South Java Tsunami of 17th July 2006, Reconnaissance Report

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GNS Science Consultancy Report 2006/33
November 2006

BIBLIOGRAPHIC REFERENCE

Cousins, W. J.; Power, W. L.; Palmer, N. G.; Reese, S.; Tejakusuma, I.; Nugrahadi, S. 2006. South Java Tsunami of 17th July 2006, Reconnaissance Report, *GNS Science Report* 2006/33 p42.

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ISSN 1177-2425
ISBN 0-478-09955-X

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ABSTRACT

On 17th July 2006, about 200 km of the south coast of Java was inundated by a tsunami generated by an offshore earthquake of M_W 7.7. The worst hit area was the resort town of Pangandaran, where water depths of up to 5 m caused destruction of 3000 buildings, killed 400 people and seriously injured a further 350.

Early reports indicated shoreline wave heights of 3 to 5 m. Data on the impacts of tsunami of such heights are relevant to New Zealand because estimated 500-year wave heights for the most populated parts of New Zealand are in the range 2 to 6 m. Hence a joint New Zealand/ Indonesian reconnaissance team visited the damage area with the aim of acquiring data for calibrating models used to estimate inundations, casualty rates and damage levels in New Zealand. Such data are in short supply internationally. The main tasks were (a) to measure ground elevations and inundation depths along multiple transects across affected areas, using specialised GPS-based surveying equipment, (b) to observe levels of damage to buildings, infrastructure and vegetation for various water depths along the transects, and (c) to obtain data on casualty rates.

KEYWORDS

Tsunami, damage, casualties, inundation, run-up, Java, GPS surveying

1.0 INTRODUCTION

At 3:24 p.m. local time (08:24 UTC) on the 17th July 2006 a shallow earthquake of moment magnitude M_W 7.7 occurred approximately 240 km offshore of Java, Indonesia. It generated a tsunami that caused damage and casualties along a 200 km segment of the south coast of Java, with the worst hit area being the resort town of Pangandaran. Early reports suggested that there were about 500 deaths, 400 injuries, 300 missing and 50,000 displaced persons (Figure 1.1). The earthquake was sufficiently far from shore that it was not felt in the tsunami area, so that the damage and casualties were due to tsunami alone.

With a reported shoreline wave height of 3 to 5 m above sea level the tsunami appeared highly relevant to New Zealand. Estimated 500-year wave heights for the most populated parts of New Zealand are in the range 2 to 4 m for Whangarei, Auckland, Tauranga, Lower Hutt, Porirua, Kapiti, Nelson, Dunedin & Invercargill, 4 to 6 m for Napier, Wellington, Christchurch and Timaru, and 8 to 10 m for Gisborne (Berryman (Compiler) 2005). Hence it was decided that a reconnaissance team from New Zealand should visit the damage area with the aim of acquiring data for calibrating models used to estimate inundations, casualty rates and damage levels in New Zealand. The main tasks were

- to measure ground profiles and water (inundation) depths along multiple transects across affected areas near the port city of Cilacap and the resort town of Pangandaran, using specialised GPS-based surveying equipment,
- to observe levels of damage to buildings, infrastructure and vegetation for various water depths, and
- to obtain data on casualty rates.

New Zealand members of the reconnaissance team were

- Jim Cousins, William Power and Neville Palmer from GNS and
- Stefan Reese from NIWA.

They were joined in Indonesia by

- Iwan Tejakusuma and Saleh Nugrahadi from the Indonesian Agency for the Assessment and Application of Disaster Mitigation Technology (BPPT).

The team was in the damaged area from Sunday 30 July to Friday 4 August. Iwan Tejaksuma had visited the area in the week following the tsunami. An itinerary is given in Appendix 1.

A key activity was the use of dual-frequency GPS receivers for measuring ground profiles and inundation depths. The equipment essentially consisted of two GPS receivers, one a base station that remained at a fixed point throughout the survey, and the other a rover that was taken to the measurement points. Provided the distance between the two units was not too great, i.e. less than about 15 km, it could be assumed that the satellite signals received by each had experienced the same atmosphere conditions, and it then was possible to remove atmospheric and other systematic effects from the measurements. Positional accuracies of ±10 mm horizontal and ±30 mm vertical were readily achievable.

The rover unit was fitted with a laser range finder that could measure distances and angles to points within a range of about 50 m. This greatly simplified the task of obtaining the heights of water marks and other depth evidence left by the tsunami. We estimate that accuracies of the depth measurements were about ±30 mm.

The positional accuracies given above were relative within a particular survey, and became absolute only when linked to a reference such as a reliable bench mark. We were unable to find any suitable benchmarks in the survey areas, and so had to resort to a method using sea level measurements and tide tables.

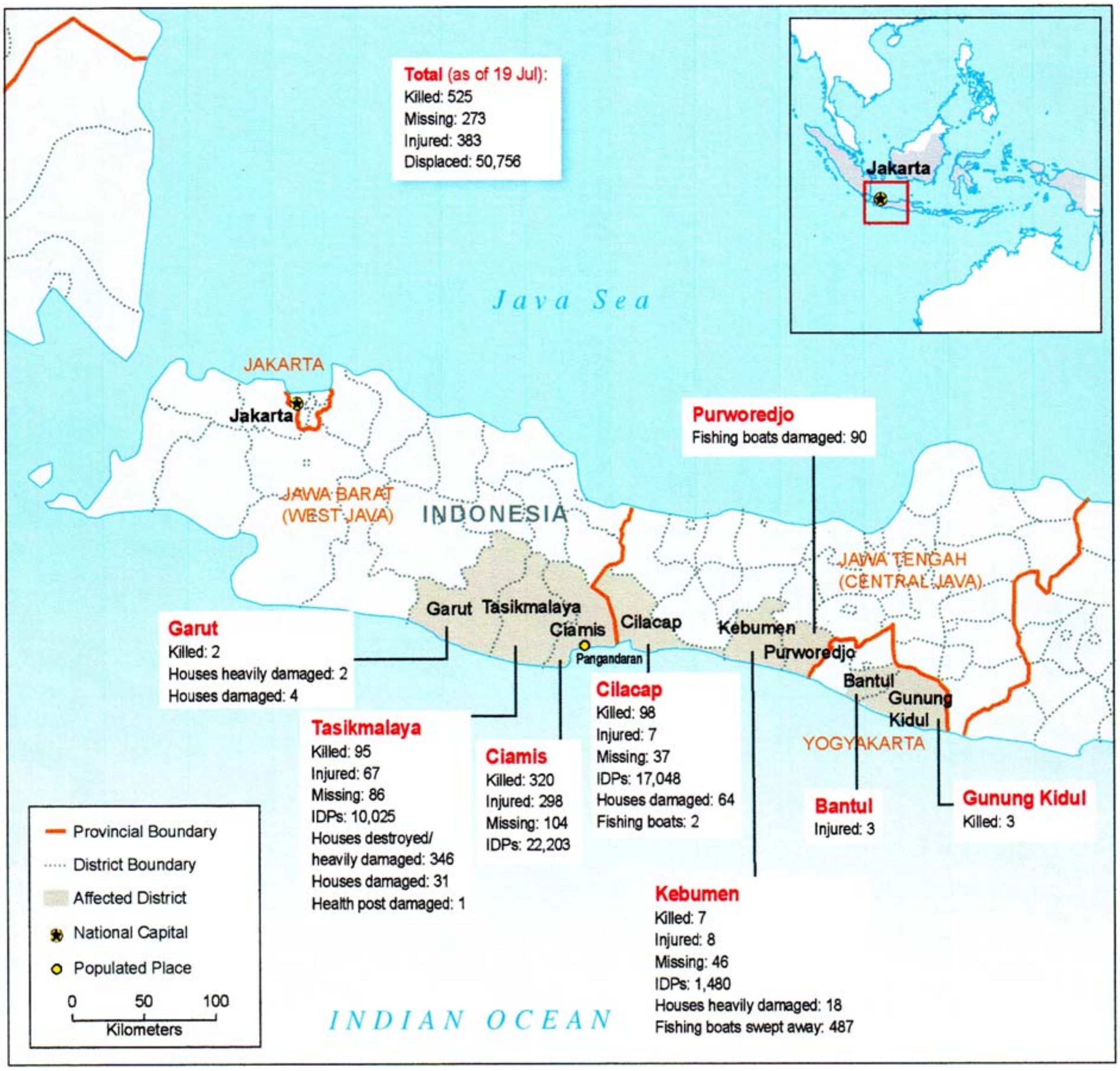

Figure 1.1 Report of 19th July 2006 from http://www.reliefweb.int/. Most of the displaced persons (IDPs) had returned to their homes by the time of our visit. We visited the Districts of Kebumen, Cilicap and Ciamis, spending most of our time near the resort town of Pangandaran.

2.0 DAILY RECORD OF ACTIVITIES AND FINDINGS

2.1 Sunday 30th July – Bulapesantren Beach (Kebumen District)

2.1.1 Damage

Bulapesantren was a straight, steeply sloping beach, several kilometres long, on the side of a broad sand dune. At the top of the dune there was one small brick building and many semi-permanent bamboo shelters (Figure 2.1.1). The tide was low at the time of our visit, but wet sand indicated that the preceding high-tide had reached the lowermost shelters. Occupants indicated that perhaps 0.5 m of water had flowed through the shelters at the time of the tsunami. (Eye witnesses from other locations stated that the tide had been low at the time of the tsunami). There appeared to be no significant tsunami damage, but given the nature of the structures it was difficult to tell. Some piles of contents could have been a result of tsunami action. There were no reports of casualties.

Figure 2.1.1 Semi-permanent shelters on Bulapesantren Beach.

2.1.2 Eyewitness Accounts

- Water depths reached 0.5 m at the buildings.

2.2 Sunday 30th July – Pantai Logending (Ayah) (Kebumen District)

2.2.1 Damage

Pantai Logending was a recreation area on flat ground adjacent to a very gently sloping beach. One side was bounded by a 50 m wide river mouth (tidal), and the other by hills. Most of the buildings were of semi-permanent wooden (bamboo) construction and were about 0.5 m above high-tide level (Figure 2.2.1). There was one brick toilet block.

Water depths appear to have reached about 1 m close to the beach, decreasing to about 0.6 m amongst the buildings. Apart from a few exceptions, the buildings appeared to have suffered little or no damage (Figure 2.2.2). Some were in use at the time of our visit. It is probable that most are occupied only when sufficient visitors are present. A short distance to the west there were several damaged shops and fishing boats.

We received no reports of casualties.

Figure 2.2.1 Semi-permanent buildings at Pantai Logending.

Figure 2.2.2 Typical damage to wooden buildings. A few were occupied, but most appeared to be vacant.

2.2.2 Eyewitness Accounts

- Water depths were about 0.5 to 1 m at the buildings
- There were no casualties

2.3 Monday 31st July – Widarapayung (Cilicap District)

2.3.1 Damage

Sixty-nine people died at Widaparayung, which was a recreational area adjacent to a gently-sloping beach (Figure 2.3.1). Before the tsunami there had apparently been several permanent houses and office buildings, several houses of semi-permanent materials, and several pools with associated toilet blocks and changing facilities. The pools and permanent buildings were brick with some reinforced concrete beams and columns. After the tsunami, only portions of a few buildings and the pools remained (Figures 2.3.2 and 2.3.3).

Figure 2.3.1 Overview of beach looking east (right image) and remains of brick buildings (left) at Widaparayung. Ground profile measurements were made here (Profile 1).

Figure 2.3.2 Remains of pools and nearby brick buildings about 50 m from the beach (left). The water depth was 3.5 m. The wooden building (right) appears to have been protected by sand ridges behind it. Sand marks on the inside of the walls indicated a depth of 1.5 m. The main structural damage was loss of windows and brick half-walls (700 mm high).

Figure 2.3.3 Foundations of brick buildings (left) and detail of wall construction (right).

The sand dune beneath the pool complex was about 150 m wide and rose to a height of about 4 m above mean sea level (msl) (Figure 2.3.6). The inland edge of the dune fell sharply to paddy fields about 1 m above msl, then a further 0.5 m to a sluggish river running parallel to the beach for several km. The tsunami flooded the paddy fields and river, and the subsequent rapid drainage had washed away the approaches to a bridge across the river (Figure 2.3.4). Inland of the river there were more paddy fields that had been lightly inundated up to about 50 m beyond the river, giving a total inundation distance of about 350 m. There were extensive deposits of fresh sand on the sand dune (Figure 2.3.5), often covering low vegetation and ground litter, and deposits of compacted sandy silt in the paddy fields between the dune and the river. The crops in those paddy fields had been destroyed.

Figure 2.3.4 Silt covered paddy fields inland of main sand dune, bounded by river running parallel to coast (left). Just visible in the centre of the image is a bridge, the approaches to which were damaged by water draining away after the tsunami (right). The bridge itself appeared undamaged. The crops in the paddy fields had been covered by sandy silt and totally destroyed.

Figure 2.3.5 There were extensive new deposits of sand over the coastal dune and paddy fields immediately beyond it. Distinct layering could be seen in places.

2.3.2 Eyewitness Accounts

- There was one large surging wave coming from the west. It reached the base of the fronds (*of a coconut palm about 50m from the beach, a depth of 3.5 to 4 m*) and appeared to be 0.5 – 1 m higher at the first palm from the beach (*implying about 4 – 5 m depth at the seaward edge of the dune*). This description was from a person who had been standing in front of his house when he saw the wave coming. His house was demolished. He escaped on his motor bike taking his wife and young son with him.
- The earthquake was not felt.
- The tsunami occurred at low tide, when the water was calm (about 16:30).
- There was no withdrawal of the sea before the wave arrived.
- A noise like a jet could be heard starting about 2 minutes before the waves arrived.
- There were three or four steps in the wave, each step building on the previous with little or no withdrawal between.
- There were more than 200 people in the area at the time, 69 were killed and more than 16 injured.
- There were more injuries than deaths *(which contradicts the previous account)*.
- There were fewer than 10 shops / kiosks near the pools.
- The whole process of inundation and subsequent withdrawal took about 15 minutes – according to a man who witnessed the tsunami from near the top of a palm tree (he remained dry throughout, but his brother in a smaller ~5-6m tree was soaked but survived).

2.3.3 Ground Profile and Inundation

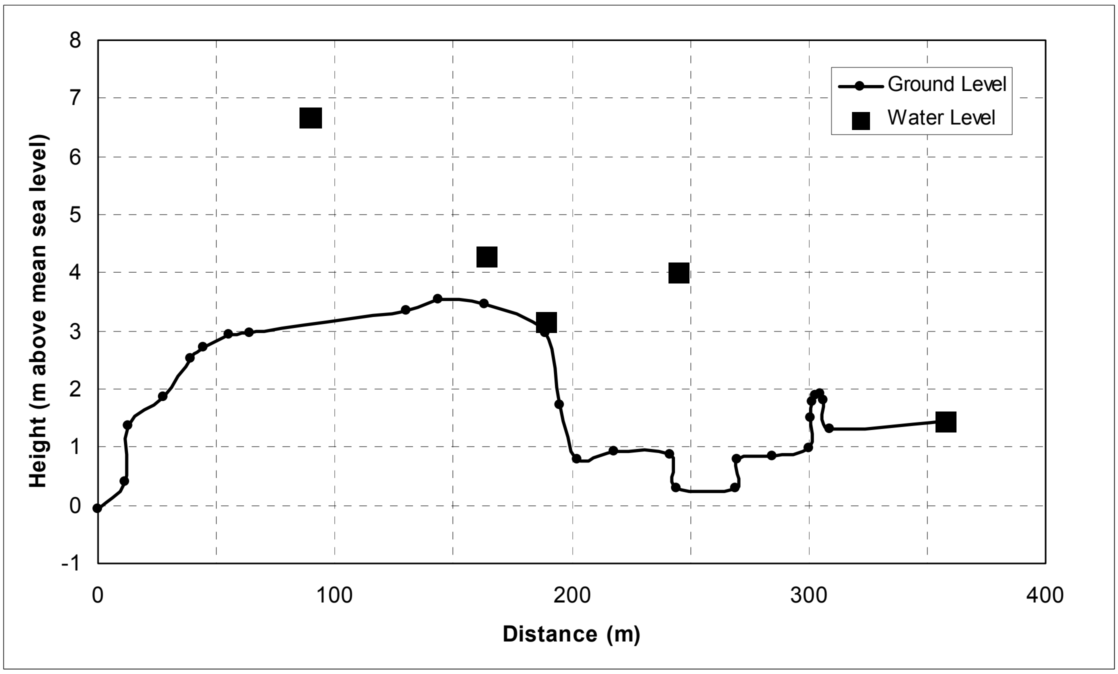

Figure 2.3.6 Ground profile 1, and estimated water levels at Widarapayung. Zero distance is the edge of the sea at the time of the profile measurement. At this location the beach was about 40 m wide. The water level estimate at 250m from the coast was from an eye witness account that the water reached the handrail on a bridge across the river behind the near-shore dune. It could have occurred during post-tsunami flood flow down the river rather than during the initial tsunami.

2.4 Tuesday 1st August – Pangandaran Peninsula (Ciamis District)

2.4.1 Overview of the Pangandaran area

Travel from Cilicap to Pangandaran occupied most of the morning. After booking into an undamaged and fully functional hotel about 300 m from the beach (well protected by dense urban construction between it and the beach) a permanent GPS base station was set up on the roof of a nearby house (Figs. 2.4.1 and 2.4.2). The locations of the hotel and GPS base station are marked (yellow star), as are the transect lines where elevation and depth measurements were made (red lines) (Fig 2.4.1).

For convenience, we refer to the narrow strip of land extending from Profile 4 southwards to the hill as the Peninsula.

Apart from the forested hill in the lower part of the map (Pangandaran National Park), the Pangandaran area is low-lying and very flat. West of the Peninsula, the beaches gently sloped up to about 3 m above msl. Inland of the beaches there was a further 1 m increase in elevation over about 300 m, often followed by a sharp decrease to low-lying paddy fields. The Peninsula itself was a little lower, being 2.5 to 3 m above msl. The west side was bounded by a gently sloping sandy beach, the east side by a gravel/sand beach and a sea wall.

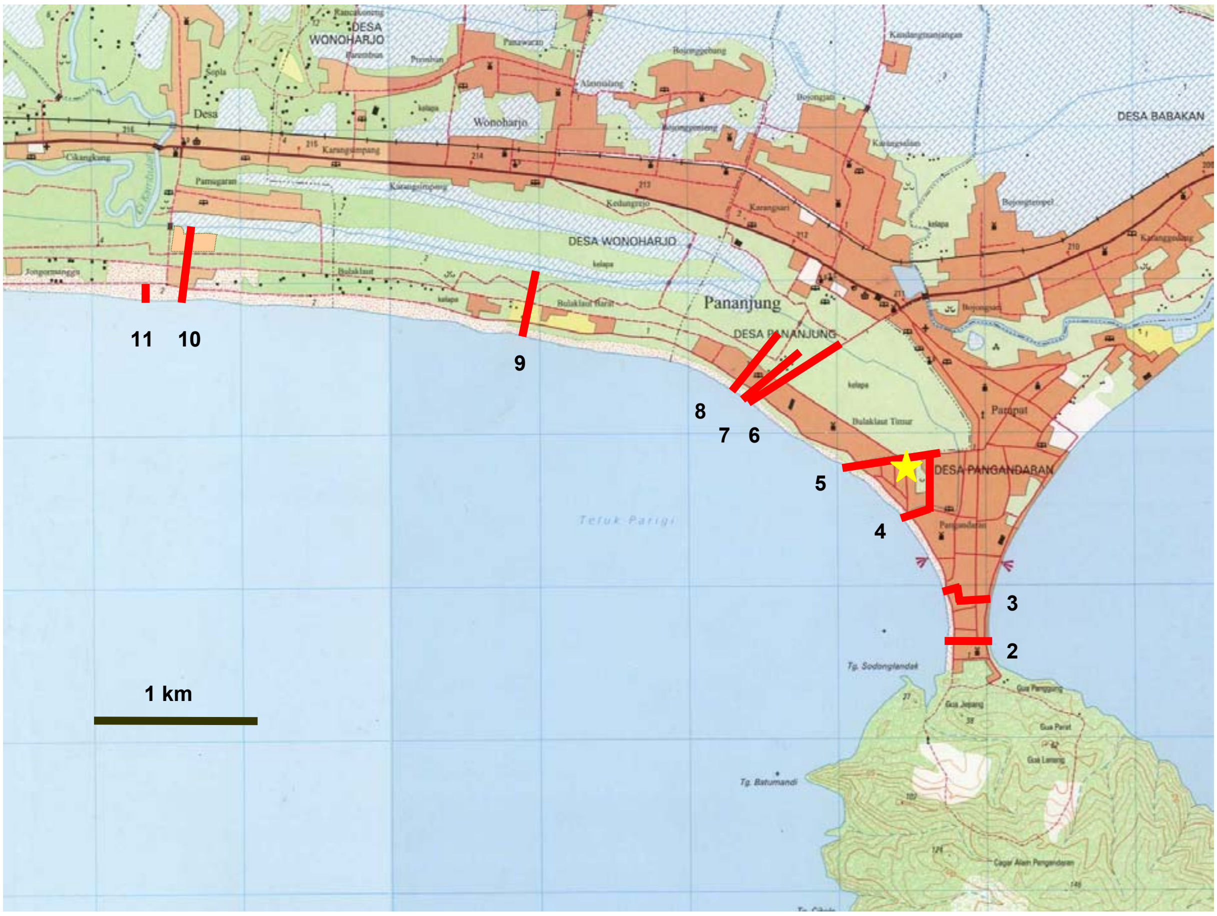

Figure 2.4.1 Pangandaran and vicinity. North is up, orange denotes built-up areas, green is tree covered areas (coconut plantations in the upper part of the map, forest on the hilly land in the lower part), and stippled blue is paddy-field. Red lines show the locations of ground profile measurements (numbered from east to west). The yellow star marks the location of the GPS base-station.

Figure 2.4.2 GPS base-station at Pangandaran (left), on the roof of a 1-storey brick house. The tsunami just reached our hotel which is at the top left of the image. The right hand image shows the view from the base-station roof towards the beach about 300 m away. Water depth in the alley was about 0.5 m, and damage to the nearby buildings was minor.

Typical construction of single-storied buildings in the hotel area was single-thickness brick with rudimentary reinforced concrete columns and beams. The columns were often 100 mm by 100 mm with four vertical strands of “No 8” wire reinforcing (c. 3 mm diameter). Ties were few. Most roofs were steeply peaked and clad with clay tiles. Dimensions of the bricks were about 160 mm x 80 mm x 40 mm. Older buildings were similar but without the reinforced columns and beams. There were relatively few wooden buildings, which were broadly similar to those shown in Figure 2.2.2.

Buildings of 2 or more stories often had more substantial columns, 200 to 300 mm in dimension, reinforced in the few cases where observation was possible with smooth bars of 12 mm diameter.

There was generally heavy damage to fragile buildings up to about 50 m from the beach, decreasing to zero by about 200m. Estimated water depths close to the beach were 3 to 4 m. On the Peninsula close to the hill, i.e. within about 300m, the damage area was much narrower, presumably because of sheltering provided by the hill. Water depths at the beach edge there were about 2.5 m.

2.4.2 Damage

Figure 2.4.3 View south along the western beach of the Pangandaran Peninsula (left), to the forested hill which starts at the end of the sandy beach. The beach was gently sloping and terminated at a step of about 0.5 m. Along the peninsula the beach was bordered by trees, within which there used to be a row of timber-framed shops/stalls. All that remained (right image) were the concrete-pad foundations. The debris had been removed before our arrival. The buildings were probably similar to those shown in Figures 2.2.2 and 2.3.2 (right). The start of Profile 3 is shown in the left image, Profile 2 (and the right image) were closer to the hill.

Figure 2.4.4 A group of relatively well-built tourist bungalows about 400 m from the hill and 25 - 90 m from the beach. There were no buildings between them and the coast. Those in the first row were heavily damaged (left image) (water depth about 2 m), while those in the third row (water depth < 1 m) had suffered little structural damage but were filled with sand and debris (right image). Ground Profile 3 was taken here. See also Appendix Figure A2.1.

Figure 2.4.5 View north along the sea wall of the eastern beach of the Pangandaran peninsula (left image). Where the blue fishing boats are parked there used to be a row of timber-framed shops/kiosks. All had been destroyed. Many of the houses across the road had suffered moderate damage to the lower storeys. A few had been destroyed. Wall punch-out (right image) was common, but the concrete columns generally had survived and so collapse was rare. There were some instances of roof damage that could have resulted from tsunami “splash” effects.

2.4.3 Eyewitness Accounts

- There were 700 occupants in the area, 60 of whom died.
- The tide was low when the tsunami struck.
- *(Near the sea wall along the eastern beach),* the wave was about 3 m deep.
- The water receded first.
- *(Lifeguard post at western beach)*, the wave was at the top of the first storey wall
- *(Lifeguard post at western beach)*, the first wave was 0.6 m above the floor, the second was almost to the ceiling *(which was 2.5 m above the floor)*.

2.4.4 Ground Profiles and Inundation

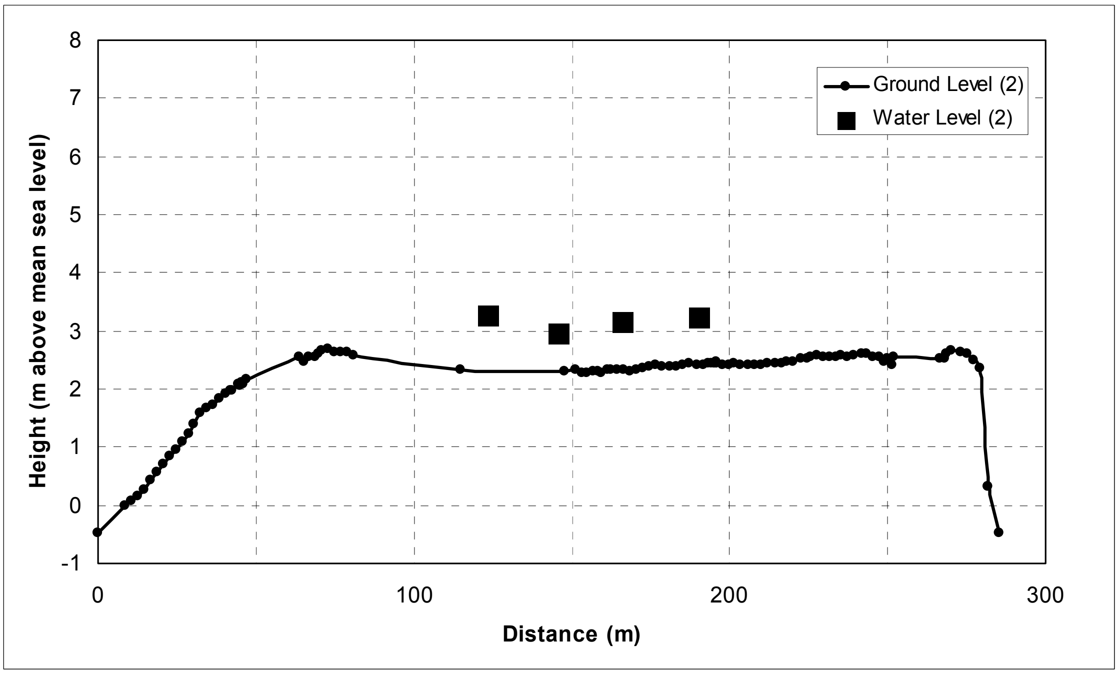

Figure 2.4.6 Ground profile 2 and estimated water levels on the Pangandaran Peninsula about 100 m north of the hill. The steep drop at the right-hand side is a sea wall. Wooden buildings adjacent to the beaches, at 70 m and 270 m (water depths probably c. 2m), were destroyed (e.g. Figure 2.4.3). Damage in the central part of the peninsula, 120 to 200 m, was minimal.

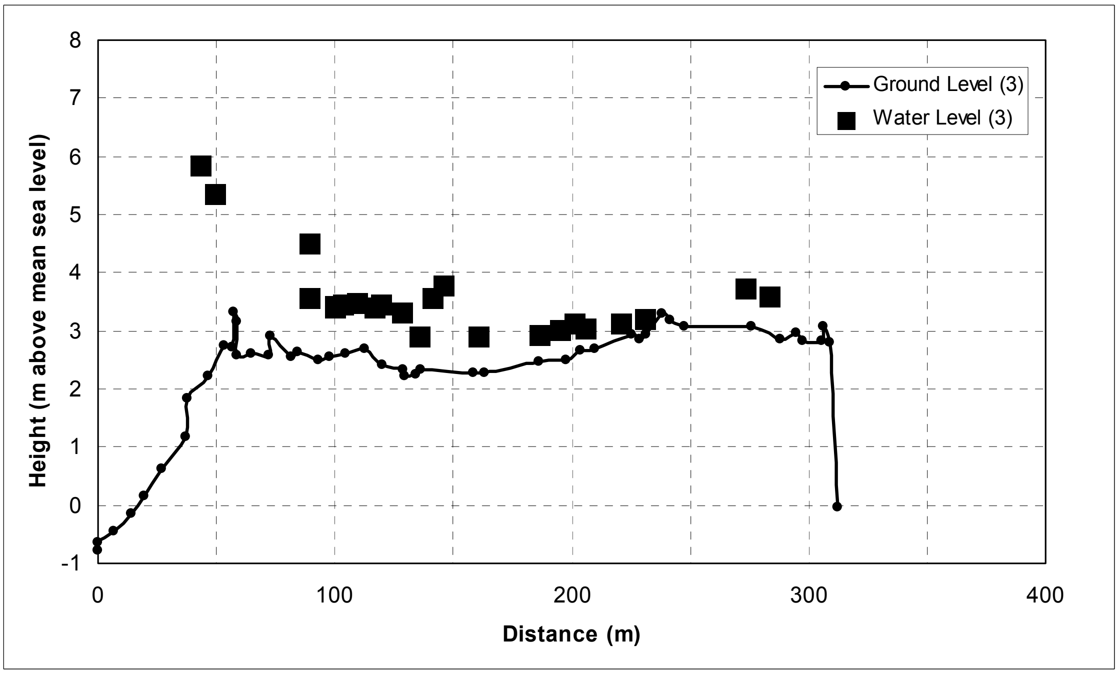

Figure 2.4.7 Ground profile 3 and estimated water levels on the Pangandaran Peninsula about 400 m north of the hill. The two points at 50 m were taken at a life-guard station at the edge of the beach. The vertical step at 60 m was a wall.

2.5 Wednesday 2nd August – Cikembulan, Wonoharjo (Ciamis District)

Three areas were visited, (1) Pangandaran peninsula (completion of transect 3), (2) Cikembulan Village (approximately 5 km west of Pangandaran), and (3) Wonoharjo, an orphanage complex containing about 15 buildings, all still standing, about 2.5 km west of Pangandaran.

2.5.1 Cikembulan: Damage

There were three distinctly different types of building in the village, (1) a group of three very well-made luxury houses very close to the beach (c. 20m distant), water depth c. 4.3 m, (2) a village of older brick houses at 70 – 200 m from the beach, water depth c. 3.5 m, and (3) a village of modern brick houses at 300 – 400 m from the beach, water depth c. 0.7m. The luxury villas were still standing and one, a well-constructed building of reinforced concrete, was only lightly damaged (Figures 2.5.1 and 2.5.2). The older brick buildings were almost totally destroyed (Figure 2.5.3), and the modern brick buildings about 150 m further inland were barely damaged at all (Figure 2.5.4). See Appendix Figure A2.2 for a plan view of the area and the ground profile routes.

Figure 2.5.1 One of three luxury villas close to the beach, viewed from the beach. It was very strongly built, with reinforced-concrete columns (c. 250 mm x 250mm), beams and floors, and walls of plastered brick infill. The reinforcement was 12 mm smooth bars, possibly 6 per column (bars were visible in one broken fence post), with stirrups at about 250 mm spacing. Damage was restricted to the loss of ground floor windows/walls that had been perpendicular to the direction of flow, the loss of most of the ground floor ceilings, collapse of concrete fences, and collapse of one balcony. The ceiling damage suggested the water had reached at least to the ceiling level. Ground Profile 11 was taken here.

Figure 2.5.2 Two relatively well-made villas adjacent to the grey villa shown in Figure 2.5.1. The construction was reinforced-concrete columns and beams with plastered brick infill. Columns were c. 100 mm x 100 mm and reinforcement was c. 8 mm smooth bar. The roof structure was bolted timber, clad with clay tiles. The left image is the view towards the beach and shows the debris field inland of the villas, and the right image the western end of the villas where two rooms appear to have been torn off. Four water storage tanks are visible in the left image, one (black) on top of the grey villa, and three on stands at the ends of the green houses.

Figure 2.5.3 The remains of older brick houses. The construction was brick, probably without concrete columns and beams. Most had been demolished. There were a few partially intact (right image), and a very few that were largely undamaged. In the left image some of the more modern and undamaged brick houses are visible behind a belt of coconut palms. Ground Profile 10 was taken here.

Figure 2.5.4 One of a group of about 60 very similar and relatively modern, well built, brick houses, exterior view (left) and garage interior view (right). A combination of strong construction and low water depth meant that damage was minimal. Ground Profile 10 passed through here.

2.5.2 Cikembulan: Eyewitness Accounts

- The concrete villa had been completed 2 weeks before the tsunami (Figure 2.5.1).
- The wave came as a wall, 4 m high. It looked like a normal wave, but larger. It broke at the coast then surged through the houses. This area had the highest waves, Pangandaran was not so high.
- The villa on the coast was designed with tsunami in mind.
- Most buildings in the area were single storey.
- Most were brick, a few bamboo.
- Of about 700 inhabitants, > 200 died, > 100 were injured, > 100 were missing.

2.5.3 Cikembulan: Ground Profile and Inundation

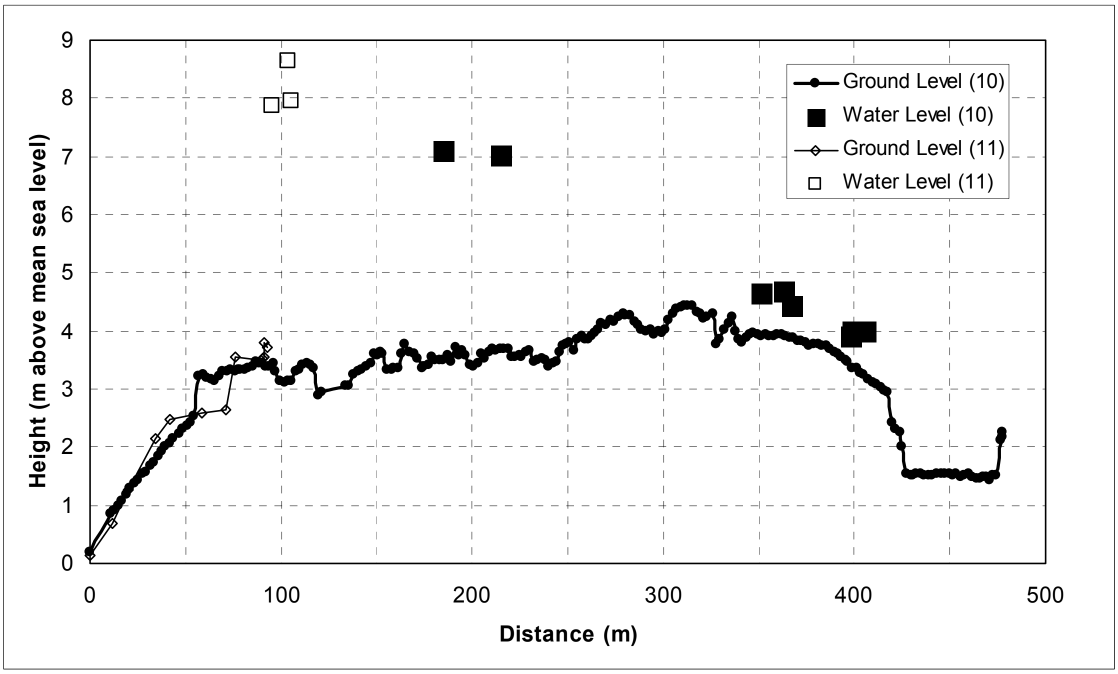

Figure 2.5.5 Ground profiles 10 and 11 and estimated water levels (10) through Cikembulan village and (11) in front of the luxury villa (Figure 2.5.1). The two profiles were about 100 m apart.

2.5.4 Wonoharjo: Damage

The Wonoharjo Orphanage contained houses, dormitories, offices, classrooms, a chapel and a gymnasium. All were standing, though many walls and windows had been punched out. The construction was reinforced concrete columns and beams, brick infill walls, timber roof framing, and clay-tile roof cladding. Many of the columns were about 200 mm x 200 mm in section, reinforced with c. 8 mm bars, and stirrups at c. 200 mm spacing.

The orphanage was studied because the standing buildings provided an opportunity for measurement of water depths. To the west of it there were extensive areas where previously there had been houses. The debris of the houses had been bulldozed away before our visit. Damage to the orphanage buildings is shown in Figures 2.5.6 to 2.5.8, and the former housing areas in Figure 2.5.9.

Figure 2.5.6 Houses (left) immediately across the road from the beach (right) at Wonoharjo Orphanage. The house closest to the beach had lost about one third of its wall area, most of which occurred in a wall perpendicular to the beach. There was extensive tile loss on the seaward side, but this was not a reliable indicator of water depth because of the likelihood of upwards splash against the seaward wall. There were no palm trees between the road and the sea. Ground Profile 9 was taken here.

Figure 2.5.7 A (probable) classroom, separated from the road by a 30 m wide paved area. About 50% of its wall area (mostly windows) had been punched out and there was significant ceiling damage (right).

Figure 2.5.8 Gymnasium with minimal damage (left) and chapel with rear wall damage (right).

Figure 2.5.9 Sites of what presumably had been brick houses, in the vicinity of Wonoharjo Orphanage. The area had been cleared by bulldozing before our visit. Orphanage buildings are visible in the right image.

2.5.5 Wonoharjo: Eyewitness Accounts

- None (the area was deserted)

2.5.6 Wonoharjo: Ground Profile and Inundation

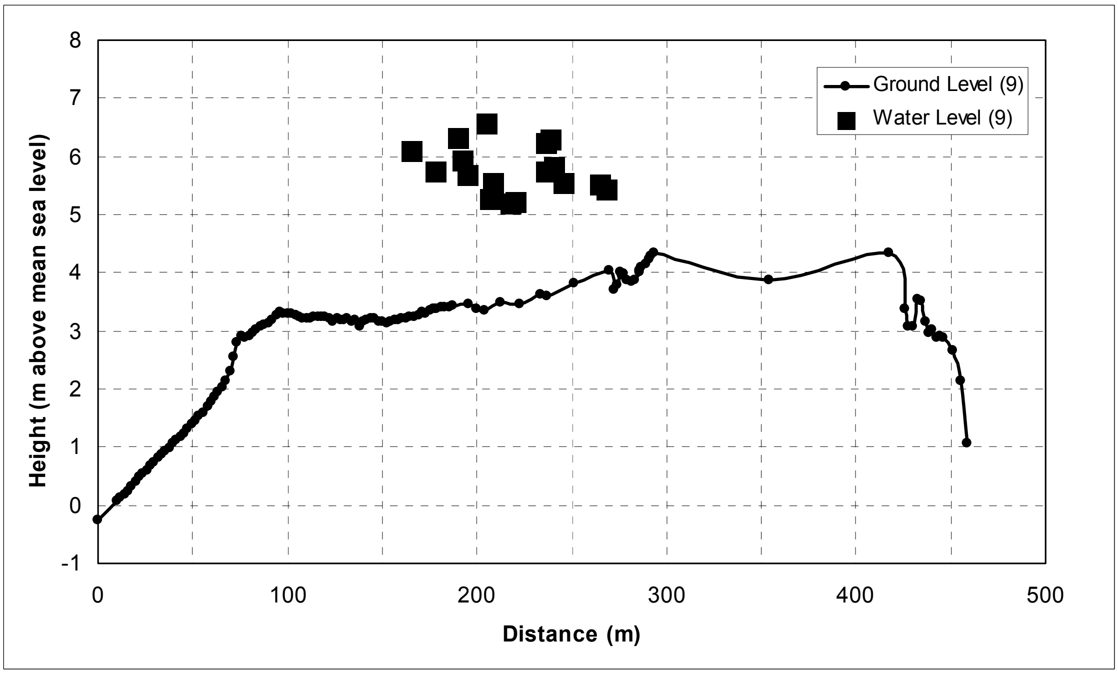

Figure 2.5.10 Ground profile 9 and estimated water levels through the Wonoharjo Orphanage. One reason for the apparent scatter in the water levels is that some of the buildings at 200 to 250 m were partly shielded by other buildings between them and the sea. This was reflected in reduced damage levels in the shielded buildings.

2.6 Thursday 3rd August – Ciliang, Pananjong (Ciamis District)

2.6.1 Ciliang: Damage

Ciliang Village was about 13km west of Pangandaran. The damaged area, Batuhiu, was located on a narrow sand dune between the beach and low-lying paddy fields (Figure 2.6.1). The sand dune was about 100 m wide and had a central crest that was 4 – 5 m above mean sea level. The houses were typically 1 – 2 m below the crest on the slope away from beach, hence were somewhat protected from the sea by the crest. Not all of the houses had been destroyed. Approximately 30% were still standing, and about half of those had suffered relatively little damage. Thus the additional 1 – 2 m near-shore elevation, compared with near-shore elevations near Pangandaran, may have significantly reduced the damage levels.

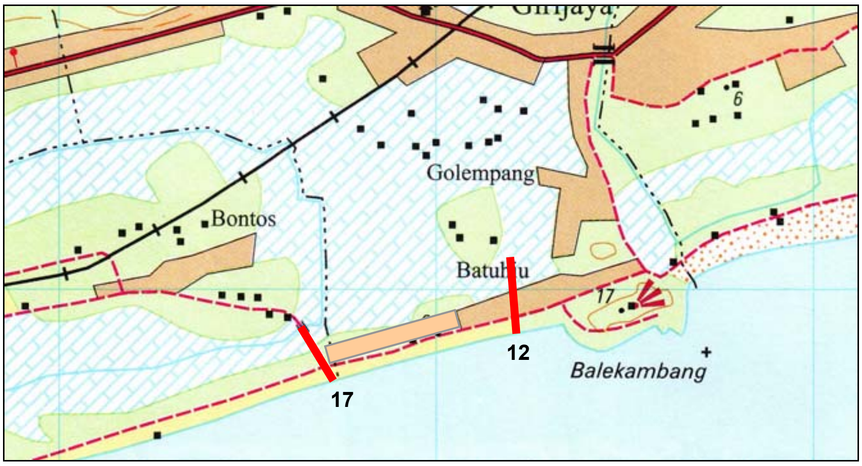

Figure 2.6.1 Map of Batuhiu area of Ciliang Village. Batuhiu occupied the inland side of a relatively narrow (about 100 m wide) sand dune between the sea and low-lying paddy fields. The road bordering Batuhiu ran along the crest of the sand dune. Ground profiles 12 to 17 were taken here, approximately equally spaced. See also Appendix Figure A2.3.

Figure 2.6.2 Relatively lightly damaged houses. Both had many broken windows (but not all) and had lost large portions of the rear walls. Both were brick. The blue one (left) had relatively substantial columns, presumably of reinforced concrete.

Figure 2.6.3 Moderately heavily damaged wooden house (left). Some walls were distorted, and the rear brick wall had been punched out. Other wooden houses had been totally destroyed (right) with just the concrete foundations remaining.

Figure 2.6.4 Foundation pad of a destroyed wooden house (left), partly covered by the remains of destroyed brick houses that had been between it and the sea. The road along the crest of the ridge is visible in the top left corner. To the right of the concrete pad were further remains of brick houses (right). Paddy fields inland of the ridge are visible in the upper right of the image. Some of the rice crop was being salvaged.

2.6.2 Ciliang: Eyewitness Accounts

- Village headman. There were 78 houses in the village before the tsunami. After the tsunami, 55 had been destroyed and 23 damaged. There had been approximately 318 people in the village (on average 4 persons per house). Eighteen were killed by the tsunami, 89 injured. The tsunami time was 4:10 pm. Women were cooking at the time. Most people were in their houses.
- The wave had a stepped appearance, 1m then 3m.
- There were three waves, the second was the biggest.
- The water depth was about 3 m at the top of the ridge.
- The water depth was about 2 m at the houses and 1 m in the paddy field. *(This informant had seen the wave approaching and had run to safety with his children, leaving his utility parked on the dune-crest road. It was later retrieved from the paddy field, about 250 m away.)*
- Some of the people who died were washed 300 m across the paddy field

2.6.3 Ciliang: Ground Profiles and Inundation

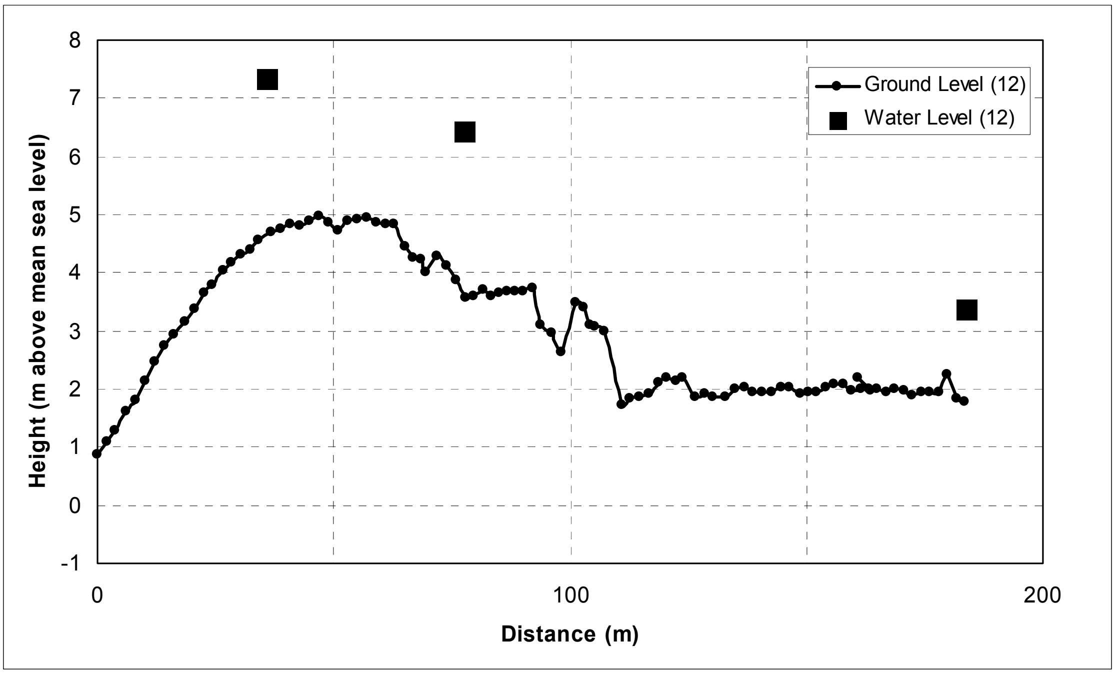

Figure 2.6.5 Ground profile and estimated water levels at the eastern end of Batuhiu. The road is near the crest of the ridge at about the 60 m mark. From the road the ground slopes down to about 3 m elevation, then falls steeply to paddy fields at 2 m elevation.

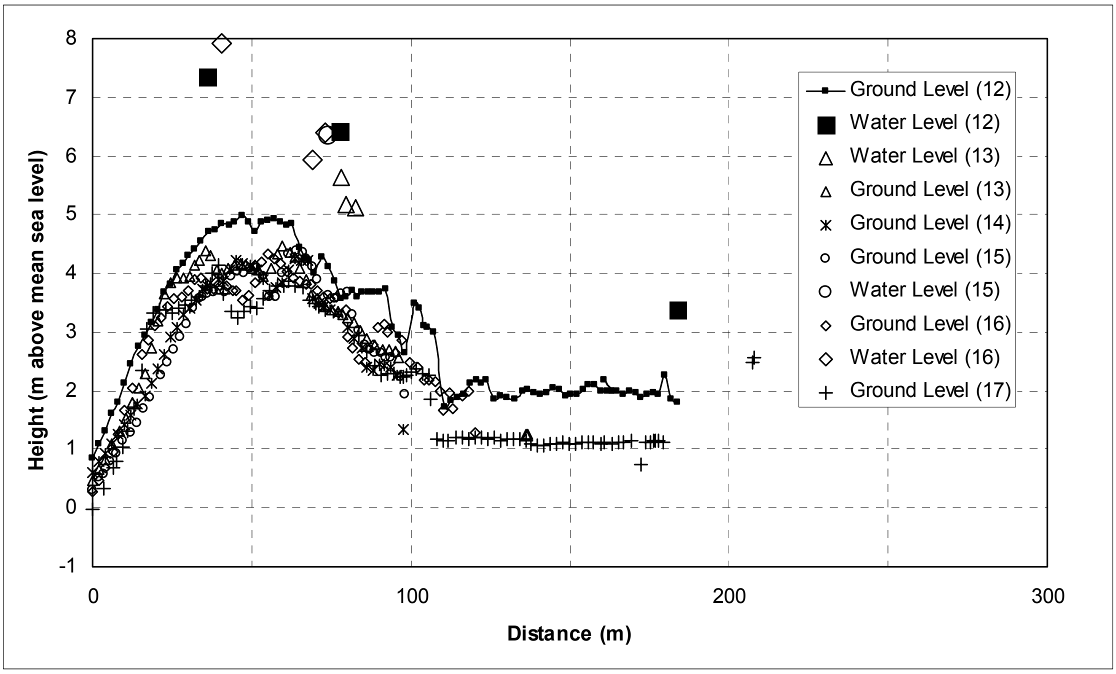

Figure 2.6.6 Ground profiles 12 -17 and water levels throughout Batuhiu. Profile 12 was at the easternmost end, profile 17 at the westernmost. There was a steady decrease in height of the ridge crest from east to west, by about 1 m. Profile 12 traversed the dune then crossed paddy fields to an "island" (Figure A2.3, p 37), while profile 17 traversed the coastal dune then parallelled a road through the paddy fields. The remaining profiles terminated at the inland edge of the coastal dune.

2.6.4 Pananjung: Damage

Pananjung Village was a residential area approximately 1 km west of Pangandaran. It appeared to have contained many older brick and wooden houses, nearly all of which had been destroyed, some relatively expensive and well-constructed houses, which had suffered moderate damage but were still standing, and several 2 – 3 storey hotels of reinforced concrete & brick infill construction that were relatively lightly damaged.

Figure 2.6.7 Hawaii Beach Hotel viewed from the beach (left). It was a well-built reinforced-concrete three-storey structure (columns and floors) with brick infill walls. Damage was restricted to punch-out of a few ground-floor walls and some ceiling damage. A few other well-built buildings in the area also had survived, but the majority of buildings had been destroyed. Part of the area had been bulldozed clear before our visit (right). Ground Profile 8 was taken here. The water depth was c. 3.5 - 4 m above ground level.

Figure 2.6.8 Tile damage on a house adjacent to the Hawaii Beach Hotel (left) (the house is visible in Figure 2.6.4 left). The roof eaves were fully sarked with timber (minimising splash effects) and so the tile damage is likely to be a good indicator of flow depth. Ceiling damage in the Hawaii Beach Hotel (right) indicated a similar flow depth.

Figure 2.6.9 A brick house immediately behind the Hawaii Beach Hotel was badly damaged (left), but had not collapsed, whereas other houses just a few metres away had been destroyed (right). Presumably the survivor had been shielded by the Hawaii Beach Hotel and another strong three-storey hotel visible behind it. Ground Profile 8.

2.6.5 Pananjung: Eyewitness Accounts

- Manager of the Hawaii Beach Hotel – was looking out to sea when the tsunami arrived – gathered staff and guests and ran upstairs. The wave broke amongst the palm trees between the hotel and the beach. The depth was about 6-7 m at the edge of the palm trees *(about 10 m away across the road in front of the hotel)* and about 3.5 m at the hotel – no water reached the first floor. The water damaged the ceilings of the hotel. The first (smaller) wave was heading north-east, the second (larger one) came straight in. It was black.

2.6.6 Pananjung: Ground Profiles and Inundation

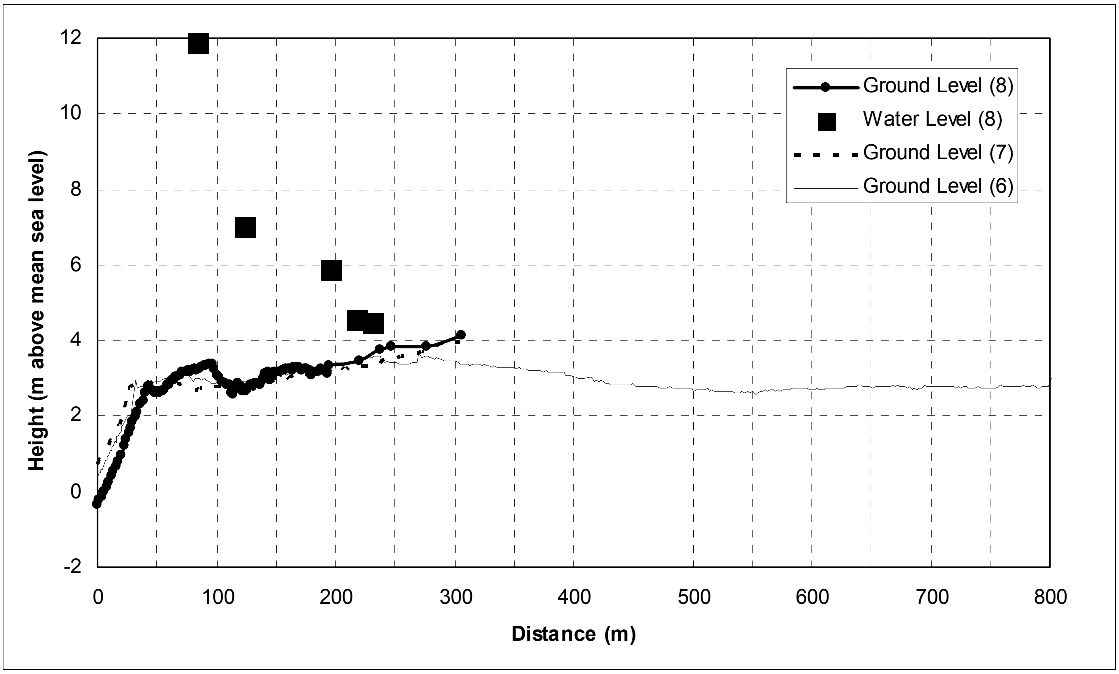

Figure 2.6.10 Ground profiles and estimated water levels through Pananjung Village. Profile 8 was just west of the Hawaii Beach Hotel, profile 6 was along a main highway approximately 200 m east of the hotel, and profile 7 was between the two. The water height of 12 m (above mean sea level – depth about 9 m above ground level) was an observation made by the manager of the Hawaii Beach Hotel in relation to palm trees between the hotel and the sea. It is much higher than all other estimates and so, assuming that it is as reliable as the others, must have been a localised phenomenon.

2.7 Friday 4th August – Pangandaran (Ciamis District)

2.7.1 Damage

Two profile measurements (4 & 5) were made in the vicinity of the GPS base station in Pangandaran, one along a street running nearly east-west and one at right angles to it. Damage was heavy in the immediate vicinity of the beach but had decreased to near zero a further 50 m inland. The seaward end of profile 4 is visible in Appendix A2.1. The white-roofed structures close to the beach (Appendix A2.1) had totally disappeared (Figure 2.7.1) by the time of our visit. Presumably they had been shops of semi-permanent wooden construction.

Figure 2.7.1 Site of a row of semi-permanent shops along the western beach of Pangandaran Village (left). All that remained were the concrete foundation pads. Image at the right shows a lifeguard station at the same location. There was considerable damage to the low wall of the upper storey – more than seemed reasonable for water pressure alone. Impact by fishing boats (Figure 2.4.5) carried by the tsunami wave was a probable cause.

Figure 2.7.2 Near the sea end of profile 4. Buildings adjacent to the street had been destroyed, but others equally close to the sea had survived apparently with minor damage only. The water depth was about 2.5 m.

Figure 2.7.3 A mix of timber and brick buildings adjacent to those of Figure 2.6.2 (left). Hold-down detail for post of wooden shop (right).

Figure 2.7.4 Pangandaran village – buildings about 120 m from the sea on profile 5. Buildings with reinforced concrete columns had suffered much less damage than those without. The two-storey building in the left image was under construction. Note the upright power pole in front of it. Damage to poles was rare.

Figure 2.7.5 Interior of a well-constructed hotel (left) and column detail (right). The worst structural damage, the minor buckling of two columns, appeared to have been caused by boat impact. The remains of the boat were in the foyer of the hotel (left).

2.7.2 Eyewitness Accounts

- The wave was c. 7 m on the beach, the water receded first about 400 m, with a sucking sound, the first wave (3m) reached the road, stopped, receded somewhat, then some seconds later the large wave arrived, with a roar like a jet, and black. *(This informant had been riding his bicycle along the street adjacent to the beach when the tsunami arrived)*.
- The life-guard station at the end of the road (profile 5) was washed away.
- An eye witness fleeing the wave on his motor-cycle was caught by the wave – he claimed to have been travelling at 80 km/h.

2.7.3 Ground Profiles and Inundations

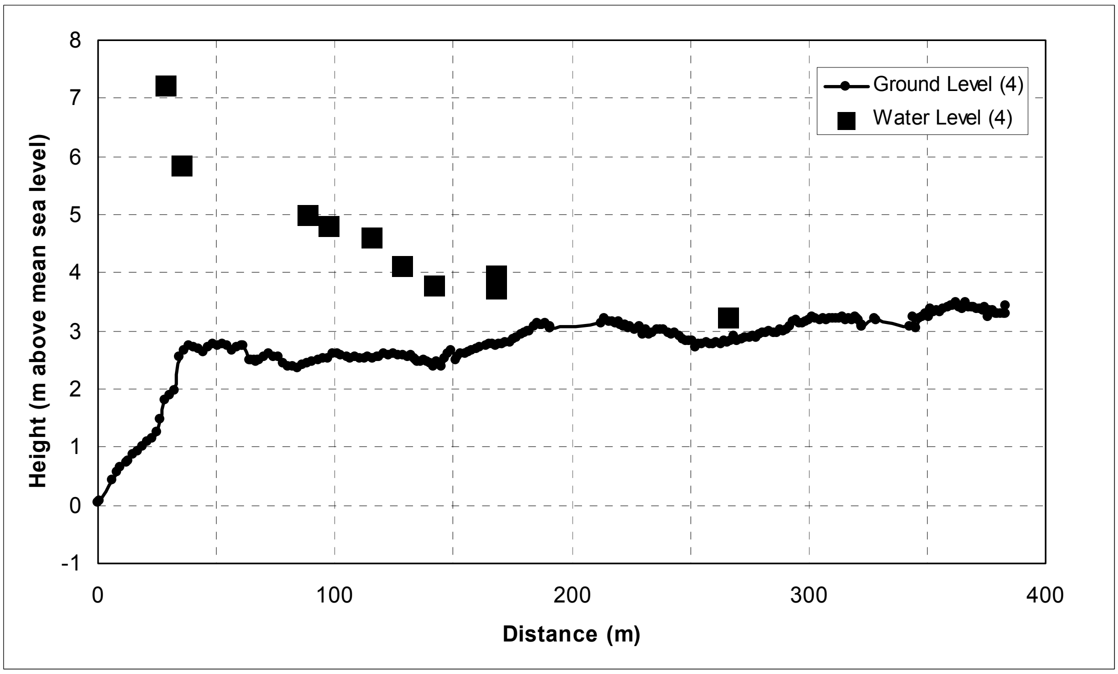

Figure 2.7.6 Ground profile 4 and water levels in Pangandaran Village. The two left-most measurements were taken on the blue lifeguard station of Figure 2.7.1 and probably bound the true water level. The site of former shops in the same figure was at a distance of 50 m.

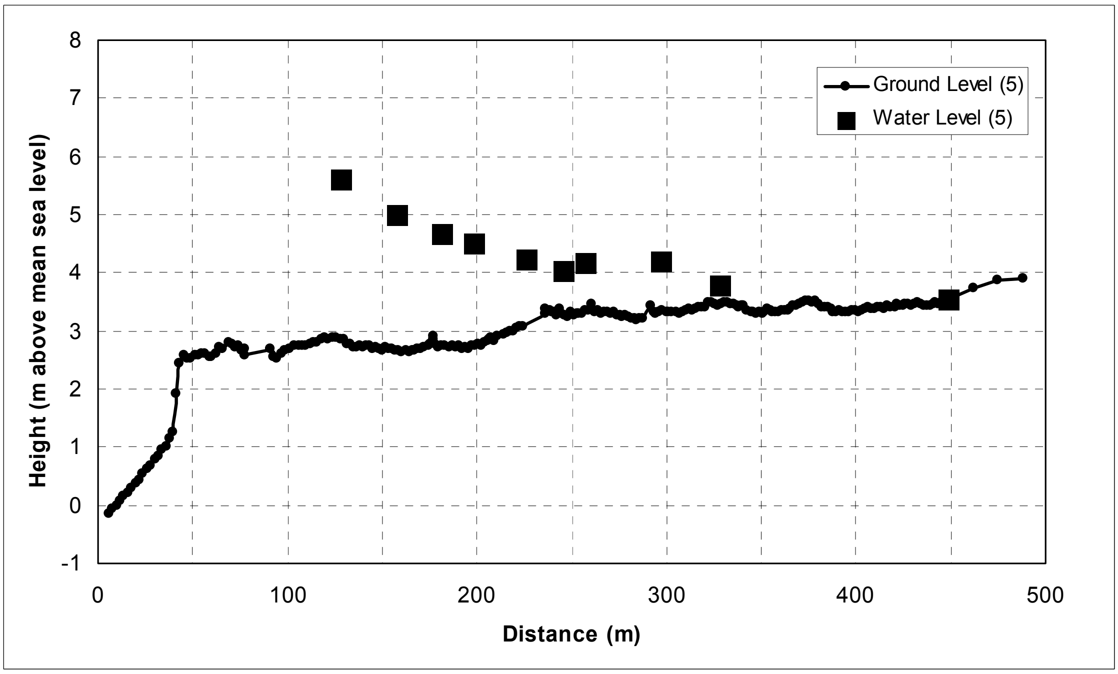

Figure 2.7.7 Ground profile 5 and water levels in Pangandaran Village.

3.0 SUMMARY OF BUILDING DAMAGE OBSERVATIONS

The main features of the damage to buildings are as follows:

Brick without reinforced concrete columns

- single storey, houses and shops
- single-skin brick walls, often plastered both sides
- 2.5 m of water – 70% of buildings destroyed, 30% lightly to heavily damaged, probably repairable
- 3 to 4 m of water – essentially total destruction, parts of a few buildings remained upright, but mostly not repairable

Timber

- single storey, houses and shops
- post and beam construction, 100 mm x 100 mm posts at c. 3 m spacing, posts attached to concrete foundations with light metal tags, light and flexible walls
- shops were classed as “semi-permanent” construction
- ≤ 1 m of water – light to moderate damage
- 2.5 m of water – 70% destroyed, 30% lightly to heavily damaged, probably repairable
- 3 to 4 m of water – essentially total destruction

Brick with reinforced concrete columns

- one and two storeys, houses and shops
- single-skin brick walls, often plastered both sides
- 3 to 4 m of water – remained standing, though often with large holes punched through the walls, which may have contributed to their survival by minimising flow resistance

Robust houses, hotels and shops

- often two or more storeys
- single-skin brick walls, often plastered both sides
- reinforced concrete columns of at least 200 mm x 200 mm, 4 to 6 bars of 8 to 12 mm reinforcement
- 3 to 4 m of water – holes often punched through walls of ground storey, no apparent damage to reinforced concrete frames (unless impacted by missiles, in this case fibre-glass fishing boats, carried by the wave)
- upper storeys untouched and so provided refuge to people
- overall damage levels usually low

4.0 DAMAGE TO INFRASTRUCTURE

4.1 Roads and Bridges

Few instances of physical damage were observed, even though we traversed many kilometres of roads that had been crossed by 3 m of water. The most serious instance was at Widaparayung (Figure 2.3.4), and probably was due to scouring of sandy soil both by the incoming tsunami and by subsequent drainage of water along a river channel. We saw no damaged bridges. Most were either too far inland or too elevated to have been damaged.

Clean-up costs are likely to have been significant, however. Given the amount of deposited sand up to 100 m from the coast, it is probable that the roads near the coast were covered by at least 100 mm of sand after the tsunami. The roads had been cleared by the time of our visit (e.g. Figures 2.7.2 and 2.7.4).

4.2 Poles (and Trees)

Power and phone poles withstood the tsunami well. A few leaning poles were noticed, but the vast majority were upright and appeared completely undamaged. Poles are visible in Figures 2.4.2, 2.4.5, 2.5.6, 2.5.8, 2.5.9, 2.6.7, 2.7.1, 2.7.2 and 2.7.4. A few coconut palms had been uprooted, but the vast majority of palms and trees appeared unharmed.

4.3 Water supply

Pangandaran Village appeared to have reticulated water, which was functional at the time of our visit, but the outlying villages relied on a combination of wells and rain water (Figure 2.5.2 - left). Bottled water was widely used for drinking. The wells close to the coast had been contaminated by salt water and were unusable. Most wells were surrounded by circular walls about 500 mm high (Figure 2.5.3 - right), which in the areas of significant structural damage to houses will have been overtopped by 1 to 3 m of water.

4.4 Sewage disposal

There was no sewer system in the area. The main method of disposal was septic tank. We observed a few septic tanks that had lost their coverings, but only in locations where houses had been destroyed.

4.5 Storm-water disposal

There was no piped system for disposal of storm-water. In Pangandaran there were surface channels up to 1 m wide by 1 m deep along a few roads. They were being emptied of sand at the time of our visit.

4.6 Sea walls

There was a 3 m high sea wall along the eastern beach of the Pangandaran Peninsula. It had failed in a few places, but the damaged length probably amounted to less than 5% of the total length.

4.7 Rail

There were no rail facilities within 1 km of the coast in the areas that we visited.

4.8 Port Facilities

The major port of Cilicap was within the tsunami zone, but had been screened from the tsunami by an island.

5.0 CASUALTIES

Detailed statistics on casualties and damage in the Ciamis District had been collected by the authorities, and were kindly provided to us. Table 5.1 lists the casualty numbers as at 3rd August 2006, 17 days after the tsunami.

Table 5.1 Details of casualties in the Ciamis District. The villages we visited are shaded. Blanks and dashes are as per the original data.

Area and Village	Deaths	Severe Injuries	Light Injuries	People Missing	Refugees
Kalipucang	**16**	**6**	**22**	**0**	**228**
Ds [(1)] Bagolo	12	6	11	-	
Ds Patra Pinggan	4		10	-	
Ds Pamotan	-		1	-	
Pangandaran	**183**	**33**	**85**	**11**	**1446**
Ds Pangandaran	41	2	3	-	
Ds Pananjung	32	12	7	-	
Ds Wonoharjo	74	-	34	-	
Ds Babakan	36	19	41	-	
Sidamulih	**65**	**9**	**13**	**-**	**447**
Ds Cikembulan	52	5		-	
Ds Palaten	3			-	
Ds Sukaresik	10	4		-	
Parigi	**31**	**17**	**99**	**-**	**176**
Ds Ciliang	18	11	95	-	
Ds Cibenda	5	2	1	-	
Ds Karangbenda	1			-	
Ds Karangjaladri	4	4	1	-	
Ds Selasari	3		2	-	
Cijulang	**16**	**11**	**2**	**-**	**115**
Ds Batukaras	16	11	2		
Cimerak	**102**	**30**	**5**	**4**	**1150**
Ds Cimerak	2			-	
Ds Legokjawa	52	13		-	
Ds Kertamukli	4	9		3	
Ds Sindangsari	1				
Ds Masawah	43	8		1	
RSUD Banjar	1	30		-	
Grand Totals	**414**	**136**	**226**	**15**	**3562**

Note 1: Ds is Desa (Village)

One of the aims of the reconnaissance was to determine the rates of deaths and injuries as functions of water depth and type of building. It was not possible to achieve that aim with precision (a) because we did not know precisely where people were at the time of the tsunami, (b) in most locations the buildings were not of uniform type, and (c) the water depths changed rapidly over relatively small distances. However, it was possible to make some progress by making reasonable assumptions about locations of people and occupancy rates of buildings.

As well as the casualties data of Table 5.1 we also were provided with numbers of damaged buildings, classified by use and severity of damage (the latter being subdivided into totally damaged, badly damaged and lightly damaged). A first assumption is that all deaths and injuries occurred in or near totally and badly damaged buildings. For four villages, Ciliang, Cikembulan, Wonoharjo and Pananjung, this is very reasonable assumption. In all four cases (a) the groups of houses were laid out parallel to the beach rather than perpendicular to it, (b) there were large gaps between them and other groups of buildings (Figure 2.4.1), and (c) the level of damage was severe throughout (e.g. Figure 2.5.3). In the case of Cikembulan we note that there were two main groups of buildings, a destroyed group at 70 – 200 m from the beach, and an undamaged group at 300 – 400 m (Appendix 2, Figure A2.2). We are assuming that the casualties were restricted to the destroyed group. For the other three the closest groups of buildings were too far inland to be reached by the tsunami.

In Pangandaran the band of severe damage was not more than about 50 m wide, typically comprising a row of shops along the beach plus one or two rows of buildings separated from the shops by the beach street (Appendix 2, Figure A2.1).

Given the above assumptions it is then possible to assign water depths to each of the areas of heavy to total damage using the ground profiles and water depths plotted above.

Finally it is necessary to estimate occupancy rates for the damaged buildings, for 4 p.m. on a Monday afternoon (Table 5.2). Various assumptions were needed, as follows:

- houses – one woman at home cooking, plus one child
- offices, mosques – arbitrary but seemingly reasonable numbers
- schools – staff only present at 4:00 p.m.
- hotels – mostly staff on ground floor
- shops – most assumed to be used only during holidays, hence vacant at the time of the tsunami (in line with observations at Pantai Logering)

It was also assumed that for every three persons indoors there was one additional person outdoors and nearby (children, workers, shoppers, tourists, fishermen). Not included were paddy-field workers, because the paddy-fields were usually further from the coast than the damaged houses. The resulting death and injury rates are plotted in Figure 5.1 as functions of water depth, along with data from earlier tsunami (Berryman (compiler) 2005, Sanders (compiler) 2006).

Table 5.2 Assumed occupancy rates for buildings that were heavily or totally damaged.

Use Category	Occupancy Rate (persons per building
Offices	5
Schools	5
Mosques	5
Houses	2
Hotels (ground floor)	5
Shops	0.1

Table 5.3 Estimated numbers of people in or near buildings that were heavily or totally damaged, (a) for villages for which estimates of water depth were available, and (b) for the Ciamis District as a whole. The water depth for the Ciamis District is an assumed average.

Village	Occupants	Dead + Missing	Injured	Death Rate	Injury Rate	Water Depth (m)
Ds. Pangandaran	792	41	5	0.05	0.006	2.75
Ds. Pananjung	709	32	19	0.05	0.03	4.0
Ds. Wonoharjo	668	74	34	0.11	0.05	3.5
Ds Cikembulan	322	52	5	0.16	0.02	3.5
Ds Ciliang	312	18	106	0.06	0.34	2.3
CIAMIS DISTRICT	4586	428	332	0.09	0.07	c. 3

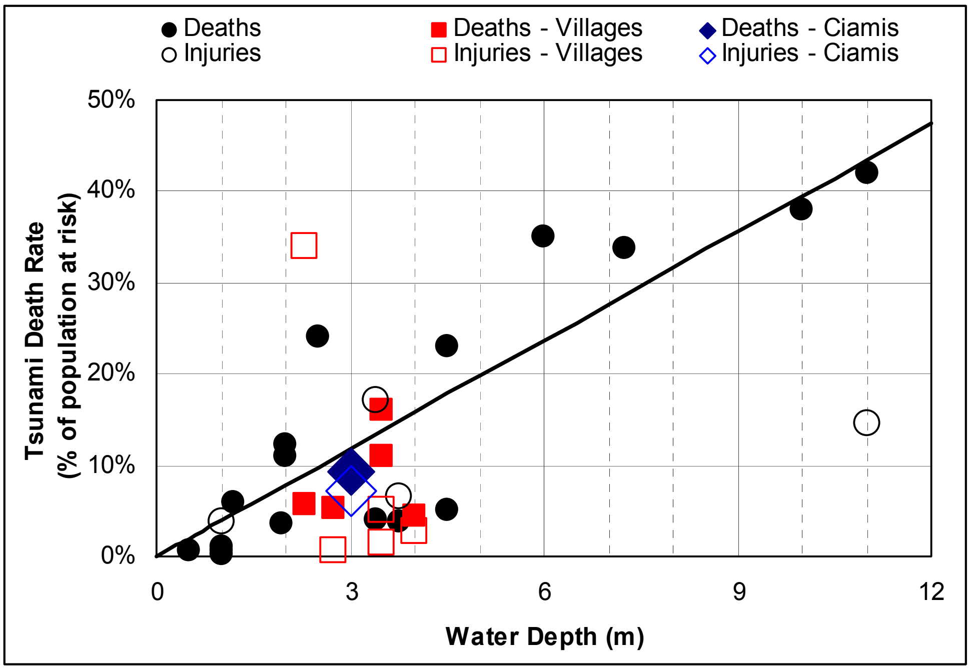

Figure 5.1 Effect of water depth on death rates (solid symbols) and injury rates (open symbols) due to tsunami. Squares are results for individual villages from the Java Tsunami of 17th July 2006, trapezoids are approximate overall results for the Ciamis District, and circles are data from other tsunami. The black line is a best fit to the pre-Java death rate data.

6.0 CONCLUDING REMARKS

The reconnaissance mission achieved all of its objectives. The surveying equipment, though cumbersome to transport, worked well in the field and has given data that we believe is unique and which will prove invaluable for calibrating tsunami inundation and loss models. Analysis of the data is ongoing and further results will be published in due course.

The one significant difficulty we encountered was in obtaining suitable reference points for the elevation measurements. There were many benchmarks in the areas that we visited, but obtaining reference elevations for them was difficult. GPS elevations are based on an

ellipsoid (i.e. an idealised elliptical model of the earth) and not the geoid (a gravity-based model that is closely related to sea levels and tides). Deviations between the two models can accumulate to several metres over horizontal distances of 10 - 20 km, and indeed did in the vicinity of Pangandaran, which meant that we were unable to use an accurately known tide gauge at the Port of Cilicap as a reference for our transects.

The presence of knowledgeable local scientists was vital to the success of the mission. They were able to take us directly to areas of interest, were aware of bureaucratic requirements and local customs, knew where to find accommodation, and were able to converse with the local people.

The scale of the disaster was about right. It was large enough that the damage was highly relevant to New Zealand, but not so large as to make travel difficult in the affected area.

The timing of the visit, about 12 days after the event, also was about right. Although a great deal of clean-up had taken place before our arrival, the delay meant that the state of emergency had been lifted, visitors were permitted, most of the local populations had returned home and were back at work, and accommodation and support were available.

7.0 ACKNOWLEDGEMENTS

We thank the many people who willingly gave assistance, advice and encouragement, particularly during the difficult period of organisation of the project. Their support was greatly appreciated. We also thank the organisations who contributed to the funding of the trip, viz. FRST (New Zealand Foundation for Research Science and Technology), GNS Science, NIWA and the EQC (New Zealand Earthquake Commission). Finally, we acknowledge the efficient and helpful support of the various Indonesian institutions that we interacted with, including the Embassy of Indonesia in New Zealand, the Agency for the Assessment and Application of Disaster Mitigation Technology in Indonesia (BPPT), and the District Authority of Ciamis District.

8.0 REFERENCES

Berryman, K. (Compiler), 2005. “Review of Tsunami Hazard and Risk in New Zealand”. Institute of Geological & Nuclear Sciences, Client Report 2005/104, Wellington.

Saunders, Wendy (compiler), 2006. “National population casualties resulting from tsunami in New Zealand”. GNS Science Consultancy Report 2006/107, Institute of Geological & Nuclear Sciences, Lower Hutt.

APPENDIX 1 — ITINERARY

Friday 28 July 2006

Travel Wellington to Sydney, departure 15:40

Overnight at Holiday Inn Sydney Airport

Saturday 29 July 2006

Travel Sydney to Denpasar (Bali), departure 9:00

Travel Denpasar to Yogyakarta (Java), departure18:50

Overnight at Inna Garuda Hotel, Yogyakarta

Sunday 30 July 2006

Travel by hire car to Cilacap, visiting two tsunami locations on the way

Overnight at Hotel Delyma, Cilacap

Monday 31 July 2006

Visit tsunami sites near Cilacap, also tide gauge

Overnight at Hotel Delyma, Cilacap

Tuesday 1 August 2006

Travel by hire car to Pangandaran (3 hours)

Survey tsunami damage on Pangandaran peninsula

Overnight at Puri Indah Beach Hotel, Pangandaran

Wednesday 2 August to Friday 4 August 2006

Survey tsunami damage in Pangandaran area

Overnight at Puri Indah Beach Hotel, Pangandaran

Saturday 5 August 2006

Travel by hire car to Yogyakarta (7 hours)

Overnight at Inna Garuda Hotel, Yogyakarta

Sunday 6 August 2006

Visit Merapi Volcano and Borobudur Temple (own time and cost)

Travel Yogyakarta to Denpasar (Bali), departure 19:00

Travel Denpasar to Sydney, departure 23:40

Monday 7 August 2006

Travel Sydney to Wellington, departure 18:00

APPENDIX 2 — IKONOS IMAGES

Figure A2.1 Ikonos satellite image of part of Pangandaran Village – before the tsunami. Portions of profiles 3 and 4 are show. The white buildings along the beach, which we believe to have been semi-permanent shops constructed from wood, were totally destroyed by the tsunami. Most of the area shown here will have been at least wetted by the tsunami, with the approximate limit of significant structural damage being the dotted black line.

Figure A2.2 Ikonos satellite image of Cikembulan Village – after the tsunami. The limit of inundation was a border dike at the edge of a paddy field, just below the dotted black line. At the top right is a group of modern houses that had largely escaped damage (water depth < 1 m), right centre is an area of near-total destruction of brick houses (water depth c. 3 m), and to the left is a group of three well-constructed buildings that did not collapse (water depth c. 4 m). The green dots are points of elevation measurement (profiles 10 and 11).

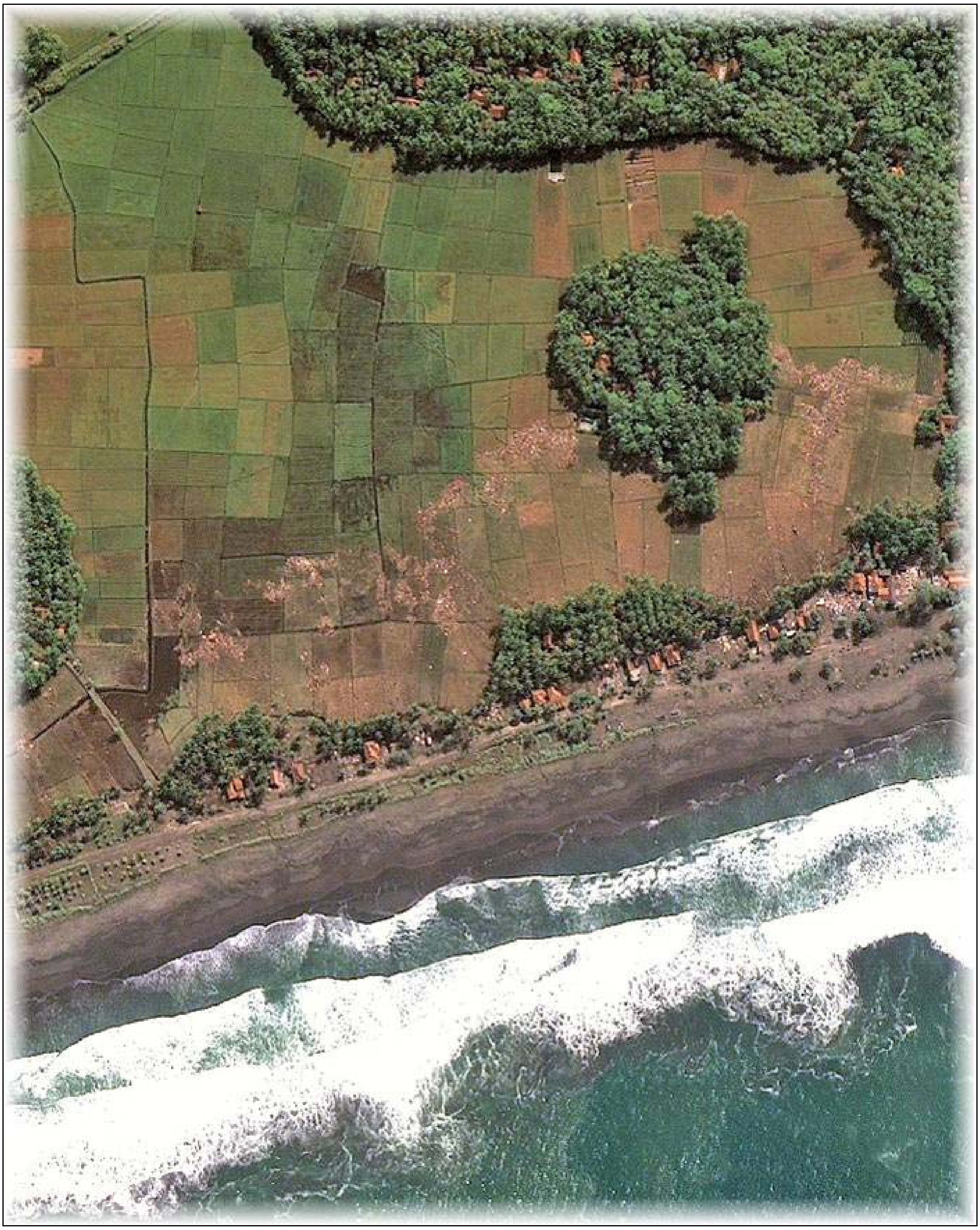

Figure A2.3 Ikonos satellite image of the coastal part of Ciliang Village – after the tsunami. The extent of inundation is clear. About 30% of the houses did not collapse. Water depth at the houses was about 2.5 m.