

RECONNAISSANCE REPORT ON THE ORMOND EARTHQUAKE — 10 AUGUST 1993

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ABSTRACT

On the 10th of August 1993, an earthquake with a magnitude of 6.3 occurred near Gisborne. This report presents observations made by a reconnaissance team which visited the Gisborne area in the days following the earthquake. Structural damage in Gisborne City and damage to services and roading was limited. Stronger ground-motions were apparent between Ormond and Te Karaka, 20km northwest of Gisborne, where soil liquefaction occurred on the Waipaoa River flats, and some natural slopes failed.

INTRODUCTION

An earthquake shook the Gisborne area on Tuesday 10 August 1993, at 21:47 hours New Zealand Standard Time (NZST). The earthquake epicentre location is at 38.52°S 177.93°E between Ormond and Waimata 20km north of Gisborne (Figures 1 and 2). The Richter local magnitude (M_L) is 6.3, and the focal depth 48km (Seismological Observatory, Institute of Geological and Nuclear Sciences Ltd). Initial reports indicated damage over a reasonably wide area, including Wairoa, as well as in the immediate Gisborne region. The earthquake was felt noticeably in Napier, and as far away as Wellington and East Cape.

The Gisborne area was visited by a field team from the Institute of Geological and Nuclear Sciences Ltd (GNS) between 11 August and 13 August with the following objectives:

- Deployment of portable seismographs in the epicentral area to record the aftershocks.
- Servicing of strong motion accelerographs to obtain the records from the main earthquake shock.
- Make an initial reconnaissance of structural damage caused by the earthquake, on behalf of the New Zealand National Society for Earthquake Engineering (NZNSEE).
- Carry out an initial reconnaissance evaluation of ground damage caused by the earthquake, including soil liquefaction and landslides.

The GNS team was joined on 12 August by a team from the University of Canterbury (UoC) to study soil liquefaction. Liaison was established with Gisborne Civil Defence, Gisborne District Council, Works Consultancy Services (Gisborne and Wairoa), Wairoa Civil Defence, and Wairoa District Council, and discussions were held with local residents.

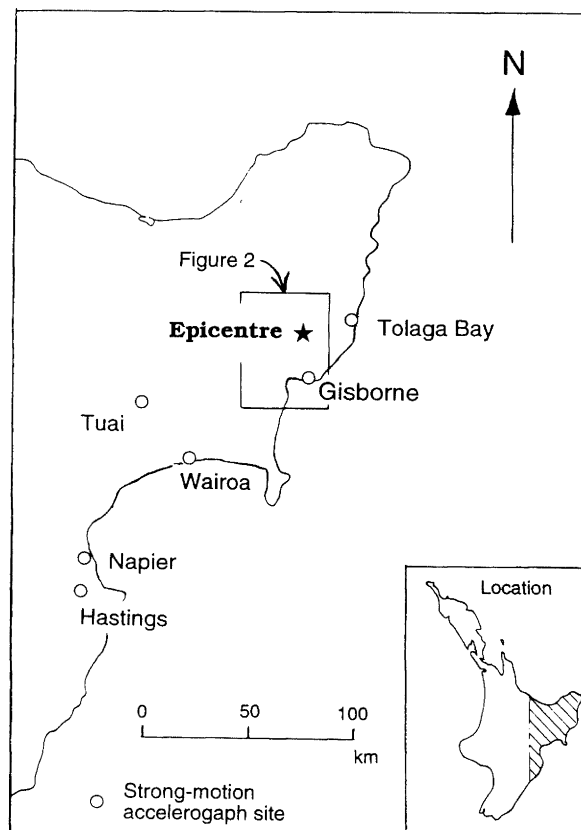


Figure 1 Location map for the Gisborne area.

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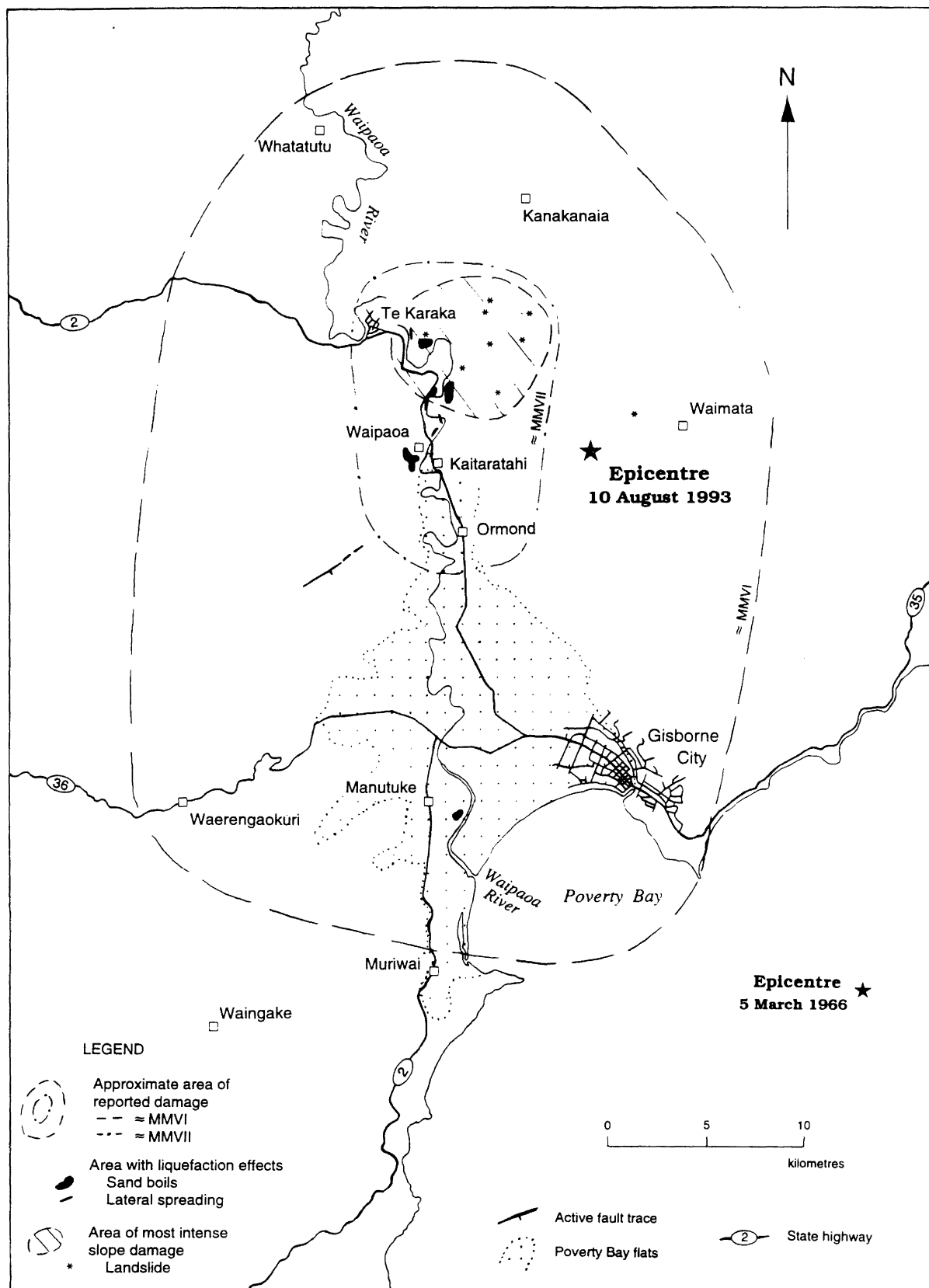


Figure 2 Preliminary map of damage features for the 10 August 1993 Ormond earthquake.

During the reconnaissance it became apparent that damage caused by the earthquake was more concentrated in the rural area between Ormond and Te Karaka, 20km northwest of Gisborne (Figure 2). This included damage to housing, bridge approaches, soil liquefaction effects, and slope failures, including damage to ridge crests. In Gisborne City, damage to structures and services was minor, as was damage to roading throughout the wider Gisborne area.

Systematic field inspections of ground damage by staff from GNS and UoC continued into the week following the earthquake. During this period teams from Works Consultancy Services, Wellington and Gracefield, also carried out inspections of bridges and areas of soil liquefaction respectively. Systematic inspections of buildings in Gisborne were carried out by the Gisborne District Council.

The August 10 earthquake is currently being referred to as the Ormond earthquake (Seismological Observatory, GNS). This report, which is based on the observations made during the reconnaissance, provides a preliminary overview of the earthquake and its effects. The records from the portable seismographs installed following the earthquake have not been analysed, and felt reports to determine Modified Mercalli (MM) intensities have not yet been systematically evaluated. Chapman (1993) and Christensen (1993) give specific details on bridging and soil liquefaction respectively.

GEOLOGICAL AND SEISMOLOGICAL SETTING

Bedrock in the Gisborne area comprises mainly sedimentary mudstones, siltstones, and sandstones of Tertiary (mainly Miocene or Pliocene) age [Moore et al. 1989]. The rocks are folded along a southwest-northeast axis resulting in a reasonably simple geological structure, with bedding having dips of up to 30°. The rocks are typical of many New Zealand sedimentary 'soft' rocks, which have unconfined compressive strengths between 1 and 10 MPa. Jointing is widely spaced, and weathering is generally to shallow depths (<10m).

The Waipaoa River drains a catchment area of 2000km² to the north and west of Gisborne. In its lower reaches there are well developed river terraces and flats that have been formed along a meandering river course. The river flats extend up to 10m above present river level, and south of Kaitaratahi are known as the Poverty Bay flats (Figure 2). These flats have an area of 20km², and are up to 8km wide near the Waipaoa River mouth. Extensive deposits of silts and sands have accumulated on the flats adjacent to and above river level over the past 3,300 years (Pullar & Penhale 1970), and the total thickness of sediments overlying Tertiary basement has a maximum of about 200m (L Brown, pers comm). The hills surrounding the river and its flood plain rise to altitudes of 500m, and are generally characterised by steep (>20°) slopes.

The only active fault mapped in the Gisborne area is located about 7km west of Ormond where there is a short (1km) northeast trending trace (Figure 2). The age of last movement is not known.

The east coast of the North Island, which includes the Gisborne area, lies in the main seismic region of New Zealand. Offshore the Pacific Plate is being subducted down to the west under the Indo-Australian Plate at a rate of 50

mm/year. The interface between the plates lies at a depth of about 15 to 20 km beneath the Gisborne area. The most significant recent earthquake to affect the Gisborne area was the M_L6.2 event of 5 March 1966 [Hamilton et al. 1969], which had an epicentre located 15km to the southeast of Gisborne City (Figure 2).

ENGINEERING ASPECTS AND SHAKING DAMAGE

Civil Defence in Gisborne went into 'Alert Phase' for several hours following the earthquake [S Clare, pers comm]. Incidents, mostly minor, were successfully dealt with by local Police and Fire Service staff, and since there were no reports of fires or serious injuries to residents, a state of emergency was not declared. Power supply in central Gisborne was lost for a few hours, and was not restored in some outlying areas until the following morning.

No major damage had been reported when the authors from GNS arrived in Gisborne on 11 August. Over the next few days it became apparent that the most severe effects of the earthquake were concentrated in rural areas outside of Gisborne City, in particular between Ormond and Te Karaka 20km northwest of Gisborne (Figure 2). More distant urban centres (e.g., Wairoa, Tolaga Bay) did not appear to have suffered significant damage. The Earthquake Commission (EQC) has received 1700 claims for damage totalling \$3 million. About 1000 of the claims are for damage to chimneys, and few of the individual claims are for more than \$50,000.

There was no disturbance of the ground surface at the active fault trace west of Ormond to indicate that surface fault rupture was associated with the earthquake. This is consistent with the size and preliminary depth estimates for the earthquake, well below the tectonic plate interface.

Felt Effects

There were reports of moderate to strong shaking over more than 1000km² (≈MMVI isoseismal boundary on Figure 2) in the Gisborne area. The occurrence of the earthquake close to 10 o'clock in the evening resulted in many people being sharply awakened from sleep by the shaking, and also objects being thrown off shelves in houses. The loss of electricity, particularly in rural areas, and the noise associated with the earthquake heightened the level of alarm experienced by many people.

Further afield in Tolaga Bay, Wairoa and Tuai the effects were less dramatic. A low frequency motion was felt in Wairoa, and there were two reports of goods being thrown off shelves. Many of the earliest reports indicated that the Wairoa area had been affected, as much as, or more than the Gisborne area, but this did not subsequently prove to be the case. Sharp jolts were felt by some people living on hills in Napier and Hastings and a rolling motion was reported by some of those living on soft ground, but there were no reports of damage.

Strong Motion Records

Twenty eight strong-motion accelerographs from the New Zealand-wide network maintained by GNS are located within an epicentral distance of 150km of the earthquake. Those in the Gisborne and Hawkes Bay regions were inspected during

Table 1 Peak horizontal accelerations for records obtained at twelve sites in the Ormond Earthquake of 10 August 1993

Site ¹	Accelerograph Type ²	Preliminary Epicentral Distance (km)	Peak Ground Acceleration ³ (g)
Gisborne, Kaiti Hill (on rock)	digital	23	0.180
Gisborne, 2ZG (on sediment)	digital	23	0.184
Gisborne, Telecom	scratch	22	0.19
Gisborne, Post Office (remote)	film	21	0.220
Tolaga Bay	scratch	38	0.09
Wairoa, Telecom	scratch	72	0.050
Wairoa, Telecom	film	72	0.050
Tuai, Power Station ⁴	scratch	74	0.045
Napier, Hospital (on rock)	digital	139	0.008
Napier, Civil Defence (on sediment)	digital	143	0.016
Napier, Museum ⁴	scratch	139	0.01
Hastings, Civil Defence	digital	157	0.008

- NOTES:**
- ¹ Locations outside Gisborne City shown on Figure 1
 - ² Digital = digital recorder, Film = film recorder, Scratch = scratch plate recorder
 - ³ Values are the stronger of two horizontal components for digital and film recorders, polar values for scratch plate accelerographs.
 - ⁴ Ground-motions not strong enough to trigger film recorder

the reconnaissance, and most were found to have recorded the earthquake. Peak ground acceleration (PGA) values from 4 sites in Gisborne and 8 other sites between Tolaga Bay and Hastings are summarised on Table 1.

The PGA values recorded in Gisborne ranged from 0.180g to 0.220g; with the maximum being recorded at a site remote from the (former) Chief Post Office building. The Post Office is a 6 storey moment-resisting structure with a fundamental period of about 1.0 sec (McVerry & Sritharan 1991). There are three interconnected film recording accelerographs in the building, in addition to the one remote from it. The accelerographs were triggered by the P wave arrival and produced the strongest set of records yet obtained from a building in New Zealand, with an estimated peak acceleration of 0.4g on the top floor.

Examples of the acceleration time-histories for two records from locations in Gisborne City - Kaiti Hill (sited on rock), and Radio Station 2ZG (sited on sediments) are compared in Figure 3. The corresponding 5% damped acceleration response spectra are shown on Figure 4. More than 75km from the preliminary epicentre the PGA values decreased to <0.05g. The two digital accelerographs in Gisborne (Kaiti Hill and 2ZG) recorded an aftershock, four minutes after the main shock, with a PGA of about 0.01g.

Buildings and Services

Over the past decade the Gisborne District Council has been carrying out a systematic study of earthquake risk buildings in Gisborne City [G Lodge & J Wells, pers comm] based on the 'red book' [NZNSEE, 1985]. Many of the older buildings

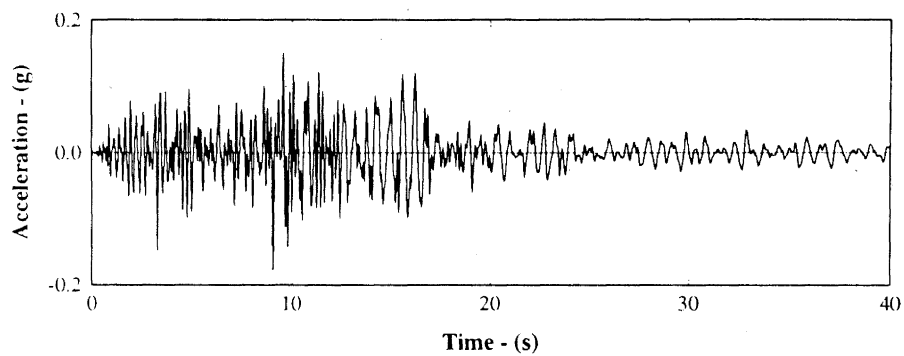
are the brick masonry type up to 3 storeys high, typical of construction in the 1920s and 1930s. Following the earthquake, identified damage at about 20 of the 120 'at risk' buildings included:

- (i) badly cracked wall from face loading in a two-storey unreinforced brick masonry building (Figure 5)
- (ii) six cases of shifted or dislodged parapets (Figure 6)
- (iii) several instances of cracking in walls (Figure 7)
- (iv) cracking and spalling of plaster in several buildings
- (v) window breakage in several buildings (Figure 8).

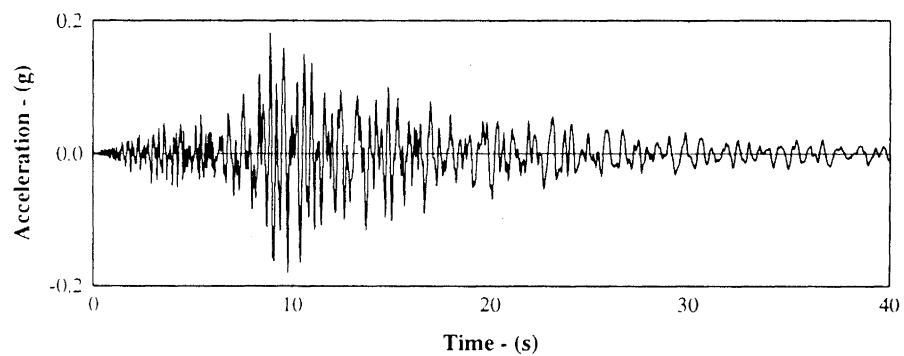
Apart from the damage to the wall in (i), no other major structural damage was seen during the reconnaissance.

No major damage to either water or sewerage services was reported in Gisborne City [B Apperly, pers comm]; the most significant immediate damage noted being the breakage of a sewer pipe jointer at the Peel Street Bridge. One power pole collapsed in Gisborne (Fitzherbert Street/Ormond Road corner), and a substation was temporarily out of service. Damage to footpaths and streets has not been reported or observed.

No damage was reported from the water supply dams near Waingake 20km southwest of Gisborne (Figure 2), or along the pipeline to Gisborne City. The recently completed (1990) 38,000m³ reinforced concrete water supply reservoir on Hospital Hill was 90% full at the time of the earthquake. The reservoir, with a floating slab roof and divided into two storage cells, suffered no structural damage, although there was some minor damage to the protective covers between the walls and roof slab due to water movement (Figures 9 and 10).



(a) N77E component at Kaiti Hill (on rock)



(b) N38E component at Radio Station 2ZG (on sediment)

Figure 3 Acceleration time histories recorded in the 10 August 1993 Ormond earthquake at two accelerograph sites in Gisborne.

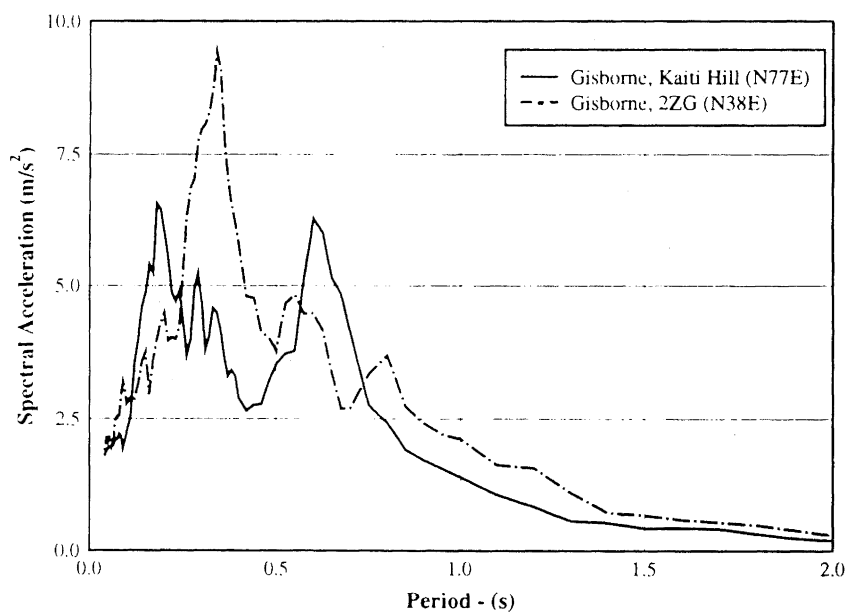


Figure 4 Comparison of the 5% damped acceleration response spectra for records from Gisborne given in Figure 3 for the 10 August 1993 Ormond earthquake.

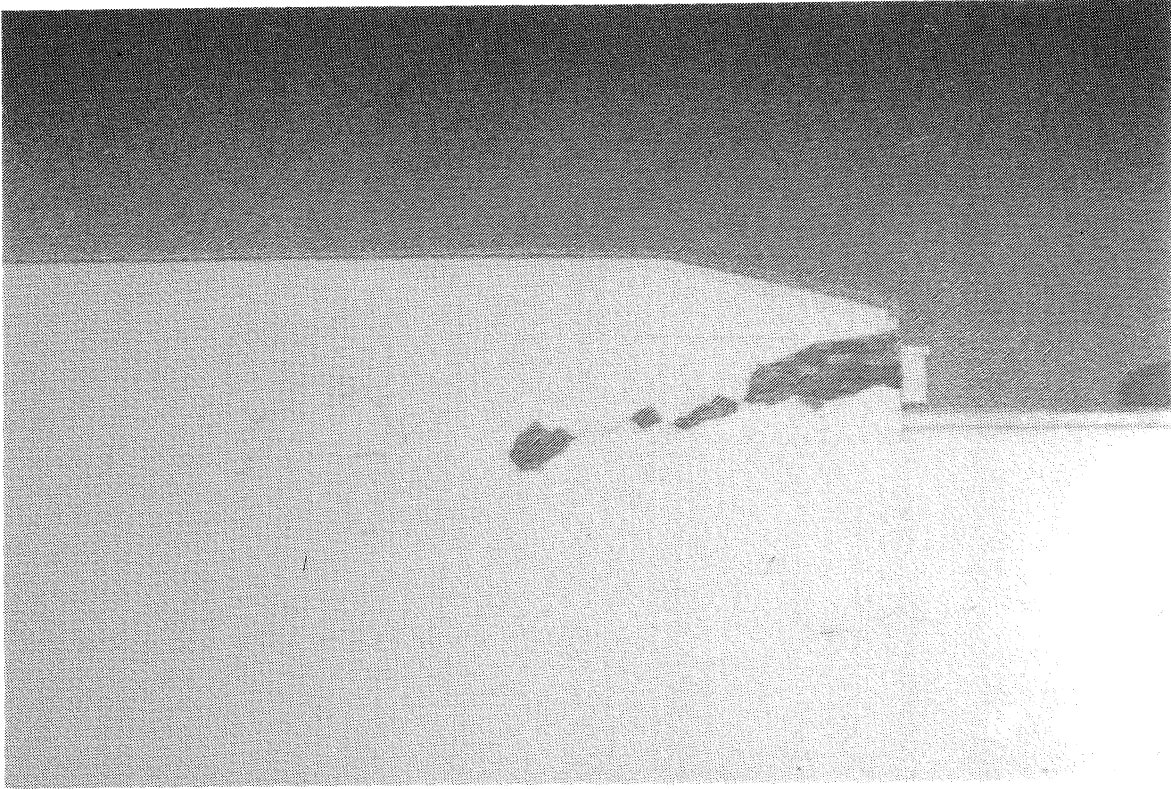


Figure 5 Cracking in southwest wall of two-storey unreinforced brick masonry building in Lowe Street, Gisborne. The cracking was more extensive in the upper storey and parapet above.



Figure 6 Close up view of cracking in parapet corner of the building in Figure 5.

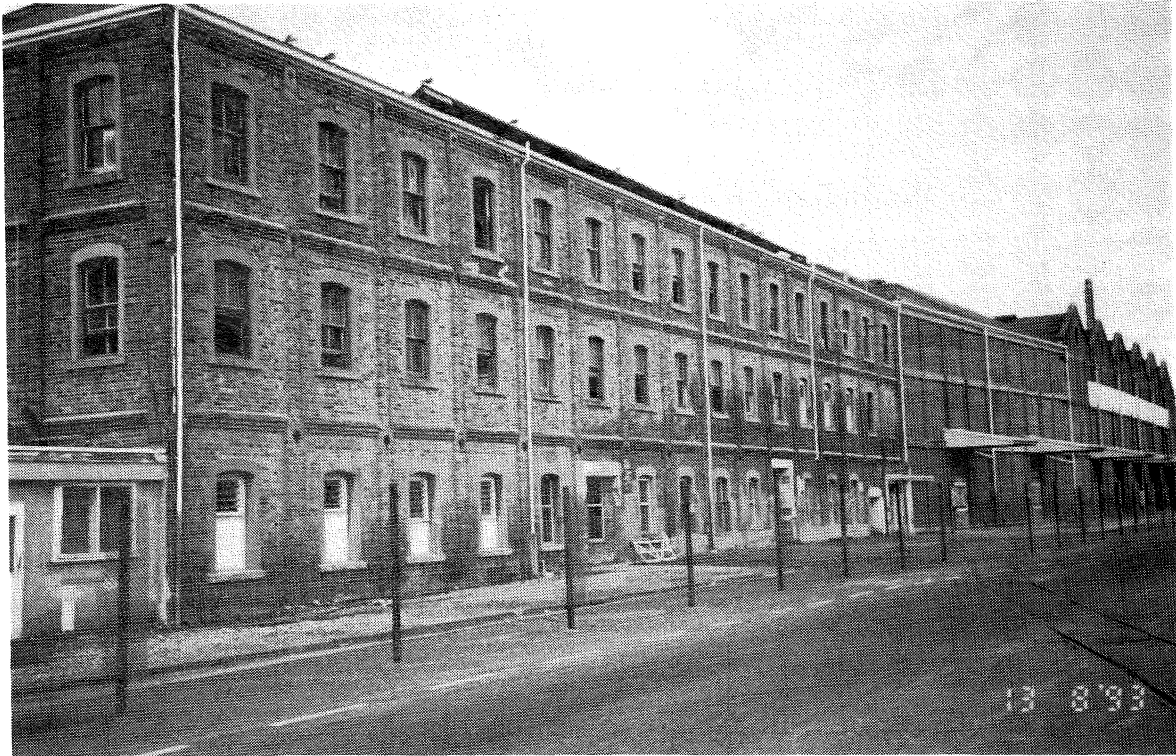


Figure 7 Part of the freezing works buildings in the Esplanade, Gisborne. Built in the mid-1920s and at the end of its operational life, the structure sustained little damage. Minor cracking in the walls was more apparent at the rear of the building.

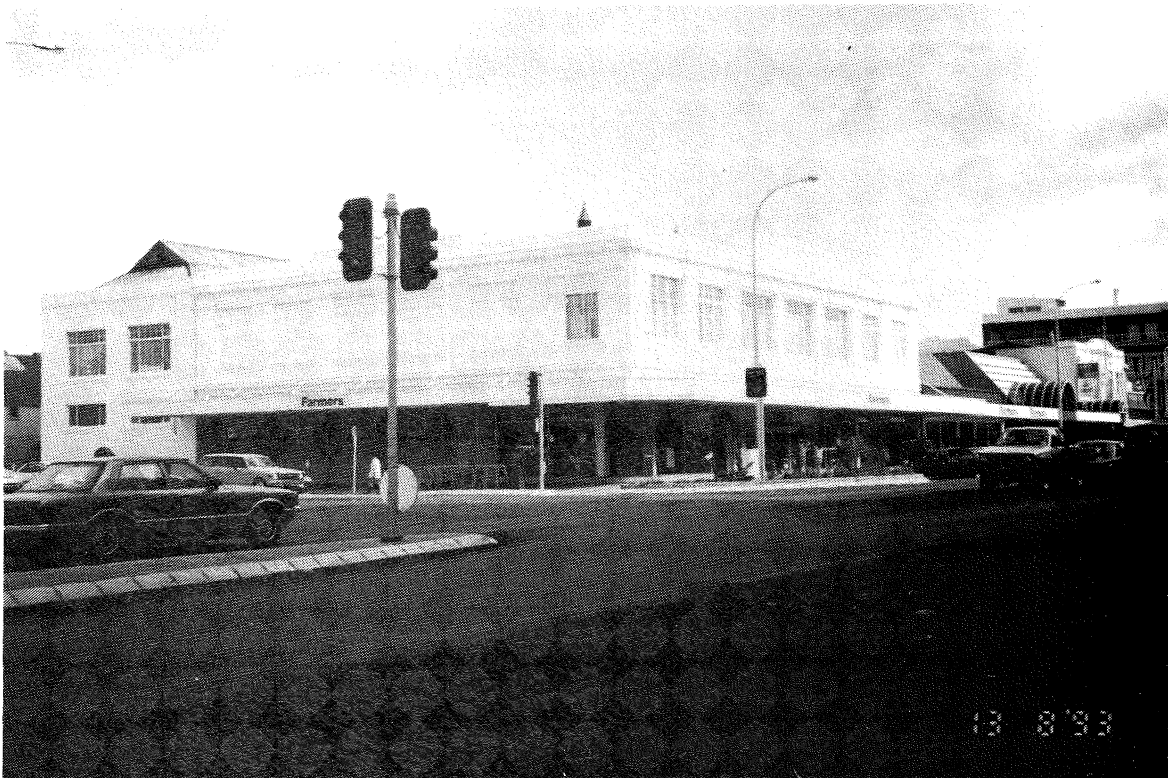


Figure 8 Farmers building on the corner of Gladstone Road and Customhouse Street, Gisborne. Plate glass windows in the bottom storey were broken during the earthquake, but otherwise there was no significant damage.



Figure 9 General view of part of the 38,000m³ water supply reservoir on Hospital Hill, Gisborne. The 140m by 70m reservoir is divided into two cells, and the flashing is in the gap between the external wall and floating slab roof.

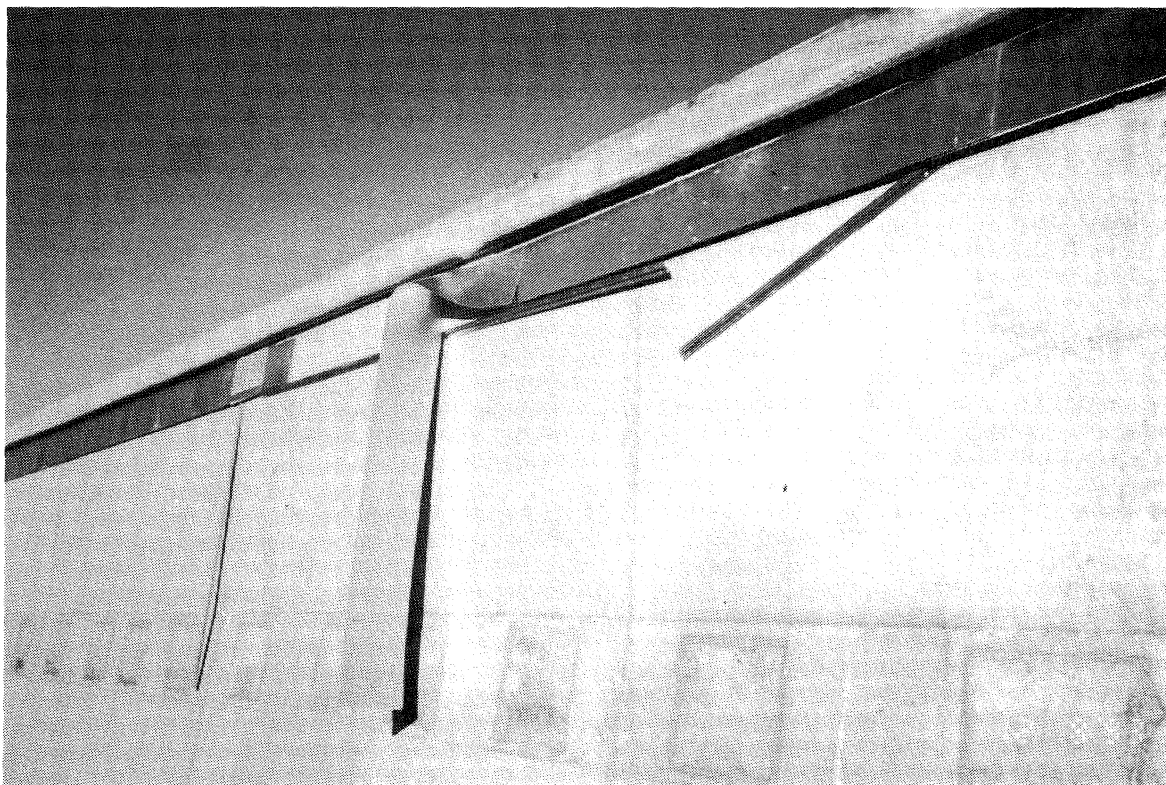


Figure 10 Close-up view of 'popping' of flashing on the southwest side of Hospital Hill reservoir, caused by water motion within the reservoir during the earthquake.

Traffic on two SH2 bridges was reduced to one lane by damage caused by the earthquake. The Waipaoa bridge, which is 8km west of Gisborne and was completed in 1956, suffered spalling of a pier cap near the east abutment (Figures 11, 12 and 13). The Kaiteratahi bridge, which is 1 km north of Kaiteratahi and was completed in 1986, was not damaged, but there was up to 50mm of settlement under one lane of the north abutment fill (Figure 14). No other significant structural damage to bridges was reported, although there was some lateral spreading adjacent to the eastern pier and west abutment of the Puha bridge, 5km west of Te Karaka. Chapman [1993] discusses the performance of bridges in more detail.

Damage to roading was minor. There were no major failures in cut slopes, both in Tertiary bedrock, or in overlying colluvial or alluvial deposits. Minor falls and failures occurred from the steeper cut slopes (Figure 15) over the wider (\approx MMVI isoseismal) area covered in Figure 2. Minor displacements of fills occurred in several places (e.g. SH2 5km north of Kaiteratahi), with cracking and settlement of the road pavement. In particular, sidling cuts and fills not founded on bedrock were damaged, for example Ngakaroa Road east of Kaiteratahi (Figure 16). Overall the level of damage was similar to that experienced during a large rainstorm.

Reports of damage to brick chimneys were widespread. Although chimneys were damaged in Gisborne City, and as far afield as Waerengaokuri and Kanakanaia (ie extending at least over the \approx MMVI isoseismal area on Figure 2), the greatest concentration of such damage was in the area between Ormond and Te Karaka. Collapses and movements of unsupported domestic water tanks were also reported. The most striking evidence of damage to a structure was to the old freezing works building in Waipaoa. The three-storey building, which was built of reinforced concrete in about 1915 and abandoned in 1931, suffered extensive shear failures to the bottom-storey columns (Figure 17).

Damage to the abandoned freezing works, plus the degree of damage to houses, indicates stronger shaking in the Ormond to Te Karaka area (\approx MMVII isoseismal area on Figure 2) than in Gisborne City. Many of the houses that suffered the most intense ground motions in the area between Ormond and Te Karaka, as well as some near Waerengaokuri, were sited on low ridges adjacent to the valley, rather than on the valley floor. Commonly microwave ovens were displaced from shelves to land in the centre of rooms. There were several reports from the Ormond to Kaiteratahi area, where a cottage was apparently displaced from its piles, which indicated greater damage from ground motion in an east-west direction. Near Te Karaka some concrete water tanks were shifted in an northeast-southwest direction by 20-50 mm.

Soil liquefaction

During an aerial reconnaissance four areas of sand boils associated with soil liquefaction were seen in the 7km stretch of the Waipaoa River flats between Kaiteratahi and Te Karaka (Figure 2). No evidence of liquefaction was seen behind the sand dunes along the Poverty Bay coast between Gisborne and Muriwai, although another area with liquefaction boils was subsequently seen close to the Waipaoa River 1km east of Manutuke (Figure 2). The features occurred in farmers' paddocks, and did not appear to affect buildings, although the pavement in Humphrey Road near

Waipaoa was broken in two places. Christensen [1993] has systematically documented more than 120 boils in areas of liquefaction totalling about 1km².

The Waipaoa River valley upstream of the Poverty Bay flats is 1-2km wide, with a meandering present day river, flanked by low terraces. The sand boils occurred on terraces approximately 3-6m above the Waipaoa River, which generally flows in a relatively confined course below these terraces. On the same terrace surface, they were often more frequent adjacent to the valley sides than in the valley centre (Figure 18). Vents for the boils typically occurred along lineations or cracks with a variety of orientations (Figures 18 & 19). Most commonly they were oriented at right angles to the valley sides or, where within very tight former meander loops, they were often aligned parallel with terrace edges. Drains up to 3m deep dug across some of the terrace surfaces did not appear to significantly influence the orientation of close-by vents. No sand boils associated with liquefaction were observed on terraces close to or above the top of the stop bank 8 to 9 metres above river level.

The Waipaoa valley is infilled with between 25 and 80 metres of sediment, predominantly silt but also containing sand and gravel horizons (L Brown, pers comm). The materials ejected from the boils were poorly graded, ranging from coarse silt to fine gravel, but were most commonly fine to medium sand. Typical particle size distributions are given in Christensen [1993]. During the reconnaissance, the depth to the water table was not systematically determined but, based on some of the water well records in the area, it is likely in many places to be >6m (ie at river level or below).

Ground cracking associated with lateral spreading was apparent in several places between Kaiteratahi and Te Karaka (Figure 2), mainly close to 3 to 5 metre high steep (20°) banks adjacent to the Waipaoa River. The cracks generally had vertical and/or horizontal (spreading) displacements toward the river channel of less than 150mm, over distances up to 200 metres. In one place they were associated with a settlement of up to 300mm over a 150m length of the stopbank on the right (west) bank of the Waipaoa River (Figure 20).

Failures on Natural Slopes

Natural slopes in the hill country surrounding Gisborne are generally steep, and the area is generally prone to slope movements and erosion. Slope instability is manifested in several forms, including shallow 'erosion-type' slips on steep slopes, and larger deeper-seated landslides including earthflows.

At least ten earthquake-generated landslides occurred in a limited 5km² area east and southeast of Te Karaka (Figure 2). The failures were shallow (<5m), developed on slopes steeper than 33° formed in homogeneous mudstones, and had volumes up to 400m³ (for example Figure 21). Most failures originated high on slopes, with basal failure planes in slightly to moderately weathered mudstone, rather than in overlying colluvial materials. Slide debris was typically 'chunky' and dry, and often had moved some distance downslope, but not to the valley floor. The 70 to 150 mm of rain that had fallen over the 3 days prior to the earthquake did not appear to have saturated the slopes, or contributed to the earthquake-triggered failures. Damage to the tops of steep (>30°) slopes or the crests of sharp ridges was also most common in this

area of slope failures (Figure 22). Two small farm dams, with reservoirs less than 5m deep and located near the tops of steep hills, were also reported to have failed. Some small local falls ($<100\text{m}^3$) were also noted on slopes steeper than 50° within a 5km radius of Te Karaka, and there were a couple of ridge crest cracks 1km southwest of Waerengaokuri.

Several larger pre-existing earthflows developed in debris overlying bedrock in the Gisborne area were slightly re-activated by the earthquake. Estimated displacements were small (generally $<5\text{m}$), in proportion to the size of the earthflows, which are typically developed on slopes between 5° and 15° and are up to $5 \times 10^6\text{m}^3$ in volume. In one case an earthflow 3km southeast of Te Karaka was noted to have moved within 12 hours after the earthquake (2m displacement of a $30,000\text{m}^3$ earthflow on an 8° slope, which had been intermittently active over the previous 6 months, - Figure 23). In another case, an earthflow 3km west of Waimata was noted to have moved several days after the earthquake (6m displacement of a $5 \times 10^6\text{m}^3$ flow on a 5° slope, although it had previously been inactive this winter). Whether the rainfall immediately preceding the earthquake was a factor that influenced movement as a result of the earthquake is not certain. The previous two months had been much drier than in a normal winter, and therefore the effect is not likely to have been great as soil moisture levels may have been lower than usual.

DISCUSSION and CONCLUSIONS

The effects of the Ormond earthquake in Gisborne City appear to have been less severe than those of the $M_L 6.2$ 5 March 1966 Gisborne earthquake, which had a reasonably similar epicentral distance (15-20 km). This is reasonably consistent with the focal depth (48km) being greater, and peak ground accelerations (0.22g) being smaller, in 1993 compared with the 1966 event (30km and 0.28g respectively). There was also more damage to buildings of comparable age in Dannevirke as a result of the 13 May 1990 Weber earthquake, for which peak ground accelerations reached 0.39g [Johnstone et al., 1993].

Following the 1966 Gisborne earthquake, Hamilton et al. [1969] reported on damage in Gisborne City, but did not describe either the performance of bridges, or the extent of ground damage outside of Gisborne. Some ground damage would have been expected in the 1966 event, based on the presence of soils susceptible to liquefaction and steep slopes in the Gisborne area.

The 1993 event is another example of a moderate size earthquake ($M_L < 6.5$) that produced shaking intensities on the threshold of causing major damage. It provides valuable information on the performance of engineering structures, and also natural ground, including earthquake-triggered landslides and soil liquefaction effects.

ACKNOWLEDGEMENTS

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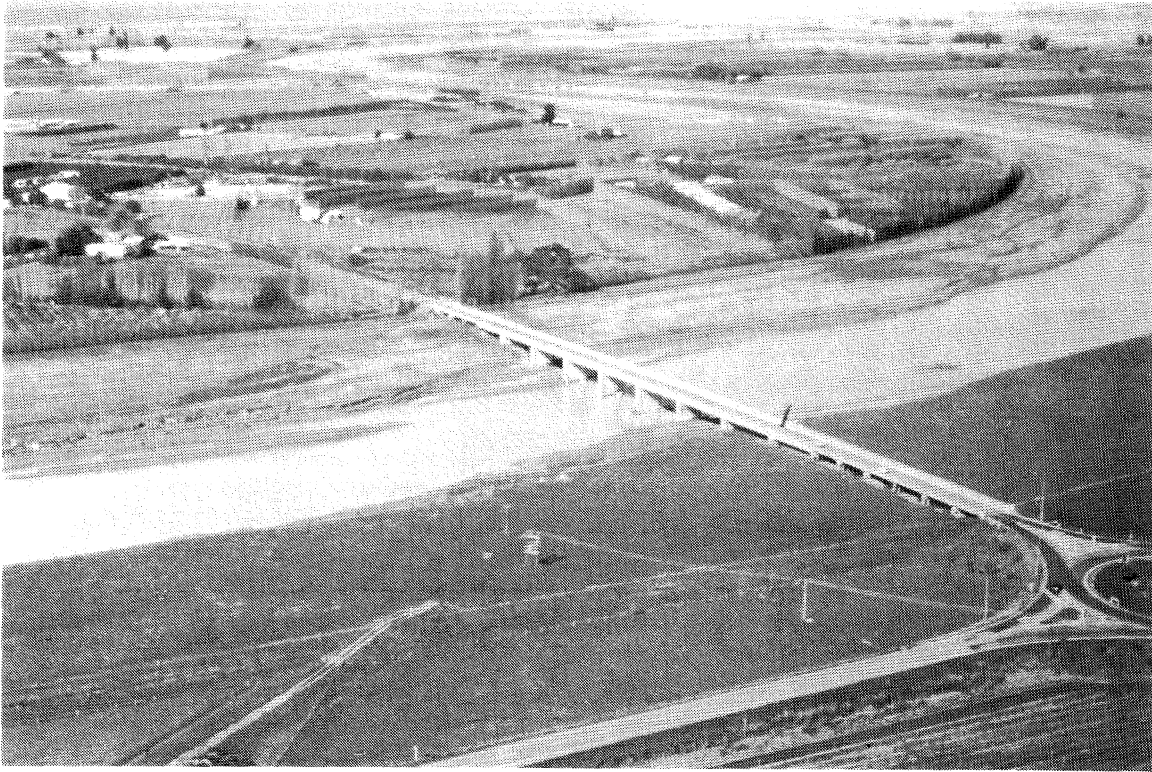


Figure 11 Aerial view of the Waipaoa Bridge, 8km west of Gisborne, looking southwest or obliquely downstream. Damage was to the last main pier on the far (eastern) bank, as shown in Figure 12.

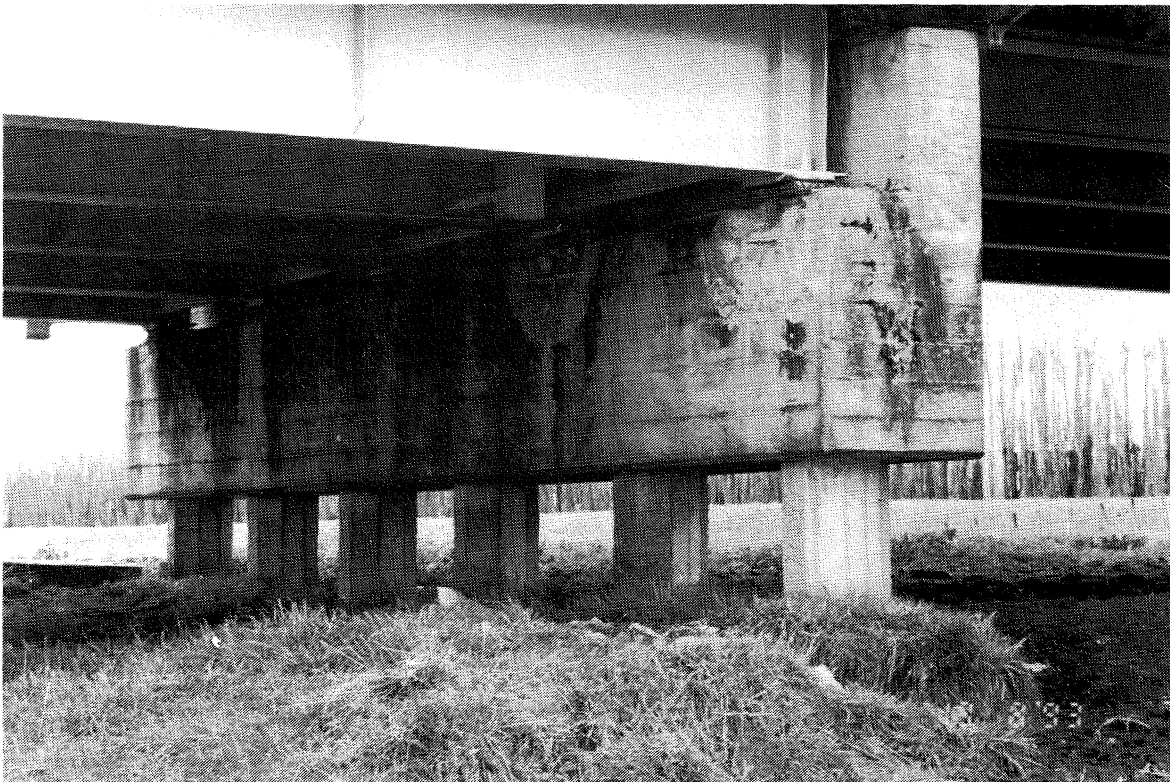


Figure 12 Waipaoa Bridge pier on the east bank of the Waipaoa River looking obliquely upstream. In addition to the spalling of pier concrete under two of the steel girder bearers, cracking under the most distant (upstream) girder on the other side of the pier indicated a similar incipient failure.

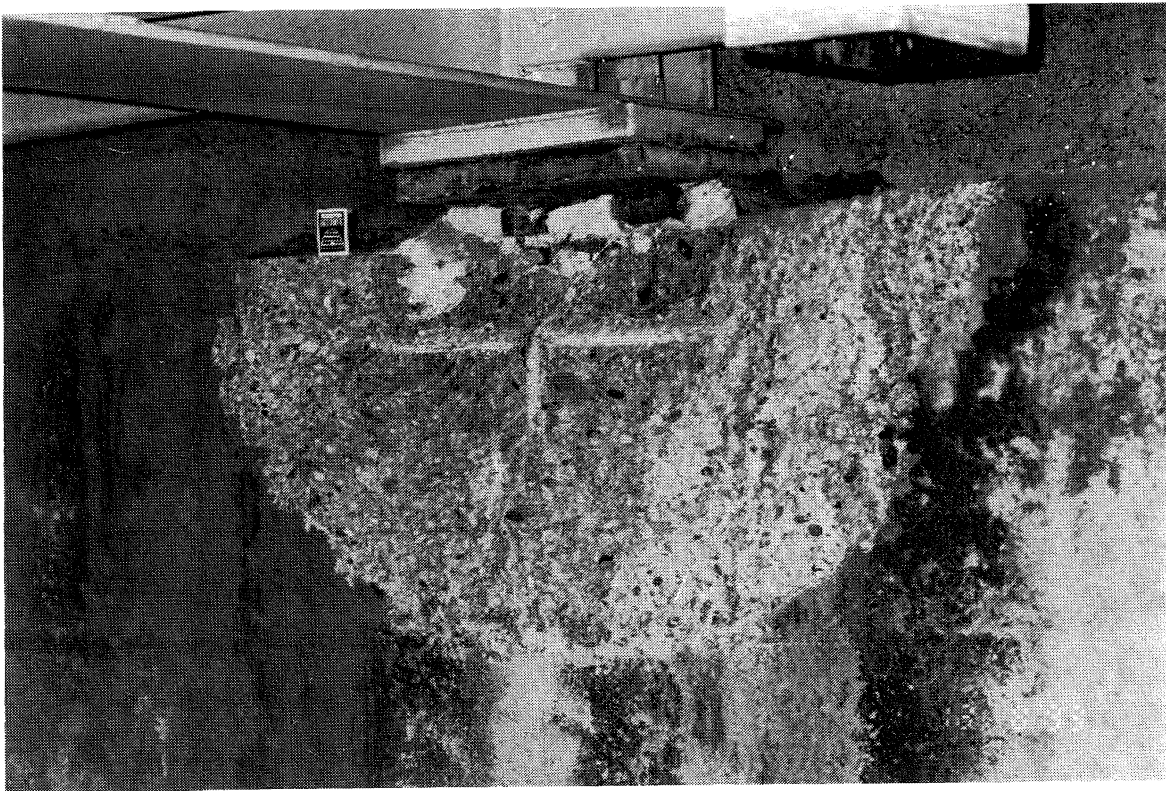


Figure 13 Close-up view of the spalling in the centre of Figure 12, illustrating the reduction of bearing area for the girder.

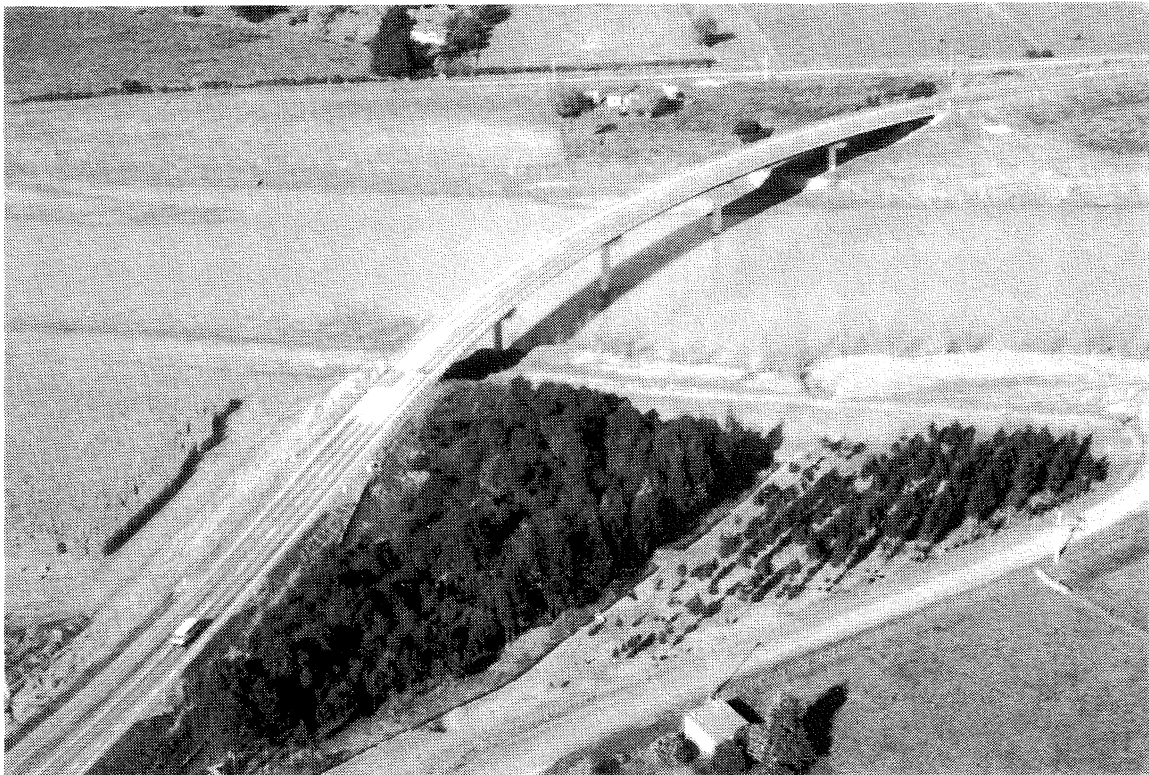


Figure 14 Aerial view of Kaiteratahi bridge, 1km north of Kaiteratahi. The box girder bridge structure was not damaged during the earthquake. The repairs to one lane of SH2 surface delineate the area of settlement on northern (near) abutment approach.



Figure 15 Typical small fall from a steep cut slope beside SH2, 3km north of Kaitaratahi. Fall volumes were typically up to 20m³, while other failures which involved bedrock and colluvium were up to 100m³.



Figure 16 Typical failure involving road surface on Ngakaroa Road, 5km east of Kaitaratahi. Slumping typically occurred on slopes between 15° and 20°, where there was either a veneer of colluvium above bedrock or fill materials.



Figure 17 Failure in shear of columns in the southwest wall of the abandoned three-storey freezing works built in about 1915 at Waipaoa. Disused since 1931, only the northwest wall of the building was not damaged.

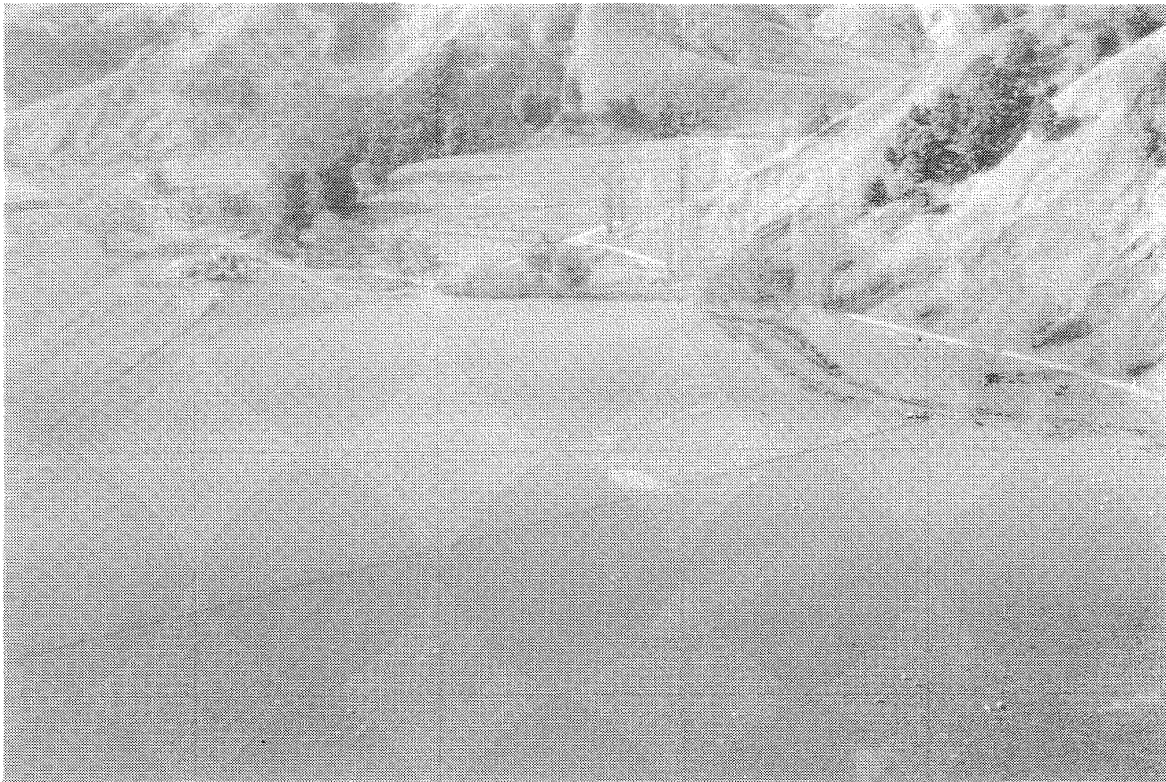


Figure 18 Aerial view of sand boils on eastern side of the Waipaoa River valley, 5km southeast of Te Karaka, showing variation in the trends of linear vents. Northern end of site 3 in Christensen (1993).

Figure 19 Typical sand boil, 3km south east of Te Karaka, showing linear vent and ejection of fine to medium sand. Boil 8 in Area 1 of Christensen (1993).



Figure 20 Cracking behind the stopbank on the right (west) bank of Waipaoa River, 2.5km north of Kaitaratahi. Close to a steep bank beside the river, the stopbank has settled by up to 300mm.



Figure 21 Small shallow landslide on steep (34°) northwest facing slope close to Newmans Road, 7km southeast of Te Karaka. The overall slope has scars from previous failures, typically those that have occurred in storm events such as Cyclone Bola.



Figure 22 Damage to top of steep west trending ridge crest, 2km east of Te Karaka. Note that soil has been thrown to one side of the crack indicating a significant vertical component of movement during the earthquake.



Figure 23 Aerial view of a 200m long earthflow 3km southeast of Te Karaka. Twin headscarps are visible in the colluvial debris at the base of steep slopes, and movement of the earthflow was down an 8° slope.