The Northridge, California Earthquake

RMS 10-year Retrospective

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Risk Management Solutions

INTRODUCTION

The January 17, 1994 Northridge Earthquake was the most damaging earthquake in the U.S. since 1906, and produced the largest earthquake insurance loss to date. The event also overturned a number of pre-existing assumptions on earthquake science and engineering. The earthquake occurred on a previously unrecognized fault and shaking from the earthquake caused the fracturing of buildings previously considered protected from earthquake-related damages. For earthquake insurers, the event caused far more extensive losses than they had ever deemed possible from an earthquake and the final losses were significantly higher than any of the initial loss predictions from catastrophe models. Taken together, these factors made the Northridge Earthquake the most influential earthquake to affect catastrophe management practice, both in terms of the depth of research that was undertaken post-event, and in how this new scientific knowledge has been incorporated into an improved ability to mitigate and predict the outcome of future earthquakes.

In some areas, the aftershocks of the Northridge Earthquake continue to be felt today. For modelers and risk management practitioners, the development of RMS' new 3rd generation earthquake model for the western United States, released in 2003 with RiskLink® 4.3, represents a decade of innovation in science and modeling practice catalyzed by the event. For the California homeowners insurance market, the initial crisis and subsequent formation of the California Earthquake Authority (CEA) and institutionalization of new standards in pricing and coverage terms stabilized the market, but the ensuing years have seen a slow decline in take-up of earthquake insurance among California homeowners. Meanwhile, commercial insurers have increased their commitment to the market by harnessing catastrophe management technology to achieve technical risk-based returns while expanding levels of coverage to their commercial insureds. The tenth anniversary of the Northridge Earthquake provides an appropriate milestone at which to review the impact that this event had on the scientific, engineering and insurance communities, and how the detailed research that followed the event directly contributed to many of the enhancements and innovations of RMS earthquake modeling technology.

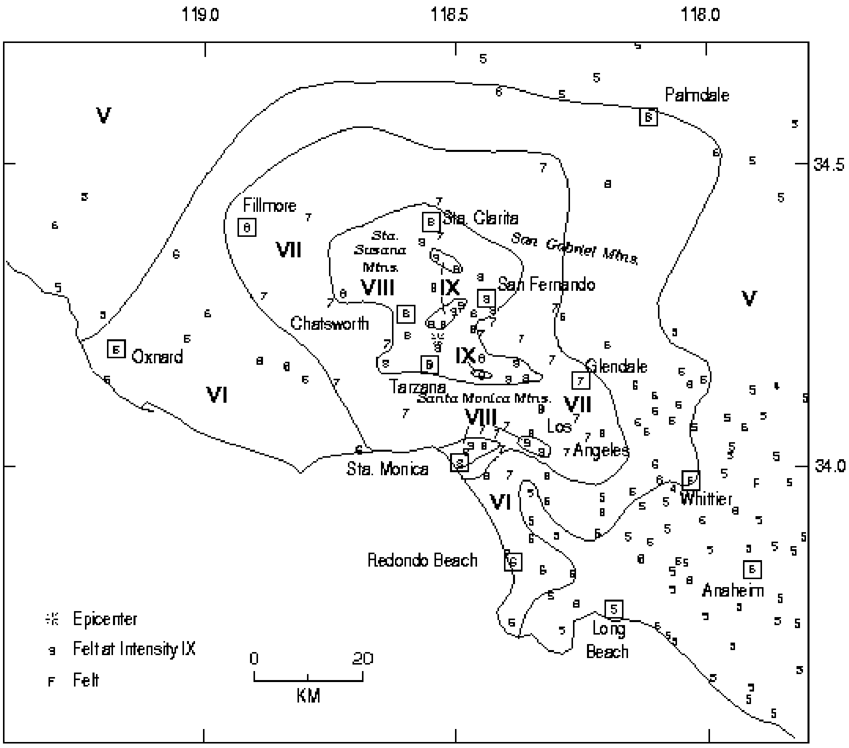
EVENT CHARACTERISTICS

The M_w 6.7 Northridge earthquake struck the Los Angeles region shortly before dawn on Monday January 17, 1994. Like the 1987 Whittier Narrows Earthquake (M_w 5.9), the Northridge earthquake was caused by the sudden rupture of a previously unknown, entirely subsurface, 'blind' thrust fault. Rupture on extensional faults and strike-slip faults (such as the San Andreas Fault) generally break through to the surface, but many thrust faults lie hidden. While blind thrusts will generally force folds to develop in the overlying layers of sediments, the lack of direct surface expression frustrates the identification and location of active structures. The system of blind thrust faults to the north of the Los Angeles basin is caused by north-south compressive stresses imposed by the "big bend" of the San Andreas Fault system that marks a principal focus of the North America – Pacific plate boundary.

The last major earthquake prior to 1994 to hit the Los Angeles area was the 1971 San Fernando Earthquake (M6.7), located immediately to the east of the Northridge earthquake fault rupture. The 1971 earthquake was itself significant for revealing the inadequacies of previous building practices, in particular for reinforced concrete structures, and thereby triggering major advances in the field of earthquake engineering. The Northridge main shock had a similar magnitude (M_w 6.7) to the San Fernando earthquake but occurred on a southerly dipping thrust fault-plane that underlies the whole of the northern part of the highly developed San Fernando Valley. In contrast, the 1971 earthquake occurred on a northerly dipping thrust fault that outcrops in the hills of the less populated Sylmar region.

The area of strongest shaking in the Northridge earthquake was about 30 miles in diameter, encompassing southern Ventura and northern Los Angeles counties: a highly urbanized region in which a large inventory of buildings and structures were exposed to intense shaking. The earthquake was the most destructive earthquake in the U.S. since the 1906 San Francisco earthquake. Overall about 4,000 buildings were severely damaged or destroyed and another 8,500 were moderately damaged. Seven major freeway bridges in the area collapsed, and 170 were damaged, disrupting traffic in the Ventura-Los Angeles region for weeks following the earthquake. Communication, water and power distribution systems were also affected. The earthquake highlighted the vulnerability of apartment complexes built over parking garages (buildings with a "soft" story). Many of these buildings sustained significant damage due to failure of columns at the parking level. Several precast tilt-up structures were also badly damaged due to the collapse of tilt-up walls. Nine parking structures collapsed, and nine hospitals had to be closed immediately after the earthquake. While much less visible than the collapses, many large steel frame buildings suffered significant cracking in their principal beam connections. Although limited in their extent, several fires broke out, including one that burned seventeen homes in a mobile home park.

The following figure shows the intensity distribution of the earthquake reproduced from ground motion measurements recorded by the U.S. Geological Survey. Considering its close proximity to the densely populated areas of downtown Los Angeles, the event had a relatively low mortality (57 people). However, the economic losses estimated at $49.3 billion[1] ($41.8 billion in direct economic loss and $7.5 billion in indirect economic loss) were the largest ever experienced from a natural or man-made disaster in the U.S.



Intensity Distribution for the Northridge Earthquake (USGS)

[1] William Petak, "The Northridge Earthquake USA and its Economic and Social Impacts." EuroConference on Global Change and Catastrophe Risk Management, IIASA, Luxemburg, Austria (July 2000)

Scientific and Engineering Significance

From a scientific standpoint, the Northridge earthquake was among the most studied geological events in history. The National Information Service for Earthquake Engineering (NISEE) at the Earthquake Engineering Research Center (EERC) of the University of California at Berkeley, which serves as an information clearinghouse for the Northridge Earthquake, has added close to 4,000 Northridge-related research citations to its volume of abstracts. In addition to studies performed by the research and academic institutions, many other investigations were undertaken by professional organizations, state and federal government institutions, research and professional organizations from several foreign countries (e.g., New Zealand, Japan, and Canada), the insurance industry, and private engineering and modeling firms. These studies and investigations have provided a wealth of new information on earthquake behavior and its impact on infrastructure and people. Altogether the earthquake has caused significant advances in many fields of earthquake and engineering science.

Earthquake Hazard

The Northridge earthquake highlighted the importance of blind thrust faults, in particular contributing to hazard in and around Los Angeles. During the 1980s, seismic source models for California had come to assume that the principal contribution to hazard came from surface mapped faults, even though two previous major earthquakes: the 1983 Coalinga Earthquake and the 1987 Whittier Narrows Earthquake had occurred on hidden subsurface structures. While the distribution of the compressional faulting caused by the "big bend" in the San Andreas Fault in the northern portion of the Los Angeles basin was generally recognized, there was no overall understanding of the extent or seismic potential of the blind thrust faults in this region.

Post-Northridge a comprehensive research mission was initiated to search for similar active faults using geophysical surveying techniques and deep borehole information. Within a year, a complex series of 'blind thrust' faults had been identified underlying the Los Angeles Basin and San Fernando Valley regions as well as in other areas of California, such as the Central coast region, the Bakersfield region, and the Santa Clara Valley.

The identification of the blind thrust faults resulted in major changes to the seismotectonic understanding of active earthquake sources and earthquake recurrence rates in Southern California. In 1995, the Southern California Earthquake Center (SCEC), composed of a consortium of California research universities, released a landmark study, proposing a completely new hazard model for the region that incorporated all those newly identified subsurface faults. In 1996, the U.S. Geological Survey showed that blind thrusts contribute (on average) about 15% of the seismic hazard in the region (when measured in terms of the ground motion that has a 10% probability of exceedence in 50 years). The exact configuration of these buried faults has continued to be debated, and around Los Angeles the extent of the faults has been reduced relative to the initial maps constructed in 1995. The latest consensus on the location, extent, activities, and maximum magnitudes of the blind thrusts in California was included in the development of the National Seismic Hazard Maps, released by the USGS in 2002-2003.

Ground Motion & Building Performance

The vibrations of the Northridge Earthquake were registered on a large array of strong motion instrumentation located across Southern California. This comprehensive collection of strong motion records provided an opportunity for engineers and scientists to better understand the functions that represent the transfer of energy from source to site (i.e., attenuation functions) and the modifications in the severity of the ground motion caused by fault rupture propagation (i.e., directivity and near field conditions) and deep and surficial geology formations and site conditions (i.e., basin effects and soil effects). Several studies showed that variations in the surficial geology have a greater impact in modifying the strong motion than had previously been appreciated. Methodologies for better integrating these effects in the estimation of site hazards were also introduced. On the basis of these studies, RMS improved its methodology for site severity estimation by incorporating additional high-resolution data on soils, liquefaction, and landslide impacts, and (in the most recent RiskLink® 4.3 California earthquake model) also including the 3-D amplification effects associated with the Los Angeles Basin structure.

However, the most notable contribution of the Northridge Earthquake to the field of earthquake engineering has been the approach to following the earthquake ground-motion time-histories through the soils and into the engineering dynamic characteristics of buildings. After Northridge the analytical formulation of this technique, referred to as the "Response Spectrum" approach, advanced significantly mainly because there was now a sufficient volume of instrumented data from buildings, and the soils on which they were founded, to allow for reliable calibration of the method. In particular, the Pacific Earthquake Engineering Research Center (PEER), comprised of nine leading research universities in the Pacific states and established by the National Science Foundation, focused its research agenda on "performance-based" design, which requires a rigorous formulation of the response spectrum method. The response spectrum methodology is now part of the core technology of RMS earthquake models.

Building Vulnerability

Growth in California, and in the Los Angeles area in particular, accelerated through the 1970s and 1980s. As a result, the Northridge earthquake provided the first large-scale test worldwide of the performance of a dense concentration of modern well-constructed buildings, including high-value engineered structures and many buildings developed to the latest building codes written in the wake of the 1971 San Fernando Earthquake. Specialized investigations on the performance of particular types of buildings spawned much new knowledge on vulnerability, which was rooted in empirical studies of damage and loss. Most notable was the discovery of widespread welding failures at the beam-column connections of steel moment resisting frame structures.

Moment resisting steel frame structures had been considered among the least susceptible to earthquake damage prior to Northridge. For almost all these structures the damage was completely hidden and the problems were only uncovered by construction crews erecting steel frames for new buildings, in which the beam-column connections had not yet been hidden beneath fire-proofing and wall cladding. Once recognized, a costly and disruptive investigation was set in place to remove the cladding at the key connectors in a total of almost 2,000 buildings of this class constructed between 1965 and 1993 in the region of strongest ground motions. Many of these were medium and high-rise buildings with large numbers of connections. Significant weld damage was uncovered in more than 100 of the buildings.

While the discoveries among the steel-frame structures were new (and were confirmed in the Kobe earthquake a year later) the Northridge earthquake also added significantly to the understanding of the performance of wood frame structures (both single-family and multi-family construction), reinforced concrete structures, tilt-up concrete structures, masonry structures, and base-isolated structures. Field observations on the performance of each of these structure types were backed up with analytical modeling and laboratory testing. Of note was the higher than expected damage to larger wood frame structures that included several catastrophic failures of condominium-type wood frame buildings. These observations resulted in extensive research efforts to determine how to improve seismic performance.

The focus on new knowledge gained from the Northridge Earthquake should not obscure the fact that the event confirmed many of the lessons learned from previous earthquakes. The earthquake demonstrated that competent design can protect buildings from collapse. Many elements of the more advanced seismic design provisions introduced following the 1971 San Fernando Earthquake were vindicated in Northridge. Although the emphasis on saving lives did not necessarily correlate to lower levels of economic loss, the earthquake showed that investments in building codes and engineering practice did yield good returns. For example, the lack of collapse and heavy damage to unreinforced masonry buildings, which were seismically strengthened under a Los Angeles ordinance passed in the early 1980s (Division 88) was credited for saving many lives as well as protecting several small businesses that typically operate in these buildings. Similarly, the post-San Fernando earthquake initiative toward making hospitals and other critical facilities more resilient to earthquake shaking resulted in improved performance of these types of structures compared to the damages seen during the 1971 earthquake. Further, the earthquake demonstrated that public awareness and preparedness efforts were efficient in improving the response of the population and facilitating the emergency procedures. These conditions limited the losses and facilitated the region's recovery.

The Northridge Earthquake itself has affected building design and construction practices in many ways. Input ground motions used in building design were modified to reflect the experience of the earthquake, and new design and detailing requirements were established for steel moment resisting frame structures. Inspection and quality procedures have been upgraded and new standards developed for the design and retrofit of pre-existing buildings. However the regulatory wheels turn slowly and some elements of the legacy of Northridge are still working their way through the code regulatory bodies. Even at present, the debate continues over whether building codes should focus beyond life-safety priorities to those of property loss and business continuation.

Catastrophe Modeling and Management Practice

From Deterministic PML to Exceedence Probability

The prevailing state of catastrophe management practices was in flux in 1993. Earthquake catastrophe models, introduced to the insurance industry in the late 1980s, were beginning to make an impact through their early adoption by specialty writers and some research-driven market leaders. Reinsurers, following the debacle of Hurricane Andrew in 1992, were beginning to promulgate more critical assessments of catastrophe accumulations. Overall, there was an appreciation that truly catastrophic earthquakes were plausible, and that industry-wide losses could well exceed Hurricane Andrew levels in a variety of Probable Maximum Loss (PML) scenarios[2].

On the other hand, this early appreciation of the nature and scale of earthquake risk remained somewhat theoretical for large segments of the P&C re/insurance market. In a keynote address at the 1994 RMS Client Conference (March, 1994), the CEO of a newly formed Bermuda Reinsurance company noted that only "10%-12% of property insurers utilized catastrophe models"[3]. For most of the industry, the state-of-the-art in earthquake risk management prior to Northridge consisted of an annual exercise in calculating PML following a methodology prescribed by the California Department of Insurance. This "California Earthquake Zoning and Probable Maximum Loss Evaluation Program" required insurers to report their aggregate accumulations by earthquake zone – principally within three earthquake subzones in the greater San Francisco Bay Area and Los Angeles regions (Zones A1-3 and B1-3, respectively) – and factor their reported exposures by construction class loss ratios (net of the assumed performance of the specified deductible), designed to approximate the aggregate impact of various PML scenarios.

This largely regulatory driven deterministic process – with its attention on annual assessment of the loss potential from a series of specific benchmark earthquakes, while a useful initial step toward technical portfolio risk management, had several unintended consequences. Some insurers, modeling or monitoring a small set of benchmark PML scenarios, built unintended and unreported concentrations of risk in the shadows of the prescribed benchmarks. A notable example of this was a regional personal lines insurer whose PML calculations across the Los Angeles basin belied a significant risk concentration specifically within the fast-growing San Fernando Valley. On the flip side, within the zone-based PML approach, no credit was given for finer-scale diversification, creating little incentive for insurers to refine their capacity allocation or encourage underwriting specificity. Moreover, by focusing attention on the distinct, but remote, possibility of a few deterministic "Big Ones" with PMLs in the $25-50+ billion range and rather small individual probabilities of occurrence[4], it was easy to relegate the problem of catastrophic earthquake loss to the margin of management discussion.

The initial focus on aggregate portfolio assessment to satisfy external reporting (regulatory or reinsurance) applications, placed little emphasis on underwriting or pricing (rating) applications. The Northridge Earthquake transformed the understanding of the technical application of catastrophe modeling far more effectively than any theoretical argument about risk management strategy. Today we find probabilistic models used routinely in support of homeowners' rate filings,

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[2] Notably a repeat of the great 1906 San Francisco Earthquake, or a major M7+ earthquake in Los Angeles on the Newport-Inglewood fault.

[3] Paul Hasse, CEO, Centre Cat Limited.

[4] In contrast, today's Exceedence Probability-based quantifications highlight the significant cumulative probabilities of moderate or large losses.

operationalized to establish and help manage business-unit specific underwriting strategies, and embedded into front-end underwriting processes, with an increasing emphasis on quantifying the dynamic linkages between the selection and pricing of an individual risk and the overall risk characteristics of the portfolio. For catastrophe modelers this transformation from providing, what was seen before 1994 as a research tool, to supplying a core business application for both underwriting and portfolio management, has presented many new challenges and responsibilities: in particular, to ensure that models are robustly developed, responsibly applied, and that all parties increasingly understand the inherent uncertainties along with the implications of periodic scientific and model enhancements.

Evolution of Data Standards

One major outcome of the earthquake, for both insurers and reinsurers, was the discovery that the exposure data that had served as the basis for risk calculations was of poor quality with locational information often incomplete, or miscoded. Information systems, designed to support policy administration and related activities, were ill-suited to capturing or reporting the exposure characteristics that govern catastrophe risk. While homeowners policy writers could reliably track the locations of the majority of their insureds, Northridge highlighted significant problems with insurance-to-value assumptions. Beyond the systematic under-reporting of aggregate exposure values, these underestimations served to significantly erode the impact of deductibles expressed as a percentage of policy limits. Northridge also overturned the prevailing assumption of homogeneity of the residential inventory in California dominated by 'wood frame' construction practices. In detailed claims research in 1996-1997, RMS identified that a diverse range of more vulnerable appurtenant structures (Coverage B), such as swimming pools, masonry block walls, detached patios and garages, etc., represented almost twice the proportion of the property value that had been assumed and were also almost twice as vulnerable to earthquake damage as the main building. The specificity and completeness of all elements of the information collected on homeowners insured exposure has increased substantially over the past decade.

For commercial lines writers, the lessons of the Northridge Earthquake were even more acute. Exposures coded at best to ZIP Code, but often to the Zone level of resolution failed to capture the geographic specificity of the risk. More generally, data coding for multi-location schedules was often incomplete or misleading, where values for 'secondary' locations were simply coded on a lump sum basis and geographically associated with the 'key' location. Construction information was found to be missing or unreliable in many cases, often on a systematic basis across entire lines of businesses or even portfolios, a problem exacerbated due to the prevailing re-use (and often misuse) of fire underwriting building classifications for earthquake risk assessment. In some cases, whole classes of exposure were overlooked, such as earthquake sprinkler leakage coverages attached to standard fire insurance policies. Difficulties in collecting accurate value information meant that, even more than for the homeowners writers, underestimation of commercial TIVs was widespread.

For the commercial insurance sector the lessons from the Northridge earthquake have been well learned. Where ZIP Code was once considered 'high-resolution data,' and zonal aggregates were deemed acceptable, street-address location data is now the standard of resolution for property catastrophe exposed accounts. Construction data is systematically captured using earthquake-specific codes, and many writers now capture and report construction details beyond just the primary characteristics. Not only is more data being captured from insureds and their brokers at a greater degree of resolution, but more data is being shared between insurers and their reinsurers, and data quality metrics are working their way into the vernacular of risk management and risk transfer conversations. In fact, an ability to provide detailed quality data is now a prerequisite to accessing the top reinsurance markets.

Demographics of Insurance Risk

In 1993, the California Department of Insurance reported that 72% of Zone A (San Francisco area), and 81% of Zone B (Los Angeles area) PMLs were contributed from commercial classes of business. This reflected the prevailing view prior to the Northridge Earthquake that the significant majority of California residential building stock that was of recent (post-1973) wood frame single-family construction, was not highly vulnerable to damage, even at more severe levels of ground motion. This view was originally established through benchmark technical studies in the early to mid-1980s[5], and empirically validated through the analysis of the available claims data from the 1989 Loma Prieta Earthquake. Moreover, California residential insurers had been progressively tightening insurance conditions following the Loma Prieta Earthquake so that by 1994 the 'standard' policy carried with it a 10% deductible. Given the low expectation of mean loss ratios, even for high intensities, losses in excess of 10% were expected to be quite modest[6].

As it turned out, of $15.3 billion in Northridge claims, over 60% were from personal lines exposures, far beyond initial expectations. Following a two-year RMS research project to collect and analyze almost $3 billion of detailed homeowners claims data, including a hands-on review of claims files, it became clear that a series of issues contributed to this significant underestimation of residential losses. These included: systemic under-insurance, a greater than expected vulnerability of appurtenant structures, the impact of price opportunism in 'demand surge,' and the presence of a greater degree of statistical variability (uncertainty) in wood frame damage than anticipated, thus reducing the previously understood impact of deductibles in mitigating losses. While part of this discrepancy in industry (and modeler) expectations of losses in the residential sector can be explained by the location of the Northridge event vis-à-vis the PML scenarios – that is, in the more 'residential' San Fernando Valley rather than the more 'commercial' heart of Los Angeles – more significant was a collective failure of insurers, regulators, and modelers to appreciate the vulnerability of residential building stock to earthquake losses, and hence the concentration of risk that was developing within those companies writing homeowners business.

Formation of the California Earthquake Authority

The Northridge Earthquake sent shock waves through the personal lines market in California. Losses equated to 28 times the aggregate earthquake premium collected in 1993, and far exceeded the historical earthquake premiums to date. A few insurers teetered on the verge of insolvency. For the majority who remained viable despite the unprecedented scale of losses, it became clear that the status quo was no longer tenable. Many insurers moved quickly to file re-calibrated rating schemes, California being a 'prior-approval' regulatory environment. These rating schedules not only reflected new appreciation of what constituted an 'adequate premium,' but included far more specific rate territory definitions based on the new understanding of the risk landscape. Faced with the uncertainties about gaining approval for true risk-based pricing, and recognizing the near-impossibility of diversifying their pre-existing books of earthquake business, many large insurers

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[5] (e.g.) Carl Steinbrugge, 1982, and ATC-13, 1985

[6] In fact, the DOI PML report assigned about a 2% net loss ratio (net of a 10% deductible) to residential frame construction within Zone B. Today, RMS models' suggest the comparable net loss ratio should be about 10%, or 5 times higher than what was considered at the time.

began to reevaluate their commitment to the homeowners market in California. As California law required insurers to make an offer of earthquake coverage as an endorsement to a homeowners' policy, one straightforward way to avoid earthquake exposure was to move out of writing homeowners coverage altogether. Faced with the implications to the State's economy, and in particular the housing market and mortgage industry, a compromise was negotiated, and in 1996 the California legislature enacted the California Earthquake Authority (CEA) as a privately funded, but publicly managed, organization set up to make standardized and limited residential earthquake insurance coverage available. Insurers could elect to participate in the CEA or offer their own policies. In 2003, the CEA insurers wrote 750,000 policies, and non-CEA insurers wrote an additional 400,000.

The standardized CEA policy, known as the mini-policy, provided a limited form of earthquake protection, covering the value of the dwelling itself but only modest coverage for contents and additional living expenses. Losses in appurtenant structures, the infamous driver of many of the Northridge claims, were excluded altogether[7]. In addition, deductibles were raised to 15%, and the product was priced using a catastrophe model at rate levels (in areas of risk) greater than those that existed pre-Northridge[8]. An unintended consequence of these actions has been to disincentivize the take-up of homeowners earthquake insurance. Today, following a decade without significant reminders of major earthquake losses, there are only 1.2 million earthquake policyholders representing 17% of California homeowners. In 1994, the state-wide average was approximately 30%, with levels above 40% in some areas such as Los Angeles.

A Changing Industry Risk Profile

While the commercial earthquake insurance market has grown since 1994, the change in the take-up and policy features of the residential earthquake insurance market has served to reduce the P&C Industry's overall exposure to California earthquake risk. If current homeowners earthquake take-up and coverage terms were in place ten years ago, the insured personal lines losses would have been 70% lower than what was incurred in Northridge. Today, RMS estimates that a recurrence of the Northridge earthquake would result in approximately $9 billion in overall (commercial and personal lines) insured losses, down from the $15.3 billion paid following the event. The significant majority of these losses would now be commercial, rather than personal lines, and a larger share of the primary losses would likely be borne by the global reinsurance market. Not only would the industry suffer less loss, the losses would be more diversified across a broader range of commercial earthquake insurers and global reinsurance markets, given the improved attention to risk management within individual companies. While a $9 billion loss would still be significant by any measure, the industry is far better positioned today to absorb losses from a comparable event, and move forward with less disruption to the market.

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[7] Recently, the CEA has begun offering a more diverse product range, including increased coverage for contents and ALE, and lower deductibles.

[8] Rates vary widely throughout the state; the average is about $1.1 per $1,000 of coverage, to a high of $5.25.

PREPARING FOR THE NEXT MAJOR EARTHQUAKE

Ten years have elapsed since the Northridge Earthquake, a blink of the eye in geologic terms, an eternity for some consumers who increasingly question the cost of their earthquake insurance premiums. For the insurance industry, the adoption of catastrophe modeling has institutionalized a measure of discipline. From underwriting and pricing, to capacity management, to reinsurance, insurers continue to factor the reality of a California earthquake ever deeper into their business practices. Even workers compensation insurers, who historically have not seriously considered their catastrophic exposures, have begun to assess their exposures to earthquake risk within the state. On the other hand, 10 years of 'peace' on the California earthquake front can be seductive, as urgent practice becomes somewhat routine, management confronts other pressing priorities, and new underwriters, actuaries, and risk managers come on board without the benefit of a 'live' experience with catastrophic earthquake losses.

Looking forward, the California market is unlikely to see another ten years of relatively loss-free experience. Over the next 10 years, there is a 65% probability of at least one significant earthquake[9] in a major metropolitan region of California. A repeat of the Northridge Earthquake under today's policy terms and insurance penetration rates would generate industry losses of $9 billion, equating to a 20-year return period for California earthquake loss[10]. Moreover, the possibility of the 'Big One' continues to loom on the horizon, with the 250-year insurance industry loss surpassing $40 billion.

While the timing, location, and severity of the next major earthquake is uncertain, two things are known for sure. The first is that the industry will be better prepared to absorb, diversify, and react to the losses than it was in 1994. The second is that there will be new lessons to learn. The scientific, modeling, risk management, and even political lessons from the Northridge Earthquake were powerful and have shaped a decade of fundamental improvements in the industry's ability to comprehend and manage its risk. However, the business of earthquake insurance, informed by probabilistic risk assessment models at all levels, remains a relatively young endeavor. Some new lessons may be technical, such as more empirical evidence on the performance of modern high-rise structures in downtown San Francisco or Los Angeles. Some new lessons may impact the very structure of the market, such as the viability of the current residential insurance market equilibrium, with only 17% of consumers carrying limited earthquake insurance coverage.

Above all the Northridge Earthquake triggered a sea change in risk management practice, not only in the California market but in pricing and managing catastrophe risk across the developed world. While there has been no comparable natural disaster in California, or anywhere in the U.S. since 1994, the experience of September 11, 2001 has served to reinforce the critical importance of catastrophe management practice, whatever the peril. Ten years on, as the memory of the last major earthquake disaster in California fades, the role of catastrophe modeling is to continue to research and implement an improved analysis of potential earthquake loss, and above all, to ensure that the reality of earthquake risk is embedded in the risk management practices of the global insurance industry.

"Building a culture of prevention is not easy. While the costs of prevention have to be paid in the present, its benefits lie in a distant future. Moreover, the benefits are not tangible; they are the disasters that did not happen."

- Koffie Annan, Secretary General of United Nations (1999)

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[9] Defined as an industry-wide loss of at least $3 billion

[10] RMS Industry Loss Curve including secondary uncertainty, demand surge, and FFEQ