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2.1.8 Short-term fluctuations

Variations in the long-term trends of shoreline advance and retreat are mostly episodic (irregular occurrences). These variations or S factors defined by Gibb (1983), occur as the maximum short-term fluctuation or fluxes of both accretion and erosion, in the long-term shoreline trend (Figures 8 and 11). Variations may occur as a result of one or a cluster of severe onshore storms, and may range from 2 m to greater than 30 m around New Zealand depending on the width of the beach and the nature of the hinterland behind. The short-term fluctuation may also be inferred to be the minimum width of a coastal hazard zone (Gibb and Aburn 1986). For cliffed areas the short-term fluctuation is the largest slump or failure that can be identified (Figure 11). It is the maximum landward fluctuation that is measured.

Large fluctuations represent greater sensitivity to natural hazards. The highest measured during field surveys was >100m at Hicks Bay (see Plate 4) where a subdivision was demolished by the sea and a migrating river mouth in the early 1970s. Lowest fluctuations are associated with very hard rock cliffs and platforms. For example, the cliffs in the Lottin Point region (East Cape) formed by the Matakaoa Volcanics experience little or no short-term movements associated with either landslides or normal cliff erosion processes.

Class	1	2	3	4	5
Short-term fluctuation (m)	<2	2 -5	6 -10	11-30	>30

User guidelines

The short-term fluctuation can be derived from comparing historic and cadastral coastal surveys, repetitive surveying of beach profiles, anecdotal evidence or estimated in the field (Gibb and Aburn 1986).

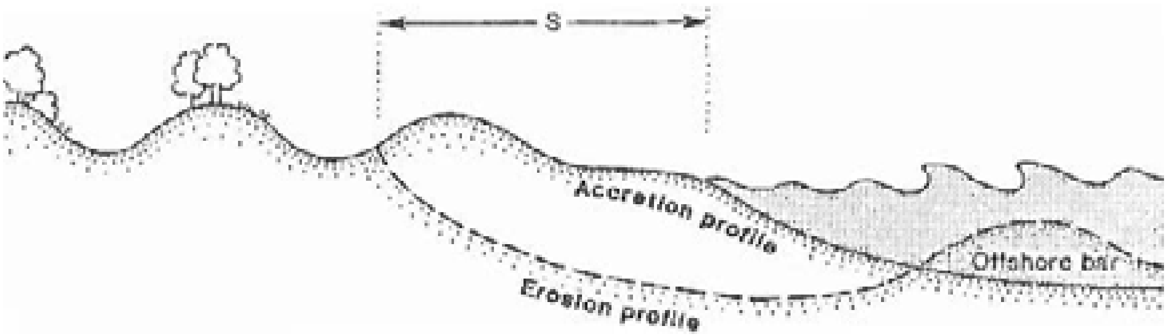
Historic shoreline positions

Comparison of shoreline positions between aerial photographic and historical surveys which note MHWM can provide information regarding fluctuations. Horizontal measurements of scarps (if identifiable), and pulses of shoreline accretion and erosion can be made, with the maximum distance of change being used.

Beach profiles

Fluctuations can be estimated by comparing various beach profile records over the longest period that they are available for. Successive erosion and accretion events (be they seasonal or episodic) can be measured and fluctuations determined as the maximum gain or loss of the shoreline.

Field observations
Field estimations of short-term fluctuation can be made where scarps are preserved marking past episodes of erosion when it is possible to measure the horizontal distance between the scarps. Gibb (1979), for example, identified a major erosion scarp at Needles Point, South Island east coast, cut during the winter of 1974. From 1974-77 accretion extended approximately 128 m during which two further phases of erosion also marked by scarps occurred.



Unconsolidated sedimentary coasts

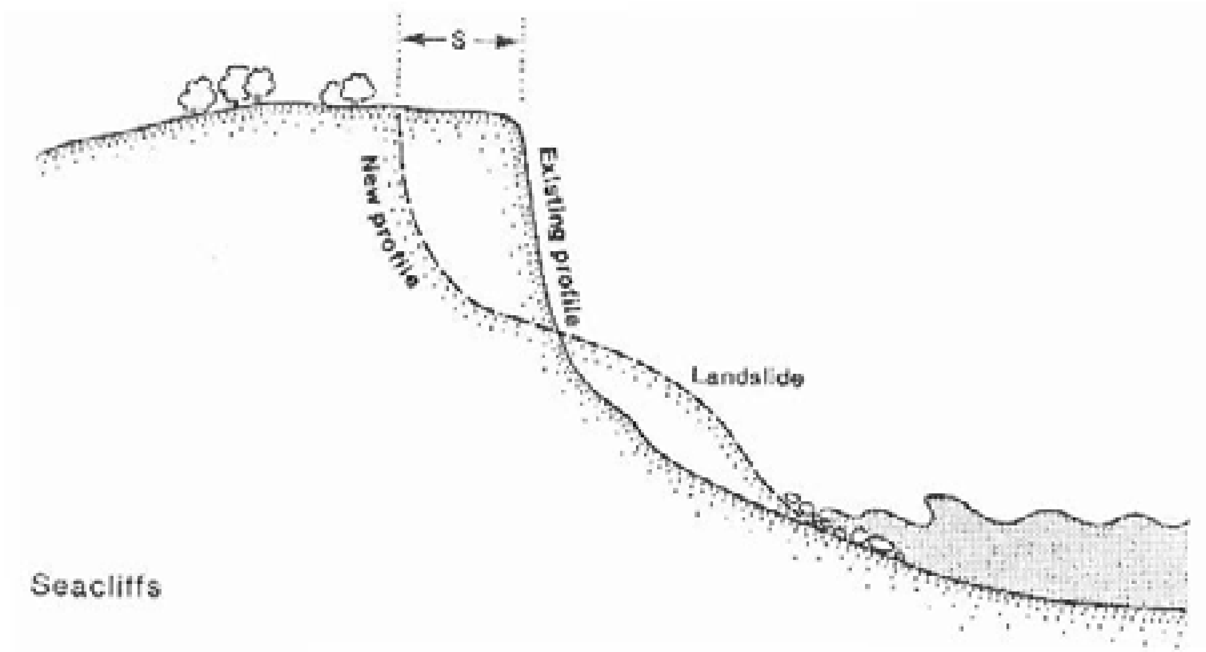


Figure 11 Diagrams illustrating determination of maximum short-term horizontal shoreline (S), for unconsolidated sedimentary coasts and seacliffs.

Seacliffs
The short-term fluctuation for seacliffs can be defined as the largest slump or failure that can be measured in the field, from aerial photographs, long-term trend maps, or minimal (<2m) if no obvious erosion/slumping occurs (very hard rock cliffs and platforms).

Fluctuations usually vary significantly along a short section of coast, so careful consideration must be given to decide whether to use an average value, or to re-calculate the CSI for specific areas depending upon the scale of interest. It is incorrect to apply an average value along a length of coast with changing short-term fluctuations from such factors as changing drainage characteristics, as in Canterbury where slumping of the coastal cliffs is affected by agricultural irrigation and drainage, lithology, gradient and height.

2.2 Parameters contributing to the selection of the actual variables

Other variables considered during development which were either not used on the basis of a lack of data, were impractical to measure in the field, or were incorporated into another variable, and are discussed below. These discussions are provided to clarify the reasoning behind not including them separately into the CSI at this stage, and to provide food for thought regarding future direction that a New Zealand Coastal Hazards Database and CSI could take.

2.2.1 Wave height and storm surge
Wave height and storm surge were originally considered separately, however in reality these actually contribute to the maximum storm wave run-up on the coast.

The maximum significant wave height was considered as a separate variable for application along open, exposed and sheltered coasts because of the ability of waves to rapidly transform the shoreline. This very useful information could be collected from wave records, however the lack of these, and the patchy coverage of New Zealand (Hume *et al.* 1992) meant that incorporation of a separate wave height variable could only be considered if and when more complete regional information becomes available in the future. Pickrill and Mitchell (1979) provide a summary of wave conditions which remains the main source of summarised wave data for New Zealand. A further point associated with this factor includes converting a deep water wave height to a shallow water wave height and allowing for shoaling.

Storm surge levels were also considered but not retained as an independent variable owing to the lack of nationally available data from tide gauge analysis, although some records are given in Heath (1979). The Institute of Water and Atmospheric Research (formerly DSIR Marine and Freshwater) has begun to analyse some regionally held tide records for the purpose of determining the magnitude of these levels from storm events (R. Bell, DSIR, pers. comm., February 1992).

2.2.2 Spring tidal range
Spring tidal range was considered as a separate variable because of the association that larger spring ranges with stronger tidal currents are capable of eroding and transporting sediments (Gornitz and Kanciruk 1989). Spring tides can also produce proportionately high equinoctial

and astronomical tides which can exacerbate coastal hazards. For example, the highest astronomical tide (HAT) occurs at some stage during the 18 year lunar tidal cycle (Gibb 1991) and is commonly used as a component in storm wave run-up studies.

Coastal landforms are however generally in equilibrium with the local tidal range, and it is not necessarily true that areas with larger tidal ranges experience greater erosion and inundation during storms, than areas with smaller tidal ranges. Spring tidal range is therefore considered to contribute to the storm wave run-up variable rather than occur as a separate variable.

2.2.3 Landslides

Acknowledged as one of the three major hazards in the coastal zone (erosion, inundation and landslip), landslides are incorporated in the calculation of a CSI in both the short-term fluctuation as mass movements, slumps and failures, and in the long-term horizontal trend as erosion of the coastline. While this variable is not separate within the matrix, it is recommended that as part of the field testing, evidence for landslides be sought from anecdotal and historic records, aerial photographic records and field observation. Should landslip be considered as a potential hazard, then this should be included as a qualifier for the CSI and attached as notes on the site record form, serving as an alert that these areas may merit further detailed geological and geotechnical studies.

2.2.4 Vegetation

While being an important physical feature on the coast, the occurrence of vegetation has not been included for the purposes of the CSI which encompasses measurable physical landform factors. It is noted, however, that vegetation such as marram, pingao and spinifex, play an important role in stabilising loose coastal sediments. Many dune stabilisation schemes exist around New Zealand and these contribute to the long-term horizontal trend by helping to minimise erosion and prevent dune blow-outs, and to the short-term fluctuation by minimising the effects of short period erosive events.

It is not intended to incorporate this as a variable, but this information can be recorded on site record forms if available. This type of information has been compiled by Johnson (1992) and Partridge (1992) as a part of the New Zealand coastal and dune vegetation inventory.

2.2.5 Overtopping

This variable was considered to indicate the effects of inundation when storm wave run-up level exceeded the elevation of the first immediate feature. "Overtopping" as a separate variable became redundant as it had been accounted for in the storm wave run-up level and elevation variables and in effect had placed a double emphasis on inundation.

Another difficulty was the use of a height or depth to assess the amount of overtopping as this can not be easily measured from field response data (R. Kirk, University of Canterbury, pers. comm., June 1992) and is also dependent on sediment size and water table effects.

2.2.6 Sediment budget

On a nationwide basis sediment transport and budget data is very localised and subject to inherent calculation errors. While sediment transport information would add to the accuracy of the CSI, it is noted that the sediment budget is an integral part of the horizontal trend variable used here. Positive sediment budgets result in accretionary horizontal trends while negative sediment budgets contribute to erosion. Sediment budgets may also be represented by the state of the foredune as growing dunes have positive budgets and eroding dunes have negative ones.

If these rates or volumes are known then these can be noted on site record forms. Beach nourishment schemes which also contribute to positive beach budgets could also be noted, for example, Mt Maunganui beach underwent renourishment in December 1990 (Foster 1991).

2.2.7 Vertical trend

This variable was initially considered to assess the sensitivity of the coast to vertical movement of the land associated with tectonics (uplift/ downdrop), and to superimpose on this the eustatic sea-level rise at the current average rate of 1.7 mm/year (Hannah 1990; Gibb 1991) around New Zealand since about 1900. The combination of a rising sea-level and subsiding shoreline will increase the sensitivity of the coast to erosion and inundation.

Rates of tectonic movement were primarily derived from uplift/ subsidence maps of New Zealand by Wellman (1979) and Pillans (1986, 1990) which assess trends during the Late Quaternary (approximately the last 200 000 years). The trends are average values that include many rapid earthquake-induced movements from discrete episodic catastrophic events (e.g., Wairarapa Earthquake, 1855; Napier Earthquake, 1931). They do not necessarily reflect a constant rate of uplift or subsidence over shorter periods (decades, centuries). It was considered inappropriate to superimpose the historic rate of sea-level rise of 1.7 mm/year on to the known tectonic trends because of the hugely differing time scales and the likelihood of either land stability or even reversals in emergence or submergence between discrete earthquake events. For example, there is clear evidence along the North Island east coast of coastal retreat in areas with a geologic history of tectonic uplift (Gibb 1981). Theoretically, the coast should be advancing in such areas. Similarly, along the Rangitiki Plains coastline, Bay of Plenty, the area is subsiding at 0.4- 2m/1000 years and yet the coast has a history of advance.

Use of this variable by Gornitz and Kanciruk (1989) was justified however, in that the North American land mass is still adjusting at a steady rate from post-glacial rebound, or in places is sinking at a steady rate as a result of the removal of groundwater in deltaic deposits such as the Mississippi River Delta. The relevance of such long-term trends to the time scales used by planners who consider the future of developments with regards to the next 20-100 years was further justification against including vertical trend information as a major variable.

2.2.8 Storm frequency

Significant stormy periods appear to occur episodically in New Zealand every 20 ± 10 years (Gibb 1978a, 1987), but damage to the coast does not necessarily happen during one storm. Far more serious may be a cluster of storms which individually cause minor damage, but collectively culminate in massive damage, overtopping, breaching and inundation as the beach system is progressively weakened allowing the hinterland to come under attack.

It is impractical to incorporate storm frequency at this stage as a discrete variable owing to a lack of data and the difficulty of assigning a probability. The effects of storms as individuals and in clusters are nevertheless accounted for by the maximum storm wave run-up level, horizontal trend and short-term fluctuation variables used here.

2.2.9 Engineering structures

Seawalls and groynes have been built in response to property and assets being threatened, or as a legacy to the engineering priorities and values of the time. Seawalls have been constructed to differing standards, from car bodies to concrete walls to rock revetments, and may actually increase erosion further along the beach. Failure during storm events may increase local erosion because the beach in front of the seawall is generally depleted of sediment by constant wave reflection entraining sediment (Plate 6) and scouring the seabed.

Plate 6 Southeasterly swells reflecting off a rock seawall at Wainui Beach, Gisborne, 1992. Breaking wave heights effectively doubled, exacerbating the erosion problem.

Seawalls also prevent the foredune from acting as a supply of sand during storm events. For example, at Raumati sand reservoirs at the end of the seawall are being depleted and the dunes are being eroded to compensate (Plate 7). Even though the seawall appears to be functioning, erosion of the foreshore is still continuing and may even be exacerbated by the presence of the seawall. Since construction of seawalls in the 1950s and 1970s the long-term rate of retreat has increased from -0.2 m/year to more than -2.0 m/year.

It may be possible to assess the performance of structures (seawalls, groynes, breakwaters) by investigating six rules which structures should have met when they were designed; adequacy of protection, adequacy of protection against end effects and outflanking, adequacy of foundation conditions, stone weights or piece fastenings, void space control, and adequacy against overtopping by green water (U.S. Army Corps of Engineers (n.d.).). Additional considerations may be how safe the wall is and whether it is being maintained. Modern seawalls are designed to give the area behind protection from overtopping to an acknowledged low return-period event, therefore it is possible by contacting the designers or local body engineers to obtain the level of wave run-up which they calculated to apply.

Seawalls had been constructed on seven of the test sites visited in this study. However, normal coastal processes such as wave run-up and erosion have been affected in these areas and therefore the CSI technique was not strictly applicable. Data on the rate of horizontal movement for example, would be inapplicable if the seawall had halted the

Plate 7 Looking south from the Raumati seawall, Kapiti Coast, 13 March 1992. Since 1974 the foredunes have retreated about 45m because of the seawall, coupled with a long- trend of retreat.

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Table 4 The combined matrix for the Coastal Information Database from which a Coastal Sensitivity Index can be derived. To calculate a CSI refer to section 3.0.

CLASS VARIABLE	***1*** ***Very low***	***2*** ***Low***	***3*** ***Medium***	***4*** ***High***	***5*** ***Very High***
Elevation above MHWS (m)	>20.0	20.0 -10.1	10.0 -5.1	5.0 -2.0	<2.0
Max. Storm Wave Run-up Level above MHWS (m)	<1.0	1.0 -1.5	1.6 -2.5	2.6 -5.0	>5.0
Gradient	>20	20 -11	10 -6	5 -2	<2
Max. Tsunami Wave Height (m)	<0.5	0.5 -1.5	1.6 -4.0	4.1 -10.0	>10
Lithology ***Igneous***	Plutonics. Intrusives.				
Metamorphic	Metamorphics (high to medium grade).	Low grade metamorphics.	Sheared metamorphics.		
Volcanic	Volcanics (lava, dikes)	Very densely and densely welded ignimbrites. Volcanic breccia.	Partially welded ignimbrite.	Non-welded ignimbrite. Consolidated volcanic ash.	Unconsolidated volcanic ash.
Sedimentary		Densely indurated sedimentary rocks (greywacke, solid argillite) Well cemented, sedimentary rocks (limestones, quartzite).	Moderately indurated sedimentary rocks (sandstones, argillite, conglomerate).	Weakly indurated sedimentary rocks (mudstones, weak weak conglomerates). Relict sands. Lignite. Loess.	Unconsolidated sediments luvium, alluvium, gravels, sands, silts, muds). Peat. Swelling bentonites.
Natural Landform	Very hard rock platforms and sea cliffs.	Hard rock platforms and sea cliffs.	Moderately hard rock platforms and sea cliffs. Moraines.	Soft rock platforms and sea cliffs. Alluvial deltas. Saltmarsh/ mangroves.	Sand beaches, dunes, and spits. Gravel barriers, beach ridges and spits. River mouths. Cuspate forelands.
Horizontal Trend (m/year)	>+ 0.50 Advance	+0.50 to -0.02	-0.03 to -0.49	-0.50 to -2.00	>-2.00 Retreat
Short-term fluctuation (m)	<2	2-5	6-10	11-30	>30

3. DEVELOPMENT OF THE COASTAL SENSITIVITY INDEX

Methods investigated

In the course of developing any classification scheme, the question arises as to how to treat the data once it has been collected. When attempting to describe an area of complex interacting processes such as the coastline, perhaps the minimum numerical description would be the mean and standard deviation. This is more applicable when the database is large, but in most regions fairly thorough coverage may be found in sites. The standard deviation tends to complicate the CSI, it being simpler and more realistic to actually look at the range of ratings assigned to an area than to interpret a mean and standard deviation.

Many methods of combining the data were considered in this study including the Gornitz (1991) original equation (Equation 1), the geometric and harmonic means (Equations 2 and 3), and the root mean square (Equation 4) set out below. The Gornitz equation, stated as the square root of the geometric mean, was initially used. This equation was sensitive to small changes in individual rankings and tended to grossly distort the original data of the matrix by expanding the range of sensitivity values (see Table 5). The geometric and harmonic means tended to weight towards the lower extreme values, while the root mean square equation was more sensitive to both the high and low extreme values. Table 5 presents a theoretical range of variable conditions that may be present on the coast, and the manipulation of the data by each method.

Table 5 Worked example using 5 methods of combining variable values (average to extreme). Comparisons across the lower portion show the effects of different equations on the raw data.

	Average			**Extreme**
Variable Values	**3 3 3 3 3 3 3 3**	**2 2 2 2 4 4 4 4**	**1 1 3 3 3 3 5 5**	**1 1 1 1 5 5 5 5**
Average	**3.00**	**3.00**	**3.00**	**3.00**
Equation 1) Gornitz (1991)	**76.80**	**57.20**	**42.70**	**17.70**
Equation 2) Geometric mean	**3.00**	**2.83**	**2.67**	**2.24**
Equation 3) Harmonic mean	**3.00**	**2.67**	**2.38**	**1.67**
Equation 4) Root mean square	**3.00**	**3.16**	**3.26**	**3.60**

Where according to Gornitz (1991) the equation is stated as the square root of the geometric mean;

$$CSI = [\frac{1}{n}(x_1 * x_2 * \dots x_n)]^{\frac{1}{2}} \qquad \textit{Equation 1}$$

the geometric mean =
the nth root of the product;

$$CSI = (x_1 * x_2 * \dots * x_n)^n \qquad \textit{Equation 2}$$

the harmonic mean = number divided by the sum of the reciprocals;

$$CSI = \frac{n}{\sum \frac{1}{x}} \qquad \textit{Equation 3}$$

and the root mean square = the square root of the mean of the squares.

$$CSI = \sqrt{\sum \frac{x^2}{n}} \qquad \textit{Equation 4}$$

Where x_i= each variable, and
n= the total number of variables present.

After discussion of these methods with university specialists (Prof. A. Sutherland, University of Canterbury, Christchurch, pers. comm., June 1992; Dr W. de Lange, University of Waikato, pers. comm., June 1992) and the presentation of a seminar to the Canterbury Coastal Research Group it was decided that the above equations had a tendency to give "false credibility" to what in effect is a value based judgement. To overcome this a straight-forward addition (Equation 5) was finally selected because it can be rapidly calculated and does not distort the data.

CSI = elevation + storm wave run-up + gradient tsunami + lithology

+ horizontal trend + short-term fluctuation

Equation 5

After all 8 variables have been assessed for each site, and assigned a class value from 1 to 5, the CSI can be calculated by simply adding up the class values.

Defining the CSI boundaries

If every variable rated either the minimum of 1 or the maximum of 5, the minimum and maximum CSI's would be 8 and 40 respectively. In this study the boundaries adopted between each sensitivity class are listed below and are based on an approximate even division of the total with the very low and very high classes being slightly less than the remaining three. . .

Very low	*Low*	*Medium*	*High*	*Very high*
8-13	14-20	21-27	28-34	34-40

Even though CSI'shave been categorised in this manner, it is the relative sensitivity of the areas whether on a national or regional scale which is important. An alternative to defining such boundaries is to note **any** area which rates a 5 for a particular variable to be in the very high sensitivity class.

The 5 classes of CSI so obtained can be used as a basis to classify the coast according to its sensitivity to natural processes which may prove hazardous to human property and values. From this classification a policy, planning and management framework can be developed to meet the requirements of the Resource Management Act 1991, for "sustainable management" and "preservation of the natural character" of the coastal environment. Such a classification of a stretch of coast would provide early warning of areas likely to pose future problems to potential developments and values.

4. APPLICATION OF THE COASTAL SENSITIVITY INDEX TECHNIQUE

4.1 Preparatory work for field assessments

There are three steps to ensure that field time and costs are kept to a minimum, while attaining maximum areal coverage.

4.1.1 Variability of the coastline and selection of sites

It is in the users' best interest to carry out a thorough survey. The number of field sites to assess should be dictated by the amount of shoreline variability there is along the coast. There is no point in repeating a field test on an area which is so similar to its neighbour that none of the boundaries on the matrix are crossed. The important point to note is whether an adjacent site varies enough in data to warrant re-assessment of the CSI. Also included for assessment should be areas of concern and interest to the user, areas with the potential to be developed, and currently threatened areas. Ease or lack of access should also be considered during field work planning.

4.1.2 Time and personnel

Along a "uniform" coast rapid progress is limited only by travelling time. In this study each site took from 15 to 30 minutes to assess where good background data were available, but these times should be flexible to enable the maximum information to be gleaned during the field phase. It is possible to assess up to 10 sites per day, or less if the user is restricted to the normal 8-hour working day. This depends on the size of the region, travel time between sites, and access.

For one region, and depending on the number of sites and availability of reliable data it would take two people 1-2 weeks to complete the field phase, and 1-2 weeks to write up and present a report. Broadly it is estimated that it would take less than one month to complete the field work and write-up for a region, providing the personnel are working full time on the project. Lack of data required for the assessment (e.g., horizontal change) would result in a proportional increase in the amount of time to complete the project.

4.1.3 Cost

It is necessary to obtain a value for all the variables in order to calculate a comparable CSI. Achievable through a combination of field work and existing information, one variable which may require a financial outlay if the data doesn't already exist is the long-term trend. The 1992 cost is outlined in Appendix 4. Other costs include photography, computing and publication.

4.2 Field procedure

The following checklist includes the equipment and data required in the field:

pens, pencils, erasers
metric scale ruler
field book for observations
protractor

long-term horizontal trend maps and data
5 m survey staff
cross-sectional profile data (if available)
calculator
geological and topographic maps
aerial photographs
camera and film, preferably one camera with **slides** Kodak Ektachrome 100 Plus) and one with **prints** as backup for presentation purposes and permanent records.

At each site a fairly rapid assessment of the field conditions can be made. For each of the following steps, the measurement or confirmation is made and the rank of sensitivity noted from the matrix. An example for each step is given for a field site used during this study at Te Araroa (Appendix 9).

1. Record the date, time, location.

2. Become familiar with the test site, looking for a) evidence of landslip, and b) the presence of dune control or restoration works, and recording this.

3. Measure the elevation of the first immediate feature.

4. *Assess the level of storm wave run-up from field and anecdotal evidence and reports.

5. Is the first immediate feature exceeded by the storm wave run-up level? **Yes:** the gradient is determined as that behind the first feature. **No:** overtopping = zero so the gradient is determined as the slope face of the first feature.

6. *From de Lange and Healy (1986a) determine the largest tsunami on record, or utilise any local additional information.

7. Confirm the lithology and landform by field observation and checks with the geology literature.

8. *From the long-term horizontal trend data assess the rate of erosion or accretion for each field site. This can be done while travelling between sites.

9. *From the long-term trend data and from field inspection make an assessment of the short-term fluctuation variable.

10. Take a photograph.

11. *Calculate an initial CSI using Table 4.

* As a time saving measure these steps can be completed prior to or after field work.

4.2.1 Data treatment and computer information storage

An important tool used for the storage of field information is the computer database-known as the Coastal Hazards Database established by the CRI Taskforce, Department of Conservation using dBase IV V1.1. A further explanation of how to use this is given in Appendix 5.

An alternative to using a computer database for storage is to manually record and store the information onto a copy of the data sheet provided in Appendix 6. Copies can be made and stored in clip-binders or in filing systems.

4.3 Applying the technique

4.3.1 Case studies

As part of the field work to establish, test and modify the method to derive a standardised Coastal Sensitivity Index, nine regions around New Zealand were visited. In order of testing the regions were Wairarapa, the Kapiti Coast, Wellington Coast, Pauatahanui Inlet, Manukau Harbour, Hawkes Bay Region, East Cape Region, Bay of Plenty, and the Canterbury Region (see Figure 1). These were visited because of the availability of good quality horizontal trend data and differences in lithology and landform types. The following case studies summarise the data and CSI results collected.

1. Wairarapa Coast

This section of coast was the first visited for field testing and provided a good initial indication of the scope of the method, changes to and of variables that could be made, and how to make practical measurements of elevation in the field.

Approximately 32 km of coast from Whareama River to Flat Point was visited and 20 sites tested over a 3.5 day period (9-12 March 1992). This region possesses a wide variety of coastal landforms ranging from river mouths to soft and hard rock cliffs and platforms to sand beaches and dunes, to gravel beaches and ridges. A corresponding wide range of lithologies was also present ranging from sands and gravels to mudstones and siltstones to unconsolidated sands and gravels. Data on horizontal shoreline movements were made available by the Wellington Regional Council.

Where access was easy sites could be rapidly assessed (from Whareama to Uruti), but where access to the coast required permission from farmers and land owners to travel across farms (Uruti to Flat Point), there was some time spent in reaching the sites.

Results

Site elevations reflected the differing nature of the landforms, ranging from >30m for the cliffs north of the Kaiwhata River down to a sand barrier 0.7 m above MHWS adjacent to the Kaiwhata River mouth.

Average erosion rates ranged from 0.2 m/yr (gravel beach at Site 4) up to 1.3 m/yr (high cliffs at Kaiwhata, Site 13). Accretion was only recorded at two sites visited along the Wairarapa coast at average rates of 0.5 m/yr (Orui Station homestead, Site 18) and 1.2 m/yr (Riversdale

Beach, Site 20). Short-term fluctuations differed considerably, from those associated with river mouths (>100m at Kaiwhata, Site 15) to those associated with beaches (20 m at Riversdale, Site 20) and cliff failure (up to 30 m along the high cliffs north of Kaiwhata, Site 13).

Tsunami information was extrapolated from the observations made at Castlepoint (1.8 m) associated with the 22 May 1960 tsunami derived from the Chilean earthquake (de Lange and Healy 1986a).

Coastal sensitivity indices
CSIs ranged from 18 (low) to 36 (very high) out of 40 (Figure 12). The results illustrate the wide variety of conditions occurring along the Wairarapa coast, with the most sensitive areas being those with unconsolidated sediments, fluctuating natures, and susceptibility to inundation (Kaiwhata River mouth CSI = 36 (very high)).

The lowest [CSI = 18 (low)] was achieved on a hard rock platform formed of greywacke which has remained static with respect to adjacent landforms and lithologies. The soft rock cliffs formed of siltstones and mudstones encountered during field work were susceptible to failure by slumping caused by undercutting and erosion by waves.

2. The Kapiti Coast

In one day (13 March 1992), 32 km of coast from the Otaki River mouth to Paekakariki was assessed over 10 sites. The region possesses predominantly sand beaches with sections of gravel beach and New Zealand's largest cuspate foreland (at Paraparaumu). Rate data in the form of cadastral maps overlain by aerial survey information was made available by the Wellington Regional Council. Storm wave run-up levels were recorded by Gibb (1978a).

Field estimation of elevation and calculation of rates from the supplied maps took the most time. Each site was selected to correspond with the end of a known road for ease of access, or to correspond with existing beach profile sites established by Gibb (1979).

Results
Site elevations ranged from an average of 1.6 m for low sand dunes up to 8 m for high sand dune areas. Erosion occurred at five sites, although at Rosetta Road, Raumati, was protected by a seawall reducing the rate of erosion, and ranged from an average of 0.4 m/yr at Paekakariki to an average of 2.5 m/yr at Raumati South (Site 29). The Raumati South site also exhibited accelerated erosion owing to the end effects of a seawall adjacent to the site. Accretion occurred at six sites, and ranged from 0.16 m/yr (Rua Road, Site 27) to 1.25 m/yr (Site 23, Te Horo).

Tsunami information for the Kapiti Coast is scarce. The nearest available information is for the Manawatu and Wanganui Rivers which have previously had tidal bores of <1 m associated with small tsunami events (de Lange and Healy 1986a). These events have been used in the absence of more localised data.

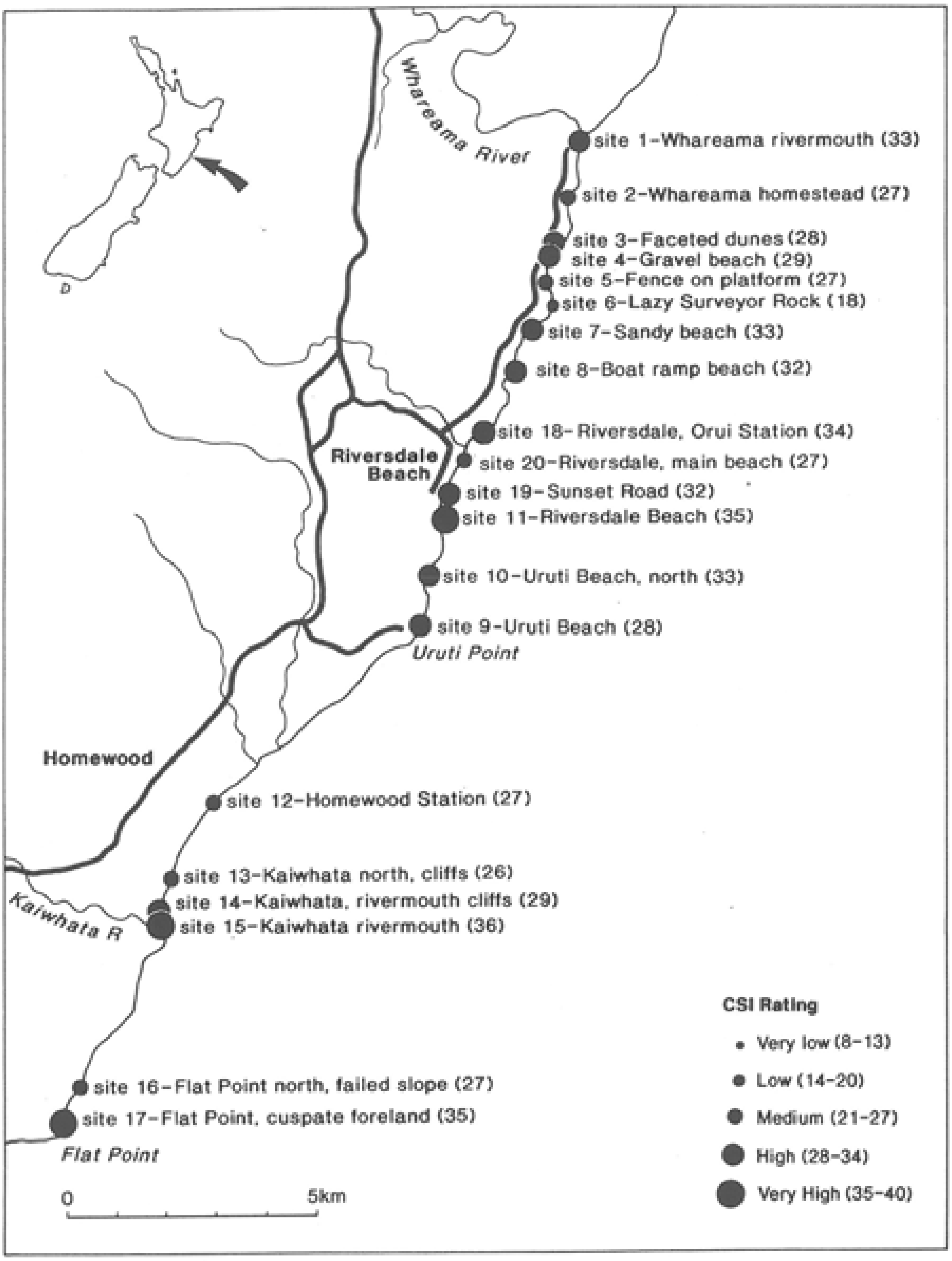

Figure 12 Sketch map showing the distribution of CSI ratings for 17 sites along the Wairarapa coast.

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