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Coastal sensitivity

CSIs ranged from 26 (medium) to 35 (very high) out of 40 (Figure 13). The results reflect the nature of the lithological materials (sands and some gravels), and the landforms (river mouths, gravel beach, sand beaches and dunes, and the foreland at Paraparaumu). The area immediately south of the Raumati seawall has the highest sensitivity (CSI = 35) owing to the seawall accelerating natural erosion. The Otaki River mouth has the next highest sensitivity (CSI = 33) owing to its highly fluctuating nature and is also sensitive to inundation of low-lying swale areas by both storm wave run-up and river flooding.

3. Wellington South Coast

The south coast of Wellington was tested over 1.5 days (19-20 March 1992), primarily to test the CSI technique on a rapidly uplifting area, although the vertical trend variable became redundant at a later date. Ten sites were visited, and one site at Lyall Bay Surf Club was protected by a seawall. This coast ranges in landform types from sand to gravel beaches. Horizontal trend data for this area were supplied courtesy of the Wellington Regional Council.

Results

Elevations ranged from low (1.6 m at Camp Bay, Site 32) to medium (6 m at Baring Head, Site 35, and Bluff Point, Site 33). Storm wave run-up levels ranged from 2.5 m (Lyall Bay, Site 44) to 6 m (Baring Head). Information from de Lange and Healy (1986a) shows that 3.05 m tsunami accompanied the 1855 Wairarapa earthquake.

Average erosion was recorded for two sites (0.2 m/yr at Lyall Bay, 0.2 m/yr adjacent to the Wellington Airport, Site 45), static horizontal trends at four sites, and average accretion at three sites (0.7 m/yr at Fitzroy Bay (Site 34), and 0.4 m/yr at both Turakirae (Site 37) and Baring Head). Short-term fluctuations of <2 m (Turakirae Head) and up to >30 m were recorded (Bluff Point, Baring Head, Camp Bay).

Coastal sensitivity indices

CSIs for this region ranged from 21 (medium) to 33 (high) out of 40 (Figure 14). The results reflect the sensitive nature of the gravel and sand beaches to the hazards of erosion and short-term fluctuations. Baring Head also has the potential to be inundated, although no structures or houses are at risk. Turakirae Head which is uplifting at 4 m/1000 years was the most stable part of the coast.

4. Pauatahanui Inlet

This estuary was selected for CSI assessment owing to its low energy and sheltered wave environment. One morning (20 March 1992) was required to assess five sites around the inlet, with each site needing only an assessment of the elevation, photograph, and storm wave run-up level measurements.

Sites were located where easy access to the water's edge was available from the road and could be easily returned to (Motukaraka Point) if further information was needed.

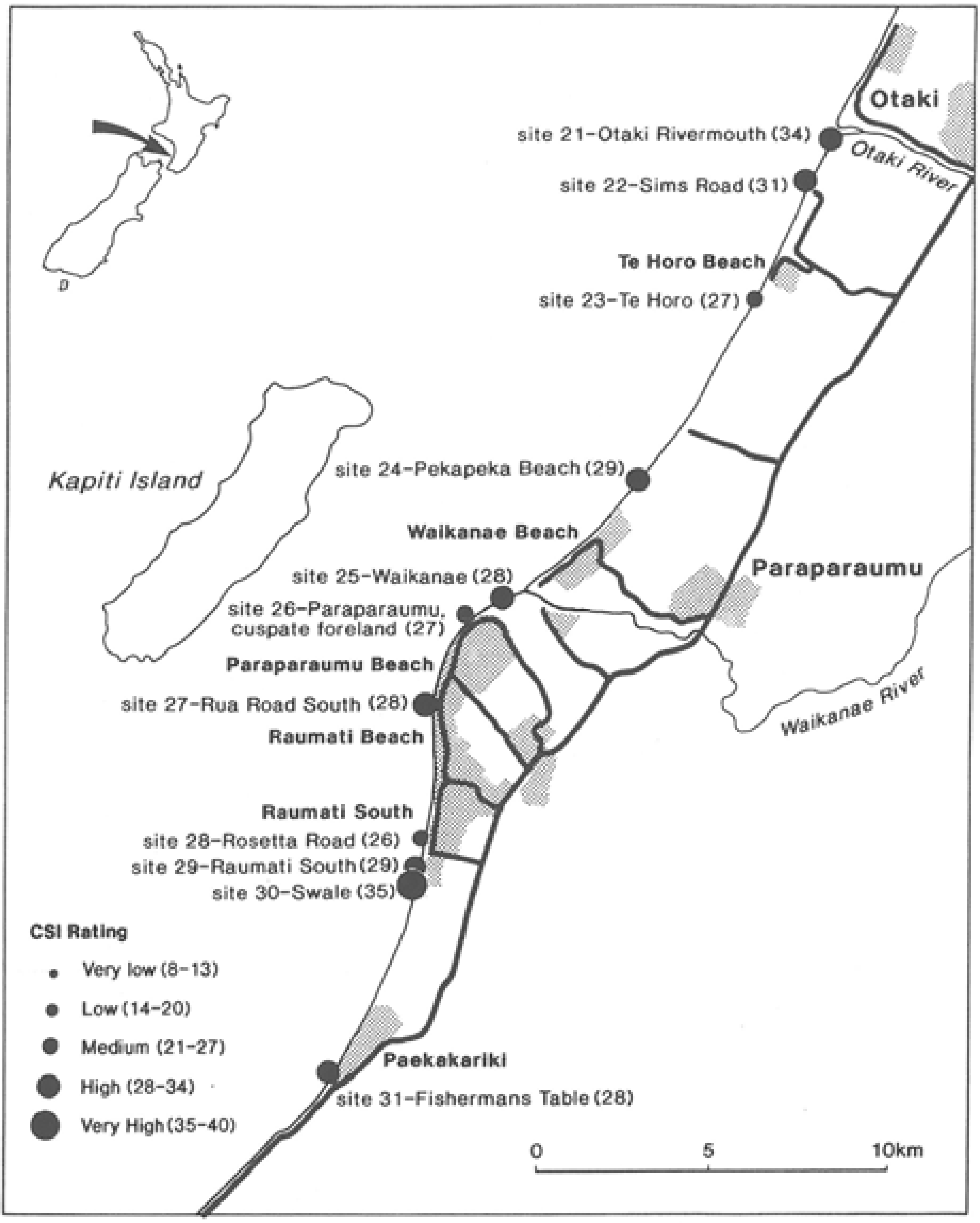

Figure 13 Sketch map showing the distribution of CSI ratings for 11 sites along the Kapiti Coast.

Results
Elevation ranged from 0.4 m up to only 1.5 m above MHWS. Landform types included saltmarsh (Wildlife Management Reserve, Site 39), alluvial outwash fans (Motukaraka Point, Site 41), and a sandy barrier (Paremata, Site 42). Long-term horizontal rates were estimated from anecdotal evidence and were shown to range from static to very low rates of erosion.

Storm wave run-up levels were measured on the day of field survey. Higher water levels were associated with strong westerly winds and equinoctial tides which occurred on that day. Storm wave run-up levels of 0.75 m near the inlet entrance up to 1.2 m near the back of the inlet were recorded. No tsunami information is available for this inlet, although likely effects could be associated with tidal bores near Paremata and raised water levels.

Coastal sensitivity indices
CSIs ranged from 23 to 26 out of 40 (medium rating), reflecting the main effect of inundation of low-lying areas adjacent to the inlet by storm wave run-up and higher tides (Figure 14).

5. Manukau Harbour

Franklin was visited to make CSI assessments in the relatively low energy environment within the Manukau Harbour. Franklin District Council possesses very little information about the effects of coastal hazards. Horizontal trend data existed for two beaches where protection works had been undertaken (Grahams and Hudsons Beaches, Sites 51 and 53) and along the cliff section of Racecourse Rd (Waiuku) where residences are threatened by cliff failure and erosion.

Eight sites were tested in one day (27 March 1992).

Results
Landform types ranged from sandy beaches, to soft rock cliffs composed of mudstones and alluvium, to similar cliffs composed of Plio-Pleistocene relict sands. Erosion predominated at all sites ranging from static (Wattle Bay, Site 54) to 0.3 m/yr (Grahams Beach).

Storm wave run-up levels were obtained from anecdotal evidence of waves associated with storms in 1978-1981, resulting in a 2.2 m storm wave run-up level above MHWS. One tsunami (0.3 m) has been recorded within Manukau Harbour as a result of the 22 May 1960 Chilean tsunami (de Lange and Healy 1986a). These waves were believed to be the result of the reflection of the primary waves off the coast of Australia.

Coastal sensitivity indices
CSIs ranged in value from 19 (low) to 30 (high) out of 40 (Figure 15), reflecting the low beach elevations with respect to storm wave run-up levels and inundation, and the overall erosive nature of the landforms.

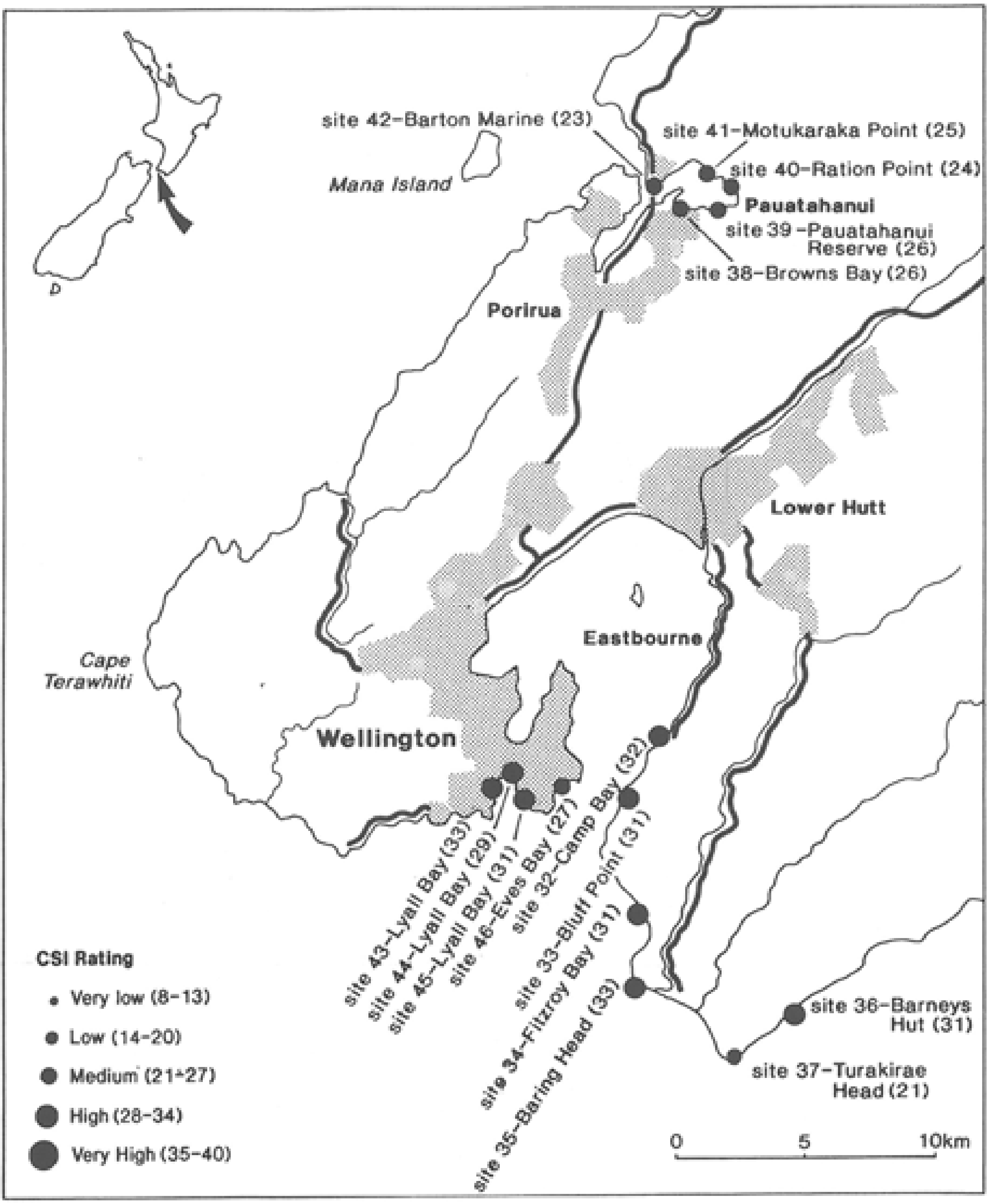

Figure 14 Sketch map showing the distribution of CSI ratings for 9 sites along Wellington's South Coast and 5 sites around Pauatahanui Inlet.

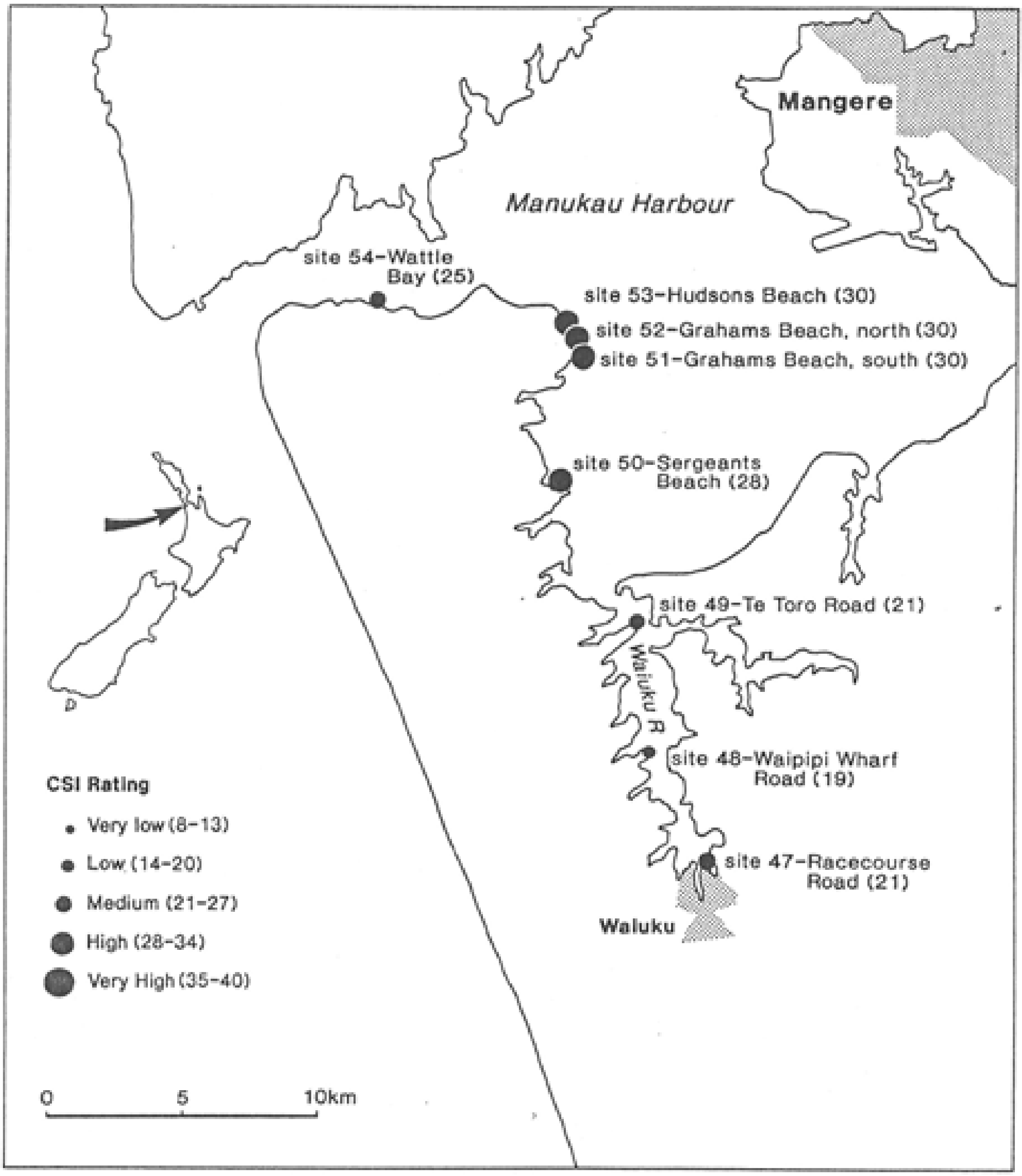

Figure 15 Sketch map showing the distribution of CSI ratings for 8 sites around the Manakau Harbour.

6. Hawkes Bay

Four beaches and sections of the Central Hawkes Bay region (Pourerere to Kairakau) and four beaches in Hawkes Bay were tested in one day (31 March 1992) with the majority of time being spent travelling between sites.

Horizontal trend and storm wave run-up data were available from Gibb (1978) and courtesy of the Hawkes Bay Regional Council (R. Black, pers. comm., March 1992).

The beach and coastal sections visited ranged from sand and gravel beaches to soft rock cliffs and platforms formed from mudstones. One beach site (Kairakau) has a seawall built to protect the local caravan park and motor-camp 15 years ago and is in a healthy state.

Results

Static to erosional horizontal trends were the norm for this section of coast, ranging from static at Kairakau (sand beach) and Pourerere South, Site 55 (soft rock cliff and platform), to rapid erosion at Te Awanga, Site 59 (1.05 m/yr in gravels), and to very high erosion opposite the Te Awanga Outfall, Site 60 (2.79 m/yr in gravels). Only two beaches showed long-term accretion, being at Awatoto, Site 61 (0.28 m/yr of gravels) and adjacent to the Port of Napier, Site 62 (0.78 m/yr of gravel material).

Storm wave run-up levels changed markedly from low levels (1.5 m at Pourerere South) to high levels (>3.5m at Te Awanga and along Hawke Bay). The effects of storm wave run-up have lead to inundation of coastal settlements (Te Awanga) and subsequently to the erection of sea exclusion walls to protect the townships and the fertile, low-lying, Heretaunga Plains.

The largest recorded tsunami (de Lange and Healy 1986a) has been a 3 m tsunami associated with the 22 May 1960 Chilean earthquake, which resulted in many coastal settlements along Hawke Bay being inundated, such as Te Awanga.

Coastal sensitivity indices

CSIs ranged from 22 (medium) to 35 (very high) out of 40 (Figure 16). The two highest results were recorded along the Te Awanga section of coast in Hawke Bay, where high rates of erosion of the gravel beaches, and high sensitivity to inundation by storm waves and tsunami events exist.

The lowest rating coastal site was that at Pourerere South. This site derives its low ranking from the high elevation and low sensitivity to storm wave run-up, **but** this section of coast is subject to mass land movements, slipping and landslides (>30m in size) of the mudstones which make up most of its lithology.

The remaining sites rated from 29 to 32 (high) out of 40, and were sensitive to inundation from storm wave run-up and tsunami, and erosion of the unconsolidated gravels and sands.

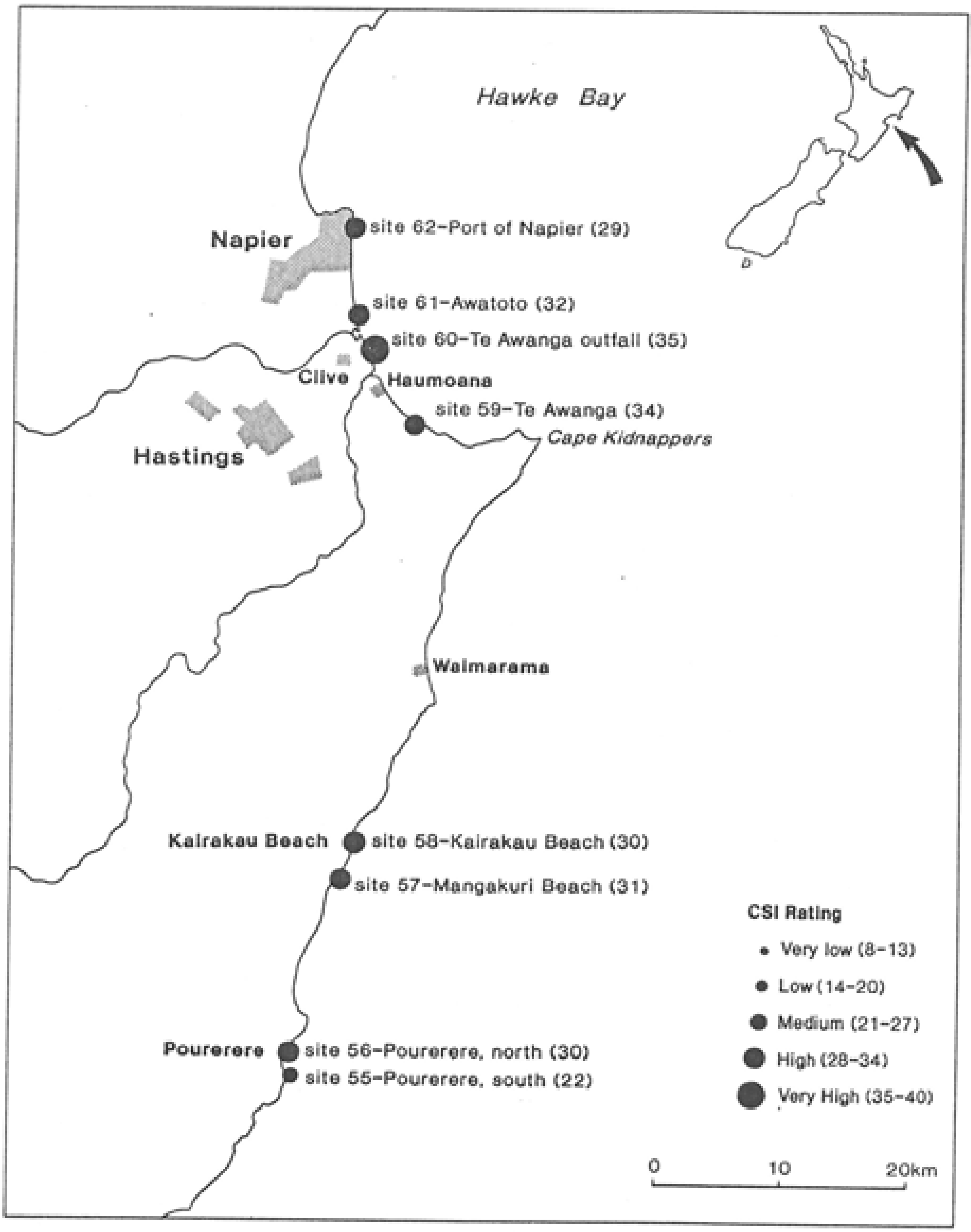

Figure 16 Sketch map showing the distribution of CSI ratings for 8 sites in southern Hawkes Bay.

7. East Cape

Twelve sites between Te Araroa and Torere were visited. This region provided a wide range of lithological (volcanics, greywackes, sands, gravels) and landform conditions (very hard and hard rock platforms, sand beaches, gravel beaches), as well as having good quality horizontal trend and short-term fluctuation data, supplied by the Gisborne District Council, and Gibb (1981). One day (1 April 1992) was used to assess 12 sites, which included travel time. The area between Gisborne and Te Araroa was not tested.

This region also gave an opportunity to make separate CSI assessments along beaches which have changing horizontal trends (from erosion to accretion) along their length (Te Araroa).

Results

Site elevations ranged from as low as 0.65 m (Hicks Bay South, Site 68) up to >30m (Lottin Point, Site 70) reflecting the change in landform type of a sand beach to very hard rock platform respectively.

Storm wave run-up levels of 2.2 to 3.3 m for the Te Araroa, Sites 63, 64, 65, Onepoto Bay, Site 67 and Hicks Bay, Sites 68 and 69, were calculated by Frisby and (1981) for Gibb (1981), reporting on Waiapu County. The calculated levels from the Wahine Storm of April 1968 indicate inundation of these low-lying beaches. Other storm wave run-up levels were estimated from storm debris and flotsam (>5 m at Hawai, Site 73 and Torere, Site 74) and from the lowest level of vegetation along shore platforms and cliffs (-1.5 m at Lottin Point, Whitianga, Site 72 and Whanarua Bays, Site 71). The latter levels indicate little inundation at these sites.

The largest recorded tsunami in the area was 3 m high noted at Cape Runaway on 15 August 1868 (de Lange and Healy 1986a).

Two sites suffer from high long-term rates of erosion (0.93 m/yr at Te Araroa B, Site 64, and 1.57 m/yr at Te Araroa A, Site 63). Six sites had average long-term rates of accretion, ranging from 0.2 m/yr (Torere) up to 1.2 m/yr (Hicks Bay South). The remaining sites were static as a result of their hard lithology (Whanarua and Whitianga Bays, greywacke, Lottin Point, basalts), although at Te Araroa C this rate reflected the "hinge point" where erosional trends changed to accretionary trends along the beach.

Short-term fluctuations ranged from negligible (0m at Lottin Point) to extreme over 100 m at Hicks Bay reflecting the unstable nature of the Wharekahika River.

Coastal sensitivity indicies

CSIs ranged from 13 (very low) to 36 (very high) out of 40 (Figure 17A). The highest CSIs were recorded at Te Araroa A and B (CSI = 36) where high erosion rates occur on the sand/gravel beach and at low elevations, which are very susceptible to inundation by storm waves and tsunami. The remaining sand and gravel beaches of the region score high CSIs (CSI = 31 to 34) and reflecting their low-lying relief and high fluctuations, although at some sites accretion is occurring.

Three of the lowest CSIs encountered during this project were found at Lottin Point (CSI = 13), Whanarua (CSI = 14) and Whitianga Bays (CSI = 15). These sites have very stable landforms and lithologies and are not affected by inundation or tsunami events.

8. Bay of Plenty

150 km of coastline and 21 sites from Ohiwa Harbour to Whangamata Harbour plus one site at Te Puru, Firth of Thames, were assessed and tested over a period of four days (2 - 4 April 1992). The predominant landforms along this coast are sand beaches, dunes and barriers. Other landforms encountered were associated with Ohiwa Harbour (saltmarsh/mangroves, sand spit), Maketu and Tauranga Harbour (soft rock cliffs of poorly welded ignimbrite), Whangamata Harbour (hard rock cliffs) and at Te Puru (an alluvial outwash fan/delta).

Results

Landform elevations ranged from 0.5 m (Munro Subdivision, Ohope) to >30m at Whangamata (Sheffield 1991). Storm wave run-up level estimates ranged from 1.44 m (Munro Subdivision, Site 78) up to 5 m above MHWS (along the Whakatane to Matata coastline).

Tsunami heights ranged from 0.9 m in 1883 (tidal bore at Maketu) to 1.8 m recorded on 15 August 1868. A 1.4 m tsunami accompanying the 22 May 1960 Chilean earthquake has also been recorded along this coast. For Te Puru (Firth of Thames, Site 97) a 0.9 m tsunami was recorded at Coromandel on 27 August 1883.

Average erosion ranged in magnitude from 0.1 m/yr (Maketu Caravan Park, Site 89) up 3.15 m/yr (Ohiwa Spit) and occurred at seven sites. Seven sites illustrated approximately static horizontal trends (with four sites being on sandy beaches, one saltmarsh/mangroves and one very hard rock cliff) while the remaining sections of coast were accreting. Average rates of accretion ranged from 1.28 m/yr (Ohiwa south) up to 1.78 m/yr (Golf Links Rd, Whakatane). Short-term fluctuations ranged from 0m (inner Whangamata Harbour, Site 96) up to >100m (Ohiwa Spit, Site 75).

Coastal sensitivity indices

CSIs ranged from 11 (very low) to 36 (very high) out of 40 (Figure 17A and B).

The highest CSI occurred at Ohiwa Spit (CSI = 36) where erosion (-3.15 m/yr), high fluctuations (>100m), and inundation by storm waves presented the greatest hazards. The lowest CSI occurred for the inner Whangamata Harbour (CSI = 11) where little effect of inundation or erosion could occur owing to its very hard volcanic rock nature and low rate of erosion or fluctuation.

The remaining sites range from CSI = 19 (low) to 32 (high). The high ranking sites reflect the sandy nature and sensitivity of the landforms to change, although some sites are in fact accreting, while the low rank sites reflect the more stable nature of the landform and lithology and little effect from storm wave run-up.

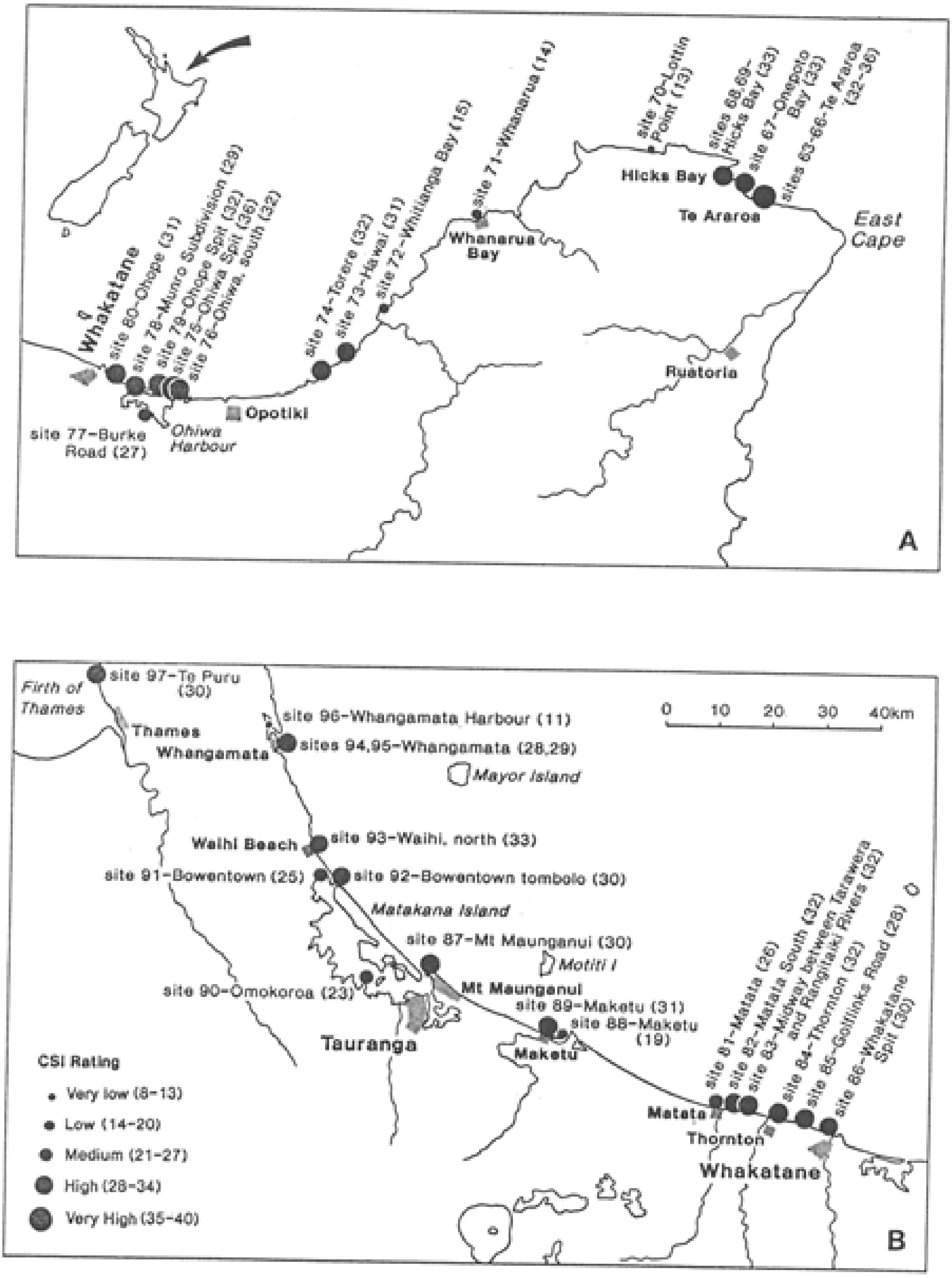

Figure 17 The distribution of CSI ratings for (A) sites 63-80 near East Cape and eastern Bay of Plenty; and (B) sites 81-97 in Bay of Plenty, and the Firth of Thames.

9. Canterbury

Approximately 250 km of coastline from Amberley Beach, Site 113, in the north to Waitaki Boys High School, Site 98 (Oamaru) in the South, excluding Banks Peninsula, was visited and tested over a 2 day period (14-15 May 1992). This region possesses a variety of landform types (sand beaches, mixed sand gravel beaches, soft rock cliffs) and lithologies (alluvium, sand, gravel, loess). Rate data for erosion/ accretion, short-term fluctuation information and beach profile data was made available courtesy of the Canterbury Regional Council. A desk test involving the calculation of a CSI based on all available published information, (but not an actual visit to the area), for the Motunau Cliffs (North Canterbury) was also undertaken using information provided in Lumsden and Kirk (1991).

It took two days to rapidly test the region. Site tests took approximately 10-15 minutes to complete, allowing for reconnaissance, confirmation of lithology and landform and a site photograph. The time spent at each site was considerably shortened by having the information for horizontal trend, short-term fluctuation and elevation already calculated in records held by the Canterbury Regional Council. Extra time in the field would have been required to complete elevation measurements using the sea-horizon technique or levelling, if the surveyed cross-sections did not exist. The majority of time was spent travelling between sites, since each site had to be reached via minor roads.

Each site corresponded to a known beach profile location surveyed by the Canterbury Regional Council. These sites are representative of similar adjacent coastline and the CSI results can be applied along that portion of coast until the next survey location or until a geomorphic break occurs (beach to cliff, cliff to river mouth, cliff to beach).

Results

Site elevations correlated with the landform type, in that soft rock cliffs formed of loess or alluvium ranged in size from 10 to 30 m in height, while sand and gravel beaches and ridges ranged in elevation from 3.5 to 6 m.

Erosion occurred at 11 sites and ranged from 0.32 m/yr (Pareora-now affected by a rip-rap seawall) to 2.5 m/yr (Washdyke, Timaru, Site 104). Accretion occurred at 5 sites and ranged from 0.24 m/yr (Brighton, Christchurch) to 5.91 m/yr (Caroline Bay, Timaru, Site 103). Erosion occurred on both soft rock cliffs and sand/ gravel beach ridges, while accretion occurred predominantly on sandy beaches where progradation is prevalent Pegasus Bay) or where port developments have occurred (Caroline Bay, Timaru).

Tsunami information from de Lange and Healy (1986a) showed that three tsunamis were recorded along the Canterbury Coast. For Timaru and South Canterbury a 1.8 m tsunami recorded on 13 August 1868 was used; for Oamaru a 2.8 m and for North Canterbury a 3.3 m tsunami was recorded on 22 May 1960.

Coastal sensitivity indices

CSI results ranged from 25 (medium) to 35 (very high) out of a possible 40 (Figure 18A). The results illustrate that the Canterbury coast is very susceptible to erosion and to inundation from overtopping by storm wave run-up for the lower lying beach areas.

Washdyke Lagoon has the highest sensitivity rating of the Canterbury region (CSI = 35 very high). The high rating reflects its highly eroding state and fluctuating nature (2.5 m/yr and short-term fluctuation of 20 m), its vulnerability to inundation by storm waves (storm wave run-up of 4 m which easily overtops the 3.5 m gravel barrier to inundate the low-lying area behind), and its lithological and landform make-up (unconsolidated sandy beach). The other highly rated areas reflect similar characteristics to Washdyke (being highly susceptible to inundation, erosion or short-term fluctuations).

Caroline Bay has a high sensitivity rating (CSI = 30, high). Although the beach is accreting at almost 6 m/yr and is located in a fairly low energy environment adjacent to the Port of Timaru, the rating reflects its lithological make-up (unconsolidated sands), its landform type (sand beach) which is susceptible to change, and its low elevation (3.8 m) which is susceptible to storm wave run-up (3.0 m) and possible inundation from tsunami events. Caroline Bay may be accreting, but there is no vertical build-up of dunes at the rear of the beach, which would render the beach very sensitive to any change in regime.

The Motunau cliffs have the lowest sensitivity rating (CSI = 25, medium). As a result of cliff failure affecting local residential properties this area is regarded as being at high risk by the Canterbury Regional Council. Any change in regime would have very little effect on this area, unlike Caroline Bay. From studying the original data, Motunau has a negligible susceptibility to flooding by both the river and inundation from storm waves.

10. Hokitika

Three desk tests were carried out for Hokitika during the course of this project. Information about this area was derived from Gibb (1987).

Results

The elevation and storm wave run-up data were derived from measured profiles in Gibb (1987). Streets and houses close to the barrier front have been inundated in the past. Tsunami data from de Lange and Healy (1987) show that the nearest tsunami was recorded on 13 August 1883 at Westport (1.2-1.5 m).

Accretion occurred at two sites and ranged from 0.08 (Hampden Street) to 1.34 m/yr (Camp Street), while a low average erosion rate occurred at Tudor Street (-0.02 m/yr).

Short-term fluctuations range from 60 m (Hampden Street), up to 200 m (Camp Street), and reflect the highly mobile nature of the Hokitika River.

Coastal sensitvity indices

The three test sites (Figure 19) all had high CSI ratings (CSI-32-33). These results reflect the highly fluctuating nature of the Hokitika river mouth and adjacent beaches, and susceptibility to flooding by both the river and inundation from storm waves.

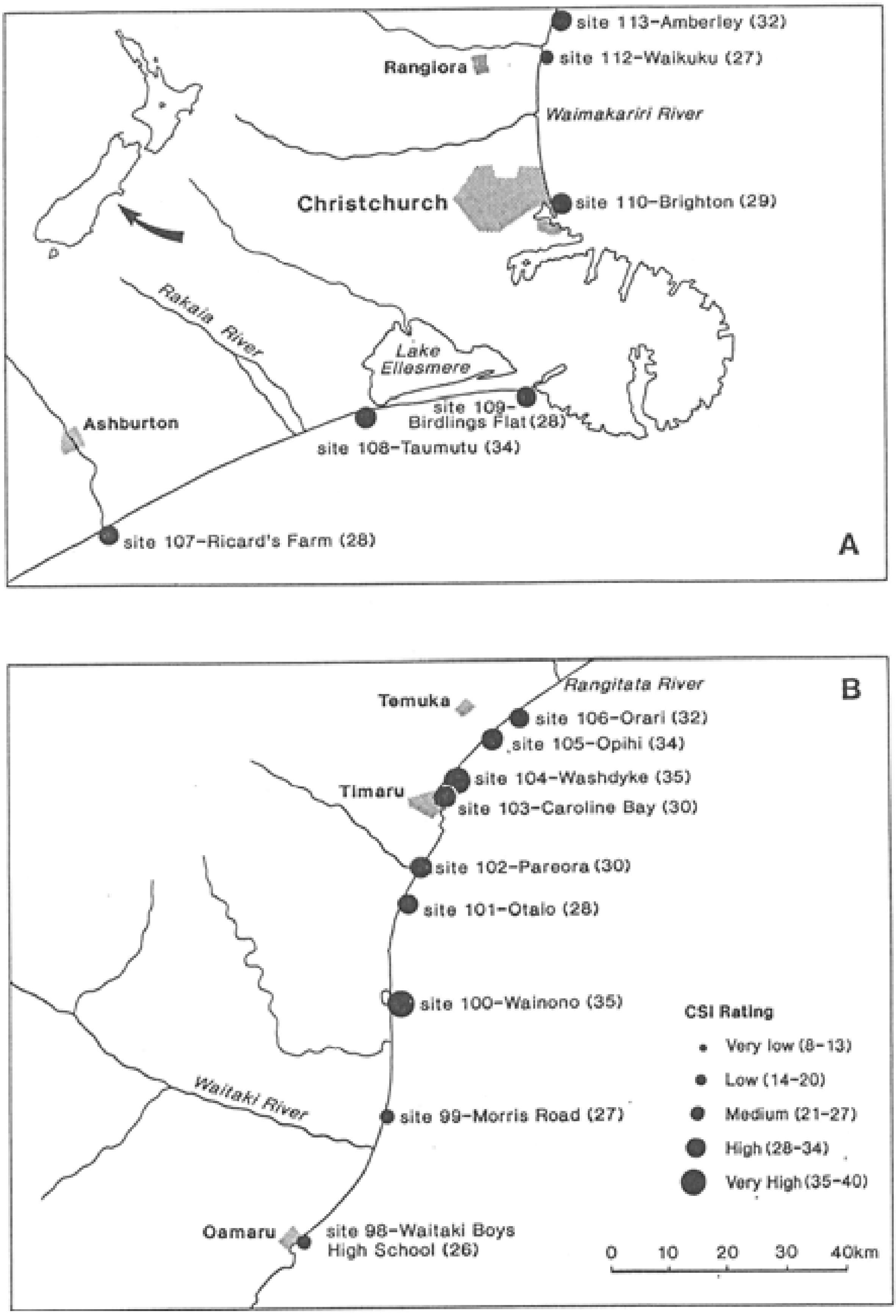

Figure 18 The distribution of CSI ratings for (A) sites 107-113 on the Cantebury coast; and (B) sites 98-106 in south Cantebury

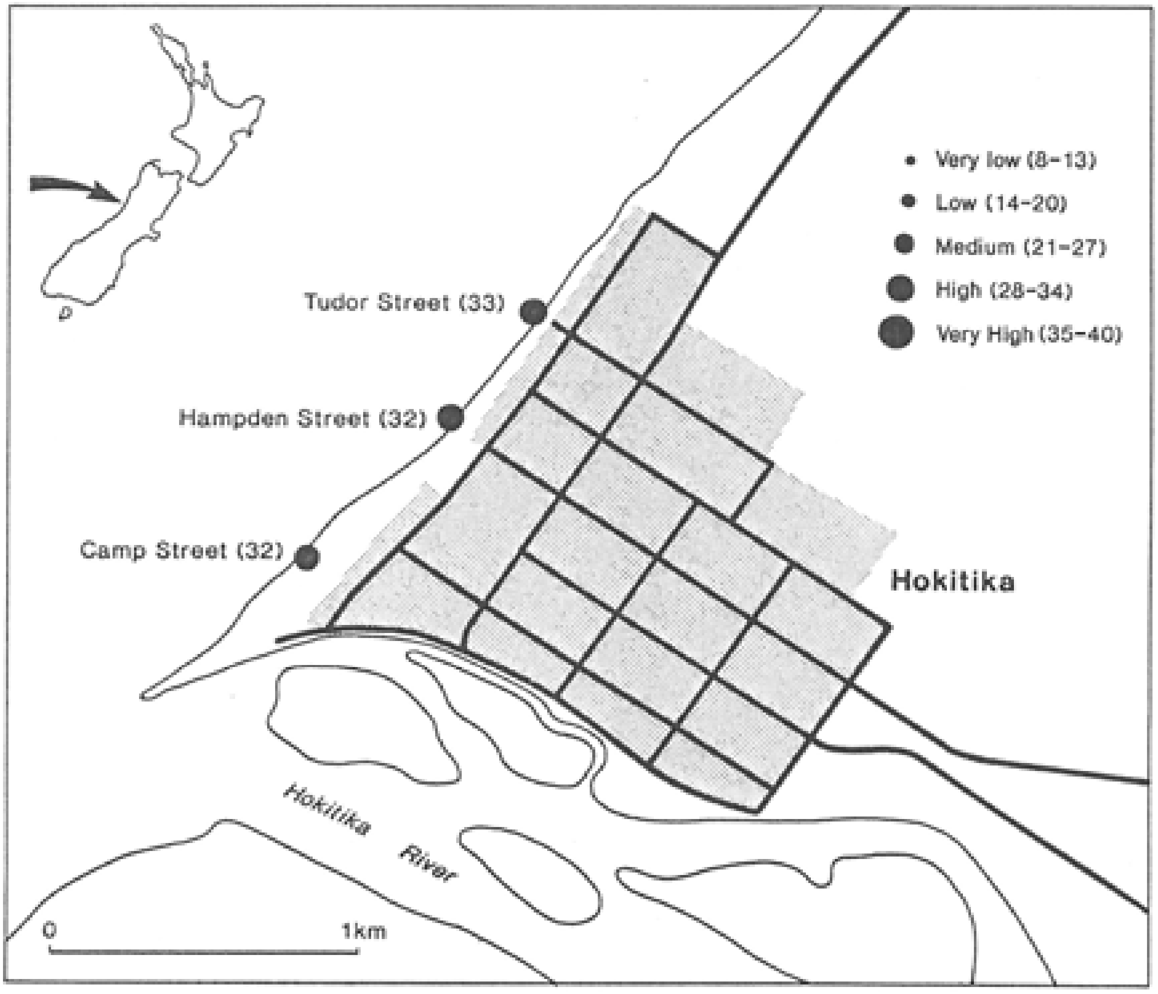

Figure 19 The distribution of CSI ratings for 3 sites along the Hokitika foreshore.

Summary
Table 6 summarises CSIs (max/min) for each study area. The highest CSIs occurred predominantly on highly fluctuating, eroding sandy shorelines (Te Araroa, Ohiwa Spit), as a result of river channels changing course, from the movement of spits or from the large scale movement of sand during storm events. The highest ranking sites also tended to have low elevations and be highly sensitive to inundation by storm waves.

Lowest CSIs occurred on landforms which are very stable in nature, that is, very hard rock platforms and cliffs. These reflect their lithological make-up (volcanics, greywackes) and have low horizontal trends and fluctuations.

Medium ranked CSIs occurred on a variety of landforms, generally being sensitive to one main hazard, but not the combination which would raise the rating to a high level.

Table 6 Summary of maximum and minimum Coastal Sensitivity indices from each study area.

Region	CSI Minimum	CSI Maximum
Wairarapa	18 low	36 very high
Kapiti Coast	26 medium	35 very high
Wellington	21 medium	32 high
Pauatahanui	23 medium	26 high
Manakau	19 low	30 high
Hawkes Bay	22 medium	35 very high
East Cape	13 very low	36 very high
Bay of Plenty	11 very low	36 very high
Cantebury	25 medium	35 very high
Hokitika	32 high	33 high

The testing of the field areas and assessment of CSIs resulted in the full range of ranks being encountered (from very low to very high sensitivities), and have provided a good documented background for the basis of this study. This published information is held in the DOC central library, entitled "Supplementary Appendix site forms for the regions tested during the development of the Coastal Sensitivity Index".

4.3.2 Examples characterising very high to very low sensitivity areas

After the boundaries were set it was possible to place the 113 test sites into five broad groups which possessed the potential ranging from very high to very low for physical change. The following areas represent a sample selected from and characterising these broad groups. The complete appendix is held at the Department of Conservation central library in Wellington.

Very high (rated 35-40)

These areas are typically characterised by unconsolidated sediments, very low-lying landforms such as spits, river mouths and beaches, which have a very highly fluctuating nature and high to very high rates of erosion. (Plates 8, 9, and 10)

High (rated 28-34)

This group contains some areas which at first glance may appear to be at very high risk, but when the actual data is investigated, the area may in fact be accreting in the long-term. These sites are also typically characterised by unconsolidated sediments which may be eroding or accreting, in addition to moderate/ high short-term fluctuations. (Plates 11, 12, 13, and 14).

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