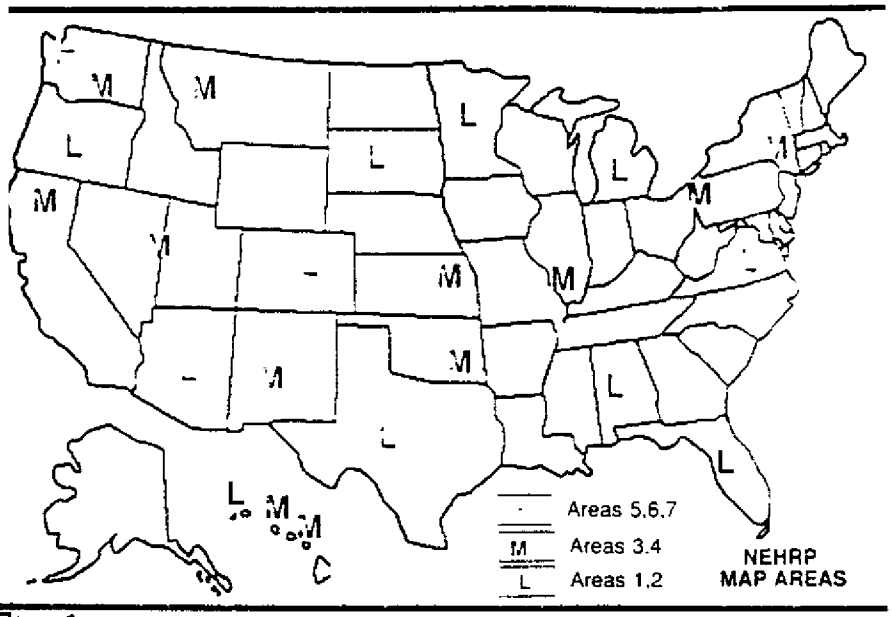


Figure 1

emergency of a lifetime--a catastrophic earthquake? The potential for major earthquakes extends far beyond California, extending to 39 of the 50 states, and many fire departments lack an adequate preparedness plan. In the following article, we outline the potential impact of a major earthquake and how to develop a preparedness plan.

Earthquakes, and the resulting dangers of building collapse, fires and hazardous materials releases, are hazards in all parts of the United States. Figure 1, taken from a *Handbook for Rapid Visual Screening of Buildings for Potential Seismic Hazards*, recently developed for FEMA, divides the country into three areas of earthquake risk: low, moderate and high. This figure is based on extensive geological and seismological investigations, as well as the locations of significant historical earthquakes.

While California receives most of the publicity, the Puget Sound, Salt Lake, the central Mississippi Valley area (including Memphis, St. Louis and other major cities), the Southeast (especially around Charleston) and the Northeast (especially Boston) are all areas that have sustained or are at risk from major earthquakes. Indeed, the largest earthquakes to ever have occurred in North America--larger than the 1964 Alaska earthquake--was not the San Francisco or another California earthquake, but rather three great earthquakes, each larger than the 1906 event, which occurred in the winter of 1811-12, in the central Mississippi Valley. Compounding the fact that earthquake risk is much more widespread than generally recognized is that buildings in most regions of the nation outside of California are not adequately designed for earthquake. This is because central and eastern earthquakes, which are felt over much wider areas than western U.S. earthquakes, are far more infrequent, so earlier building code writers were not generally aware of the potential seismic risk. Only in the past few decades have geologic and seismologic investigations revealed the true nature of the risk. As a result, many of the existing buildings in large parts of the nation are prime candidates for collapse, should a major earthquake strike.

Size up

As with most other problems, approaching the task of developing an adequate earthquake preparedness plan begins with sizing up the earthquake problem. If your department is in the moderate or high areas shown in Figure 1, you face a significant earthquake risk. If your city is moderate or large, with mid- or high-rise buildings--especially concrete or masonry buildings more than a few decades old--you could be facing multiple, simultaneous building collapses, major fires and other emergencies, all in an instant.

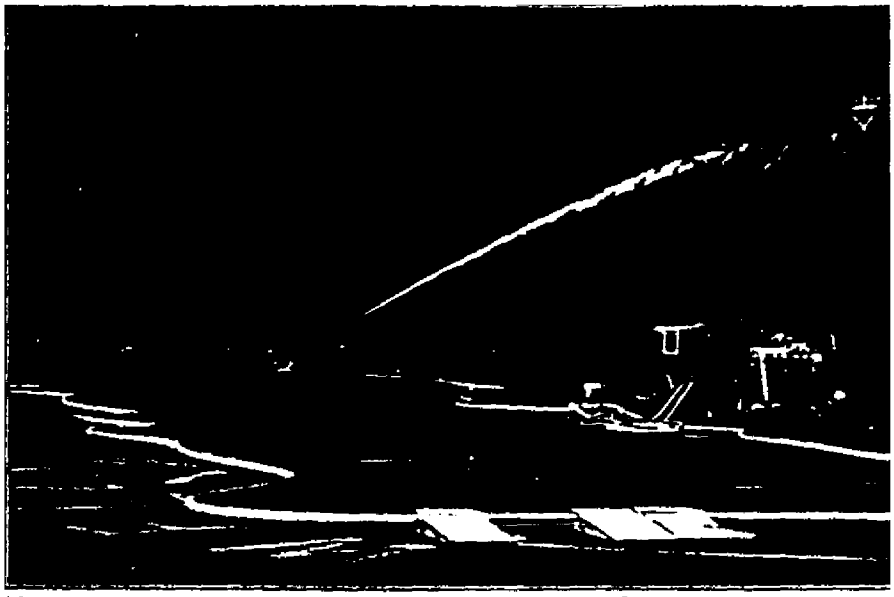
Significant portions of many cities, especially high value districts or municipal water supplies, are located in or cross old riverbeds or other alluvial or soft, wet ground areas, which tend to amplify earthquake damage. The key to your response to these problems will be the size up, your preparations and preplanning. The size-up problem has several aspects:

Earthquake impact on the department. What will the earthquake do to your department, its fire stations and the personnel and apparatus they house? Fire stations as a class of buildings are particularly vulnerable to earthquakes, due to the large spans and openness of the apparatus floors and doors.

San Francisco recently had structural surveys conducted of all its fire stations and the results were ominous. Of the 41 fire stations surveyed, 17 or more than 40 percent were judged high collapse hazards (Figure 2). Older brick or reinforced concrete frame buildings are generally the highest hazards.

The FEMA Handbook referred to above provides a simple methodology that departmental personnel or city engineers can employ to provide an initial determination regarding the seismic vulnerability of the department's

Fires following the 1906 San Francisco earthquake resulted in the largest urban, peace-time fire in history to that time.



Thousands of feet of large-diameter hose are needed for a PWSS. The hose ramps permit vehicles to pass over while protecting the hose from damage.

fire stations. Headquarters, communication centers and other critical buildings also should be included in this survey.

Search and rescue. A single building collapse typically commands the attention of the entire fire department. How many building collapses can your department expect to be faced with following a major earthquake? Having an approximate idea of the number and nature of building collapses and the associated search and rescue (SAR) problem is the key to determining what kinds of training and equipment your department should be pursuing.

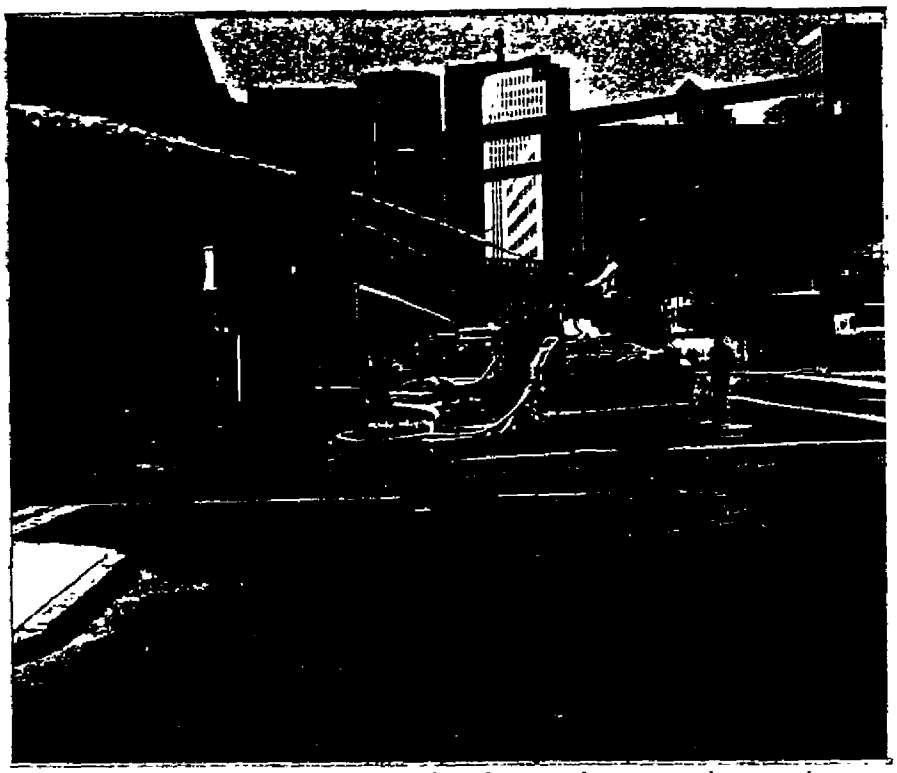
Estimation of building damage or collapse due to earthquake is not easy, but some guidelines can simplify the problem considerably. Most single-family dwellings, especially the typical wood-framed house, perform relatively well in earthquakes and can be eliminated from further concern immediately. Steel-framed mid- and high-rise buildings are also generally good buildings from an earthquake point of view and can be eliminated from immediate concern. Brick, concrete frame and pre-cast concrete buildings are generally the more likely candidates for collapse in a major earthquake, especially older buildings in these classes, which will not have benefited from recent building code changes.

The FEMA Handbook was developed to provide a simple survey form and scoring system for buildings. The city of Berkeley, California, has employed this Handbook in identifying several hundred high hazard, unreinforced masonry buildings. San Francisco has identified more than 2000 unreinforced masonry buildings. Both cities are developing mitigation programs to abate the earthquake hazards posed by these buildings.

The Handbook can be employed by city engineers or even fire department personnel during inspections to rapidly and simply rate these higher risk buildings. Buildings scoring lowest can be considered high collapse hazards in a major earthquake. The number and distribution of low scoring buildings will provide valuable insight into the location and size of the post-earthquake SAR problem confronting your department.

Fire. Fires following the 1906 San Francisco earthquake resulted in the largest urban, peace-time fire in history to that time. How bad will the fires be following a major earthquake in your city?

According to *Fire Following Earthquake, Estimates of the Conflagration Risk to Insured Property in Greater Los Angeles and San Francisco,* by Charles Scawthorn, a recent study of the post-earthquake conflagration risk in Los Angeles and San Francisco provides a rule of thumb for estimating the number of fires your department will be called upon to respond to following a major earthquake: Divide the city into those areas on firm soils or rock and those areas on softer soils (e.g., where piles often are driven for building foundations). Figure approximately one fire per 10,000 residents in the firm soil areas and twice this rate in the softer soils areas. For commercial and industrial areas (including downtown), use the working rather than the residential population. Each of these fires, following a major earthquake, will require your department's response and will be



A PWSS requires numerous fittings, portable hydrants and pressure reduction valves

larger than average fires, due to delayed reports.

Water supply. Water for firefighting following a major earthquake is vital. How will an earthquake affect your city's water supply? What districts will be cut off and where will water pressure be reduced? This is a complex geological and engineering question that probably best is answered by water department engineers. Too often, however, other more pressing problems, demanding the attention of water department staff, result in this question going unanswered for so long that finally it is forgotten. The result? The fire department is still in the dark regarding the impact of a major earthquake on its water supply.

In the interim, a simple technique is to review surficial geological maps of your city, which are available at the main library, and pinpoint areas identified as quaternary and/or Holocene (or recent) alluvium. These areas often will be old, marshy areas, old riverbeds and/or near river or waterfronts.

As a first approximation, assume that water pipes in or crossing these areas will be broken (due to major ground failure because of liquefaction and other poor soil effects). Then, with a water system map in hand, review the remaining system to determine:

- what areas of the city are near or completely isolated, due to these breaks
- what areas of the system, although not cut off by the breaks, cannot be isolated by closing valves, so that pressure in these parts of the system will be reduced to near zero.

Eliminating these areas from the water system will reveal the surviving

water system and those areas where water supply will be impaired severely or completely unavailable. This analysis, while quite simple and probably overestimating earthquake damage in some areas, will give the fire department a first approximation of the surviving water system and perhaps motivate water department personnel to examine this problem more closely.

Haz mat and EMT demands. Hazardous materials (haz mat) and emergency medical treatment demands on fire department resources can be estimated using simple guidelines and rules of thumb as presented above. EMT demands should be based, in part, on the SAR guidelines presented above, recognizing that additional demands will occur due to injuries sustained, even in undamaged buildings. A significant number of heart attacks, for example, should be anticipated. The potential for haz mat incidents should be anticipated wherever significant amounts of haz mats are present.

Developing a preparedness plan

Having sized up the potential problems and demands on your department due to a major earthquake, the nature, degree and distribution of demands should provide a good guide for the development of a preparedness plan. The plan has to address many aspects,

Communications centers are often surprisingly vulnerable.

basically in the logistics and response areas, and might do this according to the following categories:

Departmental survival and functionality. Departmental survival and functionality are the first priorities of any earthquake preparedness plan. This begins with the structural integrity of the fire department's fire stations and other critical structures. Structures should be surveyed for earthquake collapse potential, according to EQE Engineering, Inc. *Inventory and Post-earthquake Functionality of Emergency Response Resources: Fire Service Operations in the Puget Sound Area Proposal to the U.S. Geological Survey*, National Earthquake Hazards Reduction Program. Reston, Virginia. Unreinforced masonry and pre-1970s concrete frame buildings are among the highest hazard buildings, as stated in *Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook*. FEMA-154, Earthquake Hazards Reduction Series 41, July 1988. Equipment and station contents should be seismically secured so that lockers, overhead lights or other items don't become dislodged in an earthquake and injure firefighters.

Equally important is the seismic safety of departmental headquarters and the communications/dispatch and emergency operations centers. Communications centers are often surprisingly vulnerable, due to non-secured computers, inadequately braced raised floors, unsecured battery racks, etc.

Major earthquakes often are preceded by minor foreshocks, which may provide valuable warning. To take advantage of these foreshocks, your department should have a standing order to open apparatus doors and pull apparatus out of the station, preferably to a nearby, pre-designated open area

When a major earthquake strikes, large amounts of all kinds of items will be required in a very short time, including fuel, hose and fittings, spare tires, tools, gloves, helmets, turnouts, medical supplies, flashlight batteries, heavy equipment, etc. Each fire station should have a fuel tank and be equipped with an electric generator so the fuel pump, electric lights and other equipment will be operable in the absence of normal electric service Spare hose, fittings,

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tools, gloves, etc. should be stockpiled in several key fire stations selected for their accessibility. Non-department sources for these items, such as wholesalers, should be identified for rapid procurement following the earthquake. Consideration should be given to pre-existing agreements with selected suppliers, equipment owners and operators, etc.

Departmental command. Anticipate loss of normal communications, due to loss of power, damage to relay antennas, etc. Exercise back-up departmental communications regularly relying, if necessary, only on vehicle radios. Identify high points and plan (and exercise) for relocation to these points of non-essential but radio-bearing vehicles, to serve as radio relays. Expect saturation of radio frequencies and plan around this. Recognize the possibility of disrupted communications between the departmental Emergency Operations Center and individual companies and the necessity of fallback to a decentralized (e.g., battalion level) command structure.

Size up: rapid damage reconnaissance. Ordinary means of fire and other emergency reporting (i.e., telephones and automatic alarm systems) will be disabled by the earthquake, due either to damage or simple saturation. A rapid size up or damage reconnaissance of the entire city is vital to optimum allocation of departmental resources.

Many departments assign the task of damage reconnaissance to each company, which is supposed to perform this task by driving around its response district. This is a fundamental error, since companies either will be called immediately to an emergency or respond on their own to the first emergency encountered.

Realize that the fire department cannot perform the damage reconnaissance, period. Its function is firefighting and other emergency response, not intelligence gathering. No fully satisfactory alternative exists for the performance of this task. Assigning this work to the police departments offers the advantages of trained observers, familiar with the territory, emergency powers and radio communications. Disadvantages include concern on police departments' part that they cannot assume this additional task, given traffic and crime control demands immediately following an earthquake.

Adequate water supply. As discussed above, even cursory examination of your city's water system may indicate areas of water supply loss. Because fires may be counted on to break out immediately following the earthquake, alternative water supplies must be identified and developed prior to the earthquake. This includes normal fire service practice of identifying ponds, tanks, swimming pools, etc., for drafting sites.

Additionally, however, consideration should be given to two tactics San Francisco developed following the 1906 earthquake, which are as viable today as in 1906:

- construction of underground cisterns at key locations
- development of a portable water supply system.

Major reconstruction followed the San Francisco earthquake and fire, in the course of which approximately 150 underground tanks, or cisterns, were constructed at key intersections. These cisterns typically hold 75,000 gallons, or approximately one hour's supply for a pumper, and are virtually maintenance-free. They are particularly useful for counteracting the problem of portions of a city water system being isolated due to ground failure, as discussed above. San Francisco's experience has been so satisfactory that recently, a decision was made to add 94 cisterns in portions of the city developed in more recent years.

> Sources of water are only half the battle. The other half is conveying water from the source to the fireground, under post-earthquake conditions of ruptured water mains.

Sources of water are only half the battle--the other half is conveying the water from the source to the fireground, under post-earthquake conditions of ruptured water mains. Long lengths of large-diameter (5- or 6-inch) hose fulfill this function, especially if only one to two sources or destinations have to be served. In a real city, however, with multiple post-earthquake ignitions requiring very large fire flows (20,000 to 50,000 gpm, which may necessitate multiple water sources), a large-diameter, hose-gridded network or portable water supply system (PWSS) is required.

In addition to thousands of feet of

Figure 2

large-diameter hose, a PWSS requires numerous fittings, portable hydrants and pressure reduction valves. San Francisco has developed a PWSS, incorporating 16,000 feet of five-inch-diameter hose, carried on four special hose wagons equipped with monitors, portable hydrants and pressure reduction valves. This system and those responsible for its operation are drilled regularly in exercises involving the delivery of large volumes of water to multiple monitor streams, creating a water curtain several city blocks in length. The system is capable of complex gridding and has served in numerous greater-alarm fires, as well as for the furnishing of emergency drinking water (using associated portable chlorinators). Depending on your city's needs, a PWSS should be given serious consideration.

Search and rescue after the earthquake. Recent earthquakes, including the Mexico City and Armenia incidents, have highlighted the enormous search and rescue (SAR) problems following a major earthquake and the need for trained, well-equipped personnel for heavy debris victim location and extrication.

There are several issues involved in rescue operations in a heavy debris environment. These include choice of equipment, assignment of responsibility, the actual techniques of rescue and coordination of the rescue operations.

According to *Earthquake Damaged Buildings: An Overview of Heavy Debris and Victim Extrication*, FEMA-158, Earthquake Hazards Reduction Series 43, recent work has shown that current SAR capabilities tend to make burrowing and tunneling the most feasible rescue technique. Heavy equipment, for the supposed removal of large pieces of debris, is relatively ineffective in the rescue phase. Large numbers of hand tools, hand-operated power tools, gloves and protective clothing, shoring, jacks,

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EARTHQUAKE PREPAREDNESS

(continued from page 49)

air bags, etc. are most in demand at this time.

As discussed above, a departmental earthquake preparedness plan should reflect this state of the art by acquiring sufficient supplies of these items and stockpiling them at key stations. Further, identifying local alternative or supplemental supplies is advisable. Finally, several teams should be trained in heavy debris SAR.

Conclusions

A major earthquake has the potential to strike a large city in many parts of the U.S., resulting in the collapse of hundreds of buildings and the simultaneous ignition of dozens of fires. A satisfactory response to this situation requires careful planning and development of adequate logistics and tactics. These can be developed by first sizing the problem up; that is, using simple guidelines and rules of thumb to estimate the magnitude, nature and distribution of building collapses, fires and other incidents to which your department will be called to respond.

This simple analysis also will suggest many elements of the preparedness plan. Without this kind of simple analysis and resulting preparedness plan, your department will not be aware of the magnitude, nature and distribution of the incidents to which it will be called to respond, until it is too late.

Earthquake fires and conflagrations pose an enormous financial risk to any city. In studies performed for the insurance industry, it was noted that San Francisco has $41 billion of insured buildings within the city. An additional $10 to 12 billion of local, state and federal government buildings and installations are at risk. Taking San Francisco as an example, the insurance industry has an enormous fire exposure—the city is highly congested, largely of wood-frame construction and quite susceptible to a conflagration following a major earthquake.

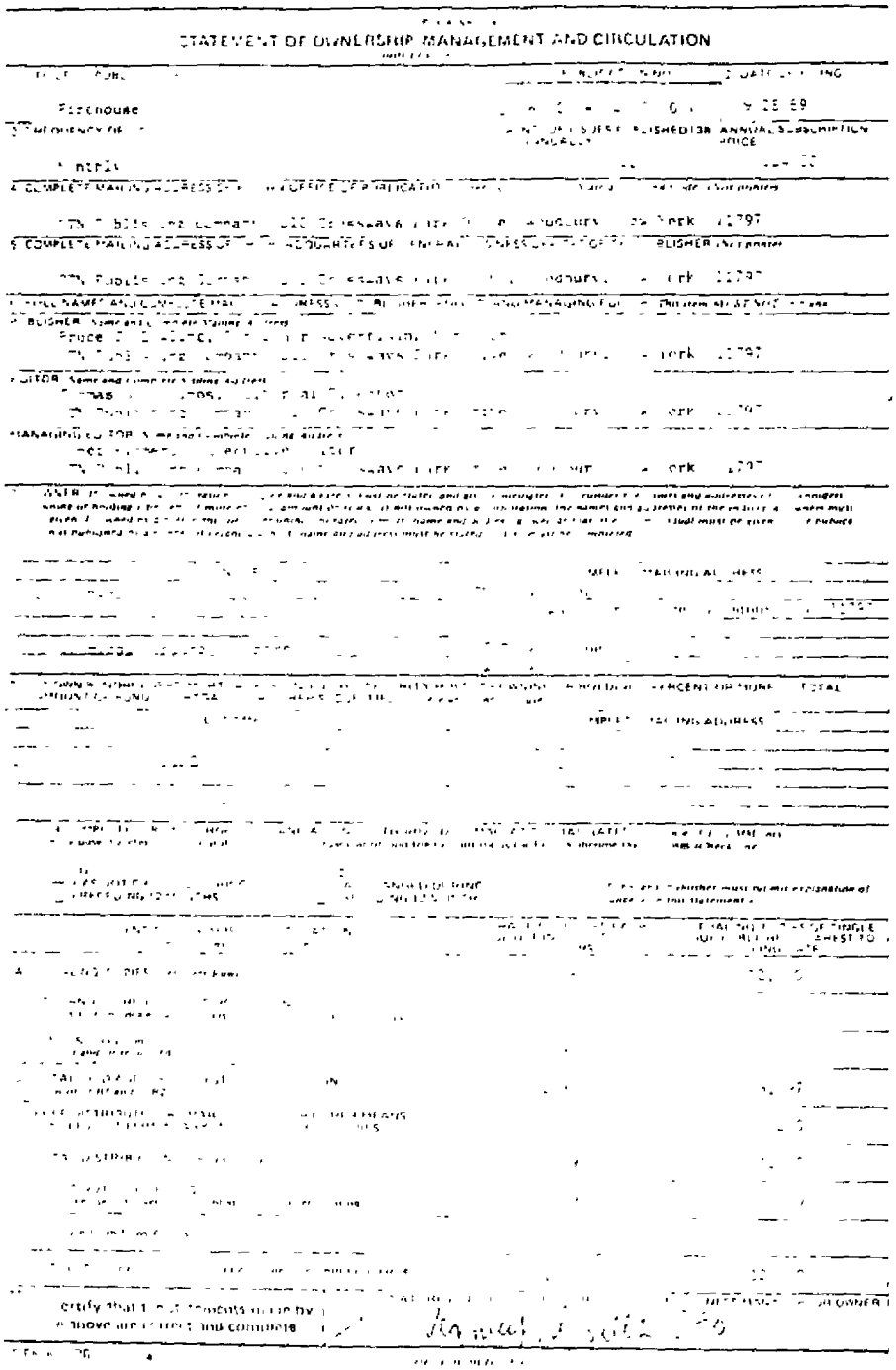
In response to this problem, the City of San Francisco recently passed a $46 million bond issue, to expand its emergency water supply. At the same time, however, it has reduced its on-duty firefighting forces from 315 to 296. Compare this with 1906, when the fire department had 562 firefighters on duty and essentially the same number of pumpers (39 in 1906, 41 today).

City administrators and fire officials should study their overall fire risk and plan accordingly. A successful earthquake preparedness program for a fire department needs three factors in sufficiency:

- water supply
- on-duty personnel
- equipment.

Weaken or remove any one factor and the department may not perform satisfactorily in time of crisis. San Francisco, according to the 1987 insurance industry-sponsored, All-Industry Research Advisory Council study, could suffer a $4 to $7 billion fire loss. With region-wide damage added to this, serious financial implications for banks, insurance companies, business and local government could very well ensue.

Analysis of the total situation--building stock, water supply, fire department capability to function, adequate resources (personnel and matériel) and economic loss due to fire and shake damage, are vital. Preparation is critical. Meanwhile, the earthquake clock continues to tick away.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1A TITLE OF PUBLICATION	1B PUBLICATION NO	2 DATE OF FILING
Firehouse	5 6 0 - 4 7 0	9/28/89
3 FREQUENCY OF ISSUE	3A NO OF ISSUES PUBLISHED ANNUALLY	3B ANNUAL SUBSCRIPTION PRICE
Monthly	12	$24.00

4 COMPLETE MAILING ADDRESS OF KNOWN OFFICE OF PUBLICATION (Street, City, County, State and ZIP+4 Code) (Not printers)

PTN Publishing Company 210 Crossways Park Drive, Woodbury, New York 11797

5 COMPLETE MAILING ADDRESS OF THE HEADQUARTERS OF GENERAL BUSINESS OFFICES OF THE PUBLISHER (Not printer)

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Chemical Venture Partners	277 Park Avenue New York, NY 10172

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