mailings which asked the targeted individuals to call the study, collect if necessary. Phone contact and home visits were made by the interviewers.

When a household was contacted, the interviewer asked to speak to the case or his or her proxy, if necessary. Once the desired person was reached, s/he was read an introductory script describing the study. To confirm that the proper person had been contacted, the interviewer asked for the case's age. When relevant, the interviewer also asked if the case visited the appropriate hospital in the 72 hours after the earthquake. If the reported age was within three years of that noted on the medical record or autopsy, and (or) the respondent confirmed a recorded hospital visit, the respondent was read an informed consent statement which describes the study's purpose, risks, and benefits. Respondents who granted consent were considered enrolled. The questionnaire was administered immediately after consent was given whenever possible. If this was not possible, the interview was scheduled for a later time.

If the reported age or hospital visit did not match the information in the medical records or autopsy report, the respondent was thanked, the session was ended, and the search for the correct respondent was continued.

RECRUITMENT AND ENROLLMENT OF THE POPULATION SAMPLE

The population sample was recruited starting in the middle of March 1991 and was continued through August 1991. The selection protocol was pilot tested in the first half of March 1991.

In general, the recruitment and enrollment process involved identifying eligible households by calling lists of randomly generated County telephone numbers.[15] Each randomly generated phone number was called up to six times, before it was discarded in favor of another one. The six calls were made at different times of day and on different days of the week. The interviewers proceeded down a list of such numbers until an eligible participant from a residence was enrolled. Persons reached at nonresidential numbers—businesses, government offices, jails, hospitals, nursing homes, and so forth—were not eligible for enrollment.

When a household was reached, the interviewer asked to speak to an adult. Once an adult was on the phone, the interviewer confirmed that the correct number was dialed and that it was a home phone. If the number was nonresidential, the session was terminated. If it was residential, the interviewer determined whether the household was eligible, that is, whether it was located in the County. If the household was eligible, the adult—the informant—was asked to list all the current residents in the household in descending order of age. The sex and relationship to the informant was also obtained for each listed member. The interviewer recorded this information on a numbered roster form. A potentially eligible respondent from the numbered list was selected using a random number table. A proxy was obtained for selected respondents who were physically or mentally unable to answer questions, or who were under 13 years old

When the selected person or proxy came to the phone, s/he was asked the questions on residency which determined eligibility. If the selected individual did not meet the residency requirements described earlier, another person on the list was randomly selected. The same steps were repeated until an eligible person was identified from the household. The selected individual was read the informed consent statement. If consent was granted, the interview began or was rescheduled. If consent was denied, the interviewer attempted refusal conversion. If this failed, contact with the household was terminated.

DATA MANAGEMENT AND QUALITY CONTROL

MANAGEMENT OF INTERVIEW DATA

Each study participant was assigned a unique identification number. A packet of materials was assembled for each hospital and dead case that included tracing information, interviewing materials, and a tracking sheet to record the

[15] See section "Population Sample Selection Plan" for a description of how the numbers were generated

time, day, and outcome of contacts. The packet for population sample members included the interview as well as materials for the selection of an eligible household member.

Once an interview was completed, the interviewer filled out a final disposition summary sheet and reviewed his or her work for accuracy, neatness, and completeness. The interviewer supervisors and (or) study coordinator then edit-checked the interview and went over any problems with the interviewer who conducted it. When information was incorrectly or incompletely ascertained, the interviewer was instructed to call the respondent back The specific questions asked or reasked were noted on the final disposition sheet.

A DBASE file was created to assist in tracing cases and monitor interviewing progress in cases and controls. Once a final disposition was reached, the information was recorded on the hard copy and was later transferred to the data base. After the interviewing phase was completed, the data base was stripped of identifying information (names, and so forth) to protect the confidentiality of those interviewed.

INTERVIEWER TRAINING

All interviewers received two days of training at the time of hire on general interviewing techniques, and procedures specific to the study. They received another two days of training on the population sample selection protocol in March 1991. The importance of maintaining the confidentiality of information collected was highly stressed. The training included role playing with the interview and doing practice interviews on noncase County residents Additional experience was obtained during the pilot testing phases. The interviewers were periodically monitored while interviewing to improve quality control.

CODING QUESTIONNAIRES

The answers to close-ended questions on the questionnaires were precoded. Coding of the open-ended questions is currently being done by the Johns Hopkins team. Spanish comments have been translated into English before being coded with the English responses. For a subset of the data, coding assignments to each open-ended question will be made independently by at least two persons so that interrater reliability can be assessed. Coders will also be asked to assign codes to the same data on different days to assess intrarater reliability

DATA ENTRY

Data entry of the coded questionnaires and the medical abstracts was subcontracted to a data entry firm in Baltimore, Maryland. The data was keypunched twice and verified for accuracy The Johns Hopkins team is currently doing additional analyses of the data tape to check for consistency and accuracy.

ASSESSMENT OF BIAS IN SELF-REPORTED INFORMATION

Information collected in the interview has two sources of potential bias, bias in the accuracy and in the repeatability of self-reported information. Accuracy for hospital and dead cases will be assessed by comparing the degree of correspondence between injury information reported in the interview and that contained in the medical records or autopsies.

Medical records are generally considered to be more accurate and complete than retrospective self-reports. However, this assumption is questionable for the first 12 to 24 hours after the earthquake, when the hospitals (especially Watsonville) were overwhelmed with visitors and treatment took a higher priority than keeping records. The hospitals reportedly resumed their normal routines after the first 24 hours. To adjust for variable degrees of completeness of the medical records, the accuracy analysis will be stratified by hospital and day of arrival at the emergency room.

Accuracy for all study groups will also be assessed by comparing self-reports of successfully reaching the 911 system to another dataset containing the logs of all 911 calls received in the 72 hours after the earthquake. The 911 dataset was compiled by study collaborator, Jim Schneider.

STATISTICAL ANALYSIS

Three basic types of analysis will be performed on the collected data: (1) a case-control analysis, which compares hospital and dead cases to noninjured controls to evaluate the significant risk factors for earthquake-related injury; (2) a study of selection factors for seeking medical treatment among the injured, which compares hospital cases to population cases that did not seek medical attention; and (3) descriptive analyses which estimate total injury morbidity and mortality in the County of Santa Cruz related to the earthquake.

CASE-CONTROL ANALYSIS

The relationship(s) among the injury and various risk factors will be analyzed through a series of steps. Exploratory data analysis will be employed to identify significant risk factors. Injury outcomes for each case will be characterized in two ways: (1) the presence or absence of injury (a binary outcome variable) and (2) the overall level of injury severity as measured by the ISS (an ordinal outcome variable). Separate analyses will be performed for cases who were injured during shaking, versus those who were injured in the next 72 hours. Some cases were injured in both time periods, and attempts will be made to model the dependence of being injured in the postshaking phase on being injured during the mainshock. Separate analyses will also be conducted for injuries directly and indirectly related to the earthquake.

When the outcome variable is the presence or absence of injury, odds ratios can be computed. Univariate and bivariate analysis will first be performed followed by multiple logistic regression to characterize the independent risk factors and their interactions adjusted for confounders. The relative odds associated with being in different physical environments, broadly defined (that is, building, vehicle, outside) will be evaluated. Subgroup analyses will also be performed for risks within each physical environment.

The ISS has a range of 1 to 75, with higher values representing greater injury severity. When the ISS is the outcome variable, it will be used to create categories of injury severity (for example, mild, moderate, severe, lethal, and so forth). ISS ranges will define each category. Logistic regression will be done where the outcome variable is defined as injury severity class (for example, severe vs. moderate; severe vs. all other) and the dependent variables are the same as before. Several categorization schemes have been used by other investigators and will be explored here (MacKenzie and others, 1986; Copes and others, 1988).

MEDICAL TREATMENT SELECTION FACTORS ANALYSIS

The selection factors for medical treatment among the injured will be evaluated in several ways. Injury severity as a selection factor will explored by comparing the distribution of ISS's for hospital cases to the distribution for population cases with back-to-back stem and leaf plots. Multiple logistic regression will also be performed where the outcome variable will be sought or did not seek medical treatment (that is, y=1 for hospital cases and y=0 for population cases). The independent variables will be the various potential selection factors including but not limited to perceived and actual injury severity level, possession of health insurance, entrapment due to the earthquake, preexisting medical conditions and mobility, the needs of others, and sociodemographic features such as age, sex, and ethnic origin.

DESCRIPTIVE ANALYSES

The total burden of physical injury in County of Santa Cruz residents associated with the Loma Prieta earthquake will be estimated. Both hospital and population cases, appropriately weighted, will be used to this end. Total morbidity and mortality will be calculated as well as age-, sex-, ethnic origin- and injury severity level-specific rates in the County population. Casualty rates for the disaster and post-disaster phases will be calculated, as will rates for injuries directly and indirectly related to the earthquake.

The ability to estimate rates is a special feature of this study. It is not possible to do this with most case-control study designs. However, it is possible to estimate rates in this study because estimates are available for both the size of the total population at the time of the earthquake and the fraction of the total sampled for each of the three geographic strata.

Spatial analyses of injuries will also be performed in collaboration with study collaborator, Jim Schneider. Spot maps which distinguish cases by injury severity, physical environment, time period of injury, and so forth will be made. The relationship between injuries, distance from the epicenter, and zone of earthquake intensity will be investigated.

PRELIMINARY PROGRESS REPORT ON CASE-CONTROL STUDY

The following preliminary results should be interpreted with caution as they have not yet been thoroughly validated. Validation efforts are currently underway, the results of which will be reported in the future.

HOSPITAL AND DEAD CASES

As noted in section "Preliminary Results of the Descriptive Study," the size of the target population of potentially eligible hospital and dead cases was 579. Interviews were obtained for 482, or 83 percent of the target population. Another 31, or 5 percent refused to do the interview, and 66, or 11 percent were lost to follow-up.

Completed interviews were provisionally reviewed to evaluate which respondents were eligible for the case-control and descriptive studies. Recall that the eligibility criteria are more stringent for the former than for the latter study. Nearly three-fourths of those interviewed (n=358) are definitely eligible for both studies, including 10 percent (n=48) who moved out of the County of Santa Cruz after the earthquake. Twelve percent (n=58) are ineligible for either study because they were not injured or their injuries were clearly not earthquake related. About 5 percent (n=26) are eligible only for the case-series study because they were not County residents at the time of the earthquake or they lacked home phones at the time of the interview. Seven percent (n=36) met the residency and phone requirements of the case-control study but had injuries whose relationship to the earthquake is questionable. This last group will be included in the case-control study but will be analyzed separately from other cases. Finally, less than one percent (n=4) are possibly eligible for the case-series but not the case-control study.

Thus, the number of hospital and dead cases which qualify for the case-control study ranges from 310 to 394, depending on the stringency of the case definition. The most stringent definition includes only those definitely eligible cases who had not moved outside the County by the time of the interview (that is, 358-48=310). The most lenient definition includes those who are definitely eligible for the case-control study, including those who moved out of the County, plus those for whom the earthquake relatedness of their injuries is unclear (that is, 358+36=394).

To date, all but 3 (0.8 percent) of the 394 hospital and dead cases have been assigned to one of the three residential strata used to match noninjured controls to cases (the remaining three cases require additional information to classify). At the time of the earthquake, 38 cases (9 6 percent) resided in the north mountainous part of the County (stratum 1), 179 (45.4 percent) lived in the coastal northern and midcounty area that includes the city of Santa Cruz (stratum 2), and 174 (44.2 percent) lived in the southern part of the County that includes Watsonville (stratum 3).

POPULATION SAMPLE: NONINJURED CONTROLS AND POPULATION CASES

The reader is again cautioned that the figures, provided below, are preliminary and await verification.

A total of 2,749 telephone numbers were called as part of the population sampling plan. Of these numbers, 780 (28.4 percent) were nonhousehold numbers (for example, businesses, disconnected numbers, FAX or modem numbers, and so forth). Another 1,823 (66.3 percent) were determined to be households. The status of another 146 numbers (5.3 percent) was unknown because no answer was ever obtained upon calling them.

Of the 1,823 households contacted, 538 (29.5 percent) were ineligible because they were either located outside of the County boundaries or contained residents who had moved to the County after the earthquake. Another 432 households (23.7 percent) were ineligible because they were contacted after the residential stratum from which they came was filled (see section "Population Sample Selection Plan") Four households (0.2 percent) posed a language barrier which precluded doing the interview, six eligible households (0.3 percent) had otherwise eligible respondents who were not available during the study period (for example, were serving in the Persian Gulf War), and five households (0.3 percent) contained a person who had been previously interviewed by the study.

One hundred thirty-six households (7.5 percent) refused to cooperate with the study, despite efforts to persuade them to do otherwise. An unknown proportion of these refusals almost certainly came from ineligible households, as many of them occurred before household eligibility could be determined, nearly a third of the cooperating households were found to be ineligible, suggesting that some of the uncooperative ones were ineligible as well. Study efforts at refusal conversion—conducted within the appropriate guidelines of informed consent—were quite successful. Initially, 299 households refused to participate in the study. It was eventually possible to convince 163 of them (54.5 percent of the refusals) to cooperate.

Finally, 701 of the 1,823 households were eligible (25.5 percent) and provided one eligible person each to interview (resulting in 696 completed interviews and 5 break-offs). These 701 respondents comprise the population sample for the case-control study.

The population sample was distributed in the following manner. At the time of the earthquake, nearly 20 percent (n=138) lived in stratum 1, 45.6 percent (n=320) lived in stratum 2, and 34.7 percent (n=243) resided in stratum 3. Just over 15 percent (n=106) of the population sample reported an earthquake-related injury and thus were classed as population cases. The majority of these injuries were minor, although a systematic review of injury severity has not yet been done. The remainder were noninjured controls (n=594) or had an unknown injury status (n=1).[16]

The proportion of reported earthquake-related injuries varied by stratum. The northern and mid-County coastal area had the lowest proportion of injuries, with 12.2 percent (n=39) of the 320 stratum 2 respondents reporting one. The northern mountainous region had the highest percentage of injuries, with 18.1 percent (n=25) of the 138 stratum 1 respondents saying they were injured. The heavily Hispanic south County area followed closely behind, with 17.3 percent (n=42) of the 243 stratum 3 respondents reporting an injury.

FUTURE DIRECTIONS

Further characterization of injuries and their associations with potential risk factors is underway. These results will be reported when available.

SAMPLE SIZE AND STATISTICAL POWER

The maximum sample size of the case group (that is, hospital and dead cases) was fixed by design. Of the 482 interviewed to date, almost 400 hospital and dead cases were provisionally found to qualify for the case-control study.

Statistical power increases as the ratio of noninjured controls to cases increases to about four when the prevalence

[16]One break-off interview ended before the injury status was determined

of exposure to a risk factor of interest is low in controls[17]. Balancing additional costs of doing extra interviews against a desire for greater power, a ratio of 2:1 noninjured controls to each hospital/dead case was sought with a 1:1 ratio as an absolute minimum. Because controls were matched to cases on residential stratum, this translated into seeking a 2:1 ratio in each stratum.

Due to resource constraints, the 2:1 goal was met only for stratum 1. The minimum goal of a 1:1 ratio was exceeded for strata 2 and 3. The ratios that were achieved were 3.0 (113/38), 1.6 (281/179), and 1.1 (200/174) noninjured controls per case for strata 1, 2, and 3, respectively. The total sample size for noninjured controls was 594. Thus, the overall ratio of noninjured controls to hospital and dead cases was 1.5 (594/394).

The statistical power actually achieved is likely to be somewhere between having one and two controls per case, all other relevant factors held constant (for example, sample size of cases, type 1 error, exposure rate of risk factor in controls, relative risk). Therefore, power calculations discussed below are presented as a range, assuming the control:case ratio of 1:1 and 2:1, all other factors held equal. A 5 percent significance level (type 1 error) is also assumed.

Most analyses will be conducted on subgroups of the total. For example, cases injured during the shaking will be analyzed separately from those injured in the next 72 hours. Approximately 75 percent, or 300, of the cases are expected to have been injured during the shaking.[18] One might wish to estimate the relative risk of injury among those in a building versus other physical environments when the earthquake began. The power to detect a significant relative risk of injury with 300 cases for a variety of relative risk values (1.25-20.0) and levels of exposure to a risk factor in controls (0.1-0.9) was calculated.[19] The power lies between 82 percent and 99.8 percent to detect any relative risks greater than or equal to two for any background exposure rate in controls of 80 percent or less.

Sample size will be further reduced when doing subgroup analyses restricted to each physical environment. The power to detect a significant relative risk of injury with 100 cases was calculated for the same range of relative risks and exposure rates in controls, and the same significance level as for the preceding example. The power lies between 80 percent and 99.4 percent to detect a relative risk of three or more for exposure rates in controls less than or equal to 70 percent. For a relative risk of 2.0, the power ranges from 24 percent to 80 percent for exposure rates in controls between 0.1 and 0.9.

[17]Personal communication with Dr Walter Stewart, Associate Professor of Epidemiology, Johns Hopkins University, Baltimore, Md

[18]This conclusion is based on a preliminary analysis of a subset of cases eligible for the case-control study.

[19]Power calculated from the formula (6.9) in Schlesselman (1982, p. 151)

STUDY LIMITATIONS

CASE ASCERTAINMENT ISSUES

Not all County hospital cases were ascertained because some visits to the hospitals made in the 72 hours after the earthquake were not recorded. An estimated 30 to 40 people were treated at Watsonville Hospital, and some small but unknown number were seen at Dominican Hospital for whom no record was made. All of the missing persons are likely to have had minor injuries (they were treated and discharged). A few of these cases may have been picked up in the population sample, a determination which awaits further analysis.

People who were injured in the 72 hours after the earthquake but who went to the hospital after 72 hours will not be ascertained as hospital cases. The magnitude of this problem is unknown but is expected to be small according to anecdotal reports of hospital personnel (Jim Schneider, County of Santa Cruz Office of Emergency Medical Services, 1990, personal commun.). Again, a few of these people may have been selected in the population sample. In contrast, all injuries that occurred in the population sample during the 72-hour ascertainment period will potentially be detected.

SAMPLING FRAME ISSUES

For practical reasons, the sampling frames were slightly different for hospital cases and the population sample. Noninjured controls and population cases had to be County residents at the time of the interview to get into the sampling frame, whereas hospital cases did not have to satisfy this criteria. As a result, hospital cases who left the County after the earthquake were included in the study. However, noninjured controls and population cases who have moved out of the County since the earthquake were not included. The frames could be made comparable by excluding outmigrating hospital cases from the case-control study. This option was rejected since outmigration may be related to both risk factors (for example, earthquake-damaged residence) and injury severity levels. Although it is not possible to obtain a probability-based sample of noninjured controls who have left the County, it is possible to evaluate the importance of outmigrators in the hospital case group by studying how risk estimates change, if at all, by their inclusion or exclusion.

Another difference in the sampling frames between hospital cases and controls is that a small subset of cases did not have a home phone at the time of the interview whereas all controls did. Similarly, a few hospital cases lived in institutions at the time of the interview (for example, in jail, hospitals, and so forth), whereas all controls lived in private residences when interviewed These distinctions arose from the different sampling methodologies used to ascertain cases and controls: cases were ascertained from medical records, independent of their home phone status or type of residence, whereas controls were ascertained from private residences using a randomly generated list of phone numbers. To make the sampling frames comparable, cases without home phones or living in institutions at the time of the interview will be excluded from the analyses. This exclusion could result in some bias; it is well known that individuals who have home phones or who live in private residences may differ significantly from those who do not. One way the study will try to measure the degree of bias introduced by excluding hospital cases that lacked a home phone or lived in institutions at the time of the interview will be to examine how risk estimates change, if at all, by their inclusion or exclusion.

It is important to note that the exclusion of persons who lack home phones or who live in institutions is an inherent limitation of the random digit dial sampling method. It is a commonly employed method, however, because it is relatively inexpensive and it generates a nonbiased, random sample of persons who have residential phones, which constitute the vast majority of the population.[20] The standard alternative sampling method—multistage sampling of first blocks, then households within selected blocks, and then individuals within selected households—is far more expensive in time and money. The latter method requires sending staff into the field to do an up-to-date census of all residential units within selected blocks. Interviewers then must attempt to contact households in person, a task which to succe· ully complete may require many visits to homes spread out over a large geographic area. The study employed the random digit dial method for selecting controls for practical reasons—that is, resource limitations.

INTERVIEWING TIMETABLE ISSUES

Noninjured controls and population cases were interviewed after hospital cases and proxies for dead cases. Several potential biases are introduced by this situation. There may be differential recall bias in self-reported information provided by the respondents. Many hospital cases or proxies were inter· ·wed less than one year after the disaster, whereas all controls were surveyed at least 17 months after the event. It can be argued that recall bias is less likely in this situation because the earthquake was a point source environmental exposure experienced by everyone in the County. In the field work, virtually everyone contacted indicated that people told their earthquake experience to others over and over again. This may enhance recall of the event. In any case, potential recall bias in the hospital case group can be examined by comparing the information contained in the medical records to self-reports to see if correspondence between the two sources declines with calendar time.

There may also be interviewer bias because the interviewers were not blinded to the injury status of the hospital and dead cases. However, the effects of nonblinding should be mitigated in part by the fact that both injured and noninjured persons from the population-based sample were interviewed in the same time period—and injury status was not determined before the interview began.

INFORMATION BIAS ISSUES

Medical records were less complete in the first day following the earthquake when the emergency rooms of the County hospitals, especially Watsonville Hospital, were overwhelmed with patients. For some cases, no diagnosis information was recorded. Missing or incomplete information will preclude or compromise the ability to compute ISS's from medical records. One possible solution to this problem is to evaluate the degree of record completeness by day of arrival at the emergency room. A stratified analysis by day of arrival at the hospital can be done to see if and how risk estimates are affected.

Another form of information (and recall) bias may also affect the computation of AIS scores. The injury questions on the questionnaire were designed to solicit the same types of information necessary to assign AIS codes to them. However, most respondents are unlikely to be able to report their injuries at the detailed level the AIS can accommodate. This problem should not preclude using the AIS on the interview data but may result in systematically underestimating true injury severity; when details on an injury are not specified, the AIS usually assigns a lower severity score. The accuracy of self-reports of injury severity will be assessed by examining the degree of correspondence between AIS scores based on interview data and those computed from medical records and autopsies. The latter procedure can be done only on hospital and dead cases.

While the medical records-based ISS's are expected to be more accurate, their use will reduce the sample size for hospital cases since the medical records for at least 10 percent of these cases had no diagnostic details. The assumption of greater accuracy of medical records recorded during a disaster over interview data may also be incorrect. This is

[20] In fact, the 1980 U S. Census indicated that 96 percent of County residents had a home phone. The comparable statistics from the 1990 Census, which coincides more closely with the time period of the study, will be evaluated when available

especially true for hospital visits made in the first 24 hours after the disaster, as noted above.

OTHER ISSUES RELATED TO THE ISS

The use of the ISS to measure injury severity presents several advantages. First, it has biological relevance in that it has been shown to correlate well with the probability of death (Greenspan and others, 1985). Second, it is the most widely used anatomically based injury severity scale, facilitating comparisons across injury studies (MacKenzie and others, 1986). Third, it has been shown to have relatively high inter- and intra- rater reliability for both blunt and penetrating injuries, even among persons without medical training (MacKenzie and others, 1985).

A limitation of the ISS is there is some heterogeneity in mortality associated with some of the same value ISS scores. This heterogeneity may be the result of several factors: (1) the ISS measures only the most severe injury within a given body region, ignoring the effect of multiple injuries to that part; (2) combinations of injuries of different severity levels—with different mortality experiences—can produce the same ISS score; and (3) the ISS gives equal weight to each body region even though same level injuries to some regions (that is, head injuries) appear to be more lethal than others (Copes and others, 1988). This heterogeneity may be reduced by aggregating ISS scores into categories (Copes and others, 1988) as proposed in the "Statistical Analysis" section above.

CONCLUSIONS

Despite the limitations discussed in the preceding sections, it is believed that the studies described herein will provide a wealth of information relative to morbidity and mortality in the Loma Prieta earthquake, and for earthquakes in general.

It is clear from literature reviews that there is a shortage of quality, quantitative data in this area. In conducting this study, at least some of the reasons for this scarcity became evident. Even in the U.S., collection of both the case and control data was difficult. The research team is most encouraged by the support it received in most phases of the study from a broad range of people (see "Acknowledgments" section).

Successful completion of the analysis phase of the study will provide useful quantitative information to epidemiologists, engineers, planners, emergency medicine personnel, and so forth, relative to earthquake preparedness for future events In addition, while it is recognized that this study provides a single-event perspective of injury patterns, it is hoped that it will form the basis for future studies in earthquakes in this country and abroad, thereby enabling comparative studies among events to be made.

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Dr Kirsten Waller is the California Department of Health Services' principal scientific advisor on the descriptive study. She wrote the medical abstract form in consultation with Prof. Gordon Smith, and co-authored early drafts of the questionnaire. She has been involved with the study since its inception and continues to provide assistance and advice on the collection of case data. Drs Alex Kelter and Roger Trent are responsible for coordinating the efforts of the various study collaborators. They also oversee the sizable California Department of Health Services' budget allocated to the study.

Peter Roeper, a consultant to the California Department of Health Services, acted as Study Field Coordinator from June through September 1990. He managed the interviewing operation and field staff in the first months of the study. He had primary responsibility for hiring and training the first group of interviewers in June 1990. He also contributed to the development of the questionnaire.

Jim Schneider and Lisa Angell, emergency medical care specialists, organized and directed the medical abstraction of hospital case records. Mr. Schneider conducted a parallel study of the utilization of emergency medical services in the County in the 72 hours after the earthquake. Ms. Angell, the hospital base coordinator for Watsonville Hospital, is the primary liaison between the cooperating County hospitals and the descriptive and case-control studies.

The Santa Cruz field staff consisted of the study coordinators, and 21 interviewers (their names are not listed here for brevity). Most of the interviewers were local college students. Three of the interviewers also served as interviewer supervisors. All of the interviewers were fluent in Spanish and English except for five. An additional student was hired to assist in translating Spanish interviews into English for coding.

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