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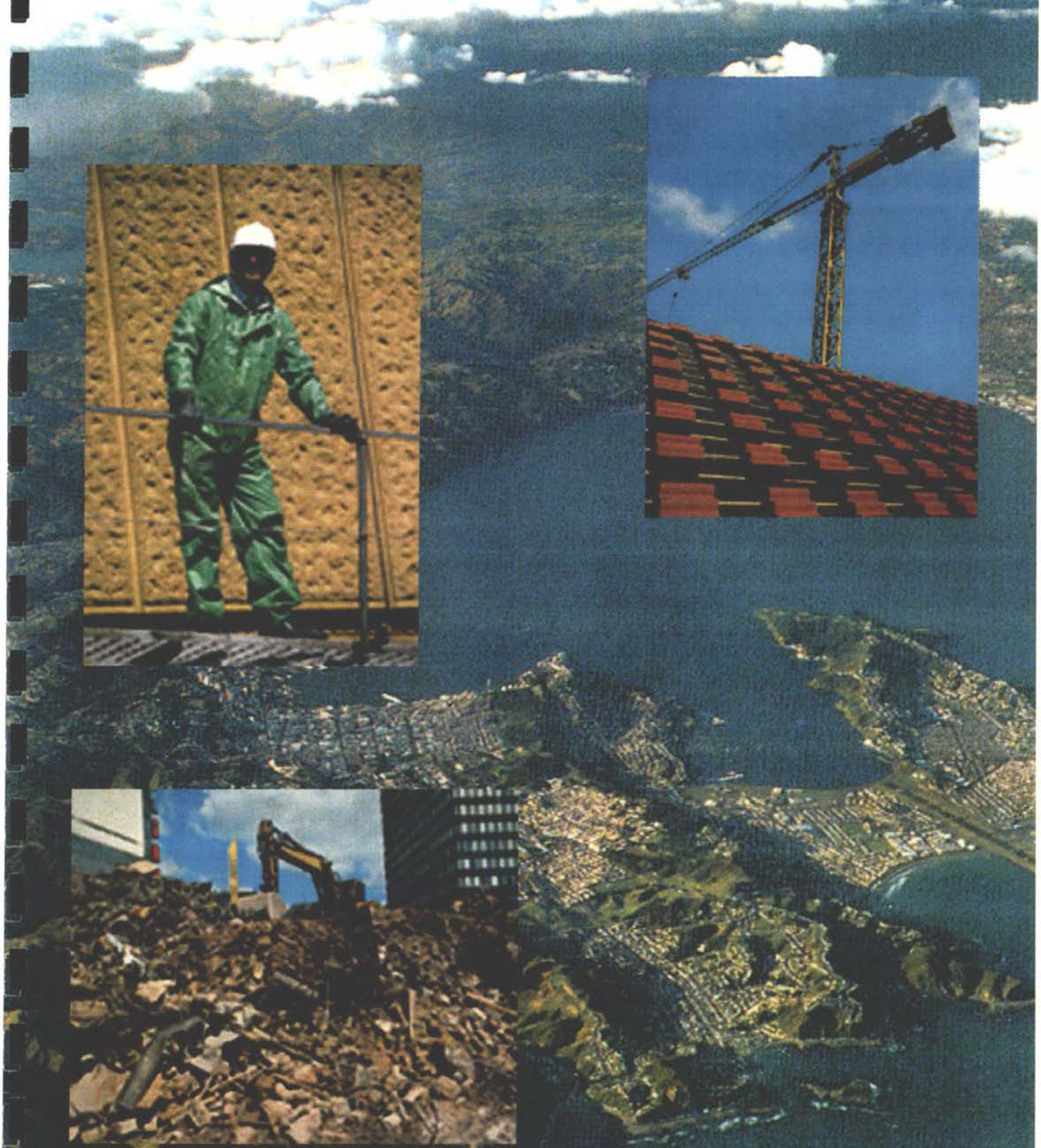
The Great Wellington Quake
A Challenge to the Construction Industry



David C Hopkins Tony Lanigan R Bruce Shephard

The Great Wellington Quake

A Challenge to the Construction Industry

David C Hopkins[1], Tony Lanigan[2], R Bruce Shephard[3]

Executive Summary

This paper examines the nature and extent of damage due to a major (Magnitude 7.5) earthquake in Wellington. Effects on both buildings and infrastructure are assessed from Palmerston North/Wanganui to Nelson/Blenheim. The value of assets at risk in each location and the estimated damage to these is presented.

Based on an assessed four year recovery period, the damage values and rates of spend and/or production required are estimated and compared with the current and potential capacity in the affected region and over New Zealand as a whole.

Results show that $73 billion of assets is at risk. Assessed damage is $6.8 billion, but could possibly be considerably more. On the basis of $6.8 billion of damage, of which $6 billion is in the greater Wellington region, peak expenditure required is 300% of Wellington region's current capacity and around 50% of New Zealand's current capacity. Mobilisation of latent production capacity, through increased local production or through importing, reduces these figures markedly but raises questions of the extent to which mobilisation could be achieved.

The increases in demand will provide a major challenge to all sections of the construction industry – contractors, designers, legislators, inspectors, territorial authorities. The industry needs to take steps to develop and maintain readiness to cope with the situation effectively.

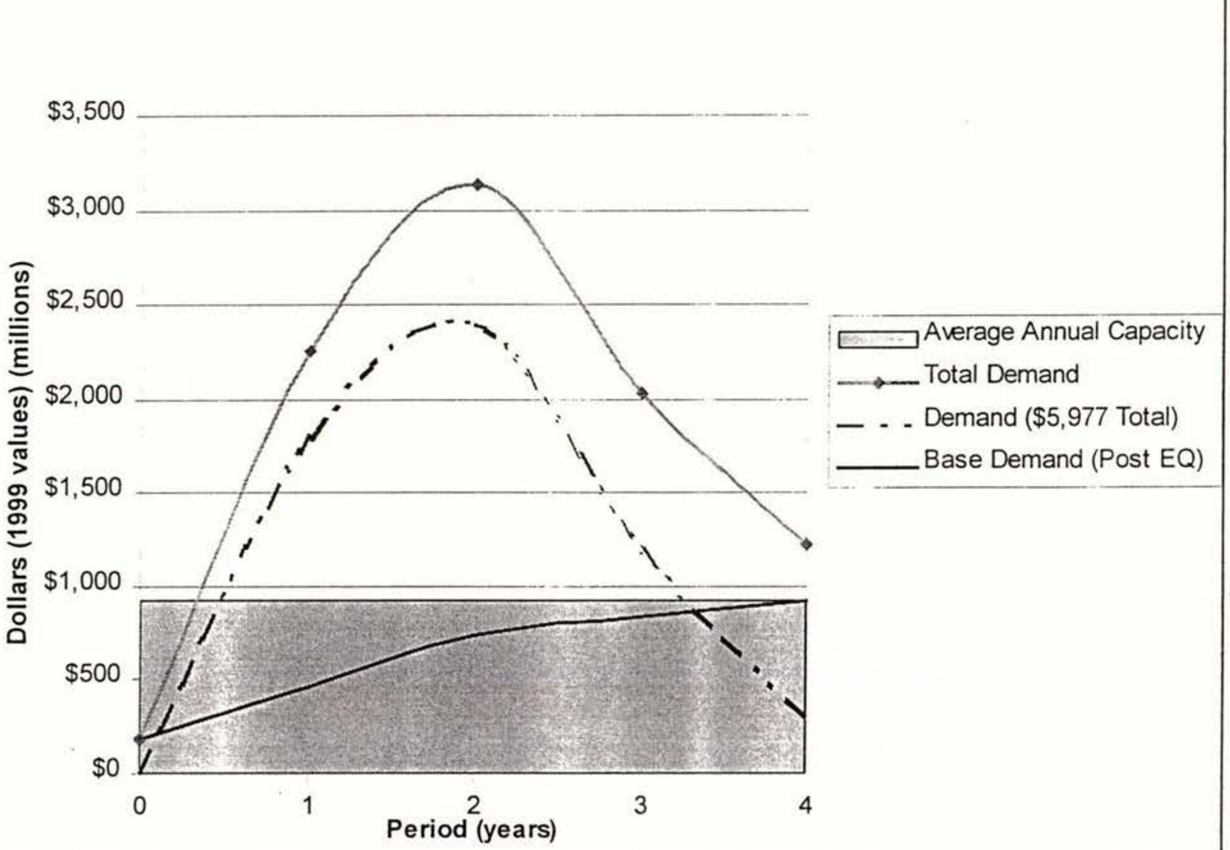
Broad issues that need to be addressed in advance of the event include:

a) The degree of control necessary from national and local government.
b) The extent to which New Zealand based contractors would participate effectively.
c) The extent to which offshore contractors become established in New Zealand.
d) The extent to which importation of competitively priced materials, plant and labour will be necessary.
e) Availability of key management and technical skills within the construction sector.
f) Relationships with major insurers and asset owners.
g) The availability of money for reconstruction and for payments to contractors.
h) The extent to which nation-wide resources can be directed to Wellington.
i) The ability of TLA's to cope with the necessary approval processes.
j) Any special measures to control the quality of construction at a time of high demand.

[1]Kingston Morrison Ltd, Wellington, [2]A G Lanigan Consultants, Auckland, [3]Seismic Consultants Ltd, Wellington

The demands on resources are summarised in Figure E1.

Figure E1 - Demand vs Capacity - All Assets



The Mercury Energy incident in Auckland in 1998 is a reminder that contingency planning must be seen as a vital activity in the sophisticated and highly technological society of the 21st century. The prospect of a major earthquake in Wellington (or any other major city) demands some basic "business continuance planning" from the construction industry, including constructors. This planning must be done on both a local and national scale.

1. Introduction

A major earthquake in Wellington will cause several billion dollars worth of damage and place severe demands on the construction industry in the rebuilding process. It is important that some advance consideration be given to the extent and nature of this challenge. What steps can be taken now to make the reconstruction process as effective as possible? What must the authorities know now to enable them to provide clear direction on the range of activities necessary to the rebuilding process? What steps can the construction industry take in advance to reduce the disruption to a practical minimum? What steps can the New Zealand construction industry take now to ensure that it is in a defensible position after a major earthquake and that it can exercise appropriate influence on the process of reconstruction?

This paper examines the nature and extent of damage in all of the affected locations, provides assessments of the resources required for reconstruction, and compares the resources required with the present capacity of the construction industry. It is intended to provide a starting point for key decision-makers in the construction industry to decide what actions need to be taken now.

The paper extends the work described in two papers presented to the Wellington After the Quake Conference [1, 2]. More sophisticated processes have been used to assess the nature and extent of damage to buildings. Damage assessments have been extended to cover all affected areas such as Palmerston North, Wanganui, Nelson, Blenheim, Masterton and the Wairarapa.

The earthquake scenario is basically the same, but closer account has been taken of attenuation and variations in soil properties within the affected region.

The paper focuses on presenting the results in summary form. Background descriptions and explanations of methodology have been kept to a minimum.

Those using the results should recognise the wide margins of uncertainty behind the assessments. Although quite detailed considerations are involved in the assessment process, the overall result should be regarded as a broad estimate of the general extent and nature of the damage and resources required.

2. Scenario Event

Movement of the Wellington-Hutt Valley segment of the Wellington Fault is generally considered the probable maximum event for loss assessment purposes in the Wellington region. The characteristic earthquake on the Wellington Fault is identified with a 60 km length of rupture causing up to 3 to 5 metres of horizontal movement and 1 metre of vertical movement. Such movement on this strike-slip fault is estimated to produce an earthquake magnitude of M7.5.

The estimated average recurrence interval for movement on the Wellington-Hutt Valley segment of the Wellington Fault is 600 years, with the most recent event estimated as occurring some 450 years ago. The probability of occurrence of the scenario Wellington fault event is about 10% in 50 years. [3]

Variation of shaking intensity with distance away from the earthquake source used, is that recommended by Smith and Smith [3]. In addition near fault effects have been taken into account.

Further allowance was made for amplification of earthquake shaking intensities in areas of soft soils and for permanent ground deformation due to liquefaction. The extent of these soils was determined from maps prepared by Wellington Regional Council for its area, and from geological maps and local knowledge for more distant areas. For areas in the Wellington Region assessment was made of the liquefaction and ground deformation potential. No specific allowance was made for earthquake-induced landslip.

Appendix C has further information and background on the scenario event.

3. Assets at Risk

The assets at risk include all buildings and infrastructure within about 100 km radius from the ends of the scenario fault rupture length. This includes areas about 150 km north of Wellington City encompassing Wanganui and Palmerston North, and areas about 100 km south of Wellington City including Nelson and Tasman District. This area is sufficiently large to ensure that damage sustained in more distant areas would have no significant contribution to resource demands. The scenario area was modelled as more than 200 geographical unit areas in order to establish earthquake ground shaking intensities. ground and inventory characteristics in some detail.

The basic inventory data for buildings was provided by Quoteable Value New Zealand (QVNZ) as the numbers of buildings, classified as residential, commercial and industrial, and their total floor area for each geographical unit area. Some approximations were necessary to aggregate buildings to these classifications to allow for unclassified data in the QVNZ database. Further approximations were made to aggregate buildings in country areas to the nearest appropriate urban areas to account for the total inventory. Building replacement values were determined by varying construction costs according to locality and building area.

Buildings represent some 75% of the assets at risk and residential buildings represent some 46% of the total.

Infrastructure assets were provided by the various local authorities and utility owners and managers in response to enquiry. For the Wellington region covered in the Hopkins paper [1], updated values of assets were sought. For the new areas covered, new values were sought. Not all infrastructure asset owners responded and some of the responses were in contrast to the previous values, so that the asset values for this assessment are a mixture of new advised values and the authors' assessment based on the 1995 figures. Appendix B shows a broad comparison of asset values and damage assessments between the 1995 and the 1999 figures.

Summaries of building and infrastructure asset values are provided in Table 6.1 and are presented in Map 6.1.

4. Damage Assessment Methodology

4.1 Damage Assessment Model

Damage assessments were undertaken by Opus International Consultants Ltd based on analysis models and data developed from earlier studies. The analysis models used were a combination and extension to those used for the Earthquake Commission, other insurers and various utility owners (confidential client reports), and Wellington Regional Council [4]. The basic approach reported for Wellington Regional Council, with modifications, extensions and extrapolations has been used in this current work. While some inconsistencies occurred in particular geographic unit areas, the overall results are expected to be consistent with the overall variation in conditions.

For full descriptions of the damage assessment models, refer to the Wellington Regional Council report(s) [4]

4.2 Confidence Limits

It is important to recognise the wide confidence limits on the results. Damage values presented in this report are based on statistical mean value assessments. This means there is an equal likelihood of the actual loss being less or greater than the figures shown. Ninety percentile damage assessments for example, are about twice the value of expected damage assessments but this level of damage would be likely in only one out of 10 actual events.

4.3 Building Damage Assessment

Geographical Considerations
The building inventory was grouped into geographical unit areas in order to establish locations, consistent risk types and characteristics, and ground conditions within each unit. Distances used to determine the ground shaking effects from the earthquake fault line source are based on centroids of inventory in each unit area.

Building Characteristics
Building characteristics for each unit area were determined by extrapolation of data from site surveys, which identify vulnerability characteristics including building age, number of stories, construction material and form, form irregularities, construction style and features.

Building Damage States

The assessment of building damage has been addressed in more detail for the Wellington Region. This detail enabled building damage to be assessed in respective damage states as shown in the accompanying Table.

Building Damage States

- None - no appreciable damage
- Light - between none and 10% replacement value damage
- Moderate - between 11% and 30% replacement value damage
- Extensive - between 31% and 99% replacement value damage
- Complete - 100% replacement value damage

Light Damage State includes internal disruption caused by planters, furniture, bookshelves, or other items that are free to shift around during shaking and some slight damage to permanent building elements such as ceilings, lighting fixtures, or partitions. Damage may require clean-up and minor repair that requires a maximum of a few days to complete.

Buildings in **Moderate Damage State** will suffer more extensive damage to internal elements than those in light damage state, and may also have minor structural damage such as cracks in concrete or masonry walls. The damage would be sufficient to require repair, and the building could be partially or completely closed, pending analysis and/or repairs. Partial closure is expected while repairs and clean-up are completed.

The **Extensive Damage State** will include damage to structural elements such as walls, columns, and beams. Buildings may be leaning or certain floor levels or walls may be out-of-plumb. Internal elements may be damaged beyond repair. Owners of buildings that have been damaged this severely often must wait for engineering and economic studies to be completed to determine if it is economically justifiable to repair the building or whether to simply demolish it.

The **Complete Damage State** includes both collapsed buildings and those that are so severely damaged that repair are clearly uneconomical. Because of the many structural requirements placed in modern codes specifically for the purposes of preventing collapse, this damage state should be rare in new buildings.

Building Classes

For areas in the Wellington Region, buildings have been considered in four classes:

1. Residential
2. Commercial/Industrial
   - Group 1, low vulnerability, ductile,
     (e.g. timber frame, light steel frame buildings.)
   - Group 2, medium vulnerability, ductile
     (e.g. concrete and steel, frame and wall buildings.)
   - Group 3, high vulnerability, non-ductile,
     (e.g. unreinforced masonry.)

For the other outer areas the commercial and industrial building types were combined.

Building Vulnerability
Building risk vulnerabilities relate the extent of damage to the intensity of earthquake ground shaking. [4]

Vulnerability models for buildings were extended to determine the distribution of damage about the mean values. Thus, given a mean damage state of a set of buildings, the proportions that suffer no damage and those with complete damage, and all damage states in between, were assessed.

Damage from fire and tsunami following earthquake has been allowed in the buildings damage assessments.

4.4 Infrastructure Damage Assessments

General
Infrastructure components were considered in two categories, those expected to be mainly sensitive to ground shaking, (e.g. bridges and pumping stations), and those expected to be mainly sensitive to ground deformations, (e.g. underground piped services.)

Damage vulnerabilities for infrastructure sensitive to ground shaking were extracted from the HAZUS model [5]. HAZUS component types do not always correspond with the component types used in this study so that appropriate combinations of HAZUS vulnerabilities are used.

Shaking hazard maps prepared by Wellington Regional Council for the Wellington Fault scenario were used to estimate the proportion of the infrastructure components in each of three shaking hazard intensity zones. This data was combined with the vulnerability data to calculate the expected damage ratios for lifeline components in each of the study areas.

Damage ratios expected for infrastructure components sensitive to ground deformation were mostly estimated using data obtained from previous Opus studies of Wellington regional bulk water supplies and of telecommunication outside plant. [6]

Piped Services
Damage ratios expected for piped services, in each of the six ground deformation zones, were estimated from data extracted from the Wellington regional bulk water supply study [6]. Damage ratios were extracted for ductile, intermediate ductility and non-ductile pipes.

Approximate proportions of each type of pipe in each of the main study areas were obtained from the relevant local authority for each lifeline piped service (water, wastewater, stormwater and gas).

The above data allowed the damage ratios expected for piped services in each study area to be estimated. These were adjusted to reflect the likely repair cost of a pipe break relative to the replacement cost of the various piped services. For example, the Wellington gas company, Enerco, expect that most repairs to the regional gas pipelines (trunk lines) will need to be carried out with the gas line in use. The repair costs in this case were very high ($200,000 per repair) resulting in a relatively high damage ratio for the regional gas network in Wellington.

Electricity Network
Damage ratios were developed for the electricity network lifeline components from HAZUS data, modified for local conditions using data from the telecommunication reticulation study. [5]

Roading
For roading networks the damage ratios expected in each of the ground deformation zones were estimated from HAZUS data. The "best estimate" damage ratios from the HAZUS fragility curves for peak ground deformations for each damage category were considered to be high and so the minimum damage ratio values obtained were selected for this study. [5]

Data Interpretation
As data was available from the previous studies for the main Wellington – Hutt – Porirua region only, damage ratios for the other outer areas were obtained by extrapolation.

Infrastructure asset replacement values were combined into regions similar to those used for the building data on a population basis.

Wellington Regional component damage ratios were obtained using a weighted average of infrastructure evaluated for areas such as Wellington and Porirua. The district values were weighted using the number of residential properties in each district.

For some infrastructure components such as sewerage, the breakdown in value to sub-components of reticulation and distribution/storage etc was not identified. In this case, a weighted average damage ratio was used for the "not identified" sub-component based on values evaluated for the other sub-components. The weighting was based on values obtained for sub-components in other districts and/or using reasonable judgement.

4.5 Additional Post Event Inflation

No additional increase in medium and long-term inflation has been allowed for in the damage assessments. There is no generally accepted figure to account for this effect and it was considered best not to apply any factor. Given the wide possible variation in damage estimates, the inclusion of post-event inflation is not seen as significant.

4.6 Analysis Method

Computer systems based on extended spreadsheet capabilities were used to perform the damage analyses. Models used relate the earthquake ground shaking at any particular site to the type of asset, its characteristics, value and damage ratio and calculate the damage. Damage for the various assets from their respective geographic unit areas have been aggregated for this presentation.

5. Resources Assessment

The results of the damage assessments in the various categories and locations were used to assess the split of values into materials, plant and labour. These values provided the basis for assessing the resources required in relation to capacity.

The calculations took account of location, category, and in the case of buildings, the damage state.

For infrastructure assets the proportional split was not changed from the 1995 figures used by Hopkins [1]. The same splits were used for all locations.

For buildings, a more detailed process was used than in 1995. The split was made using assessed percentages for each of the three components (materials, plant, labour), and varied with the nature of work. For instance, repairs to lightly damaged residences were taken to be more labour intensive proportionately than reconstruction of completely destroyed residences.

The paper by Hopkins [1] split the dollar values of damage into quantities of materials, plant and labour of different kinds. It was decided not to make this detailed split, but to rely more on the dollar values as a measure of the work required. It was considered that the construction industry representatives using this data would find the dollar values sufficient, and possibly more appropriate, to assess the implications.

The breakdown into detailed quantities included in this paper result from a direct scaling of the 1995 results according to the revised dollar values in each category.

Further details are given in the Appendix A.

6. Results

6.1 Damage and Resources Assessment

Summaries of asset values and expected building and infrastructure damage are provided in Tables 6.1, 6.2 and 6.3 and Map 6.1 and 6.2

Note that buildings represent some 75% of the asset inventory but result in 88% of the expected damage, with residential buildings representing some 46% of the asset inventory and resulting in 41% of the expected damage.

Table 6.1(a) shows the building values and estimated losses by location, presented in detail of sub-categories and damage states for the Wellington region.

Table 6.1(b) shows the infrastructure values and estimated losses by location and categories and sub-categories.

Table 6.2 is a summary of results showing values of assets at risk, estimated losses and the split between materials plant and labour.

Table 6.3 provides further detail of split between material, plant and labour and includes the resulting damage ratios, by location and asset category.

Table 6.1: Values and Losses by Category, Location and Damage State - Buildings.

Category	Wellington City		Lower Hutt City		Upper Hutt City		Porirua City		Wellington Region		Kapiti		PNorth et al		Wairarapa		Nelson/Tasman		Marlborough		Total Value		Total Loss	
	Value $Million	Loss $Million	Value $Million	Loss $Million	Value $Million	Loss $Million	Value $Million	Loss $Million	Value $Million	Loss $Million	Value $Million	Loss $Million	Value $Million	Loss $Million	Value $Million	Loss $Million	Value $Million	Loss $Million	Value $Million	Loss $Million	Total $Million	Sub Total $Million	Total $Million	Sub Total $Million
A Buildings																								
1 *Group 1 (Light frame construction)*	319	49	110	14	42	2	115	3			174	13			309	10					1,069		90	
None	43	0	22	0	13	0	87	0			63	0			158	0						386		0
Light	163	8	59	3	23	1	22	1			79	3			127	5						472		20
Moderate	73	14	19	4	4	1	4	1			22	4			19	3						141		25
Extensive	34	21	8	5	2	1	2	1			9	5			6	3						60		35
Complete	7	6	1	1	0	0	0	0			1	1			0	0						10		9
2 *Group 2 (Other construction types)*	7,108	1,664	884	243	376	63	305	90			499	55			546	20					9,717		2,134	
None	205	0	27	0	30	0	55	0			104	0			262	0						683		0
Light	3,083	148	351	18	191	9	92	5			259	11			236	9						4,211		199
Moderate	2,274	437	280	57	98	18	62	13			90	16			37	5						2,841		546
Extensive	1,214	758	177	118	47	28	71	47			38	22			12	6						1,550		978
Complete	333	320	48	50	10	9	25	26			7	6			0	0						423		410
3 *Group 3 (Masonry construction)*	915	739	67	62	1	1	7	5			5	2			184	31					1,179		839	
None	0	0	0	0	0	0	0	0			0	0			15	0						15		0
Light	33	2	1	0	0	0	1	0			1	0			94	4						130		6
Moderate	130	29	4	1	0	0	1	0			1	0			48	9						185		39
Extensive	362	265	19	14	0	0	1	1			2	1			23	13						406		295
Complete	392	442	43	47	0	0	3	4			1	1			5	4						443		499
5 *Comm/Ind (Not assigned to Groups)*													5,927	77			2,059	31	1,399	17	9,386		125	
None													4,334	0			1,421	0	1,052	0		6,807		0
Light													1,407	44			564	18	307	10		2,279		71
Moderate													148	18			59	7	32	4		240		30
Extensive													37	15			15	6	8	3		60		24
Complete													0	0			0	0	0	0		0		0
4 *Residential*	8,377	1,155	4,498	904	1,531	173	1,993	107			2,350	259	7,647	85	1,935	59	3,343	33	1,722	14	33,396		2,790	
None	1,024	0	335	0	156	0	691	0			479	0	5,907	0	965	0	2,652	0	1,437	0		13,648		0
Light	4,634	215	2,170	108	825	29	1,025	39			1,185	48	1,537	48	827	29	611	19	252	8		13,065		543
Moderate	1,784	332	1,209	240	360	50	205	31			449	73	162	20	112	16	64	8	27	3		4,372		774
Extensive	804	486	633	408	162	74	68	33			198	105	41	16	31	14	16	6	7	3		1,960		1,146
Complete	131	122	151	149	28	20	5	3			38	31	0	0	0	0	0	0	0	0		353		326
Sub Total - Buildings	16,720	3,606	5,558	1,223	1,951	239	2,421	204			3,027	328	13,574	162	2,974	119	5,402	64	3,121	31	54,747	54,747	5,977	5,977

Table 6.1: Values and Losses by Category, Location and Sub Category - Infrastructure.

Category	Wellington City Value $Million	Wellington City Loss $Million	Lower Hutt City Value $Million	Lower Hutt City Loss $Million	Upper Hutt City Value $Million	Upper Hutt City Loss $Million	Porirua City Value $Million	Porirua City Loss $Million	Wellington Region Value $Million	Wellington Region Loss $Million	Kapiti Value $Million	Kapiti Loss $Million	PNorth et al Value $Million	PNorth et al Loss $Million	Wairarapa Value $Million	Wairarapa Loss $Million	Nelson/Tasman Value $Million	Nelson/Tasman Loss $Million	Marlborough Value $Million	Marlborough Loss $Million	Total Value Total $Million	Total Value	Total Loss Total $Million	Total Loss
B Roading																								
1 Regional	0	0	0	0	0	0	0	0	540	36	41	0	204	0	60	0	236	0	116	0		1,196		37
2 District	476	36	0	0	173	1	125	6	0	0	0	0	23	0	367	1	328	0	160	0		1,652		45
3 Suburban	0	0	0	0	0	0	0	0	0	0	0	0	160	0	0	0	0	0	0	0		160		0
4 Not subdivided	0	0	320	26	0	0	0	0	0	0	209	1	452	0	0	0	0	0	0	0		981		27
Sub Total	476	36	320	26	173	1	125	6	540	36	250	1	839	1	427	1	564	0	276	0	3,989		110	
C Bridging																								
1 Regional	0	0	0	0	0	0	0	0	209	27	16	0	79	0	23	0	58	0	29	0		414		28
2 District	3	0	0	0	23	3	9	1	0	0	4	0	131	0	81	2	82	0	40	0		373		8
3 Not subdivided	0	0	43	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		43		9
Sub Total	3	0	43	9	23	3	9	1	209	27	20	0	210	1	104	2	140	0	69	0	830		44	
D Rail Network																								
1 Formation (incls track, tunnels, bridges etc)	0	0	0	0	0	0	0	0	1,606	98	165	2	830	1	161	1	0	0	212	0		2,973		103
2 Signals, communications, power	0	0	0	0	0	0	0	0	214	50	22	2	110	3	21	2	0	0	42	1		410		50
3 Ways and Works Mech items	0	0	0	0	0	0	0	0	55	14	6	1	28	1	6	1	0	0	11	0		106		16
4 Locos, rolling stock, misc	0	0	0	0	0	0	0	0	796	26	82	0	411	0	80	0	0	0	158	0		1,525		27
5 Not subdivided	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0
Sub Total	0	0	0	0	0	0	0	0	2,670	188	274	5	1,380	5	267	4	0	0	423	2	5,014		205	
E Airport Infrastructure																								
1 Runways, taxiways etc	0	0	0	0	0	0	0	0	0	0	0	0	13	0	1	0	0	0	9	0		23		0
2 Seawall and other civil works	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0		3		0
3 Not subdivided	0	0	0	0	0	0	0	0	108	18	2	0	1	0	0	0	4	0	0	0		115		18
Sub Total	0	0	0	0	0	0	0	0	108	18	2	0	17	0	1	0	4	0	9	0	141		19	
F Port Infrastructure																								
1 Wharves, Structures etc	0	0	9	2	0	0	0	0	0	0	0	0	0	0	0	0	40	0	30	0		80		3
2 Cranes/equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	3	0		10		0
3 Containers/contents	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0
4 Not subdivided	402	125	0	0	0	0	0	0	0	0	0	0	10	0	0	0	5	0	0	0		417		125
Sub Total	402	125	9	2	0	0	0	0	0	0	0	0	10	0	0	0	53	1	33	0	507		129	
G Water Supply																								
1 Reticulation	0	0	123	3	38	0	46	1	113	3	0	0	53	0	29	0	66	0	12	0		482		7
2 Distribution Storage	0	0	20	1	8	0	6	0	74	2	0	0	0	0	9	0	14	0	3	0		134		3
3 Pumping Stations	0	0	2	0	0	0	0	0	13	3	0	0	39	1	0	0	1	0	0	0		54		5
4 Plant and Misc Buildings	0	0	0	0	0	0	0	0	71	12	0	0	0	0	6	0	3	0	2	0		83		13
5 Not subdivided	400	19	0	0	0	0	0	0	0	0	37	1	94	0	2	0	0	0	0	0		533		20
Sub Total	400	19	145	4	47	0	53	1	271	21	37	1	186	2	46	1	83	0	18	0	1,286		48	
H Sewerage System																								
1 Reticulation Main	0	0	121	3	0	0	77	1	0	0	0	0	0	0	34	0	77	0	13	0		321		4
2 Local Reticulation	0	0	50	1	148	1	0	0	0	0	0	0	49	0	27	0	33	0	11	0		318		3
3 Treatment Stations	0	0	15	6	0	0	43	10	0	0	0	0	26	1	5	1	9	0	2	0		101		18
4 Not subdivided	450	23	0	0	0	0	0	0	0	0	74	1	233	1	0	0	0	0	0	0		757		26
Sub Total	450	23	186	9	148	1	120	12	0	0	74	1	308	2	67	1	119	1	26	0	1,497		51	
I Stormwater Sytem																								
1 Reticulation	0	0	168	4	71	0	79	1	0	0	40	0	267	0	9	0	87	0	14	0		735		5
2 Not subdivided	250	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		250		7
Sub Total	250	7	168	4	71	0	79	1	0	0	40	0	267	0	9	0	87	0	14	0	985		12	
J Gas Network																								
1 Regional (minimal)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0
2 Local	0	0	54	5	21	0	12	1	0	0	10	0	45	0	0	0	0	0	0	0		142		7
3 Not subdivided	65	12	0	0	0	0	0	0	0	0	0	0	62	0	0	0	0	0	0	0		127		12
Sub Total	65	12	54	5	21	0	12	1	0	0	10	0	107	0	0	0	0	0	0	0	269		19	
K Electricity Network																								
1 Regional Reticulation	0	0	0	0	0	0	0	0	78	1	17	0	288	0	8	0	45	0	22	0		458		1
2 Local Reticulation	271	4	158	3	63	0	76	1	0	0	63	0	199	0	65	0	161	0	78	0		1,134		9
3 Nodes	0	0	0	0	0	0	0	0	456	7	3	0	19	0	62	0	11	0	5	0		556		7
4 Not subdivided	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0
Sub Total	271	4	158	3	63	0	76	1	534	8	83	0	506	0	135	0	217	0	106	0	2,148		17	
L Telecommunications																								
1 Buildings and Plant	332	95	56	21	23	7	60	15	0	0	54	9	250	11	54	8	25	1	12	1		806		107
2 Reticulation	115	2	76	1	35	0	41	1	0	0	30	0	142	0	30	0	7	0	4	0		480		4
3 Not subdivided	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0
Sub Total	447	97	132	22	58	7	101	15	0	0	84	9	392	11	84	8	32	1	16	1	1,347		171	
M Broadcasting																								
1 State Owned	0	0	0	0	0	0	0	0	115	22	0	0	62	1	10	1	20	0	13	0		220		24
2 Private	0	0	0	0	0	0	0	0	35	7	0	0	19	0	3	0	6	0	4	0		66		7
3 Not subdivided	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0
Sub Total	0	0	0	0	0	0	0	0	150	28	0	0	81	2	13	1	26	1	17	0	286		32	
Sub Total - Infrastructure	2,764	324	1,215	85	603	14	574	38	4,483	326	874	18	4,303	24	1,153	19	1,325	4	1,004	4	18,299		856	
GRAND TOTAL	19,484	3,931	6,773	1,308	2,554	253	2,995	242	4,483	326	3,901	346	17,876	186	4,127	138	6,727	68	4,126	34	73,046		6,833	

[illegible]

Table 6.2: Summary of Values and Losses Split by Location into Materials, Plant and labour

		Category	Total Value $Million	Total Loss $Million	Loss $Million Materials	Loss $Million Plant	Loss $Million Labour
A		Buildings					
	1	Group 1	1,069	90	24	11	55
	2	Group 2	9,717	2,134	613	314	1,207
	3	Group 3	1,179	839	274	173	392
	4	Residential	33,396	2,790	757	360	1,663
	5	Comm/Ind	9,386	125	25	13	76
		Sub Total	54,747	5,977	1,694	871	3,392
B		Roading	3,989	110	31	36	42
C		Bridging	830	44	13	9	23
D		Rail Network	5,014	205	54	70	81
E		Airport	141	19	5	6	8
F		Port Infrastructure	507	129	52	33	44
G		Water Supply	1,286	48	23	9	16
H		Sewerage System	1,497	51	21	11	19
I		Stormwater Sytem	985	12	5	2	5
J		Gas Network	269	19	7	5	7
K		Electricity Network	2,148	17	8	3	6
L		Telecommunications	1,347	171	83	29	58
M		Broadcasting Facilities	286	32	17	5	10
		Sub Total	18,299	856	318	219	319
		Grand Total	73,046	6,833	2,011	1,090	3,711

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Table 6.3: Values, Losses, Damage Ratio and Material, Plant and Labour Split by Location

Category	Wellington City						Lower Hutt City						Upper Hutt City					
	Value $Million	Loss $Million	Damage Ratio	Loss $Million			Value $Million	Loss $Million	Damage Ratio	Loss $Million			Value $Million	Loss $Million	Damage Ratio	Loss $Million		
	Total	Total	DR	Materials	Plant	Labour	Total	Total	DR	Materials	Plant	Labour	Total	Total	DR	Materials	Plant	Labour
A Buildings																		
1 Group 1	319	49	0.15	13	6	29	110	14	0.12	4	2	8	42	2	0.06	1	0	2
2 Group 2	7,108	1,664	0.23	479	245	941	884	243	0.27	71	37	135	376	63	0.17	18	9	37
3 Group 3	915	739	0.81	242	153	343	67	62	0.93	21	14	27	1	1	0.50	0	0	0
4 Residential	8,377	1,155	0.14	315	147	693	4,498	904	0.20	256	128	521	1,531	173	0.11	47	23	103
5 Comm/Ind																		
Sub Total for Buildings	16,720	3,606		1,049	552	1,601	5,558	1,223		351	180	532	1,951	239		66	31	142
B Roading	476	36	0.08	10	12	14	320	26	0.08	7	9	10	173	1	0.01	0	0	0
C Bridging	3	0	0.13	0	0	0	43	9	0.21	3	2	5	23	3	0.15	1	1	2
D Rail Network	0	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0.00	0	0	0
E Airport	0	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0.00	0	0	0
F Port Infrastructure	402	125	0.31	51	32	42	9	2	0.23	1	1	1	0	0	0.00	0	0	0
G Water Supply	400	19	0.05	9	4	6	145	4	0.03	2	1	1	47	0	0.01	0	0	0
H Sewerage System	450	23	0.05	9	5	9	186	9	0.05	4	2	3	148	1	0.01	1	0	0
I Stormwater System	250	7	0.03	3	1	3	168	4	0.02	1	1	2	71	0	0.00	0	0	0
J Gas Network	65	12	0.18	4	3	4	54	5	0.10	2	1	2	21	0	0.02	0	0	0
K Electricity Network	271	4	0.02	2	1	1	158	3	0.02	1	1	1	63	0	0.00	0	0	0
L Telecommunications	447	97	0.22	47	17	33	132	22	0.17	11	4	8	58	7	0.12	3	1	2
M Broadcasting Facilities	0	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0.00	0	0	0
Grand Total	19,484	3,931		1,184	627	1,714	6,773	1,308		384	201	564	2,554	253		72	34	147

Category	Porirua City						Wellington Regional					
	Value $Million	Loss $Million	Damage Ratio	Loss $Million			Value $Million	Loss $Million	Damage Ratio	Loss $Million		
	Total	Total	DR	Materials	Plant	Labour	Total	Total	DR	Materials	Plant	Labour
A Buildings												
1 Group 1	115	3	0.02	1	0	2						
2 Group 2	305	90	0.29	27	15	48						
3 Group 3	7	5	0.67	2	1	2						
4 Residential	1,993	107	0.05	27	11	69						
5 Comm/Ind												
Sub Total for Buildings	2,421	204		56	27	83						
B Roading	125	6	0.05	2	2	2	540	36	0.07	10	12	14
C Bridging	9	1	0.14	0	0	1	209	27	0.13	8	5	14
D Rail Network	0	0	0.00	0	0	0	2,670	188	0.07	49	64	74
E Airport	0	0	0.00	0	0	0	108	18	0.17	4	6	8
F Port Infrastructure	0	0	0.00	0	0	0	0	0	0.00	0	0	0
G Water Supply	53	1	0.02	1	0	0	271	21	0.08	10	4	7
H Sewerage System	120	12	0.10	5	3	4	0	0	0.00	0	0	0
I Stormwater System	79	1	0.01	0	0	0	0	0	0.00	0	0	0
J Gas Network	12	1	0.07	0	0	0	0	0	0.00	0	0	0
K Electricity Network	76	1	0.01	0	0	0	534	8	0.02	4	2	3
L Telecommunications	101	15	0.15	7	3	5	0	0	0.00	0	0	0
M Broadcasting Facilities	0	0	0.00	0	0	0	150	28	0.19	15	4	9
Grand Total	2,995	242		72	36	97	4,483	326		101	97	128

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Table 6.3: Values, Losses, Damge Ratio and Material, Plant and Labour Split by Location

	Category	PNorth/Wanganui/Horowhe/Rangitli/Manawatu						Nelson/Tasman						Marlborough					
		Value $Million	Loss $Million	Damage Ratio	Loss $Million			Value $Million	Loss $Million	Damage Ratio	Loss $Million			Value $Million	Loss $Million	Damage Ratio	Loss $Million		
		Total	Total	DR	Materials	Plant	Labour	Total	Total	DR	Materials	Plant	Labour	Total	Total	DR	Materials	Plant	Labour
A	Buildings																		
1	Group 1																		
2	Group 2																		
3	Group 3																		
4	Residential	7,647	85	0.01	20	7	58	3,343	33	0.01	8	3	23	1,722	14	0.01	3	1	9
5	Comm/Ind	5,927	77	0.01	18	6	53	2,059	31	0.02	7	3	21	1,399	17	0.01	4	1	12
	Sub Total for Buildings	13,574	162		37	13	111	5,402	64		15	5	44	3,121	31		7	2	21
B	Roading	839	1	0.00	0	0	0	564	0	0.00	0	0	0	276	0	0.00	0	0	0
C	Bridging	210	1	0.00	0	0	0	140	0	0.00	0	0	0	69	0	0.00	0	0	0
D	Rail Network	1,380	5	0.00	1	2	2	0	0	0.00	0	0	0	423	2	0.00	0	1	1
E	Airport	17	0	0.01	0	0	0	4	0	0.01	0	0	0	9	0	0.01	0	0	0
F	Port Infrastructure	10	0	0.01	0	0	0	53	1	0.01	0	0	0	33	0	0.01	0	0	0
G	Water Supply	186	2	0.01	1	0	1	83	0	0.00	0	0	0	18	0	0.00	0	0	0
H	Sewerage System	308	2	0.01	1	1	1	119	1	0.00	0	0	0	26	0	0.01	0	0	0
I	Stormwater System	267	0	0.00	0	0	0	87	0	0.00	0	0	0	14	0	0.00	0	0	0
J	Gas Network	107	0	0.00	0	0	0	0	0	0.00	0	0	0	0	0	0.00	0	0	0
K	Electricity Network	506	0	0.00	0	0	0	217	0	0.00	0	0	0	106	0	0.00	0	0	0
L	Telecommunications	392	11	0.03	6	2	4	32	1	0.03	1	0	0	16	1	0.03	0	0	0
M	Broadcasting Facilities	81	2	0.02	1	0	1	26	1	0.02	0	0	0	17	0	0.02	0	0	0
	Grand Total	17,876	186		48	18	120	6,727	68		17	6	46	4,126	34		8	4	22

	Category	Kapiti						Wairarapa					
		Value $Million	Loss $Million	Damage Ratio	Loss $Million			Value $Million	Loss $Million	Damage Ratio	Loss $Million		
		Total	Total	DR	Materials	Plant	Labour	Total	Total	DR	Materials	Plant	Labour
A	Buildings												
1	Group 1	174	13	0.08	3	2	8	309	10	0.03	2	1	7
2	Group 2	499	55	0.11	15	7	33	546	20	0.04	5	2	13
3	Group 3	5	2	0.45	1	0	1	184	31	0.17	9	4	18
4	Residential	2,350	259	0.11	71	33	155	1,935	59	0.03	14	5	40
5	Comm/Ind												
	Sub Total for Buildings	3,027	328		90	42	132	2,974	119		30	12	78
B	Roading	250	1	0.00	0	0	0	427	1	0.00	0	0	1
C	Bridging	20	0	0.02	0	0	0	104	2	0.02	1	0	1
D	Rail Network	274	5	0.02	1	2	2	267	4	0.02	1	1	2
E	Airport	2	0	0.08	0	0	0	1	0	0.01	0	0	0
F	Port Infrastructure	0	0	0.00	0	0	0	0	0	0.00	0	0	0
G	Water Supply	37	1	0.01	0	0	0	46	1	0.01	0	0	0
H	Sewerage System	74	1	0.02	1	0	0	67	1	0.01	0	0	0
I	Stormwater System	40	0	0.00	0	0	0	9	0	0.00	0	0	0
J	Gas Network	10	0	0.01	0	0	0	0	0	0.00	0	0	0
K	Electricity Network	83	0	0.00	0	0	0	135	0	0.00	0	0	0
L	Telecommunications	84	9	0.10	4	1	3	84	8	0.09	4	1	3
M	Broadcasting Facilities	0	0	0.00	0	0	0	13	1	0.07	1	0	0
	Grand Total	3,901	346		97	46	138	4,127	138		37	16	85

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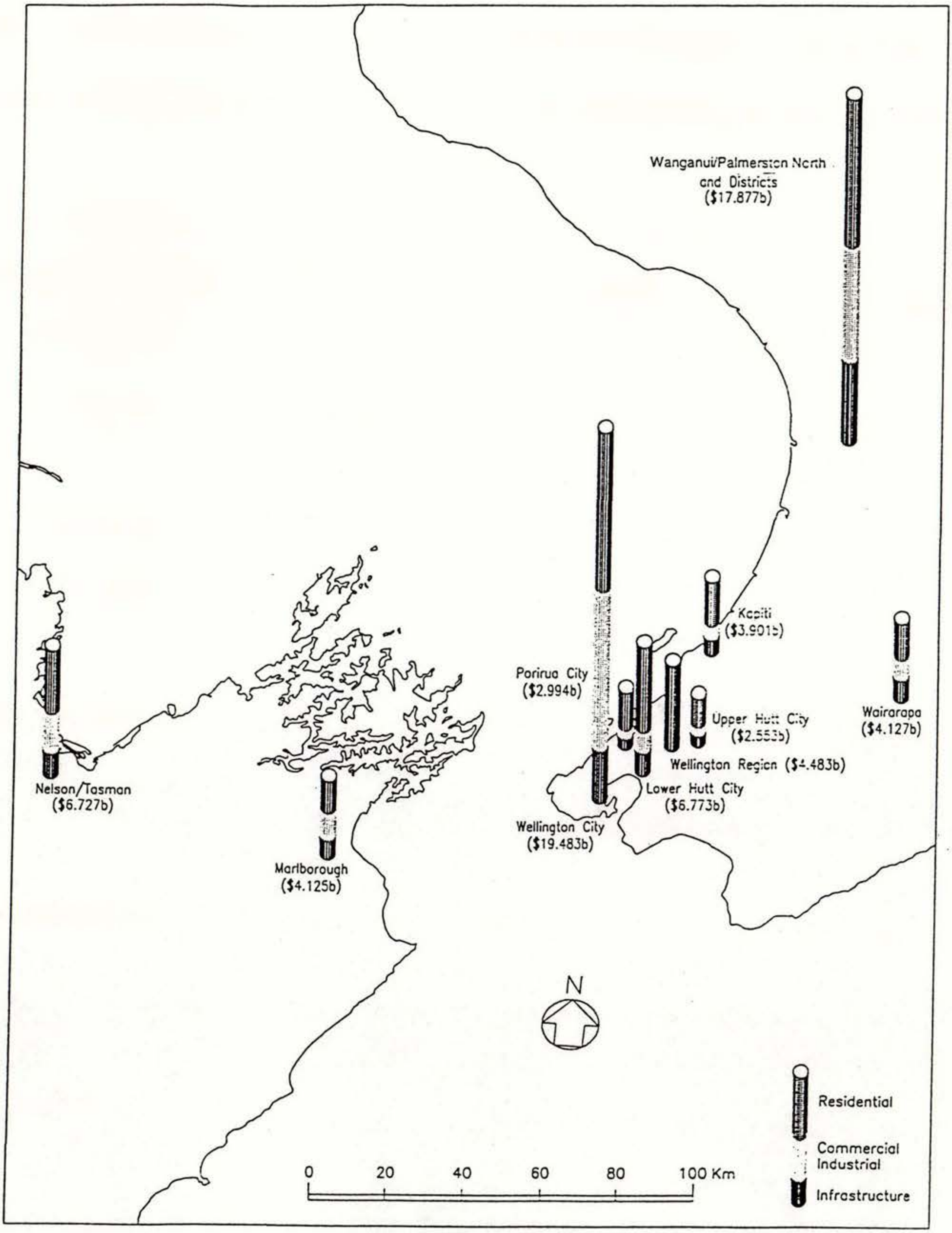
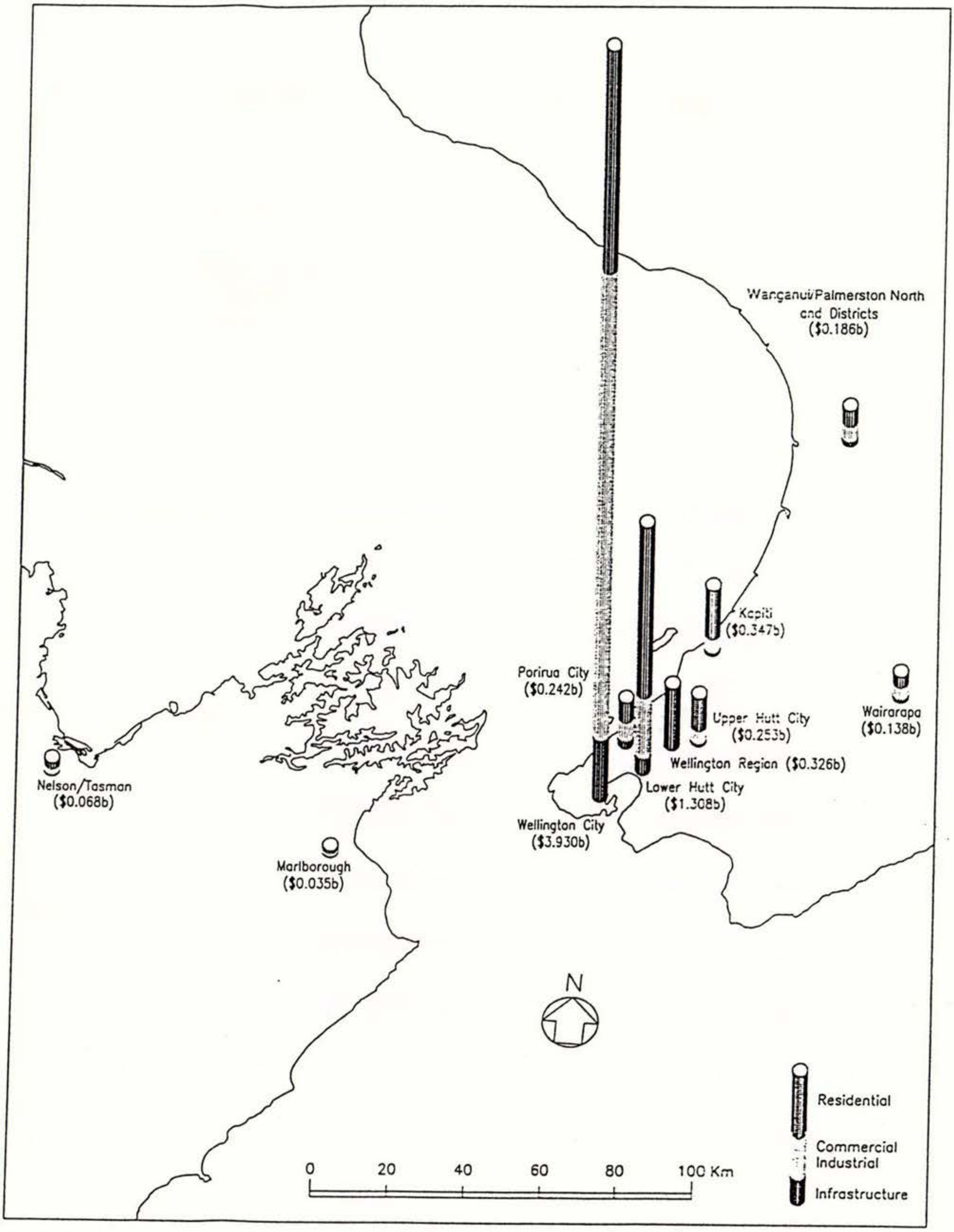
Map 6.1: Asset Values by Category and Location.



Map 6.2: Asset Losses by Category and Location.



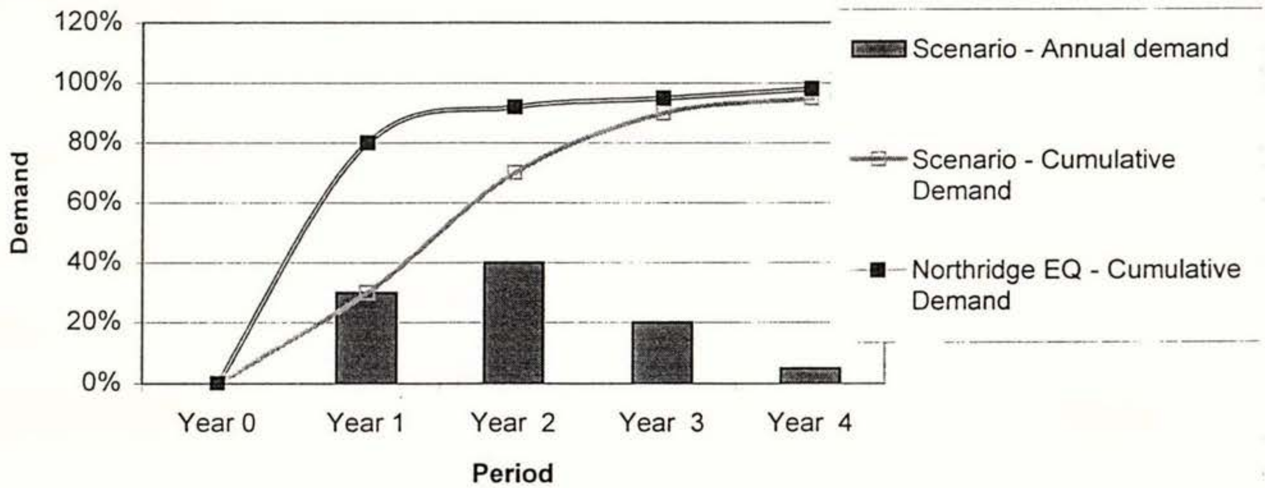
7. Timetable for Reconstruction

For the purpose of this paper, the authors have chosen the demand buildup shown in Table 7.1:

Table 7.1 Demand vs Time

	Year 0	Year 1	Year 2	Year 3	Year 4
Scenario - Cumulative Demand	0%	30%	70%	90%	95%
Scenario - Annual Demand	0%	30%	40%	20%	5%
Northridge EQ - Cumulative Demand	0%	80%	92%	95%	98%
Northridge EQ - Annual Demand	0%	80%	12%	3%	3%

Figure 7.1 : Comparative Demand Curves



The values for the Northridge Earthquake of 1994 are given for comparison [7]. These reflect insurance payments, not necessarily construction.The Comparative Demand – Curves and annual demand histogram are shown in Figure 7.1.

In the previous paper by Lanigan [2] a simple S curve spread over four years was used to arrive at the build up in demand following the Wellington event. Following the Northridge Earthquake in 1994 it was noted that the rate of insurance payments occurred much more quickly than actual reconstruction progress. Northridge was "an island of demand in a sea of resources" [8]. For a Wellington earthquake many resources would have to cross the sea to reach the island of demand. Furthermore reconstruction following Northridge was probably faster than it would be for Wellington. Should the demand in Year 1 in Wellington approach the Northridge build-up, then the peak annual resource requirements described elsewhere in this paper could be understated by 2-2.5 times.

8. Resource Capacity

Resource capacity serves as a basis for estimating base demand which must be added to the earthquake induced demand.

Definitions

NZ Residential Totals	- Value of Residential Building Consents throughout NZ for period quoted.
Wellington Residential Totals	- Value of Residential Building Consents in damage region for period quoted.

Similar definitions apply to Non-Residential Totals

NZ and Wellington Total Consents refer to the sum of residential and non-residential

Average Annual Capacity:	This is the six-year annual average total value of Building Consents in the area in question, adjusted to 1999 values using CPI indices.
Base Demand:	This is the assessed demand for ongoing construction following the earthquake. Base demand has been assumed to drop immediately but to return to pre-earthquake values after four years. Base Demand pre-earthquake and Average Annual Capacity are taken to be equal i.e. the amount of building work carried out in any given city is taken as equal to the capacity at that place.
Earthquake Demand:	This is equal to the damage value either as a total or as an assessed annual demand. Annual Demands were computed using the percentages given in Table 7.1.
Annual National Capacity:	This is equivalent to Average Annual Capacity for the whole of New Zealand.
Annual Capacity over Rest of NZ	This is equivalent to Average Annual Capacity for all of NZ **except** the damage area.

Using building consent information provided by Statistics New Zealand [9], the average annual capacities (i.e. work put in place) over the last six years, adjusted to 1999 dollar values using movements in the NZ Consumer Price Index – Housing Group, have been calculated and are summarised below:

Table 8.1 NZ and Wellington Building Consent Values/Capacities

Building Description	Average Building Consent Values 1999 Dollars (millions) (Average Capacities)	% of Totals
NZ Residential Totals	$3,655	
Wellington Residential Totals	$523	14%
NZ – Non-Residential Totals	$2,259	
Wellington Non-Residential Totals	$403	18%
NZ Total Consents	$5,914	
Wellington Total Consents	$925	16%

A fundamental premise of this paper is that resource capacity is virtually unconstrained by local manufacturing capacity because of the opportunity to import alternative or supplementary materials from offshore. Logistical arrangements are considered to be manageable utilising NZ based companies supplemented with the resources of offshore companies as may be necessary.

This paper does not attempt to examine the logistical challenges which would undoubtedly present themselves.

9. Resource Demands

9.1 General

Earthquake induced demand was calculated using the damage/resources figures explained in Section 5. The estimates presented are of the effect of current demands in the affected region in the years following the earthquake event. Subsequent calculations included an allowance for Base Demand over the four year period as follows. Base Demand was established as a varying percentage of the Annual Average Capacity described in Section 8. Over the four year period of the rebuild, the Base Demand percentages have been set at 20% for Year 1, 50% for year 2, 80% for Year 3 and 100% for Year 4 and beyond.

Total Demand at each period is equal to Base Demand plus Earthquake Induced Demand.

9.2 Assessed Demand

Assessments of Resource Demand are presented in Figures 9.1, 9.2 and 9.3 which show All Assets, All Buildings and Residential Buildings respectively.

Each figure gives a graphical representation of the comparisons of Demand with Average Annual Capacity. Tabulations on each figure include the ratios of total Demand to Average Annual Capacity, expressed as a percentage.

These results provide a clear insight into the magnitude of the tasks of reconstruction after the Wellington Fault Event.

Figure 9.1: Demand Curve - All Assets ($ Millions)

Year Following Event		0	1	2	3	4
Average Annual Capacity	a	$1,234	$1,234	$1,234	$1,234	$1,234
Base Demand %	b	20%	50%	80%	90%	100%
Base Demand	c = a x b	$247	$617	$987	$1,111	$1,234
Demand ($6,833 Total)	d	$0	$2,050	$2,733	$1,367	$342
Total Demand	c + d	$247	$2,667	$3,720	$2,477	$1,576
Total Demand/Avg Ann Cap	(c + d) /a	20%	216%	301%	201%	128%

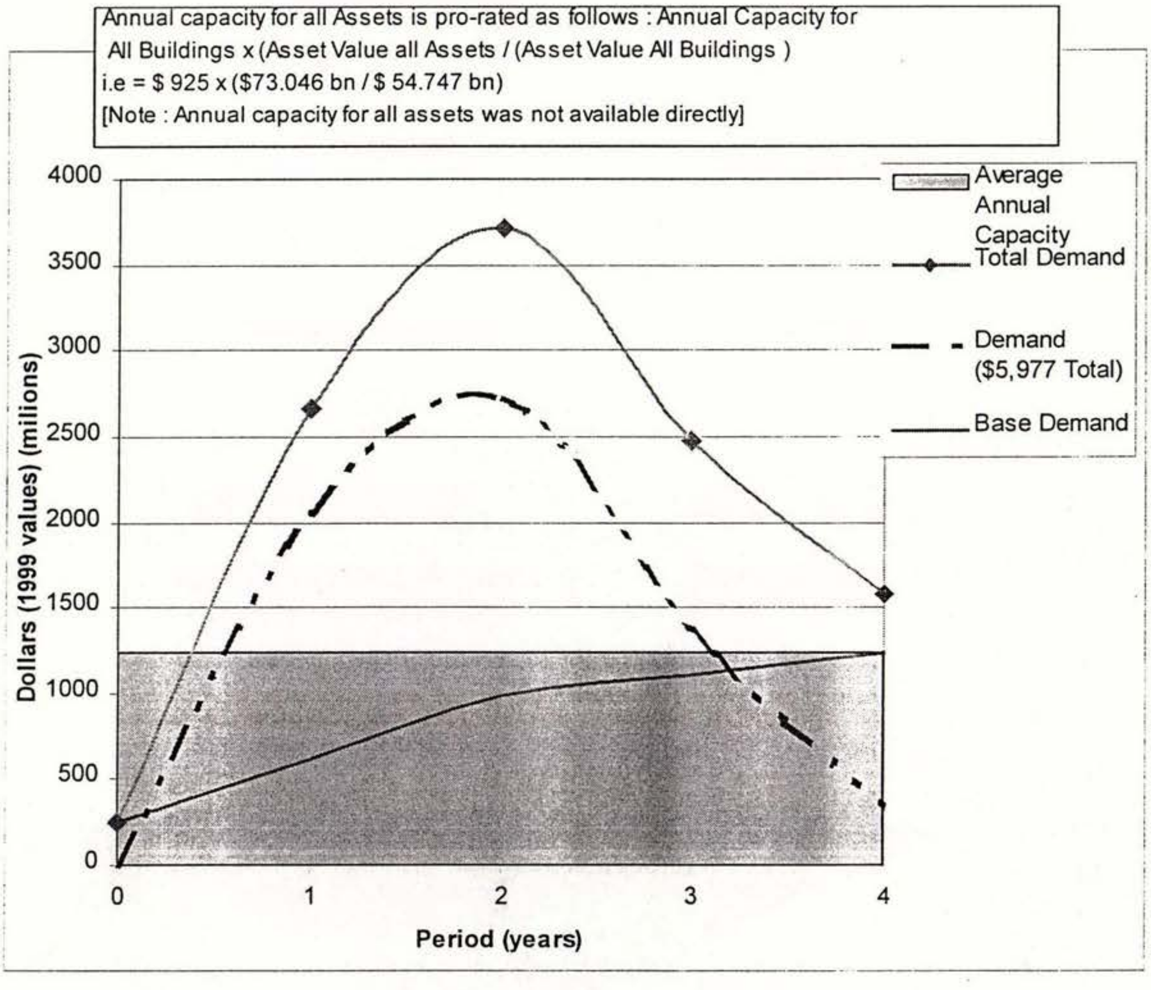


Figure 9.2 : Demand Curve - All Buildings ($ Millions)

Year Following Event		0	1	2	3	4
Average Annual Capacity	a	$925	$925	$925	$925	$925
Base Demand %	b	20%	50%	80%	90%	100%
Base Demand (Post EQ)	c = a x b	$185	$463	$740	$833	$925
Demand ($5,977 Total)	d	$0	$1,793	$2,391	$1,195	$299
Total Demand	c + d	$185	$2,256	$3,131	$2,028	$1,224
Total Demand/Avg Ann Cap	(c + d) /a	20%	244%	338%	219%	132%

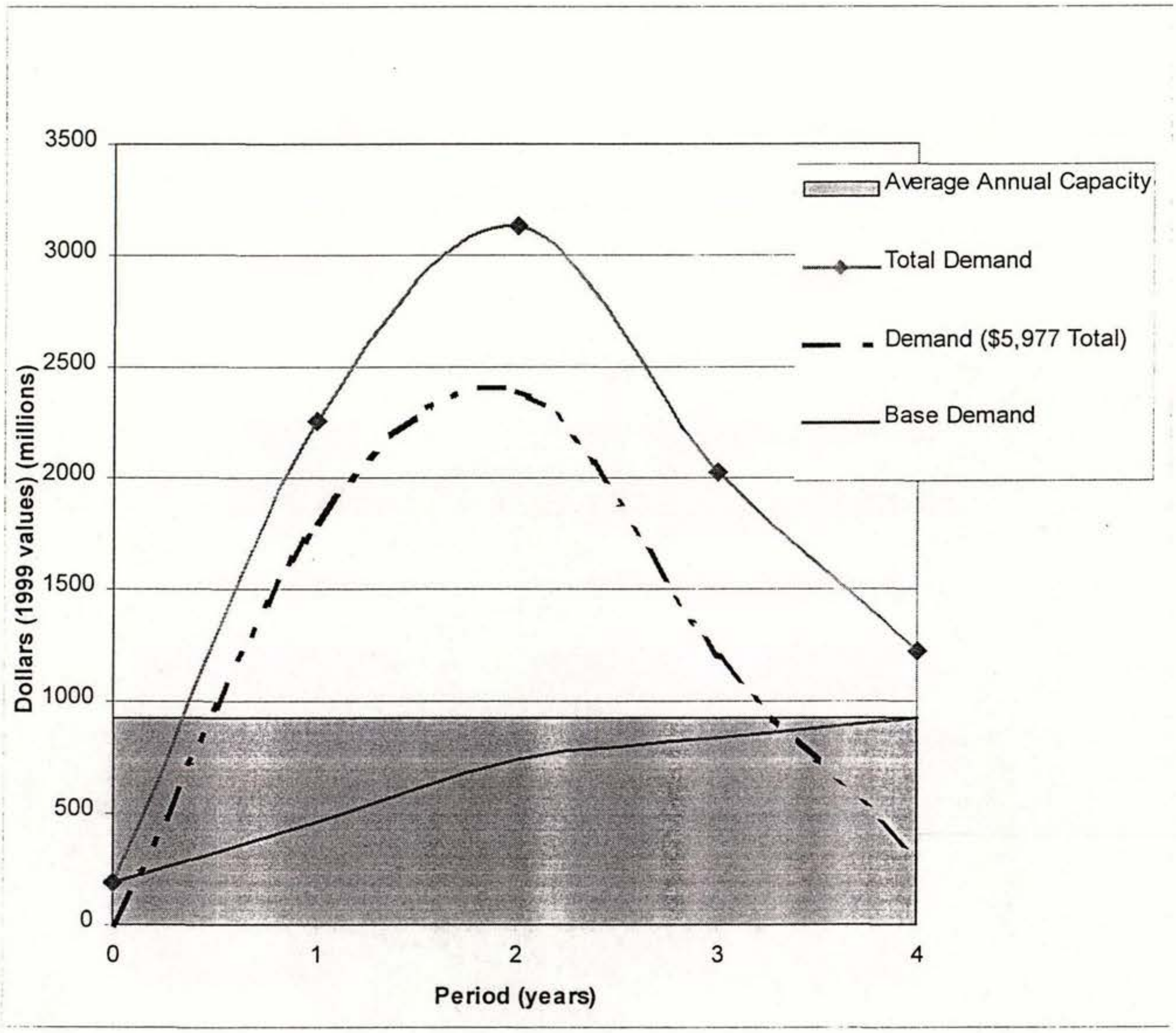
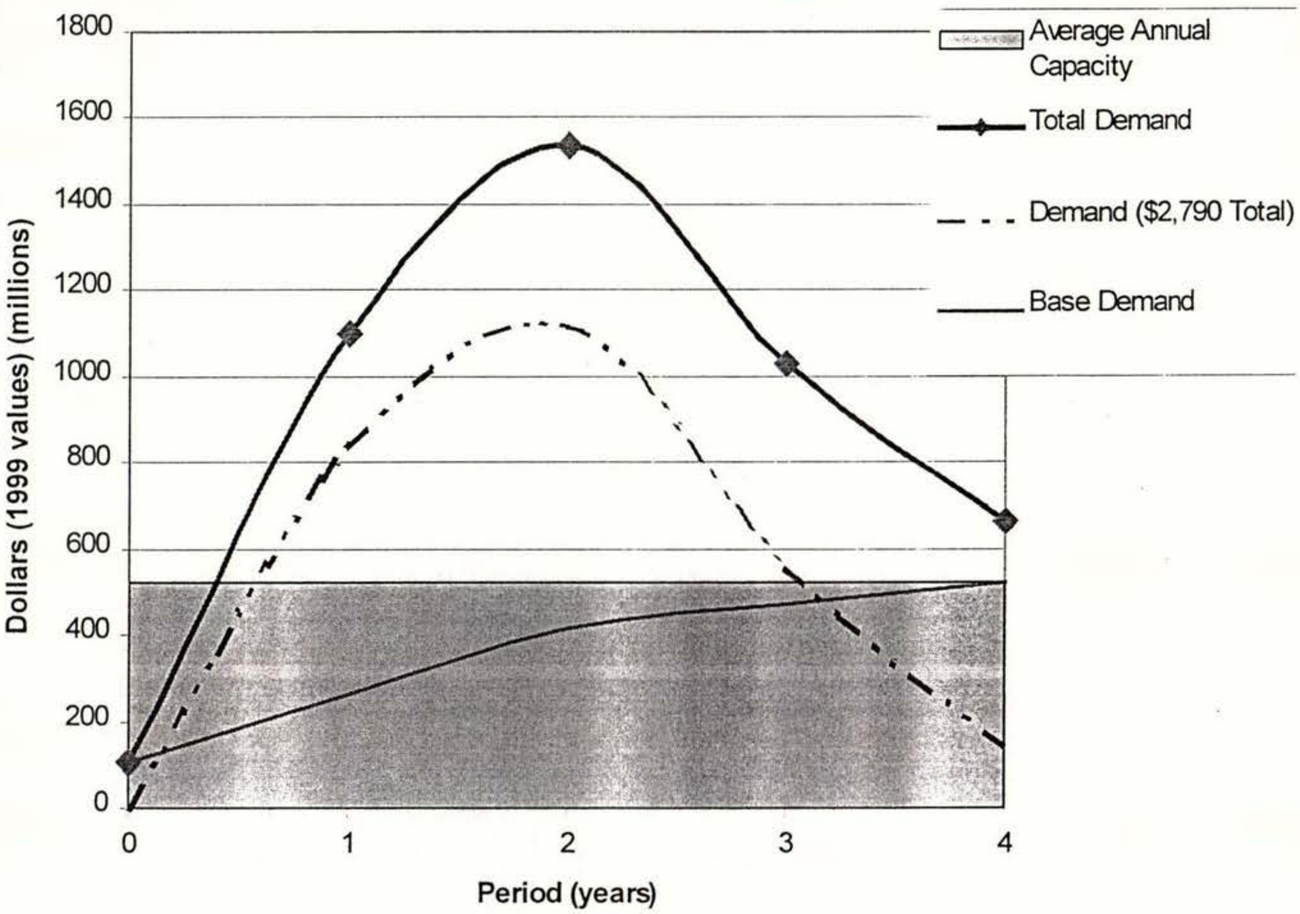


Figure 9.3 : Demand Curve - Residential Only ($ Millions)

Year Following Event		0	1	2	3	4
Average Annual Capacity	a	$523	$523	$523	$523	$523
Base Demand %	b	20%	50%	80%	90%	100%
Base Demand	c = a x b	$105	$261	$418	$470	$523
Demand ($2,790 Total)	d	$0	$837	$1,116	$558	$140
Total Demand	c + d	$105	$1,098	$1,534	$1,028	$662
Total Demand/Avg Ann Cap	(c + d) /a	20%	210%	294%	197%	127%



10. Demand vs Capacity

10.1 Overall

All results show a peak demand of around three times the Average Annual Capacity over the whole region. Figures 9.1 to 9.3 show how this excess of demand over normal capacity varies over time.

It is clear that a sustained high level of building activity will be required over three to four years.

In all cases the total earthquake induced demand is well in excess of four years of average normal demand.

10.2 Regional Locations

In order to gain some understanding of demand/capacity relationships at locations throughout the scenario region, Tables 10.1 and 10.2 together with Figures 10.1 and 10.2 were developed for the end of Year 2 after the event.

What both Figures demonstrate is that in locations such as Nelson, Tasman District, Marlborough District, the total demand is less than the annual average capacity, indicating the probability of rapidly reallocating resources from the outlying districts to the more heavily damaged areas.

Figure 10.1 : CPI Adjusted - All Buildings - End of Year 2

Total Demand Over 4 Years	Locations Within Region	Annual Average Capacity	Base Demand End Year 2	Demand End Year 2	Total Demand End Year 2	(Total Demand)/ (Annual Average Capacity)
a		b	c = b x 80%	d = a x 40%	e = c + d	e / b
$3,606	Wellington City	$309	$247	$1,442	$1,690	547%
$1,223	Lower Hutt City	$64	$51	$489	$540	845%
$239	Upper Hutt City	$27	$22	$96	$117	435%
$204	Porirua City	$42	$33	$82	$115	276%
$162	PN - Manawatu	$165	$132	$65	$197	119%
$64	Nelson / Tasman	$138	$111	$26	$136	99%
$31	Marlborough District	$72	$57	$12	$70	97%
$328	Kapiti Coast District	$76	$61	$131	$192	252%
$119	Wairarapa	$33	$26	$48	$74	225%
$5,976	All Buildings Totals	$925	$740	$2,390	$3,131	338%

Figure 10.2 : CPI Adjusted Residential Only - End of Year 2

Total Demand Over 4 Years	Locations Within Region	Annual Average Capacity	Base Demand End Year 2	Demand End Year 2	Total Demand End Year 2	(Total Demand)/ (Annual Average Capacity)
a		b	c = b x 80%	d = a x 40%	e = c + d	e / b
$1,155	Wellington City	$137	$110	$462	$572	417%
$905	Lower Hutt City	$35	$28	$362	$390	1108%
$173	Upper Hutt City	$15	$12	$69	$81	550%
$106	Porirua City	$28	$22	$42	$65	232%
$84	PN - Manawatu	$85	$68	$34	$102	119%
$33	Nelson / Tasman	$94	$75	$13	$88	94%
$14	Marlborough District	$47	$38	$6	$43	92%
$257	Kapiti Coast District	$61	$49	$103	$151	249%
$59	Wairarapa	$21	$17	$24	$40	193%
$2,786	Residential Totals Only	$523	$418	$1,114	$1,533	293%

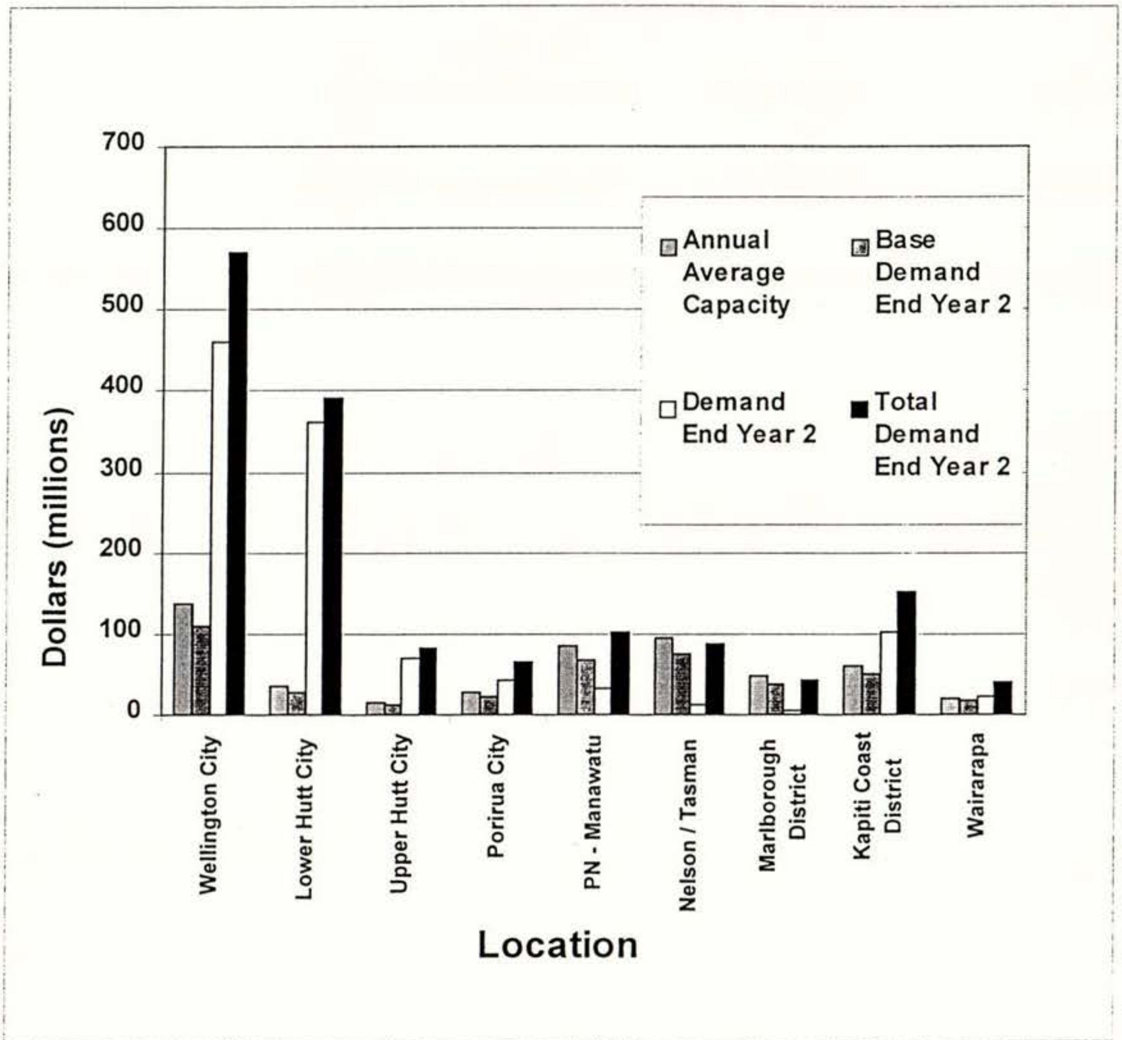


Figure 10.1 : Demand vs Capacity by Location
CPI Adjusted – All Buildings – End of Year 2

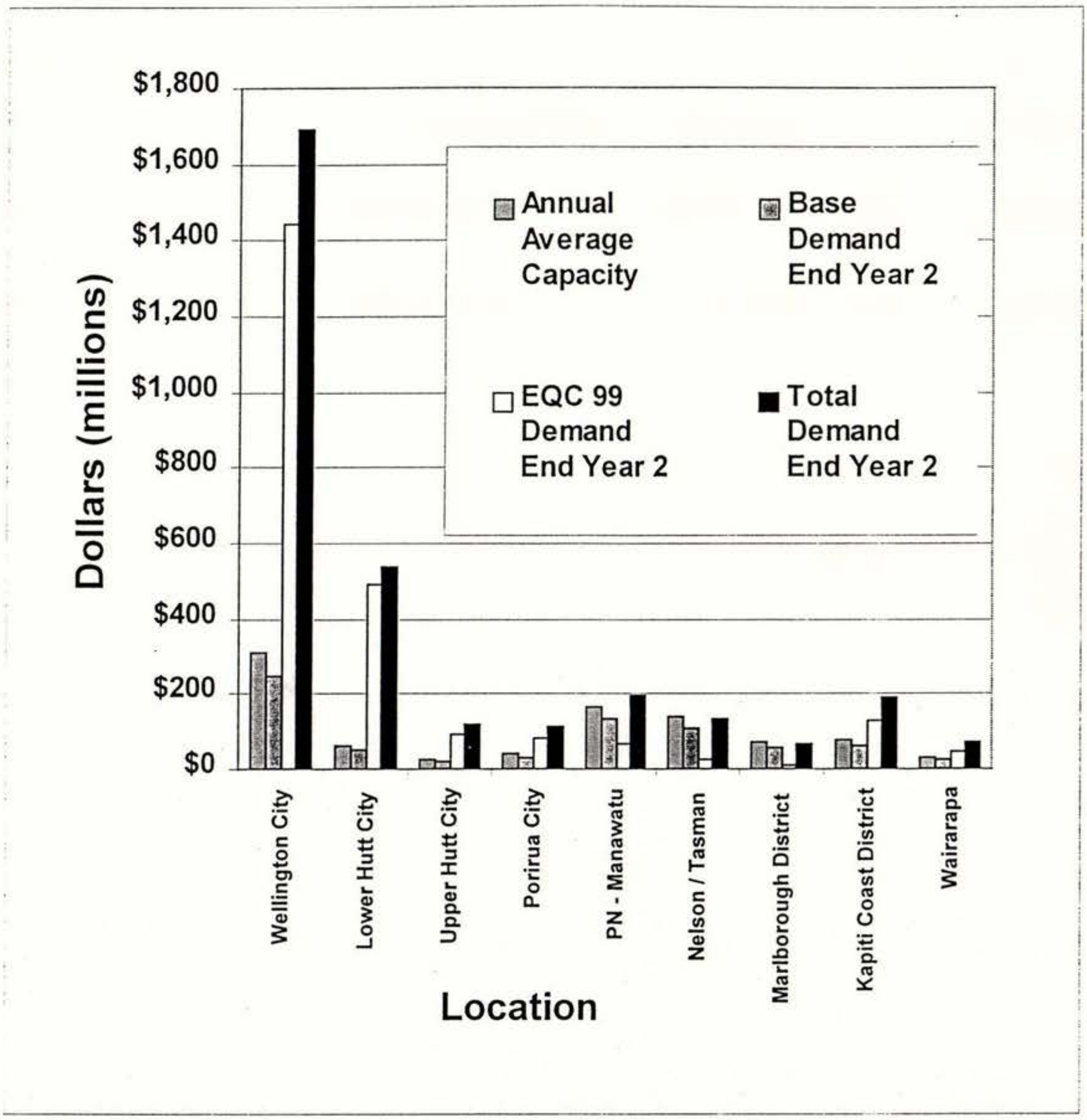


Figure 10.2 : Demand vs Capacity by Location
CPI Adjusted – Residential Only – End of Year 2

10.3 Variation with Time – Residential Buildings

Table 10.3 below shows the ratio of Total Annual Demand over Average Annual Capacity for All Buildings reconstruction, for the four years following the event, for the various locations contributing to the damage region. The general overcapacity of outlying districts is evident. However, for most of the region, at the end of Year 4, there is still a significant demand for resources. For the whole region this averages out in the order of 30% greater than the average annual capacity.

Table 10.4 shows corresponding figures for Residential Buildings only.

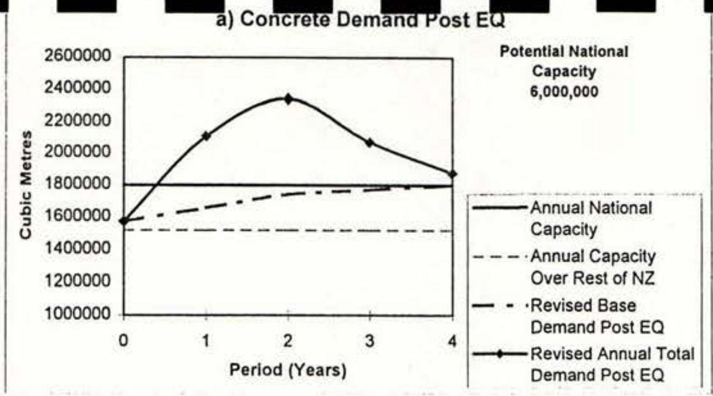
Table 10.3 : Ratio (Total Annual Demand / Average Annual Capacity) % by Location - All Buildings				
Locations Within Region	Year 1	Year 2	Year 3	Year 4
Wellington City	400%	547%	323%	158%
Lower Hutt City	624%	845%	473%	196%
Upper Hutt City	316%	435%	267%	144%
Porirua City	197%	276%	188%	124%
PN - Manawatu	79%	119%	110%	105%
Nelson / Tasman	64%	99%	99%	102%
Marlborough District	63%	97%	99%	102%
Kapiti Coast District	179%	252%	176%	122%
Wairarapa	159%	225%	163%	118%
All Buildings Totals	244%	338%	219%	132%

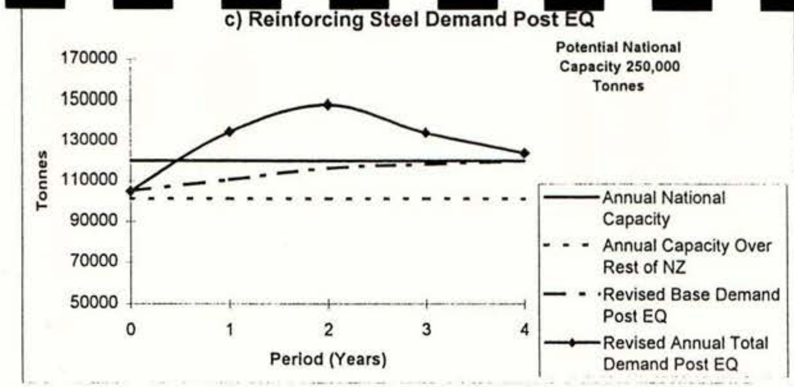
Table 10.4 : Ratio (Total Annual Demand/Average Annual Capacity) % by Location - Residential Buildings Only				
Locations Within Region	Year 1	Year 2	Year 3	Year 4
Wellington City	303%	417%	259%	142%
Lower Hutt City	821%	1108%	604%	229%
Upper Hutt City	402%	550%	325%	159%
Porirua City	164%	232%	166%	119%
PN - Manawatu	80%	119%	110%	105%
Nelson / Tasman	61%	94%	97%	102%
Marlborough District	59%	92%	96%	101%
Kapiti Coast District	177%	249%	174%	121%
Wairarapa	134%	193%	146%	114%
Residential Totals Only	210%	293%	197%	127%

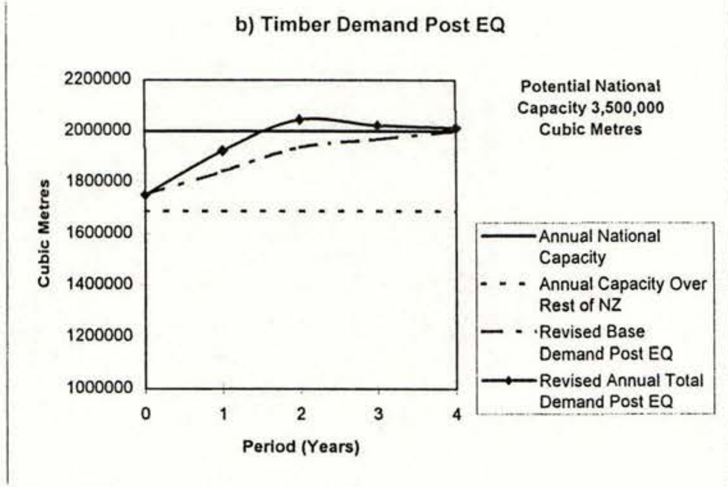
10.4 Construction Materials

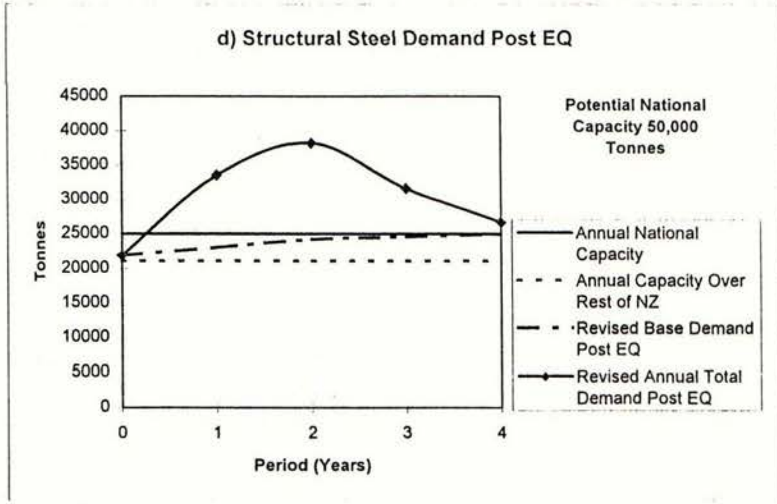
Figures 10.3 a) to e) have been prepared to demonstrate the effect of the earthquake event on a limited range of key building materials. For each materials the total demand in each year has been approximated by scaling and rounding the material quantities provided in Table 5 [1], by the ratio of the total building damage $5,977 million for the earthquake to the total damage presented in Table 3 of Reference 1 i.e $7,725 million.

National annual supply capacities and national potential supply capacities have been rounded from the values presented in Table 3 of [2]. Without a doubt local resources would be severely strained – at least initially. The graphs in Figure 10.3 demonstrate the degree to which resources will need to be secured from increased manufacturing within NZ and/or supplemented by supplies from offshore. The results give an indicative view of what might occur under earthquake scenario.









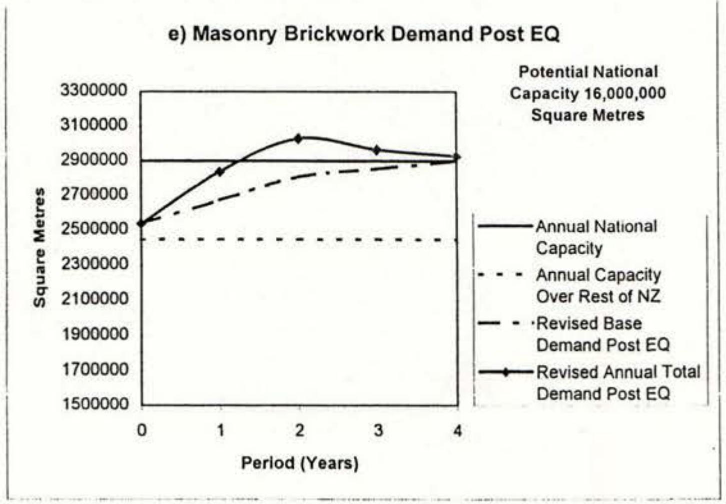


Figure 10.3
Construction Materials - Supply/Demand

11. Discussion

The build-up of the overall assessment of damage and then of resources requires assumptions or judgements at every turn. This introduces wide scope for debate as to the values derived. Individual numbers should be viewed with the wide range of uncertainties in mind. Although the calculations are precise, the input data is subject to wide variation. Nevertheless, there is reasonable confidence in the overall assessment of the scale of the task facing the construction industry, and the country generally.

In comparison to the 1995 Study [1] the addition of areas more remote from the source has increased the assets at risk by around 100%, and the damage by 13%. This is a significant amount of additional damage and acts as a reminder that resources to rebuild Wellington will face increasing pressure and have to come from well outside the worst affected region.

It is tempting to use the results of this study to determine in more detail what the effects are and what the response should be. However, the results are best regarded as a general assessment and used to identify general actions that should be taken in advance. The *detailed* effects of a major earthquake are impossible to assess precisely and it is pointless to plan ahead in such detail.

The results presented provide some interesting insights into the challenge of reconstruction including:

- The sustained high level of demand for construction, peaking in the region at over 300% of normal and in Wellington city at over 1000% (10 times normal).
- Construction materials on a national basis should be available within normal or extended capacity.
- The logistics of bringing resources – materials, plant and labour – to Wellington deserves close consideration. Most centres in the vicinity of the earthquake will experience higher than normal demand.
- The effect nationally is difficult to predict. To what extent will, say, Nelson or Christchurch construction resources be diverted to Wellington in this artificial boom? What effect will this have on the demand in Nelson or Christchurch?
- Figures presented are based on an assumed drop in Wellington base demand following the earthquake. The same relationship has been assumed for all locations studied. In fact, these would vary from place to place depending on overall damage. Furthermore, the relationship chosen is based on the authors' intuitive judgement. If base demand in the first year does not dip as much as assumed, the resources required will increase in this period.
- Many factors will influence demand and capacity in the various locations. If prices rise, some construction will be deferred. If resources are diverted from Auckland or Christchurch, prices may rise in those places. Demand there could reduce as a result.

12. Key Implications for the Construction Industry

Clearly New Zealand would face considerable economic, physical and social challenges following a major earthquake in Wellington. This paper highlights the nature and extent of the physical challenge – that of reconstruction over an extended period of several years.

In today's climate of international trade linkages and relatively open markets, many options exist for dealing with the reconstruction. Exact arrangements will depend to some extent on the circumstances at the time. But there are issues that can be addressed in advance. These include:

a) The degree of control necessary from national and local government.
b) The extent to which New Zealand based contractors would participate effectively.
c) The extent to which offshore contractors become established in New Zealand.
d) The extent to which importation of competitively priced materials, plant and labour will be necessary.
e) Availability of key management and technical skills within the construction sector.
f) Relationships with major insurers and asset owners.
g) The availability of money for reconstruction and for payments to contractors.
h) The extent to which nation-wide resources can be directed to Wellington.
i) The ability of TLA's to cope with the necessary approval processes.
j) Any special measures to control the quality of construction at a time of high demand.

13. Concluding Remarks

Given the magnitude of the task and the deep social and economic impacts of a major earthquake in Wellington, it is difficult to argue that the construction industry should not or need not do anything in advance. Certainly, what can be done in advance will be limited. Detailed effects can only be forecast and may not be replicated in an actual event. Key decision makers involved now in some basic elements of planning may not be around when the time comes. However, what is needed is business continuance planning on a national scale. Such prior planning has the potential to reduce significantly the effects on the Wellington region, and on the country as a whole. The Mercury Energy incident reminds us of the benefits of examining the consequences and giving some thought to how we would respond. Some key strategic thinking now could save a great deal of money and anguish. No-one doubts that people and organisations will respond well in the aftermath – that is not the point. A small amount of strategic thinking and key preparatory actions could save a great deal of effort, expense and disruption when the time comes to deal with a major earthquake in Wellington.

In today's sophisticated and highly technological society, there is an expectation that the consequences of reasonably foreseeable events will be considered by those involved in recovery and reconstruction. Those affected will expect that, to the extent possible, forward planning had been done.

This is the challenge to the construction industry.

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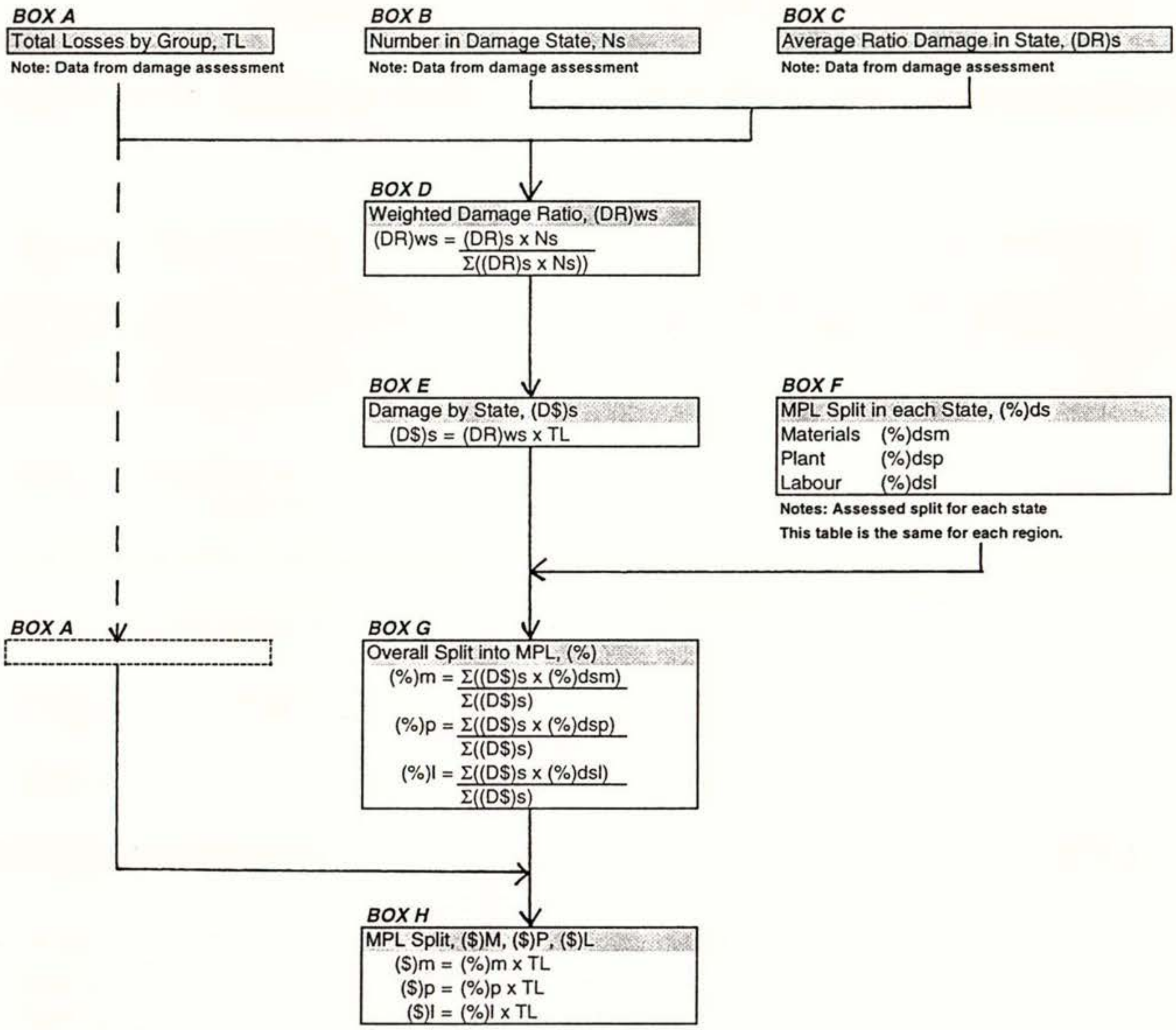
Appendix A – Calculation of Value Splits into Materials Plant and Labour

The calculation methodology is given in Figure A1. An example for Wellington City is given in Figure A2.

Table A1 which forms the basis of Tables 6.1, 6.2 and 6.3, provides details of the calculated results.

Figure A1: Study Methodology - Diagrammatic Representation.

Buildings



Infrastructure

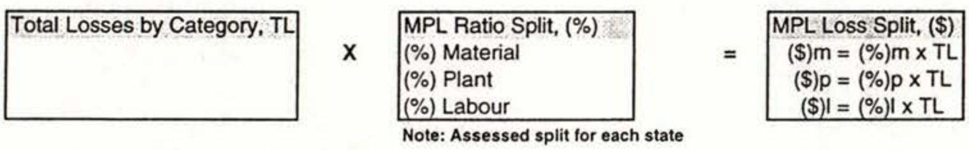


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Figure A2: Example of Study Methodology - Wellington City.

Buildings

BOX A

Wellington	*NZ$M Total Loss*
Const Group	
Group 1	48.6
Group 2	1663.9
Group 3	738.6
Residential	1155.4

BOX B

No in Damage State

None	Light	Moderate	Extensive	Complete
217	819	366	172	34
113	1693	1249	667	183
0	65	256	714	774
6429	29097	11205	5051	824

BOX C

Average Damage in each state

0	5	20	65	100

BOX E

NZ$M

Damage Value in Damage State

None	Light	Moderate	Extensive	Complete	Check
0	8	14	21	6	48.6
0	148	437	758	320	1663.9
0	2	29	265	442	738.6
0	215	332	486	122	1155.4

BOX F

MPL Split by Damage State

	None	Light	Moderate	Extensive	Complete
Materials	0	0.2	0.25	0.3	0.35
Plant	0	0.05	0.1	0.15	0.25
Labour	0	0.75	0.65	0.55	0.4

Note: This table is the same for each region.

BOX A

BOX G

%

Split into Materials/Plant/Labour

Materials	Plant	Labour
28%	13%	59%
29%	15%	57%
33%	21%	46%
27%	13%	60%

BOX H

Value NZ$M

Split into Materials/Plant/Labour

Materials	Plant	Labour	Check
13.4	6.5	28.7	48.6
478.5	244.9	940.5	1663.9
242.0	153.3	343.2	738.5
314.0	147.4	693.4	1154.8
1047.9	552.1	2005.8	3605.8

Infrastructure

	NZ$M Total Loss
Roading	36
Bridging	0
Rail Network	0
Airport	0
Port Infrastructure	125
Water Supply	19
Sewerage System	23
Stormwater Sytem	7
Gas Network	12
Electricity	4
Telecommunications	97
Broadcasting Facilities	0

x

Ratio Split			
Material	Plant	Labour	Check
28%	33%	39%	100%
29%	20%	52%	100%
26%	34%	40%	100%
25%	31%	44%	100%
40%	26%	34%	100%
49%	19%	32%	100%
41%	22%	37%	100%
37%	20%	43%	100%
37%	27%	36%	100%
45%	20%	35%	100%
49%	17%	34%	100%
54%	15%	31%	100%

=

Loss/Split		
Material	Plant	Labour
10	12	14
0	0	0
0	0	0
0	0	0
51	32	42
9	4	6
9	5	9
3	1	3
4	3	4
2	1	1
47	17	33
0	0	0

Wellington

BOX A

Const Group	NZ$M *Total Loss*
Group 1	48.6
Group 2	1663.9
Group 3	738.6
Residential	1155.4
Total	3606.5

BOX B

Average Damage in each state				
0	5	20	65	100

BOX C

No in Damage State					
None	Light	Moderate	Extensive	Complete	Sum D*N
217	819	366	172	34	25963.78
113	1693	1249	667	183	95059.8
0	65	256	714	774	129235.8
6429	29097	11205	5051	824	780284.7
6758	31675	13075	6604	1814	

Note: This summation does not include the Unid Com/Ind group, hence the damage states are proportioned accordingly.

BOX E

NZ$M Damage Value in Damage State					
None	Light	Moderate	Extensive	Complete	Check
0	8	14	21	6	48.6
0	148	437	758	320	1663.9
0	2	29	265	442	738.6
0	215	332	486	122	1155.4
0	373	812	1531	890	3606.5

BOX F

Proportioned Damage State	None	Light	Moderate	Extensive	Complete
Materials	0	0.2	0.25	0.3	0.35
Plant	0	0.05	0.1	0.15	0.25
Labour	0	0.75	0.65	0.55	0.4

Note: This table is the same for each region, hence willl only be shown here.

BOX G

% Split into Materials/Plant/Labour		
Materials	Plant	Labour
28%	13%	59%
29%	15%	57%
33%	21%	46%
27%	13%	60%

BOX H

Value NZ$M Split into Materials/Plant/Labour			
Materials	Plant	Labour	Check
13.4	6.5	28.7	48.6
478.5	244.9	940.5	1663.9
242.0	153.3	343.2	738.6
314.6	147.4	693.4	1155.4
1048.5	552.1	2005.8	3606.5

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M *Total Value*	NZ$M *Total Loss*
Roading	476.0	36.4
Bridging	3.0	0.4
Rail Network	0.0	0.0
Airport	0.0	0.0
Port Infrastructure	402.0	125.1
Water Supply	400.0	18.8
Sewerage System	450.0	23.1
Stormwater Sytem	250.0	7.3
Gas Network	65.0	12.0
Electricity	270.9	4.2
Telecommunications	447.4	97.1
Broadcasting Facilities	0.0	0.0
Total	2764.4	324.2

Ratio Split			
Material	Plant	Labour	Check
28%	33%	39%	100%
29%	20%	52%	100%
26%	34%	40%	100%
25%	31%	44%	100%
40%	26%	34%	100%
49%	19%	32%	100%
41%	22%	37%	100%
37%	20%	43%	100%
37%	27%	36%	100%
45%	20%	35%	100%
49%	17%	34%	100%
54%	15%	31%	100%

Loss/Split		
Material	Plant	Labour
10.2	12.1	14.1
0.1	0.1	0.2
0.0	0.0	0.0
0.0	0.0	0.0
50.6	32.1	42.4
9.1	3.5	6.1
9.5	5.0	8.6
2.7	1.4	3.1
4.5	3.2	4.3
1.9	0.8	1.5
47.2	16.6	33.2
0.0	0.0	0.0
135.8	74.9	113.5

Note: The ratio split is the same for each region, hence willl only be shown here.

Table [illegible]: Values of Damage by Category and Location.

Lower Hutt

BOX B

Average Damage in each state				
0	5	20	65	100

BOX A

Const Group	NZ$M *Total Loss*
Group 1	13.6
Group 2	242.7
Group 3	62.3
Residential	904.5
Total	1223.2

BOX C

No in Damage State Damage State					
None	Light	Moderate	Extensive	Complete	Sum D*N
270	714	235	98	17	16356
85	1101	876	556	152	74298
0	5	24	115	256	33591
2494	16175	9010	4720	1122	680090
2850	17995	10146	5488	1547	

BOX E

NZ$M Damage Value in Damage State					
None	Light	Moderate	Extensive	Complete	Check
0	3	4	5	1	13.6
0	18	57	118	50	242.7
0	0	1	14	47	62.3
0	108	240	408	149	904.5
0	129	302	545	248	1223.2

BOX G

% Split into Materials/Plant/Labour		
Materials	Plant	Labour
27%	12%	61%
29%	15%	56%
34%	23%	44%
28%	14%	58%

BOX H

Value NZ$M Split into Materials/Plant/Labour			
Materials	Plant	Labour	Check
3.7	1.7	8.3	13.6
70.6	36.7	135.4	242.7
21.0	14.0	27.2	62.3
256.1	127.9	520.6	904.5
351.4	180.3	691.5	1223.2

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M *Total Value*	NZ$M *Total Loss*
Roading	319.6	26.0
Bridging	42.8	8.8
Rail Network	0.0	0.0
Airport	0.0	0.0
Port Infrastructure	9.3	2.2
Water Supply	145.2	4.1
Sewerage System	185.9	9.4
Stormwater Sytem	168.1	3.5
Gas Network	53.8	5.4
Electricity	157.5	3.1
Telecommunications	132.3	22.3
Broadcasting Facilities	0.0	0.0
Total	1,214.6	84.8

Loss/Split		
Material	Plant	Labour
7.3	8.6	10.1
2.5	1.7	4.5
0.0	0.0	0.0
0.0	0.0	0.0
0.9	0.6	0.7
2.0	0.8	1.3
3.9	2.1	3.5
1.3	0.7	1.5
2.0	1.5	1.9
1.4	0.6	1.1
10.9	3.8	7.6
0.0	0.0	0.0
32.1	20.3	52.5

Upper Hutt

BOX B

Average Damage in each state				
0	5	20	65	100

BOX A

Const Group	NZ$M *Total Loss*
Group 1	2.4
Group 2	63.1
Group 3	0.5
Residential	172.9
Total	238.9

BOX C

No in Damage State Damage State					
None	Light	Moderate	Extensive	Complete	Sum D*N
27	47	8	3	0	626
46	289	149	71	15	10563
0	2	3	3	2	465
1224	6473	2828	1273	222	193874
1297	6812	2989	1351	239	

BOX E

NZ$M Damage Value in Damage State					
None	Light	Moderate	Extensive	Complete	Check
0	1	1	1	0	2.4
0	9	18	28	9	63.1
0	0	0	0	0	0.5
0	29	50	74	20	172.9
0	38	69	102	29	238.9

BOX G

% Split into Materials/Plant/Labour		
Materials	Plant	Labour
25%	10%	65%
28%	14%	58%
31%	18%	51%
27%	13%	60%

BOX H

Value NZ$M Split into Materials/Plant/Labour			
Materials	Plant	Labour	Check
0.6	0.2	1.6	2.4
17.6	8.6	36.8	63.1
0.2	0.1	0.3	0.5
47.5	22.5	103.0	172.9
65.8	31.5	141.6	238.9

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M *Total Value*	NZ$M *Total Loss*
Roading	172.9	1.1
Bridging	23.2	3.5
Rail Network	0.0	0.0
Airport	0.0	0.0
Port Infrastructure	0.0	0.0
Water Supply	46.8	0.5
Sewerage System	147.9	1.3
Stormwater Sytem	71.3	0.4
Gas Network	20.7	0.4
Electricity	63.0	0.1
Telecommunications	57.5	7.0
Broadcasting Facilities	0.0	0.0
Total	603.4	14.2

Loss/Split		
Material	Plant	Labour
0.3	0.4	0.4
1.0	0.7	1.8
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.2	0.1	0.2
0.5	0.3	0.5
0.1	0.1	0.2
0.1	0.1	0.1
0.1	0.0	0.0
3.4	1.2	2.4
0.0	0.0	0.0
5.8	2.8	8.6

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Table A1: Values of Damage by Category and Location.

Porirua

BOX B

Average Damage in each state				
0	5	20	65	100

BOX A

Const Group	NZ$M Total Loss
Group 1	2.7
Group 2	89.6
Group 3	4.6
Residential	107.0
Total	203.9

BOX C

No In Damage State Damage State None	Light	Moderate	Extensive	Complete	Sum D*N
495	126	23	10	2	1895
135	227	154	175	63	21897
0	15	13	10	36	4581
5067	7513	1505	497	34	103302
5698	7881	1695	691	135	

BOX E

NZ$M Damage Value in Damage State None	Light	Moderate	Extensive	Complete	Check
0	1	1	1	0	2.7
0	5	13	47	26	89.6
0	0	0	1	4	4.6
0	39	31	33	3	107.0
0	45	45	82	33	203.9

BOX G

% Split into Materials/Plant/Labour Materials	Plant	Labour
26%	11%	63%
30%	17%	53%
33%	22%	44%
25%	10%	65%

BOX H

Value NZ$M Split into Materials/Plant/Labour Materials	Plant	Labour	Check
0.7	0.3	1.7	2.7
27.1	14.9	47.6	89.6
1.5	1.0	2.0	4.6
26.8	11.0	69.2	107.0
56.1	27.2	120.6	203.9

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M Total Value	NZ$M Total Loss
Roading	125.0	6.4
Bridging	8.7	1.2
Rail Network	0.0	0.0
Airport	0.0	0.0
Port Infrastructure	0.0	0.0
Water Supply	52.8	1.2
Sewerage System	119.9	11.7
Stormwater Sytem	78.7	0.9
Gas Network	12.4	0.8
Electricity	75.6	1.1
Telecommunications	101.2	15.1
Broadcasting Facilities	0.0	0.0
Total	574.4	38.4

Loss/Split Material	Plant	Labour
1.8	2.1	2.5
0.3	0.2	0.6
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.6	0.2	0.4
4.8	2.6	4.4
0.3	0.2	0.4
0.3	0.2	0.3
0.5	0.2	0.4
7.4	2.6	5.2
0.0	0.0	0.0
16.0	8.3	24.4

Kapiti

BOX B

Average Damage in each state				
0	5	20	65	100

BOX A

Const Group	NZ$M Total Loss
Group 1	13.1
Group 2	54.7
Group 3	2.1
Residential	258.6
Total	328.5

BOX C

No In Damage State Damage State None	Light	Moderate	Extensive	Complete	Sum D*N
411	520	146	60	7	10149
344	856	299	127	22	20765
0	4	4	7	4	953
3302	8163	3092	1364	264	217729
4057	9543	3540	1559	298	

BOX E

NZ$M Damage Value in Damage State None	Light	Moderate	Extensive	Complete	Check
0	3	4	5	1	13.1
0	11	16	22	6	54.7
0	0	0	1	1	2.1
0	48	73	105	31	258.6
0	63	93	133	39	328.5

BOX G

% Split into Materials/Plant/Labour Materials	Plant	Labour
26%	12%	62%
27%	13%	60%
31%	18%	50%
27%	13%	60%

BOX H

Value NZ$M Split into Materials/Plant/Labour Materials	Plant	Labour	Check
3.5	1.5	8.1	13.1
14.8	6.9	33.0	54.7
0.7	0.4	1.1	2.1
70.6	33.4	154.6	258.6
89.5	42.2	196.7	328.5

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M Total Value	NZ$M Total Loss
Roading	249.5	1.1
Bridging	20.1	0.5
Rail Network	274.0	5.2
Airport	2.0	0.2
Port Infrastructure	0.0	0.0
Water Supply	37.0	0.6
Sewerage System	73.7	1.3
Stormwater Sytem	40.1	0.1
Gas Network	10.4	0.1
Electricity	82.9	0.1
Telecommunications	84.4	8.6
Broadcasting Facilities	0.0	0.0
Total	874.1	17.8

Loss/Split Material	Plant	Labour
0.3	0.4	0.4
0.1	0.1	0.3
1.4	1.8	2.1
0.0	0.0	0.1
0.0	0.0	0.0
0.3	0.1	0.2
0.5	0.3	0.5
0.1	0.0	0.1
0.0	0.0	0.0
0.1	0.0	0.0
4.2	1.5	2.9
0.0	0.0	0.0
7.0	4.2	11.2

Table A1: Values of Damage by Category and Location.

Wairarapa

BOX B

Average Damage in each state				
0	5	20	65	100

BOX A

Const Group	NZ$M *Total Loss*
Group 1	9.7
Group 2	19.9
Group 3	30.7
Residential	59.0
Total	119.4

BOX C

No In Damage State Damage State					
None	Light	Moderate	Extensive	Complete	Sum D*N
1490	1192	175	52	0	12825
1295	1166	181	58	0	13246
58	376	194	91	19	13602
5800	4970	672	184	2	50439
8644	7704	1223	385	21	

BOX E

NZ$M Damage Value in Damage State					
None	Light	Moderate	Extensive	Complete	Check
0	5	3	3	0	9.7
0	9	5	6	0	19.9
0	4	9	13	4	30.7
0	29	16	14	0	59.0
0	47	33	36	5	119.4

BOX G

% Split into Materials/Plant/Labour		
Materials	Plant	Labour
24%	9%	67%
24%	9%	67%
28%	14%	58%
24%	9%	67%

BOX H

Value NZ$M Split into Materials/Plant/Labour			
Materials	Plant	Labour	Check
2.3	0.9	6.5	9.7
4.8	1.8	13.3	19.9
8.6	4.2	18.0	30.7
14.0	5.2	39.8	59.0
29.8	12.1	77.6	119.4

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M *Total Value*	NZ$M *Total Loss*
Roading	427.2	1.4
Bridging	104.1	2.4
Rail Network	267.0	4.4
Airport	0.5	0.0
Port Infrastructure	0.0	0.0
Water Supply	45.7	0.6
Sewerage System	67.0	1.0
Stormwater Sytem	8.9	0.0
Gas Network	0.0	0.0
Electricity	135.3	0.1
Telecommunications	84.4	7.7
Broadcasting Facilities	13.0	0.9
Total	1,153.0	18.5

Loss/Split		
Material	Plant	Labour
0.4	0.5	0.5
0.7	0.5	1.3
1.1	1.5	1.7
0.0	0.0	0.0
0.0	0.0	0.0
0.3	0.1	0.2
0.4	0.2	0.4
0.0	0.0	0.0
0.0	0.0	0.0
0.1	0.0	0.1
3.7	1.3	2.6
0.5	0.1	0.3
7.2	4.2	7.1

PNorth/Wanganui/Horowhenua/Rangitikei/Manawatu

BOX B

Average Damage in each state				
0	5	20	65	100

BOX A

Const Group	NZ$M *Total Loss*
Residential	85
Unid. Com/Ind	77
Total	162

BOX C

No In Damage State Damage State					
None	Light	Moderate	Extensive	Complete	Sum D*N
45867	11933	1259	315	0	105287
15104	4905	516	130	0	43295
60971	16838	1775	445	0	

BOX E

NZ$M Damage Value in Damage State					
None	Light	Moderate	Extensive	Complete	Check
0	48	20	16	0	84.9
0	44	18	15	0	77.0
0	92	39	32	0	161.9

BOX G

% Split into Materials/Plant/Labour		
Materials	Plant	Labour
23%	8%	69%
23%	8%	69%

BOX H

Value NZ$M Split into Materials/Plant/Labour			
Materials	Plant	Labour	Check
19.6	6.9	58.3	84.9
17.8	6.3	52.9	77.0
37.5	13.2	111.3	161.9

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M *Total Value*	NZ$M *Total Loss*
Roading	839.4	0.5
Bridging	209.9	0.6
Rail Network	1,380.0	5.1
Airport	17.0	0.2
Port Infrastructure	10.0	0.1
Water Supply	186.5	1.8
Sewerage System	307.9	2.4
Stormwater Sytem	267.2	0.1
Gas Network	106.7	0.2
Electricity	505.7	0.1
Telecommunications	391.7	11.3
Broadcasting Facilities	80.5	1.7
Total	4,302.5	24.3

Loss/Split		
Material	Plant	Labour
0.2	0.2	0.2
0.2	0.1	0.3
1.3	1.7	2.0
0.1	0.1	0.1
0.0	0.0	0.0
0.9	0.3	0.6
1.0	0.5	0.9
0.1	0.0	0.1
0.1	0.1	0.1
0.0	0.0	0.0
5.5	1.9	3.9
0.9	0.3	0.5
10.2	5.3	8.7

Table A1: Values of Damage by Category and Location.

Nelson/Tasman

BOX B

Average Damage in each state				
0	5	20	65	100

BOX A

Const Group	NZ$M Total Loss
Residential	33
Unid. Com/Ind	31
Total	64

BOX C

No in Damage State Damage State					
None	Light	Moderate	Extensive	Complete	Sum D*N
20079	4624	486	121	0	40738
5776	2294	241	60	0	20210
25855	6918	727	182	0	

BOX E

NZ$M Damage Value in Damage State					
None	Light	Moderate	Extensive	Complete	Check
0	19	8	6	0	33.4
0	18	7	6	0	30.9
0	37	15	12	0	64.3

BOX G

% Split into Materials/Plant/Labour		
Materials	Plant	Labour
23%	8%	69%
23%	8%	69%

BOX H

Value NZ$M Split into Materials/Plant/Labour			
Materials	Plant	Labour	Check
7.7	2.7	23.0	33.4
7.1	2.5	21.2	30.9
14.9	5.2	44.2	64.3

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M Total Value	NZ$M Total Loss
Roading	563.8	0.4
Bridging	140.3	0.4
Rail Network	0.0	0.0
Airport	4.0	0.1
Port Infrastructure	53.0	0.7
Water Supply	83.1	0.1
Sewerage System	118.8	0.5
Stormwater Sytem	87.2	0.0
Gas Network	0.0	0.0
Electricity	217.3	0.0
Telecommunications	32.0	1.1
Broadcasting Facilities	25.7	0.6
Total	1,325.3	3.9

Loss/Split		
Material	Plant	Labour
0.1	0.1	0.1
0.1	0.1	0.2
0.0	0.0	0.0
0.0	0.0	0.0
0.3	0.2	0.2
0.1	0.0	0.0
0.2	0.1	0.2
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.5	0.2	0.4
0.3	0.1	0.2
1.7	0.8	2.5

Marlborough

BOX B

Average Damage in each state				
0	5	20	65	100

BOX A

Const Group	NZ$M Total Loss
Residential	14
Unid. Com/Ind	17
Total	31

BOX C

No in Damage State Damage State					
None	Light	Moderate	Extensive	Complete	Sum D*N
11335	1986	209	52	0	17465
4164	1214	128	32	0	10716
15499	3199	337	84	0	

BOX E

NZ$M Damage Value in Damage State					
None	Light	Moderate	Extensive	Complete	Check
0	8	3	3	0	13.8
0	10	4	3	0	16.8
0	17	7	6	0	30.6

BOX G

% Split into Materials/Plant/Labour		
Materials	Plant	Labour
23%	8%	69%
23%	8%	69%

BOX H

Value NZ$M Split into Materials/Plant/Labour			
Materials	Plant	Labour	Check
3.2	1.1	9.5	13.8
3.9	1.4	11.5	16.8
7.1	2.5	21.0	30.6

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M Total Value	NZ$M Total Loss
Roading	275.6	0.2
Bridging	68.6	0.2
Rail Network	422.7	1.8
Airport	9.0	0.1
Port Infrastructure	32.5	0.4
Water Supply	17.8	0.1
Sewerage System	25.8	0.1
Stormwater Sytem	14.0	0.0
Gas Network	0.0	0.0
Electricity	105.7	0.0
Telecommunications	15.6	0.5
Broadcasting Facilities	17.2	0.4
Total	1,004.5	3.9

Loss/Split		
Material	Plant	Labour
0.1	0.1	0.1
0.1	0.0	0.1
0.5	0.6	0.7
0.0	0.0	0.1
0.2	0.1	0.1
0.0	0.0	0.0
0.1	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.0	0.0	0.0
0.3	0.1	0.2
0.2	0.1	0.1
1.3	1.1	2.4

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Table A1: Values of Damage by Category and Location.

Wellington Regional

1995 Value Splits used to Calculate Percentage Splits for Materials, Plants and Labour.

	NZ$M	***NZ$M***	Loss/Split		
	Total Value	***Total Loss***	Material	Plant	Labour
Roading	540.2	36.3	10.2	12.0	14.0
Bridging	209.4	26.6	7.6	5.2	13.7
Rail Network	2670.3	188.3	49.5	64.4	74.4
Airport	108.0	17.9	4.5	5.5	7.9
Port Infrastructure	0.0	0.0	0.0	0.0	0.0
Water Supply	271.1	20.5	10.0	3.9	6.7
Sewerage System	0.0	0.0	0.0	0.0	0.0
Stormwater Sytem	0.0	0.0	0.0	0.0	0.0
Gas Network	0.0	0.0	0.0	0.0	0.0
Electricity	534.2	8.1	3.7	1.6	2.8
Telecommunications	0.0	0.0	0.0	0.0	0.0
Broadcasting Facilities	149.5	28.2	15.2	4.3	8.8
Total	4483	326	101	97	128

Note: Buildings were not used in analysis.

Appendix B – Comparison of 1999 and 1995 Values

Table B1 shows a comparison of the asset values used in 1995 and those used in 1999 for this study.

The inclusion of the areas beyond Wellington has doubled the assets at risk and resulted in a 13% increase in damage assessment. The difference in these changes is clearly due to the lower intensity of shaking in the more distant areas, and hence the lower damage ratios.

The 1999 figures for building assets and damage values can be expected to be more reliable and accurate. This also applies to infrastructure where new figures were obtained and where more applicable damage ratio data has been developed.

Summary of Principal Changes from the 1995 Analysis (Reference 1)

Assets
- ❑ Some improved detail
- ❑ Some corrections
- ❑ Extended area considered
- ❑ Specific characteristics of each unit area and building groups developed

Seismicity Model
- ❑ Specific attenuation relationships
- ❑ Amplified shaking on soft ground
- ❑ Liquefaction effects

Damage Ratios
- ❑ Ongoing development
- ❑ Shake and ground deformation effects for infrastructure
- ❑ Distribution of damage state for buildings

Appendix C – Scenario Event

Seismic activity in the Wellington region results from subduction movement of the Pacific tectonic plate under the Australian plate. Extensive research has identified six sources of major earthquakes:

- ❑ one subduction interface zone, at a depth of about 30 km beneath Wellington City
- ❑ five active surface faults; Wairarapa Fault, Wellington Fault, Ohariu Fault, Shepherds Gully/Pukerua Fault and Wairau Fault extension.

The subduction interface zone is the source of most frequent earthquakes and is considered capable of generating Magnitude (M) 8 earthquakes. However it is not considered critical as the main source of damage because of the depth at which earthquakes occur.

Of the surface fault earthquake sources the Wellington Fault event is considered the probable maximum event for loss assessment purposes. Larger events, up to perhaps M8.5, are possible on other faults in the greater Wellington Region but their potential sources are at greater distances from the centre of major risk exposures and they have longer average recurrence intervals that the Wellington Fault event.

The characteristic earthquake on the Wellington Fault is identified with a 60 km length of rupture and about 3 to 5 metres of horizontal movement and 1 metre vertical movement. Such movement on this strike-slip fault is estimated to produce an earthquake magnitude in the range of M7.1 - M7.8 with an average of M7.5. While there is argument that the scenario earthquake should be considered at the upper range of magnitude as that having a small likelihood of being exceeded, the average magnitude (M 7.5) event has been adopted for this study to be consistent with previous similar studies.

The estimated average recurrence interval for movement on the Wellington-Hutt Valley segment of the Wellington Fault is 420-780 years, with the most recent event estimated as occurring 380-530 years ago (from 1995). Taking factors of average time between movements, time since last movement, and inter-dependence of movements of the regions major faults into account, the probability of occurrence of the scenario Wellington fault event is about 7-11% in 50 years. [An equivalent 700-400 year recurrence interval, taking into account reduction in accumulated regional strain by the 1855 M 8 Wairarapa Fault earthquake].

The isoseismals for the scenario event have been determined using attenuation of ground shaking intensity with distance away from the earthquake source as recommended by Smith and Smith, [3] with recognition of additional near fault effects. This results in Modified Mercalli Intensity (MM) of ground shaking within about 5 km of the Wellington Fault of MM10 affecting the cities of Wellington and the Hutt Valley, intensities of MM10 for the Wellington region, and intensities of MM9 for the Wellington region, and intensities of MM9 for the more distant areas of the damage accumulation area.

Further allowance is made for amplification of earthquake shaking intensities in areas of soft soils and for permanent ground deformation due to liquefaction. The extent of these soils is determined from maps prepared by Wellington Regional Council for its area, and from geological maps and local knowledge for more distant areas. For areas in the Wellington Region assessment is made on the liquefaction and ground deformation potential. No allowance has been made for Earthquake induced landslip.