## NZ SOCIETY FOR EARTHQUAKE ENGINEERING RECONNAISSANCE TEAM TO SEATTLE, USA: THE FEBRUARY 28, 2001 NISQUALLY EARTHQUAKE

#### Report of the NZSEE and MCDEM Reconnaissance Team

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Our report describes the observations and assessments of the members of the reconnaissance team which visited Seattle, Tacoma, Olympia and surrounding areas a few days after the magnitude 6.8 Nisqually earthquake struck on 28 February, 2001. The report covers the tectonic setting and geology of the region, the source of the earthquake, its strong ground motions, ground damage – liquefaction and landslides, damage to buildings, bridges, lifelines, emergency management, community response, and lessons for New Zealand.

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### MINISTRY OF CIVIL DEFENCE AND EMERGENCY MANAGEMENT

A feature of the reconnaissance was the full involvement of Emergency Management whose participation has added a new and valuable dimension to a NZSEE reconnaissance. Science reports, and engineering damage description and assessment reports from local reconnaissance teams appeared on the internet within several days of the earthquake, and to some extent are inevitably repeated here. However, the emergency management assessment and lessons for NZ are unique and most relevant studies.

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#### 1 INTRODUCTION & SUMMARY

The Nisqually Earthquake, with moment magnitude ( $M_{\rm W}$ ) 6.8, occurred at 10:54 am local time (18:54:32 UTC) on Wednesday 28 February 2001. Its source was located at 52 km depth beneath the Nisqually delta at the southern end of Puget Sound, 20 km northeast of Olympia, 60 km southwest of Seattle, and 24 km southwest of Tacoma (Figure 1). Because of its magnitude and depth, the earthquake was felt over a wide area. It caused significant damage in urban Olympia and Seattle and in rural areas, but little damage in urban Tacoma. One person died as a result of a heart attack attributed to the earthquake, and some 400 were injured to the extent of requiring medical treatment. Initial damage estimates were US\$2 billion. Washington State declared a state of emergency the day of the earthquake, and federal assistance was requested the following day, followed by a federal emergency declaration.

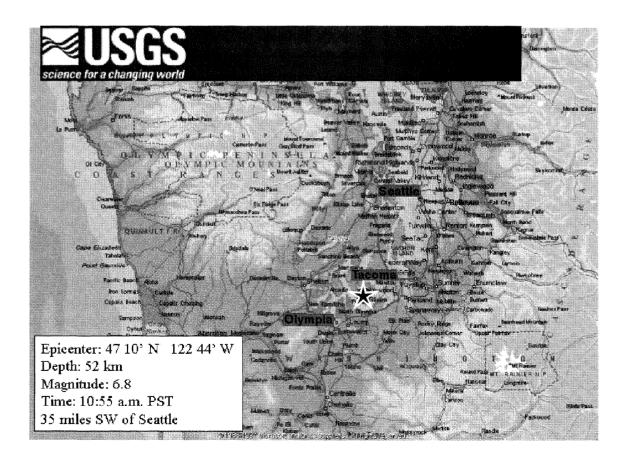


Figure 1: A topographical map of Washington State showing Puget Sound, Seattle, Tacoma and Olympia, and the epicentre of the Nisqually earthquake.

The NZSEE and MCDEM decided that because of similarities with building stock, infrastructure and tectonic environment, the earthquake was most relevant to NZ and quickly assembled a reconnaissance team who arrived in Seattle less than 3 days after the event. Their first action on arrival was to attend a local reconnaissance teams debriefing at the University of Washington. This provided contacts and linkages for the remainder of the 7 day visit. The warmth and generosity of our US colleagues was a feature of the visit.

In the Pacific Northwest region the Juan de Fuca oceanic plate is being subducted beneath the North American continental plate at the Cascadia Subduction Zone. This tectonic structure gives rise to three primary earthquake sources that affect seismic hazards in the Puget Sound area. Sudden displacement between the two plates at the subduction zone gives rise to great (> M8) interplate earthquakes, the last of which occurred about 300 years ago, and is dated accurately from historical records of when the devastating tsunami it generated struck Japan. Secondly the subducting Juan de Fuca plate is subject to deep intraplate earthquakes beneath Puget Sound, such as this earthquake and similar events in 1949 and 1965. Thirdly there are shallow near-surface crustal faults, such as the Seattle Fault, a reverse fault that runs through Seattle and Bellevue. These are the potential source of the highest intensity shaking that might affect the main metrapolitan areas of Seattle, Tacoma and Olympia.

Damage caused by the Nisqually Earthquake was relatively light and variable across the region. The damage is correlated with local soil conditions. Modified Mercalli (MM) shaking intensity may have reached MM8, but was generally lower. Peak ground acceleration (pga) was variable across the region and greater than 0.25g at only a few sites, and greater than 0.1g at about half of the 30 to 40 stations for which data were available. The duration of strong shaking was also variable from less than 10 seconds to almost 30 seconds. At the stronger levels of shaking experienced from this event ground damage (liquefaction, differential settlement, lateral spreading, and landslides) and amplification by soft ground can be expected. In the relatively shallow water, low energy, esturine environment of Puget Sound, its meandering rivers, deltas, and lakes there are ample areas of soft sediments that are highly susceptible to liquefaction and ground amplification effects. Some of these areas have now been urbanised. At the urban centre ports, there are large areas of esturine land reclaimed in the early to mid 1900's by methods such as hydraulic sluicing.

Damage to buildings was generally non-structural, such as cracking of exterior veneer brickwork, interior plaster and stone finishing panels, dislocation of suspended ceilings and lights, failure of service pipes and free standing shelving, broken windows, and disruption of fittings such as unrestrained cabinets and computers. The majority of structural damage was to old unreinforced masonry (heritage) buildings. Many bridges were slightly damaged and several older bridges were closed for repairs. Lifelines generally fared well. Several leaks to gas and

water mains were repaired quickly. Power and telephone services were barely disrupted. Sea-Tac airport was closed because of severe damage to the control tower but was reopened to reduced traffic when a temporary tower was quickly made operational. Settlement and liquefaction damage closed the runways at King County Airport (Boeing Field) to all but light traffic.

Emergency management and supporting staff at State, city and county levels were well organised and prepared by regular exercises. They swung quickly into action immediately after the earthquake. Rapid assessment of damage, and rescue from and inspection of damaged buildings appeared to proceed efficiently and effectively. The earthquake was a dominating media (TV, newspaper and radio) event. Established links emergency management had with the media were used effectively to inform the public and to relay messages of importance. Emergency management web sites received a huge number of hits and provided up-to-date information on damage and disruption. Disaster awareness campaigns had been conducted at County, State and Federal levels, and public awareness of earthquakes and their effects appeared to be relatively good.

#### 2 TECTONICS AND SEISMOLOGY

#### 2.1 Earthquake Location

On Wednesday, 28 February 2001, a moment magnitude 6.8 earthquake occurred beneath the southern Puget Sound area of Washington State (Figure 1). The preliminary location by the University of Washington Seismological Laboratory placed the earthquake at 52 km depth with epicentre at 47.149°N and 122.727°W. The epicentre is near the Nisqually River delta, the locality from which the eathquake derives its name, about 18 km from the State capital city Olympia. The earthquake epicentre is 24 km SW of the city of Tacoma and 58 km SW of the city of Seattle, the largest city and port in the state, and the home of many large industries such as Boeing, Microsoft, Amazon.com, and Starbucks.

#### 2.2 Tectonic Interpretation

The Nisqually Earthquake occurred within the eastward-dipping Wadati-Benioff zone of the Juan de Fuca oceanic plate, which is being subducted beneath the North American plate (Figures 2 & 3). Its hypocentre is located near many past earthquakes. The preliminary seiesmic interpretation is that the event ruptured a north — south striking fault over a length of 16 km in an extensional normal fault mode, consistent with down-dip extension and bending in the subducted plate (Reference 1 and 2). The peak slip on the fault is approximately 3 m and the fault area 350 km2. Measurements from Global Positioning Satellite (GPS) geodetic surveys conducted before and after the earthquake showed that crustal movements at the surface from the event were small and of the order of several mm.

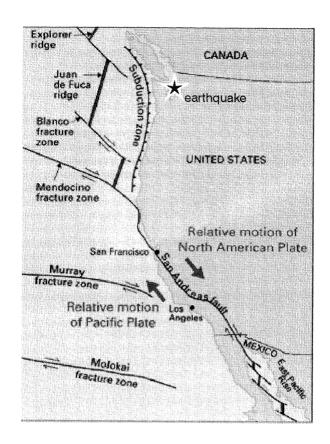


Figure 2: Tectonic outline of western North America.

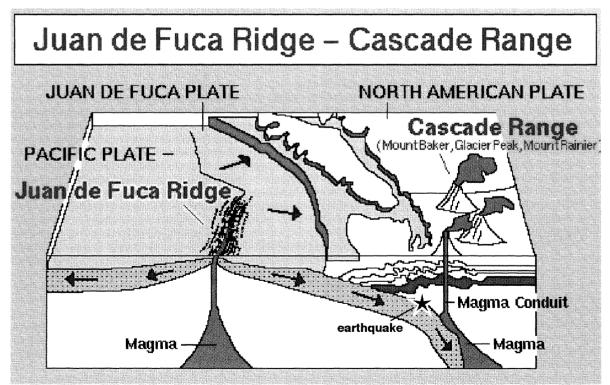


Figure 3: Diagrammatic cross-section showing the oceanic crust (arrows) being subducted beneath the North American continent.

The approximate source of the Nisqually earthquake is shown.

caused damage in western Washington State are listed in Table 1.

Table 1. Historical earthquakes similar to Nisqually EQ (Reference 1).

Magnitude	Date	Notes
M 6.2	1939	Deep event within the Juan de Fuca Plate. Epicentre within 60 km of the
		Nisqually EQ.
M 6.4	1946	Ditto above.
M 7.1 Olympia EQ	1949	Occurred within 20 km of the Nisqually EQ and may have ruptured the same
		fault.
M 6.5 Seattle EQ	1965	Occurred 40 km northeast of the Nisqually EQ and had similar fault
		orientation.
M 5.8 Satsop EQ	1999	Occurred within the subducting Juan de Fuca plate ~60 km west of the
		Nisqually EQ.

The Nisqually EQ mainshock was followed by two small aftershocks that may have been on the same fault. The first was a M 3.4 event at 1:10 am local time on 1 March that was located at 52 km depth about 6 km north of the mainshock. The second was a M 2.7 event at 6:23 am local time on 1 March that was located at 51 km depth about 2.5 km north of the main shock. In addition to the two aftershocks, two small earthquakes of magnitude 1.2 and 1.3 occurred at depths of 25 and 28 km, almost directly above the mainshock. Based on past experience and advice from seismologists, it was publicly recognised that significant or damaging aftershocks from the event were most unlikely. This knowledge was of great benefit and comfort in the after-event recovery.

#### 2.3 Earthquake Ground Motions

The Nisqually earthquake caused moderate ground motions throughout the Puget Sound region. Reports indicate that some 56 strong motion recorders of the United States Geological Survey (USGS) and the Pacific Northwest Seismograph Network (PNSN), centred at the University of Washington, were triggered by the earthquake. Recorded peak ground accelerations (pga's) are highly variable from site to site with about half greater than 10% g and a few more than 25% g (Figure 4). These variations do not appear to follow simple patterns based on distance or geologic unit (Figure 5). For example, station TBPA on valley fill in Tacoma had the same pga as station UPS on stiff glacial tills 9 km away. Both these Tacoma stations sited within 35 km of the epicentre recorded smaller pga than some of the stations in Seattle, 25 km further from the epicentre, and less than station MBPA at epicentral distance of 115 km. (References 1 & 2. Figure 6 gives examples of actual strong motion records). Although some of these variations may be due to radiation pattern, they show that a moderately dense network of strong motion recorders do not allow more than very general conclusions to be drawn. As well, they highlight the need for more than the analysis of just the pga's from such earthquakes. For example, in Reference 3 the corrected ground acceleration time-histories and the associated pseudo-acceleration response spectra with 5% damping at five representative locations are presented along with the elastic design response spectrum, based on the 2000 International Building Code for soil type D. The amplitude for this design spectrum is two-thirds of the amplitude of the Maximum Credible Earthquake for the region (corresponding to a return period of 2500 years). These data show that the intensity of ground shaking at sites in Seattle and Tacoma was a half to a quarter or less than the design earthquake, except for one case at

the WSDOT Test Laboratory in Olympia, where the pga in the north-south direction reached 0.25g and the duration of strong shaking reached 30 seconds. Here the response spectra show the dominant frequency content of the ground motions is between 0.1 and 0.8 seconds, and the N-S component of the earthquake has a spectral acceleration that matches the design spectrum at a period of 0.7 seconds. Consequently, structures with a fundamental period in the range 0.7 seconds would be subjected to the design level of ground shaking.

Our conclusion for New Zealand is that strong motion recorders at specific sites and in buildings can provide very useful data for analysis and comparison with building code criteria, but cannot provide more than very general indications of ground shaking intensity. Although in some developed countries there is a trend away from felt intensity reporting to rely solely on instrumental earthquake records, we recommend that a vigorous programme of Modified Mercalli Intensity (MMI) reporting be retained in NZ. MMI reporting may be somewhat subjective according to the person involved, but the large quantity of reports that can be obtained provide essential supplementary data on local intensity variations and earthquake radiation patterns.

#### 3 GEOTECHNICAL OBSERVATIONS

The damage caused by the Nisqually earthquake appeared to be strongly influenced by geological and geotechnical factors. The earthquake provided useful information on liquefaction and lateral spreading, landslides, and the performance of earth structures. Locations of ground failures in Puget Sound and Seattle are shown in Figures 7 & 8.

#### 3.1 Geology Overview

The Puget Sound lowland geology is dominated by a complex, alternating sequence of glacial and non-glacial deposits that rest on an irregular bedrock surface. In places bedrock outcrops and elsewhere is up to 1000 m deep. Numerous faults and folds have deformed the bedrock and overlying Quaternary sediments across the lowland.

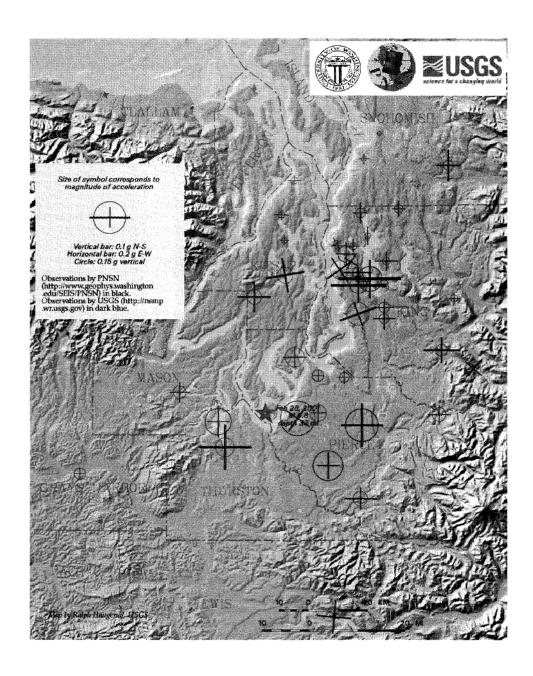
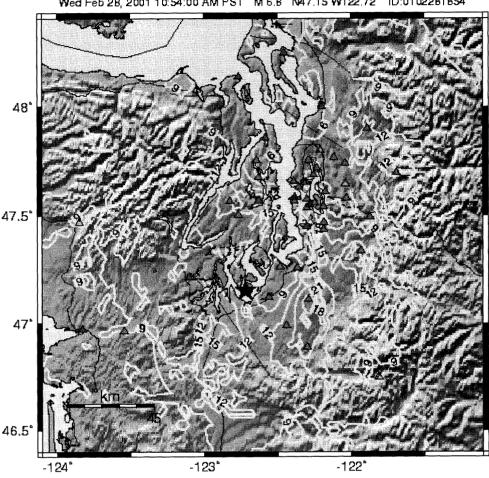


Figure 4: Preliminary peak ground accelerations for the Nisqually earthquake.

The landscape has been largely formed from repeated cycles of glacial scouring and deposition, recent river action, landsliding and volcanic action. North-south ridges and troughs of the lowland are the result of glacial scouring and stream action. The Pleistocene glacial and interglacial deposits that generally form the ridges are dense and stiff soils over-consolidated by multiple advances of ice sheets up to 1,000 m thick. Pleistocene river and lake deposits of the last advance are present locally and often

blanketed by normally consolidated Holocene (last 10,000 years) deposits from colluvium, lake, river, beach peat, tephras, and volcanic mud flows. The major river valleys contain alluvial sediments that are often uniform sands up to 100 m thick. Steep bluffs and hillsides bordering river valleys, streams, Lake Washington, and the coastline of Puget Sound are mantled with colluvium that is prone to landsliding during wet periods.



PNSN Peak Accel. Map (in %g) Epicenter: 17.6 km NE of Olympia, WA Wed Feb 28, 2001 10:54:00 AM PST M 6.8 N47.15 W122.72 ID:0102281854

Figure 5: Contours of peak ground acceleration in %g. The triangles are strong motion instrument sites.

Rivers that have their origin on the slopes of Mt Rainier, an active volcano that is a spectacular feature of the landscape, have formed Holocene deltas at their mouths. Sediments from Mt Rainier, some as lahars, have occasionally filled the river channels with sediment and have contributed to the growth of the river deltas now heavily developed at Seattle and Tacoma. Urban use of these areas has required extensive man-made modifications, principally by filling and use of retaining structures. At Seattle, extensive filling of meanders, depressions and tidal flat areas along the Duwamish River and adjacent to its mouth, were made often by hydraulic sluicing and nonengineered fills between 1890 and 1930 (Figure 8). Thus important industrial, transport and port facilities are located on loose, saturated natural and man-made soil deposits (Reference 1).

#### 3.2 Liquefaction

Soil liquefaction in the form of expulsion of water and sand boils, ground cracking, differential ground settlements, and lateral spreading was common in low-lying alluvial valleys, river deltas and in poorly compacted fills. These are also the places where liquefaction has occurred in the past 1949 and 1965 earthquakes.

Extensive liquefaction occurred at King County Airport (Boeing Field) where sand boils, ground settlement and sink-holes reportedly disrupted parts of the runway that were located above areas corresponding to old meanders of the Duwamish River (Figure 8). Those areas not associated with meanders were unaffected by ground shaking and liquefaction. Numerous liquefaction features were also reported along the Duwamish River north of Boeing Field in the Sodo District, where some building foundations were extensively damaged.

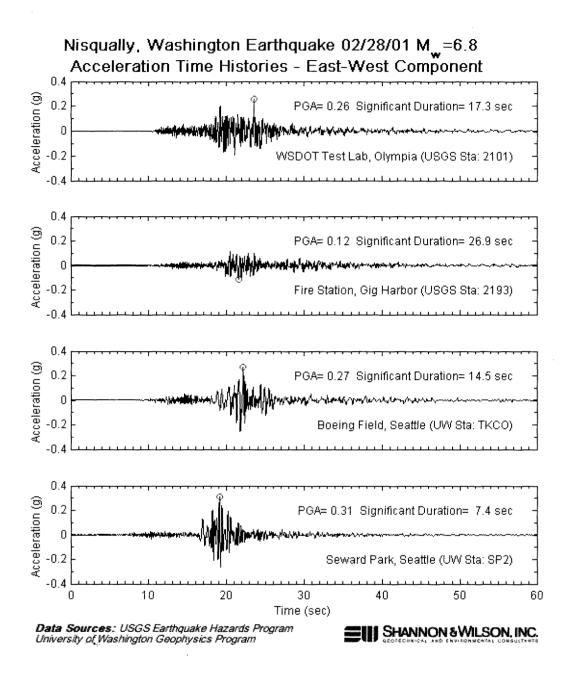


Figure 6: Nisqually Earthquake Acceleration-Time Histories.

Spectacular and damaging examples of cracking, lateral spreading and ground slumping occurred in Olympia along the margins of Capitol Lake and at Sunset Lake, Tumwater. Displacements of up to several metres affected nearby roads, footpaths, railway lines and utilities and resulted in road closures that will require expensive repairs (Figures 9 & 10).

Reconnaissance of other susceptible areas, such as the ports of Olympia and Tacoma, the Puyallup River valley, and the Nisqually River delta, revealed evidence of liquefaction and

minor lateral spreading that caused little damage. An excellent description of the earthquake shaking at Harbour Island, Seattle Port, and the subsequent formation of a large sand boil is presented by Bob Norris, a seismologist with the USGS (Reference 4).

#### 3.3 Landslides

A number of landslides within the Puget Sound region were triggered by the earthquake. Many of the landslides occurred in natural materials, such as on the north-east side of Capitol Lake, Olympia. A few were in engineered fills particularly where

these spanned low-lying areas of natural soils, such as at Martin Way and Highway 101 at Olympia. A landslide caused a temporary blockage of the Cedar River at Renton, and there were a few cases where houses were damaged by landslides.

Some landslides occurred in the colluvial materials that mantle slopes in the Puget Sound basin, although the dry weather being experienced at the time may have helped to reduced the formation of these.

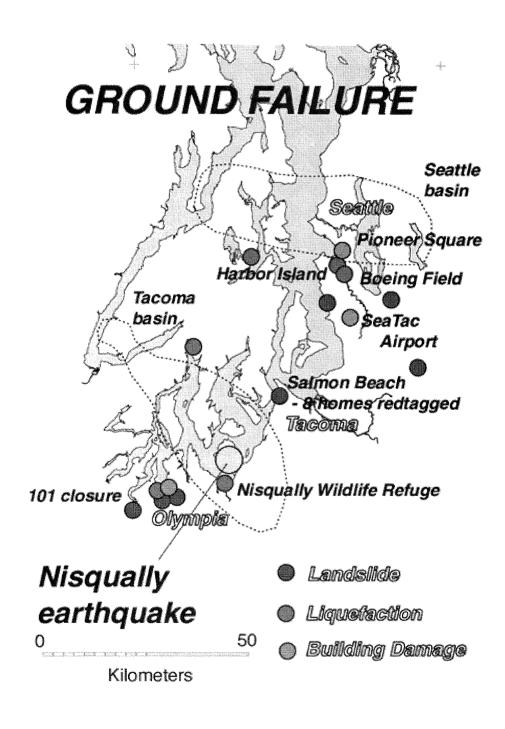


Figure 7: Main locations of ground damage (landslides and liquefaction) and building damage.

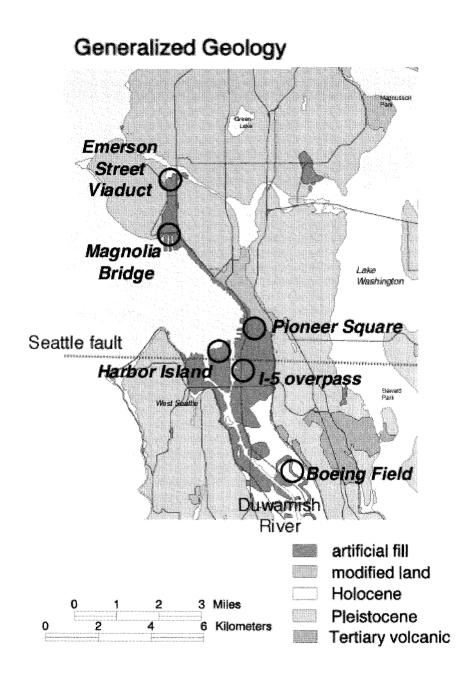


Figure 8: Localities of ground and building damage are circled. The pga in this area was about 15%g.

#### 3.4 Earth Structures

A mechanically stabilised earth wall supporting a parking lot in Tumwater failed following the earthquake, although this failure may be due to a burst water main. Liquefaction caused minor settlement and movement to earth retaining structures at the Port of Seattle, but movements were small and the function of these facilities could continue.

#### **LESSONS FOR NEW ZEALAND**

- Analysis of data from modern monitoring networks, including seismographs, strong motion recorders and GPS geodetic stations is required to understand the tectonics and seismology of complex areas, such as subduction zones:
- A good understanding of the tectonic structure and seismology of the Pacific North-West region reassured

- people that there would not be significant aftershocks that might disrupt the earthquake recovery;
- Because of wide variations in their values and little correlation with ground type and epicentral distance, peak ground accelerations on their own from a moderately dense instrument network were not a particularly useful indicator of the earthquake. However, detailed analysis of strong motion records from specific sites and structures
- can provide very useful information. We recommend that we retain a vigorous programme to capture MM Intensity information from earthquakes in NZ so that vital supplementary data on the events and their effects can be obtained.
- Significant ground damage and liquefaction affects can occur in highly susceptible materials at modest levels of shaking.

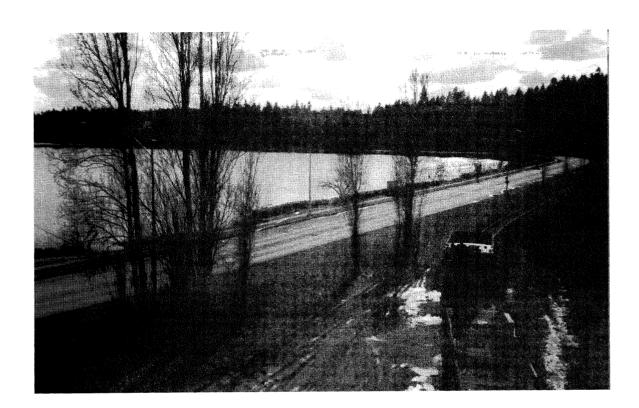


Figure 9: Sand boils indicating liquefaction by the rail wagons. This road along the margin of Capitol Lake, Olympia, was closed due to extensive lateral spreading damage about the middle part of this view. Similar lateral spreading causing extensive damage occurred nearby at Tumwater.



Figure 10: Slumping/lateral spreading at the margin of Capitol Lake, Olympia. Sand boils, indicating liquefaction, were present to the right of the road. The road was closed due to extensive lateral spreading damage to it beyond this view.

#### 4 BUILT ENVIRONMENT

#### 4.1 Buildings

Building damage was generally limited to older unreinforced masonry buildings, but there was evidence of minor damage to concrete and timber structures.

#### 4.1.1 Unreinforced Masonry Buildings

The older downtown areas of Olympia, Tacoma and Seattle contain significant numbers of unreinforced masonry buildings. However, the central area of Tacoma fared better than the other centres. The reason for this may be partially due to the stiff glacially consolidated deposits buildings are founded on and partially due to earthquake directivity effects. The masonry buildings in the main centers are generally low rise, but there were some that are up to about six storeys in height.

The observed damage levels indicated a generally good performance, but the strength of the earthquake may have been too small to really test these structures. From the outside, it was sometimes difficult to determine whether buildings had been retrofitted or not and some structures which appeared not to have been retrofitted suffered no damage (Figure 11). Our observations highlighted the importance of ensuring that the parapet elements of these structures are well tied back. The disruption and threat of injury caused by instability of parapets in this earthquake was significant, with many footpath areas still roped off three days after the event (Figure 12). Downtown Seattle and Olympia were very lucky that there was no serious injury caused by falling bricks in the earthquake.

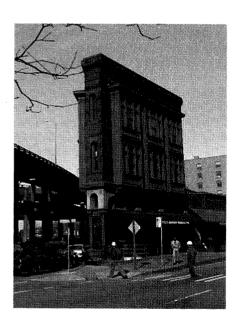


Figure 11: Undamaged brick masonry downtown Seattle.

There were instances of whole and partial collapses of unreinforced masonry boundary walls, particularly where the buildings were founded on soft soil, as in 1<sup>st</sup> Avenue South in Seattle (Figure 13). This building had a reinforced concrete bond beam at about ceiling level but it was ineffectual in retaining the brick wall because there were only two ¾" plain rebars in the beam and at the corner of the building the bar had not been returned into the adjacent beam. Rather, the bars from each beam hooked to their neighbouring beam bars with 180°

hooks which straightened in the earthquake. Sections of wall were dislodged from both low (one to two storey) up to six storey unreinforced masonry structures. In some instances it was difficult to tell whether the unreinforced masonry was load-bearing or architectural cladding on a reinforced concrete column and floor frame.

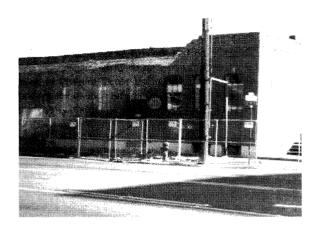


Figure 12: Lost parapet.



Figure 13: Complete unreinforced masonry frontage lost.

There were many instances of badly cracked exterior walls on unreinforced masonry structures. The pattern was indicative of in-plane racking where diagonal crack lines had formed in two opposing directions (Figure 14). In these cases it is likely that the damaged facade would eventually need to be either removed or tied back to the structure and grouted to make the façade waterproof.

There were a number of incidents of pounding between older brick structures because of the close proximity of the buildings at their boundaries (Figure 15). It was hard to imagine how these relatively stiff squat structures could deform to the degree that they would impact on adjacent buildings. A possible explanation is that there may have been surface waves (like ocean waves) travelling in the poor foundation soil which caused the buildings to "rock and roll". The remedy in this case would likely be removal of the damaged areas and reinstatement with like materials. Several instances were noted where the

impact force between two such structures had been sufficient to buckle the face of the wall out-of-plane (Figure 16).



Figure 14: Diagonal crack patterns in unreinforced masonry walls.



Figure 15: Pounding damage.

One structural engineering consultant interviewed noted that epoxied-in anchors on unreinforced masonry buildings where historic significance prevented the use of through-the-wall anchors apparently didn't perform well. Unfortunately, at the time he did not have full information on the poor performance and further details are being sought.

#### 4.1.2 Concrete Structures

Small amounts of minor cracking were evident in older reinforced concrete structures (Figure 17). Horizontal cracks, suggesting that movement had occurred on a dry construction joint at floor level, were evident on this building. The cracking evident in the columns was at the spandrel level between windows (Figure 18) and was therefore not typical of an expected short column-deep beam shear failure. Cracking of the cover concrete had also occurred in the ground floor columns of this structure but this would be relatively easy to repair.

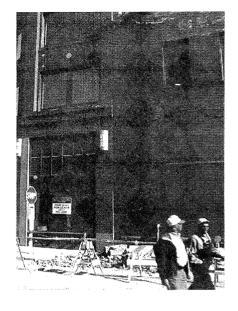


Figure 16: Brick façade buckled out-of-plane.

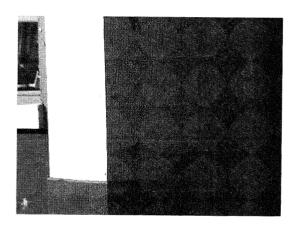


Figure 17: Minor cracking in older concrete building.

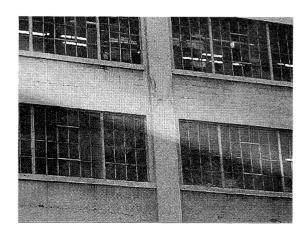


Figure 18: horizontal cracking at floor level and in column at spandrel.

Inside one older concrete-framed building with brick cladding there was a single diagonal crack, indicating a likely shear failure, on what appeared to be an infill shearwall element (Figure 19). The crack width was not sufficient for catastrophic failure to occur.

Modern reinforced concrete frame structures designed to current codes showed no signs of damage.

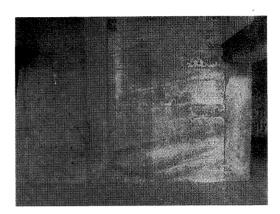


Figure 19: Diagonal crack in infill shearwall.

#### 4.1.3 Retrofitted Concrete Structures

The Starbucks (famous for coffee) headquarters is located in a reinforced concrete slab-column structure with extensive brick cladding (Figure 20). A retail building had been built adjacent to the south end of the original building and a parking structure had been built adjacent to the north end. The concrete slab-column structure appeared to experience greater ground accelerations in the east-west direction (from front to back) and there were substantial cross cracks in the brick cladding (Figure 21).



Figure 20: Starbucks Headquarters.

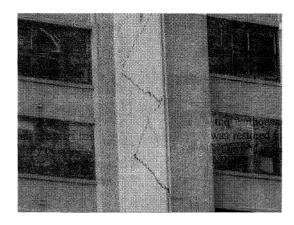


Figure 21: Close-up of diagonal cracking.

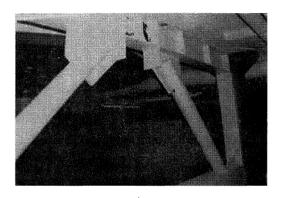


Figure 22: Eccentric K brace with signs of shear panel yielding (Photo credit UCSD).

The building had been retrofitted with two rows of eccentric "K" braced steel frames in both directions in 1995. Photographs taken by a team of investigators from UCSD showed evidence of yielding in the shear links of the east-west direction frames (Figure 22). Along the building, the links had not yielded.

It appeared that the retrofitting had served to provide excellent life safety for the occupants but building damage was not prevented. Large sections of the exterior cladding required removal before the building could be reoccupied. There was apparently also significant non-structural damage inside the building, particularly to suspended ceilings.

The different natural periods of the three adjacent structures meant that there was significant differential movement between them causing substantial damage to the flashings over the joints between them. There did not appear to be any structural impact damage.

#### 4.1.4 Timber Structures

Domestic timber dwellings were essentially undamaged except for damaged chimneys. Secondary damage from ground slumping and slips had been caused to 3 or 4 houses visited by the team. Two houses, one at Salmon Beach in Tacoma and the other at Renton in Seattle, were demolished by landslides. Television footage showed that some houses had extensive disruption of contents such as overturned dressers, televisions and the like.

One older heavy post and beam timber commercial building in downtown Seattle was observed to have a permanent drift at roof level of 100-200 mm after the earthquake. The structure was a two-storey building with weatherboard sheathing on the two outside walls that had racked (Figure 23). On a parallel interior wall, one sheet of lining material had detached from the framing along two adjacent edges, due to racking forces (Figure 24). A front door to the building was significantly misaligned with the frame around it. The front face of the building was transverse to the observed racking and the misalignment may have been due to earlier settlement of the foundations as the building was sited on poor ground.



Figure 23: Leaning 2 storey timber structures.



Figure 24: view of detached panel.

#### 4.1.5 Steel Structures

While steel structures appeared to fair well, there were odd incidences of failures. The control tower at the SeaTak airport lost nearly all of its window panels. The roof structure over the control room was supported on RHS steel columns and from photographs provided by others, it appeared that the welded joint at the bottom of at least one of these columns had failed. The terminal building at the Seatak airport appeared also to be a steel-framed structure. There were no incidences of collapse of the structure but the building was sufficiently flexible to cause

extensive cosmetic damage to the cladding materials around the frame elements (Figure 25). A brief tour of the King County International Airport terminal at Boeing Field showed similar damage to the cladding elements of this steel-framed structure.

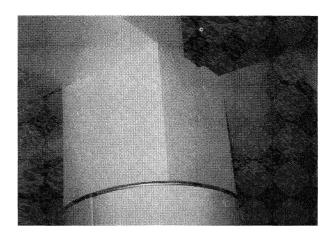


Figure 25: Damage to cladding around steel column.

#### 4.1.6 General Comments on Buildings

The intensity of the earthquake was possibly not high enough to test the retrofitted buildings to the design load levels. A comment from an engineer at the City of Tacoma was that one building that he would have "red-tagged" before the earthquake sustained relatively minor damage. There was no evidence of pull through of the plates used to tie floors and roofs to unreinforced masonry exterior walls.

In discussions with a Seattle consulting engineer, it was noted that there is no requirement in Seattle for buildings to be retrofitted to resist any particular level of earthquake loading. When buildings undergo substantial change of use the owners are encouraged to carry out some strengthening as the council works on the policy that some improvement is better than none at all.

There have been generations of retrofit in Seattle. In the 1970's the main aim was to tie walls to floors; in the 1980's frames and walls were also added for strengthening. In the 1990's, retrofits incorporated blends of both of the above in a performance goal oriented approach.

The City of Tacoma has adopted the UBCB retrofitting requirements but with some modifications. Buildings which are "substantially renovated" are required to meet the requirements of the Uniform Building Code for new construction. If the remodeling or alteration of or addition to an existing building within a two year period has a cost exceeding 60% of the value of the building, calculated using the latest "Evaluation Table" printed in the "Building Standards" magazine published by the International Conference of Building Officials, based on the existing occupancy and the most closely appropriate type of construction, then that is defined as "substantial renovation".

#### 4.2 Non-structural components

#### 4.2.1 Suspended Ceilings

Suspended ceiling panels and their supporting rails were damaged at SeaTak airport where they met the surrounding structure. They had obviously swung and impacted against the structure (Figure 26). Many components of a slatted ceiling at the SeaTak airport terminal had also fallen to the floor, some seven or so metres below. There was also similar suspended ceiling damage at the King County International Airport (Boeing Field) terminal.

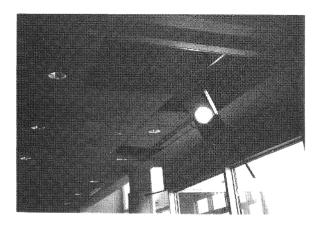


Figure 26: Damage around the perimeter of the suspended ceiling.

A large pile of fluorescent luminaries lay on the ground outside Sears store next to Starbucks headquarters. Brief glimpses through the doorway indicated that there was damage to the ceiling, of which the luminaries had been a part, in the building.

#### 4.2.2 Library Shelving

Shelving systems on the top three floors of a total of four in the University of Washington engineering library suffered significant distortion (Figure 27). Two types of shelving had been used. The one with superior junction details had shown a better performance than the other, but both were damaged to the point that repairs would be required. Generally the books had remained on the shelves and the shelves had racked longitudinally. There were approx. 5 mm diameter rod cross braces along the spine of the shelves but the hooks at the end of the rods were too weak to resist the tension generated in the rods and had straightened. Light gauge steel channel links between the tops of the shelves worked reasonably well in tension to maintain the spacing between rows but they were not able to resist compression or bending forces.

Few books fell from the shelves but it was the head librarian's opinion that he would rather have picked up books that had fallen from a stiff/strong shelf system after the earthquake than have to wait to get a new system installed, an estimated time period of 3 months.

#### 4.2.3 Piped Services

There were incidences of ruptured piped services in buildings. The UW engineering school library suffered a joint failure in a pipe network which caused some water damage on one floor before the water could be turned off (about ½ hour delay).

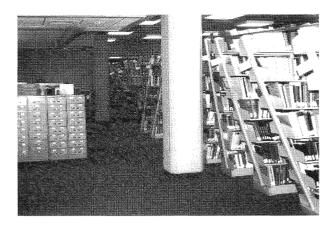


Figure 27: Distorted library shelving.

The team were advised that there had been some flooding in the Amazon.com building and the Ramada Inn in Olympia was drying out after flooding. Apparently, a 75 mm diameter pipe in the plant room at the top of the Ramada Inn ruptured when an unsecured tank moved, causing 3000 litres of water to flood the building.

#### 4.3 Bridges 4.3.1 Older Bridges

The 4<sup>th</sup> Avenue bridge in Olympia was closed to traffic because of damage to the concrete frame structure. The Magnolia bridge in Seattle was also closed because of failure of concrete diagonal braces beneath the taller part of the structure (Figure 28). Both of these structures were old and the 4<sup>th</sup> Ave bridge was planned for demolition and replacement before the earthquake. The Magnolia bridge has now been repaired at a cost of US\$4 million. Interestingly, the Magnolia bridge was constructed in 1929 and its columns included spiral reinforcing steel ties which was thought to be a very early use of this method for confining main steel. Inspection of the structure revealed that the columns were still in very good condition after the earthquake (Figure 29).

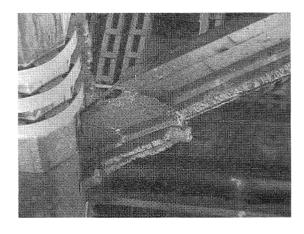


Figure 28: Severed diagonal brace Magnolia Bridge.

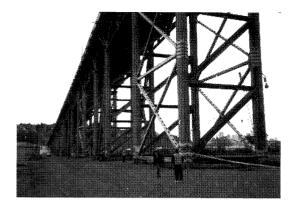


Figure 29: Magnolia Bridge spiral reinforced columns.

#### 4.3.2 Modern Bridges

Some more modern bridges were damaged to the extent that traffic was diverted until structural safety inspections had been carried out.

The Holgate St overpass over the I5 interstate freeway suffered a shear failure of its shortest cylindrical pier. The bridge was constructed in 1966 and consisted of a series of cylindrical piers of increasing height as the bridge climbed over Airport Way and the I5 freeway (Figure 30 photo looking up the length). It appeared that the longer columns had sufficient flexural flexibility to accommodate the motion, which was predominantly longitudinal to the bridge, without damage, whereas the shortest column suffered a shear failure (Figure 31 closeup of shear failure).



Figure 30: View of Holgate Street overpass.

Confinement of the column steel was provided with ties spaced at approximately 300 mm centres and the ties did not include bends into the core at the end of their laps. Cover concrete had spalled as the ties were loaded and the core concrete was heavily cracked. There was no evidence of buckling of the main steel. Traffic was prevented from using the bridge for about five days after the earthquake but the bridge was reopened without any temporary strengthening to the pier.

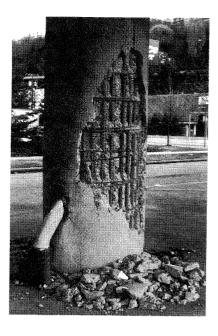


Figure 31: Close-up of pier shear damage.

The SR99 freeway was damaged where it crossed the West Seattle Freeway (known as the Spokane St overcross). The Washington State Department of Transportation has a retrofit programme underway on this structure, which was built in 1958, and some pier strengthening has already been carried out. The spans over Spokane St were steel girder spans whereas the approaching spans from either side were reinforced concrete. Some retrofitting of the superstructure had been undertaken Concrete corbels had been added to provide previously. increased bearing length for the steel beams (Figure 32). Angle brackets had been fixed to the top of the corbels to provide some lateral restraint to the steel beams. Some of these brackets had broken away from the corbel under impact from the steel beams and were on the ground beneath the structure (Figure 33). Approximately 15 mm thick rubber bearing pads were also lying on the ground beneath the structure, suggesting that sufficient movement had occurred to rachet the pads from the bearings.

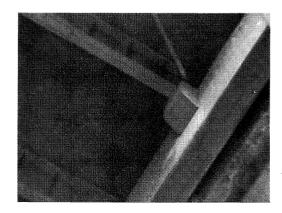


Figure 32: Added corbels for extra support.

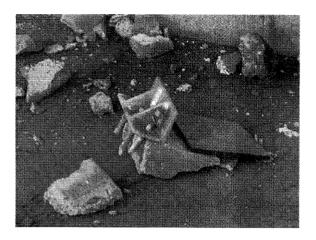


Figure 33: Failed steel lateral restraint brackets.

Eight tie rods had also been added (two between each main beam) at the time of the retrofit to link the concrete deck to the top of the piers. Each rod was about 25 mm in diameter and was anchored off to the deck about 3 m from the pier (Figure 34). The rods appeared to have been epoxy or cement grouted into drilled holes about 300 mm deep in the pier and most of these joints had failed in tension.

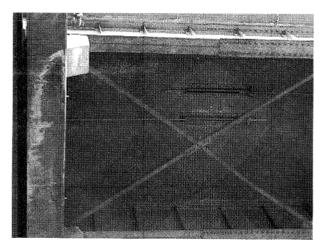


Figure 34: Retrofit tie rods (note one has failed by pull-out from its anchorage).

#### 4.4 Utilities

#### 4.4.1 Water Supply

At the time of the visit there were no disruptions to the water supply in any of the cities visited. There was some evidence of repaired water main ruptures in the 1<sup>st</sup> Ave Sth area of Seattle and repair works were being undertaken on Alaskan Way adjacent to the ferry wharves at the time of the visit. Reports at the time of arrival indicated that there had been some disruption to the water supply but these were only for short periods.

#### 4.4.2 Gas Supply

There were reports of leaks in gas supply mains but these appeared to be mostly repaired before the team arrived in the

area. A gas main that crossed the King County airport runway ruptured in the earthquake and caused the evacuation of one of the emergency management buildings because the smell was initially thought to have been caused by a pipe rupture in that building.

#### 4.4.3 Power Supply

There were power cuts immediately after the earthquake as circuit breakers tripped out, but the supply was restored in the majority of areas within hours after the event. On 1 March (one day after the earthquake) power had been restored to 80% of customers. One instance of a power pole under some stress was noted by the reconnaissance team. The pole appeared to have rotated in the poor soil during the earthquake and had been temporarily braced.

#### 4.4.4 Telephone Communications

Telephone communications were disrupted by overload clogging of lines as people attempted to speak to emergency services and other members of their families. At the State Emergency Operations Centre at Camp Murray there was about a 20 minute period when computer links to other centres were lost.

#### 4.5 Lifeline Structures

#### 4.5.1 Roads

In the early period after the earthquake, there were many reports of road damage. This ranged from road embankment slumping to slips onto the road. Other roads remained passable but settlement had occurred beneath them, making the road surface uneven. While the instances of road blockages were not large, they appeared to be spread over a wide area.

#### 4.5.2 Wharfs

Wharf structures apparently faired well in the event. There were reports of damage to a US Navy pier at the south end of Lake Union. Piles had broken and there was up to 450 mm of lateral movement between the wharf and the ground.

Near the ferry terminals along Alaskan Way, a section of paved area had slumped and the steel sheet piling supporting the slumped fill had noticeably bulged. However, port activity seemed to be back to normal within one or two days of the earthquake.

#### 4.5.3 Airports

The SeaTak terminal and control tower have already been mentioned. Part of the main runway at the Boeing Field was closed for landing and takeoff because of ground subsidence (up to 300 mm deep slumping had been reported). The terminal building and the runway are built over an old river channel and localised soft soil conditions apparently led to the settlement during the earthquake.

#### 4.5.4 Reservoirs

There were no reports of overtopped tank reservoirs nor breaches of embankments retaining water supplies. The area had suffered from a very significant lack of rain over recent months and newspapers reported very low storage levels at the time of the earthquake.

#### LESSONS FOR NEW ZEALAND

#### Buildings

Wellington and other older towns and cities have similar older brick structures to those in the downtown area of Seattle, Olympia and Tacoma. These could be expected to perform in a similar fashion to the Seattle buildings unless they have been retrofitted. Observations indicated that while retrofitting improves the performance of the structures, it must not be lost sight of that damage will still be expected, particularly in a major event. Life safety issues appeared well addressed in the retrofitting of the Starbucks headquarters building, but the high cost of repairing the damage sustained is an important issue. Parapets and appendages must be well restrained in any retrofitting process.

In the Seattle area there were very high initial demands on the technical staff of the administering authorities to conduct immediate safety surveys on buildings. These staff appeared to be well prepared and because the USA tends to be more regulated than New Zealand, there were more people available than we are expected to have in New Zealand after an earthquake.

#### Services

Damage to services in this earthquake were relatively minor. The age of the downtown area of Seattle is similar to Wellington and therefore the services are expected to be constructed with similar materials. Cast iron type water pipes are not likely to survive if subjected to any differential ground settlement as might be expected to occur in areas where land has been reclaimed at a time where the importance of compaction was not realised.

The NZ natural gas reticulation network may be newer due to later development of the NZ gas fields than in the USA and may therefore be less susceptible to damage.

The privatisation of New Zealand's communications network has meant that there is now more than one telecommunications provider for the country. There is therefore likely to be a certain amount of duplication and redundancy in our telecommunications networks to cover isolated outages in any one provider's system.

#### • Bridges

Mostly new bridges performed well and damage was limited to such things as impact damage to sacrificial drift restraints on bridges with rubber bearings.

Older bridges constructed before 1970 showed signs of weakness. Deficiencies in reinforcing detailing, such as not returning hoop tie ends into the core of columns, were highlighted and reinforced the drive for the provision of jacketing of such columns.

When carrying out a bridge retrofit, it is important to agree on a level of strengthening that will be carried out and the retrofit details need to be designed for the agreed or expected load levels. New Zealand is fortunate in that it has a review system in place for any strengthening work to be undertaken on its national highway structures and because it is a small country, uniform assessment procedures have been established. Retrofitted bridge structures are therefore likely to perform well in future earthquakes.

#### Roads

Road blockages have occurred in past in NZ earthquakes and are expected to occur in the future due to slips and slumping. Washington State was reasonably fortunate to have alternative routes for most problem areas. In New Zealand, a city such as Wellington with only two road accesses, may be vulnerable in an earthquake.

#### 5 EMERGENCY MANAGEMENT LESSONS

For the Nisqually earthquake reconnaissance the Ministry of Civil Defence and Emergency Management had a particular interest in:

- Hazard mitigation measures the effectiveness of a decade of programmes; evidence that damage/casualty limitation was a result of such initiatives
- Impact assessment coordination, sharing and prioritising of information
- Response co-ordination effectiveness, learning points, intelligence gathering, refinements, and
- Public information effectiveness, mechanisms, refinements

Our challenge was to make meaningful comparisons with New Zealand's reduction, readiness and response arrangements at both our central and local government levels.

The Nisqually Earthquake event triggered emergency declarations at the federal, state, county and city level. The most significant was the Presidential Major Disaster Declaration, delivering federal aid to the affected communities.

While our observations of the mechanisms for federal response and funding were enlightening, they are not in themselves particularly relevant for the New Zealand emergency management community. The State of Washington (population 6m), rather than the Federal Emergency Management Agency (FEMA) was seen as a more useful comparison for New Zealand's central government response. At the local government level we viewed the City of Seattle (pop'n 570,000) as a metropolitan response equivalent to Auckland, Wellington, or Christchurch, the City of Olympia (pop'n 50,000) as the equivalent to that of a provincial New Zealand city and the counties as the nearest equivalent to our regional government response.

The most significant of all the emergency management processes we observed was a key organisational arrangement – the Disaster Management Committee – mirrored at each level of government. The committee comprises politicians and officials and ensures that participating agencies are assigned either primary or support responsibilities for any disaster response. The committees meet monthly, assign emergency support responsibilities, arrange regular exercises, and guarantee that networking amongst participating agencies occurs. They also appear to require full plan reviews every 2 years. This commitment to planning and exercising means that disaster response and recovery remains linked to each department or agency's day-to-day operating procedures. And this is a "whole of government" approach to emergency management planning

and response. When an emergency occurs state and local government employees know what their role and responsibility is – and it is not something completely divorced from normal daily tasks. The emphasis *will* change and the workplace *may* move to an emergency operations centre but the tasks are known, exercised and part of the agreed job description.

For New Zealand this is an example to be emulated. Unlike New Zealand, American utilities are still largely government owned and operated, and the emergency services are departments of state and local government. The challenge to coordinate and plan is greater in New Zealand and while the new Civil Defence Emergency Management Groups will provide the organisational arrangement at a local level, the commitment to planning, coordination and "normalisation" of emergency support functions will have to come from the participating agencies. Currently at Central Government level the National Civil Defence Plan serves as our planning vehicle for ensuring that each Department and national agency recognises its response role in an emergency. However the organisational arrangements are not as clearly defined as those observed in Washington State and it is hoped that under our new Civil Defence Emergency Management legislation the National Strategy and the National Plan will help close those gaps known to exist with regard national capability.

#### 5.1 Hazard Mitigation

Washington State has a commitment to Emergency Management, modern facilities (Figure 35) and a high "mitigation" profile. The state itself and several of its communities have participated in a federal initiative called Project Impact aimed at "Building Disaster Resistant Communities". Seattle was one of seven pilot communities to receive seed money from FEMA in 1997 for community-based mitigation programmes. Project Impact focuses on reducing damage potential and accelerating recovery through preventative action - encouraging communities to think about the hazards that confront them and act before an event to protect themselves. In Seattle's case they promoted the retrofitting of residential homes, the identification and mitigation of nonstructural hazards in public schools and undertook mapping of landslide and seismic hazards within the area. The programmes adopted by later Project Impact participants within the state were not identical but they were directed to the same end. Ironically on the day of the Nisqually earthquake President Bush announced budget cuts which included the axing of Project Impact programme stating that it "has not proven effective".

Because the City of Olympia, situated 17 km from the earthquake epicentre, had **not** been party to this federal and state initiative, commentators sought evidence of Seattle outperforming Olympia in terms of damage limitation, productivity losses, casualty numbers and personal behaviours. While anecdotal evidence indicated that preparedness activities paid off in the Project Impact communities, it was acknowledged that the earthquake's depth had tempered impact, precluding any meaningful comparisons.

#### 5.2 Impact Assessment

At the State level their planning assigns responsibility for damage assessments to local jurisdictions or state agencies. Each provides damage assessment estimates to the state Emergency Operations Centre (EOC) (Figures 35 & 36).

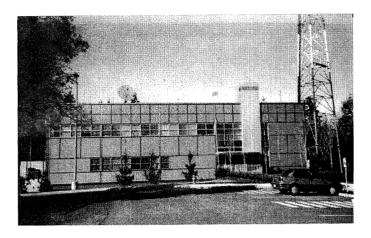


Figure 35: The Washington State Emergency Management Division operations building; new, state-of-the-art and purpose built at a cost of US\$9 million. It is a braced, steel framed, two level building with a friction pendulum base isolation system that is designed to survive the 1,000 year earthquake without significant damage. It is staffed 24 hours a day and is the primary warning point for all natural and technological hazards in the State, including civil disturbances, earthauakes. volcanic eruptions, forest fires, terrorist activities, dam failure, floods, severe weather systems and tsunami. In a crisis the building can house 230 staff rather than the normal 70. Its independent generators can keep the entire building operational for 7 days before requiring new fuel

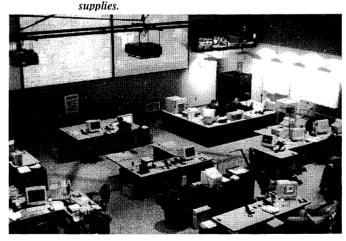


Figure 36: The main operations room of the Washington State Emergency Management Division. The room is superbly equipped with computers, radio communications systems, TV's, audio visual system links, and 3 x 12 foot projector screens.

#### 5.2.1 Rapid Impact Assessment:

Initial damage assessments or Rapid Impact Assessments proved to be an Emergency Services' responsibility. This type of assessment is a quick, cursory evaluation, usually accomplished by driving through the affected areas conducting a "windshield survey" of damage. (Trained personnel from the American Red Cross supplement this process.) This arrangement ensured the EOC had an immediate and professional assessment of the event's impact and the likely demand for available resources.

For New Zealand this is a key lesson – ensure Civil Defence response planning assigns responsibility for a rapid impact assessment of this nature.

#### 5.2.2 Inspection of Damaged Buildings

The structural damage inspection process was also pre-planned and responsibility assigned according to ownership or the nature of the structure. Commercial and public building inspections are the responsibility of local government's Housing or Urban Development Departments. Building inspectors armed with appropriate kits, containing their basic inspection checklist and placards for posting on buildings to indicate their safety status, were underway immediately the shaking stopped. While some local government officials indicated that their processes required improvement, the NZ team was impressed by the preplanned response and believe it should be emulated in New Zealand. To have officials aware of their responsibility to respond automatically, to have the kits available (in both vehicles and pre-assigned "safe" locations), routes planned on the basis of local hazard identification, arrangements in place to activate a call centre, and a logging and tracking methodology prepared for monitoring inspections, inspectors and building safety status are crucial to an effective response.

In NZ the NZSEE has developed Post-Earthquake Building Safety Evaluation Procedures for territorial authorities. These need to be actively promoted and local government planning needs to dovetail with Civil Defence response planning to ensure a creditable response is assured.

#### 5.2.3 Business Interruption

In Washington State there appeared to be no mechanism for assessing or assigning a financial value to commercial business interruption impact. The business community was largely silent on how they were impacted – such information being commercially sensitive.

#### 5.2.4 Financial Impact Estimates and HAZUS

Traditionally the State Emergency Management Agency will complete a Preliminary Disaster Assessment, collated from estimates/assessments provided by agencies of state and local government, in order to request a Presidential Disaster Declaration (PDD) and thus federal financial assistance. In this instance Washington State used a tool developed and supplied by FEMA - a loss estimation software programme called HAZUS which uses mathematical formulae and information about building stock, local geology and the location and size of potential earthquakes, economic data and other information, to estimate losses from a potential or real earthquake.

Once the local database had been developed actual earthquake data could be input and HAZUS delivered an estimate of groundshaking, the likely number of buildings damaged, damage/ disruption to lifeline utilities, plus estimated casualties and homeless. Most significantly it provided an estimate of the dollar losses and anticipated repair costs arising from the event in this case US\$2 billion – sufficient to trigger the Presidential Disaster Declaration. In the past local authorities would have submitted preliminary estimates of damages and economic consequences over the days following such an event until gradually the scale of the event would have emerged. This method provided the results required quickly without tying up local authority resources.

It should be noted however the financial data modelled by HAZUS was to be verified by the on-going process. While we were there the Emergency Management offices were already collating repair estimates for Public Assistance Programme claims and submitting them to Washington State. Presumably this information will ultimately justify both the model and the declaration request.

The significance of the decision to use HAZUS in calling for federal aid may have ramifications in the future in the USA. As far as New Zealand is concerned the focus remains on the value of such a loss estimation software tool. HAZUS was initially developed for pre-event mitigation, to guide response planning and to speed response and relief efforts. There are a number of variations of this type of software currently in use in New Zealand but to date their application has been organisation specific. We need to explore the use/development of a model for general use in NZ emergency management.

#### 5.3 Response Co-ordination

The affected jurisdictions of Washington State fully activated their Emergency Operations Centres (EOCs) in response to the earthquake. The Federal Emergency Management Agency (FEMA) Regional Operations Centre, Region 10, activated in support of Washington State.

Due to the time of day the EOC activation was achieved within minutes. However King County EOC had a problem with of loss of power, temporary loss of communications and an evacuation due to a suspected gas leak. Washington State EOC co-ordinates information and arranges additional resources. County and City EOCs are the organisations that collect information and respond to community needs.

Damage assessment information gathered by a range of agencies (including the emergency services, departments of each level of government, and utilities in public ownership) was forwarded to the relevant EOC. All EOCs had intelligence collection plans within which the various agencies carried out predetermined tasks. The strength of the reporting responsibilities is the Mutual Agreements between and within departments and utilities. These agreements assign lead responsibilities and detail tasking and assessment activity on behalf of the respective organisations.

State, County and City emergency management organisations employ full time professional staff, and provide stand alone EOCs. Other agencies of local government provide appropriate staff to meet their commitment during events and exercises.

As a backup to the telephone system a state-wide emergency radio system has been put in place, connecting County and City EOCs with the State Emergency Management EOC.

Welfare activity is the responsibility of the American Red Cross. During this event they initially opened 9 shelters (Welfare Centres). By the time the NZ team arrived on 2 March only one remained open in the City of Olympia. In addition to opening the shelters the American Red Cross deployed fifteen Emergency Response vehicles (field kitchens) and three fixed feeding sites to provide evacuees and emergency staff with meals. Between 18 Feb and 4 Mar they served 3,200 meals. At one stage the American Red Cross deployed 327 staff and volunteers.

#### 5.4 Public Information

With the exception of the Washington State EOC (own staff), staffing for the Joint Information Centres at EOCs is drawn from the public affairs staff of local government departments and utilities. They are used as a pooled resource and work for the respective local government EOC for the duration of the activation. Networks, contacts and personalities remain in place - the difference is the location from which the people work and the messages themselves. Emergency Management organisations have learnt from past experience that there is a need to monitor the information provided and to maintain consistency in the messages.

Post-event, the Joint Information Centre function needs to be maintained. In some instances people have not been listening or have not fully understood the messages being released by the Public Information unit. The message changes to one of workplace safety, or for some other reason (language), the broadcast messages may need prolonged reinforcement of what to do or what not to do.

As well as informing the community, the public information function must not overlook fellow government workers, who will also be fielding questions on what is happening – "where do I go to seek assistance in regard to the event?"

Joint information centres also constantly monitor the various media outlets to ensure that the correct information is being passed to the community. Where a message is incorrect, confusing or out-of-date, such monitoring means that the message can be clarified or corrected quickly – before it becomes a problem.

TV played a significant part in presenting the message at the various levels (State, County and City). Television was right there as it happened. TV crews from the various stations were out and about filming news; such things as a seminar being run by Microsoft in Seattle and the visit by a Mongolian Government delegation to the State Capitol Campus in Olympia. The cameras kept on rolling and filmed the earthquake impacts as they occurred.

This was a web event. EOCs used the various web sites to post information re emergency contact numbers, media releases etc.

King County EOC reported 700,000 hits on their county government web page between the 28 Feb and the morning of the 2 Mar. With telephone and cell phones not getting through, many in the community turned to the Internet. One provider is reported to have had as many as 5 million more emails than normal on the afternoon of the earthquake. Individuals reporting earthquake experiences quickly dominated Internet chat rooms.

#### SUMMARY OF CDEM LESSONS LEARNED

- Pre-planning is the key to emergency response success.
- Emergency response must be a "whole of government" activity.
- New Zealand should continue to promote the mitigation rationale that every dollar spent in damage prevention saves two in repairs.
- New Zealand emergency management would benefit from the development of a generic and nationwide lossestimation software package.
- Rapid Impact Assessment arrangements need to be preplanned with primary and back-up responsibility assigned and accepted.
- The building inspection process needs to be planned in detail at local government level. Involvement of the engineering fraternity should be actively sought.
- The NZSEE Post-Earthquake Building Safety Evaluation Procedures must be actively promoted - internet web access would be a starting point.
- Regular Civil Defence Emergency Management exercising benefits real-event response.
- Every agency participating in emergency response must ensure that the emergency response tasks and activities expected of staff are as familiar and commonplace as their day-to-day routine. The emergency response tasks should be an extension of the daily work routine and not something totally alien.
- Privatisation of ownership of Utilities within New Zealand means that there is an even greater need for co-ordination in the planning of response. Contractual assignment of responsibility and written agreements defining service delivery expectations in emergency situations are mechanisms that Councils must utilise in order to ensure a smooth restoration of essential services.
- Pooling public affairs staff from the various government departments within a Joint Information Centre has manifold benefits. Existing expertise and networks are exploited. Consistency, continuity and accuracy of message are guaranteed.
- Maintaining the joint public information centre as the emergency moves from *response* to *recovery* is essential.
   The need remains after the immediate response period ends, to coordinate messages to the Public, avoiding duplication and inconsistencies.
- Monitoring of all forms of media print, electronic and broadcast – is essential. Taking early corrective action to counter inaccurate or misleading reporting is part of effective media management.

- Public information messages should be promulgated through every mechanism available in order to keep the community informed on public safety issues. The internet is now an integral part of the news media and should be utilised where possible.
- Public information managers need to take into account the diversity of their community and pitch their messages accordingly. English may not always be the most appropriate language.

Having identified these lessons as useful to the civil defence emergency management community in New Zealand, the Ministry will endeavour to not only share these observations but to also promote the adoption of such lessons by including them in best practice guidelines where appropriate.

The Nisqually earthquake, because of its depth and because of drought conditions prevailing in the Puget Sounds area at the time, did not cause the devastation that may otherwise have resulted from an earthquake of this magnitude. The Emergency Management agencies in the Washington State were thus not fully tested but it was clear to the team that they did perform well. We would be pleased if we could assume we would do as well in a similar event.

#### 6 ACKNOWLEDGEMENTS

The Reconnaissance Team thanks the New Zealand Society for Earthquake Engineering for the privilege of participating in the reconnaissance of the Nisqually earthquake in Washington State, USA, and the Ministry of Civil Defence and Emergency Management and the Earthquake Commission of NZ for their support.

Many individuals willingly assisted our reconnaissance work. The Team acknowledges the help of many colleagues in the USA who provided information and support. In particular we would like to thank Gregory McRae and others at the University

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